TECHNICAL PROGRAM SUMMARY

Acoustics in Focus, 180th Meeting of the Acoustical Society of America

8–10 June 2021

FP: Focused Presentations / LR: Lightning Round / PAN: Panel / TUT: Tutorial

TUESDAY MORNING

FP	1aAA	Show Your Data: Architectural Acoustics Metrics
FP	1aABa	Fish Bioacoustics: The Past, Present, and Future
FP	1aABb	Session in Memory of Thomas F. Norris I
TUT	1aBAa	Pre-Clinical Models for Therapeutic Ultrasound
LR	1aBAb	Instrumentation and Simulation in Biomedical Acoustics
FP	1aCA	Computational Methods for Complex Media and Geometries I
FP	1aEA	Emerging Topics in Engineering Acoustics I
FP	1aMU	Guitar Acoustics
FP	1aNS	Acoustic Wave Propagation Through Polydisperse Scatterers I
PAN	1aPP	Open Source Audio Processing Platform--Live Workshop!
FP	1aSC	Ideas Worth Reconsidering in Speech Perception and Production I
FP	1aSPa	Methods and Applications for Autonomous Vehicles
FP	1aSPb	Signal Processing for Environmental Sensing I

TUESDAY AFTERNOON

PAN	1pAA	Noise and Vibration Control in 2021
FP	1pAB	Session in Memory of Thomas F. Norris II
TUT	1pBA	Instrumentation and Simulation in Using k-Wave for Simulation of Ultrasound Pulses
FP	1pCA	Computational Methods for Complex Media and Geometries II
FP	1pEA	Emerging Topics in Engineering Acoustics II
FP	1pED	Reflections on Teaching Acoustics During a Pandemic
FP	1pID	Excellence in Acoustics Around the World
FP	1pNS	Pandemic Noise Reduction/Impact II
FP	1pPA	Acoustic Wave Propagation Through Polydisperse Scatterers II
FP	1pSCa	Ideas Worth Reconsidering in Speech Perception and Production II
LR	1pSCb	Ideas Worth Reconsidering in Speech Perception and Production III
FP	1pSP	Signal Processing for Environmental Sensing II
PAN	1pUW	Underwater Sound Modeling: Comprehensive Environmental Descriptions

TUESDAY EVENING

KEY NOTE	1eID	Keynote Lecture: Speech Acoustics and Mental Health Assessment

WEDNESDAY MORNING

FP	2aAO	Long Term Acoustic Time Series in the Ocean
PAN	2aBAa	Advances in Ultrasound Imaging: Novel Imaging Methods
LR	2aBAb	Advances in Ultrasound Imaging
FP	2aCA	Normal Mode Methods Across Acoustics
FP	2aMU	Numerical Methods for Musical Acoustics
FP	2aNS	Soundscape Projects: Networking, Participation, and New Technology I
FP	2aPA	Sonic Boom: Modeling, Measurement, Annoyance and Standards Development I
FP	2aPP	Linking Psychological and Physiological Acoustics I
FP	2aSA	Acoustic Metamaterials I
FP	2aSC	Speech Studies Conducted Remotely: Methods and Examples I
FP	2aSP	Bayesian Signal Processing and Machine Learning I
FP	2aUW	The Effects of COVID-19 on Global Ocean Soundscapes

WEDNESDAY AFTERNOON

PAN	2pAA	Advances in Architectural Acoustics for Cultural Heritage Research and Preservation
FP	2pAO	Long Term Acoustic Time Series in the Ocean II
TUT	2pBAa	Advances in Ultrasound Imaging: Passive Cavitation Imaging/Mapping
PAN	2pBAb	Advances in Ultrasound Contrast Agents and Bubble Nuclei
TUT	2pCA	Tutorials on Computation Techniques and Best Practices
FP	2pEA	Acoustic Transducers and Transduction Mechanisms
FP	2pMU	Acoustics of Harps and Zithers
FP	2pNS	Soundscape Projects: Networking, Participation, and New Technology II
FP	2pPA	Sonic Boom: Modeling, Measurement, Annoyance and Standards Development II
FP	2pPP	Linking Psychological and Physiological Acoustics II
FP	2pSA	Acoustic Metamaterials II
TUT	2pSCa	Speech Studies Conducted Remotely: Methods and Examples II
LR	2pSCb	Speech Studies Conducted Remotely: Methods and Examples III
FP	2pSP	Bayesian Signal Processing and Machine Learning II
KEY NOTE	2eID	Keynote Lecture: A Personal Perspective and Journey through DEI & STEM

THURSDAY MORNING

FP	3aAA	Acoustics in Coupled Volume Systems
LR	3aBA	Therapeutic Ultrasound
FP	3aEA	Back to the Future: Historical Perspectives and Current Engineering Topics
FP	3aMU	Focus on Student and Early Career Researchers
FP	3aNS	Non-Occupational Noise and Hearing Loss I
FP	3aPA	Acoustical Methods and Sensors for Challenging Environments I
FP	3aSA	Capabilities and Limitations of the Computational Analysis of Metamaterials
FP	3aSC	Teaching Speech and Hearing Science to Undergraduates I
LR	3aSP	Recent Research in Acoustic Signal Processing
FP	3aUW	Seabed Characterization Experiment 2017 Studies

THURSDAY AFTERNOON

FP	3pAO	Long Term Acoustic Time Series in the Ocean III
PAN	3pBAa	Instrumentation and Simulation in Rapid Prototyping for Focused Ultrasound Sources
PAN	3pBAb	Future Directions in Therapeutic Ultrasound
LR	3pCA	Innovative Ideas for Computational Acoustics
FP	3pEA	Engineering Acoustics in Industry
FP	3pNS	Non-Occupational Noise and Hearing Loss II
FP	3pPA	Acoustical Methods and Sensors for Challenging Environments II
FP	3pSCa	Teaching Speech and Hearing Science to Undergraduates II
LR	3pSCb	Teaching Speech and Hearing Science to Undergraduates III
LR	3pSCc	Speech Studies Conducted Remotely: Methods and Examples IV
FP	3pUW	Seabed Characterization Experiment 2017 Studies II

TECHNICAL PROGRAM CALENDAR
Acoustics in Focus, 180th Meeting of the Acoustical Society of America
8–10 June 2021

Tuesday Morning

9:30	1aAA	**Architectural Acoustics:** Show Your Data: Architectural Acoustics Metrics
9:30	1aABa	**Animal Bioacoustics:** Fish Bioacoustics: The Past, Present, and Future
11:20	1aABb	**Animal Bioacoustics, Acoustical Oceanography, and Underwater Acoustics:** Session in Memory of Thomas F. Norris I
9:30	1aBAa	**Biomedical Acoustics:** Pre-Clinical Models for Therapeutic Ultrasound
9:30	1aBAb	**Biomedical Acoustics:** Instrumentation and Simulation in Biomedical Acoustics
9:30	1aCA	**Computational Acoustics:** Computational Methods for Complex Media and Geometries I
9:30	1aEA	**Engineering Acoustics:** Emerging Topics in Engineering Acoustics I
9:30	1aMU	**Musical Acoustics, Structural Acoustics and Vibration, and Computational Acoustics:** Guitar Acoustics
9:30	1aNS	**Noise and ASA Committee on Standards:** Pandemic Noise Reduction/Impact I
9:50	1aPA	**Physical Acoustics, Biomedical Acoustics, Signal Processing in Acoustics, Computational Acoustics, and Structural Acoustics and Vibration:** Acoustic Wave Propagation Through Polydisperse Scatterers I
9:30	1aPP	**Psychological and Physiological Acoustics:** Open Source Audio Processing Platform--Live Workshop!
9:30	1aSC	**Speech Communication and Psychological and Physiological Acoustics:** Ideas Worth Reconsidering in Speech Perception and Production I
9:30	1aSPa	**Signal Processing in Acoustics, Physical Acoustics, Structural Acoustics and Vibration, Engineering Acoustics, and Underwater Acoustics:** Signal Processing Methods and Applications for Autonomous Vehicles
11:30	1aSPb	**Signal Processing in Acoustics and Animal Bioacoustics:** Signal Processing for Environmental Sensing I

Tuesday Afternoon

12:55	1pAA	**Architectural Acoustics:** Noise and Vibration Control in 2021
12:55	1pAB	**Animal Bioacoustics, Acoustical Oceanography, and Underwater Acoustics:** Session in Memory of Thomas F. Norris II
12:55	1pBA	**Biomedical Acoustics:** Instrumentation and Simulation in Biomedical Acoustics: Using k-Wave for Simulation of Ultrasound Pulses
12:55	1pCA	**Computational Acoustics:** Computational Methods for Complex Media and Geometries II
12:55	1pEA	**Engineering Acoustics:** Emerging Topics in Engineering Acoustics II
12:55	1pED	**Education in Acoustics and Psychological and Physiological Acoustics:** Reflections on Teaching Acoustics During a Pandemic
12:55	1pID	**Interdisciplinary:** Excellence in Acoustics Around the World
12:55	1pNS	**Noise and ASA Committee on Standards:** Pandemic Noise Reduction/Impact II
12:55	1pPA	**Physical Acoustics, Biomedical Acoustics, Signal Processing in Acoustics, Computational Acoustics, and Structural Acoustics and Vibration:** Acoustic Wave Propagation Through Polydisperse Scatterers II
12:55	1pSCa	**Speech Communication and Psychological and Physiological Acoustics:** Ideas Worth Reconsidering in Speech Perception and Production II
2:00	1pSCb	**Speech Communication and Psychological and Physiological Acoustics:** Ideas Worth Reconsidering in Speech Perception and Production III
12:55	1pSP	**Signal Processing in Acoustics and Animal Bioacoustics:** Signal Processing for Environmental Sensing II
12:55	1pUW	**Underwater Acoustics:** Underwater Sound Modeling: Comprehensive Environmental Descriptions

Tuesday Evening

4:30 1eID **Keynote Lecture:** Speech Acoustics and Mental Health Assessment

Wednesday Morning

9:30 2aAO **Acoustical Oceanography, Underwater Acoustics, Animal Bioacoustics, and Signal Processing in Acoustics:** Long Term Acoustic Time Series in the Ocean I

9:30 2aBAa **Biomedical Acoustics:** Advances in Ultrasound Imaging: Novel Imaging Methods

9:30 2aBAb **Biomedical Acoustics:** Advances in Ultrasound Imaging

9:30 2aCA **Computational Acoustics, Biomedical Acoustics, Physical Acoustics, and Underwater Acoustics:** Normal Mode Methods Across Acoustics

9:30 2aMU **Musical Acoustics:** Numerical Methods for Musical Acoustics

9:30 2aNS **Noise, Architectural Acoustics, Animal Bioacoustics, ASA Committee on Standards, and Psychological and Physiological Acoustics:** Soundscape Projects: Networking, Participation, and New Technology I

9:30 2aPA **Physical Acoustics, Noise, Structural Acoustics and Vibration, ASA Committee on Standards, and Computational Acoustics:** Sonic Boom: Modeling, Measurement, Annoyance and Standards Development I

9:30 2aPP **Psychological and Physiological Acoustics:** Linking Psychological and Physiological Acoustics I

9:30 2aSA **Structural Acoustics and Vibration, Engineering Acoustics, and Physical Acoustics:** Acoustic Metamaterials I

9:30 2aSC **Speech Communication:** Speech Studies Conducted Remotely: Methods and Examples I

9:30 2aSP **Signal Processing in Acoustics and Computational Acoustics:** Bayesian Signal Processing and Machine Learning I

9:30 2aUW **Underwater Acoustics:** The Effects of COVID-19 on Global Ocean Soundscapes

Wednesday Afternoon

12:55 2pAA **Architectural Acoustics:** Advances in Architectural Acoustics for Cultural Heritage Research and Preservation

12:55 2pAO **Acoustical Oceanography:** Long Term Acoustic Time Series in the Ocean II

12:55 2pBAa **Biomedical Acoustics:** Advances in Ultrasound Imaging: Passive Cavitation Imaging/Mapping

3:10 2pBAb **Biomedical Acoustics:** Advances in Ultrasound Contrast Agents and Bubble Nuclei

12:55 2pCA **Computational Acoustics and Musical Acoustics:** Tutorials on Computation Techniques and Best Practices

12:55 2pEA **Engineering Acoustics:** Acoustic Transducers and Transduction Mechanisms

12:55 2pMU **Musical Acoustics and Structural Acoustics and Vibration:** Acoustics of Harps and Zithers

12:55 2pNS **Noise:** Soundscape Projects: Networking, Participation, and New Technology II

12:55 2pPA **Physical Acoustics:** Sonic Boom: Modeling, Measurement, Annoyance and Standards Development II

12:55 2pPP **Psychological and Physiological Acoustics:** Linking Psychological and Physiological Acoustics II

12:55 2pSA **Structural Acoustics and Vibration, Engineering Acoustics, and Physical Acoustics:** Acoustic Metamaterials II

12:55 2pSCa **Speech Communication:** Speech Studies Conducted Remotely: Methods and Examples II

2:45 2pSCb **Speech Communication:** Speech Studies Conducted Remotely: Methods and Examples III

12:55 2pSP **Signal Processing in Acoustics:** Bayesian Signal Processing and Machine Learning II

Wednesday Evening

4:30 2eID **Keynote Lecture:** A Personal Perspective and Journey through DEI & STEM

Thursday Morning

9:30 3aAA **Architectural Acoustics, Musical Acoustics, Noise, Structural Acoustics and Vibration and Computational Acoustics:** Acoustics in Coupled Volume Systems

9:30 3aBA **Biomedical Acoustics:** Therapeutic Ultrasound

9:30 3aEA **Engineering Acoustics:** Back to the Future: Historical Perspectives and Current Engineering Topics

11:00 3aMU **Musical Acoustics:** Focus on Student and Early Career Researchers

9:30 3aNS **Noise, ASA Committee on Standards, and Psychological and Physiological Acoustics:** Non-Occupational Noise and Hearing Loss I

9:30 3aPA **Physical Acoustics, Engineering Acoustics, and ASA Committee on Standards:** Acoustical Methods and Sensors for Challenging Environments I

9:30 3aSA **Structural Acoustics and Vibration, Computational Acoustics, Engineering Acoustics, and Physical Acoustics:** Capabilities and Limitations of the Computational Analysis of Metamaterials

9:30 3aSC **Speech Communication, Psychological and Physiological Acoustics, and Education in Acoustics:** Teaching Speech and Hearing Science to Undergraduates I

11:00 3aSP **Signal Processing in Acoustics:** Recent Research in Acoustic Signal Processing

9:30 3aUW **Underwater Acoustics:** Seabed Characterization Experiment 2017 Studies I

Thursday Afternoon

12:55 3pAO **Acoustical Oceanography:** Long Term Acoustic Time Series in the Ocean III

12:55 3pBAa **Biomedical Acoustics:** Instrumentation and Simulation in Biomedical Acoustics: Rapid Prototyping for Focused Ultrasound Sources

2:40 3pBAb **Biomedical Acoustics and Physical Acoustics:** Future Directions in Therapeutic Ultrasound

12:55 3pCA **Computational Acoustics:** Innovative Ideas for Computational Acoustics

12:55 3pEA **Engineering Acoustics:** Engineering Acoustics in Industry

12:55 3pNS **Noise:** Non-Occupational Noise and Hearing Loss II

12:55 3pPA **Physical Acoustics, Engineering Acoustics, and ASA Committee on Standards:** Acoustical Methods and Sensors for Challenging Environments II

12:55 3pSCa **Speech Communication, Psychological and Physiological Acoustics, and Education in Acoustics:** Teaching Speech and Hearing Science to Undergraduates II

2:15 3pSCb **Speech Communication, Psychological and Physiological Acoustics, and Education in Acoustics:** Teaching Speech and Hearing Science to Undergraduates III

3:30 3pSCc **Speech Communication:** Speech Studies Conducted Remotely: Methods and Examples IV

12:55 3pUW **Underwater Acoustics:** Seabed Characterization Experiment 2017 Studies II

Session 1aAA

Architectural Acoustics, Signal Processing in Acoustics and Noise: Show Your Data: Architectural Acoustics Metrics

Ana M. Jaramillo, Cochair
Ahnert Feistel Media Group, 8717 Humboldt Ave. N., Brooklyn Park, MN 55444

Bruce Olson, Cochair
Olson Sound Design LLC, Brooklyn Park, MN 55444

Chair's Introduction—9:30

Contributed Papers

9:35

1aAA1. Industrial pipe acoustic treatments investigation per ISO 15665. Kevin M. Herreman (Core Technologies, Owens Corning, 2790 Columbus Rd., Granville, OH 43023, kevin.herreman@owenscorning.com)

Reducing noise levels in industrial environments are critical as exposure to high noise levels has been related to health issues like fatigue and stress that can compromise safety of workers. Many types of acoustic products can be applied to various noise emitting equipments in an effort to reduce the noise levels in industrial spaces. Jacketed pipe insulation is one such product applied across many industries for controlling pipe emitted noise emission. As with most products, standards for evaluating performance have been created to validate performance claims by manufacturer's. For jacketed pipe insulation ISO 15665, an international standard defining a testing process for measurement of the acoustical performance of installed and jacketed pipe insulation systems, is the accepted testing method. The measurement process provides for the determination of the insertion loss of jacketed insulation applied to a pipe. A recently conducted study to identify the performance of over 30 variations of jacketed pipe insulation, including combinations of two types of insulation material, is presented herein.

9:50

1aAA2. Broadband optimization of volumetric sound metadiffusers. Neel Shah (Mech. Eng., San Jose State Univ., 1 Washington Sq., San Jose, CA 95192, neelshah95@gmail.com) and Feruza Amirkulova (Mech. Eng., San Jose State Univ., San Jose, CA)

Broadband volumetric sound metadiffusers are designed by using gradient-based optimization and by means of multiple scattering theory (MST) employed to evaluate the scattered pressure field by a uniform planar configuration of cylindrical scatterers. The method is illustrated by giving numerical examples for planar configurations of rigid cylinders and thin elastic cylindrical shells situated in the air medium. By rearranging the position of each cylinder, a metadiffuser is optimized to have a high diffusion coefficient. Multiple scenarios are evaluated considering a single frequency and broadband optimization. Single frequency optimization is performed to optimize a configuration of cylinders at a specific wavenumber. Broadband optimization is used to optimize a cylinder configuration for a range of wavenumbers by optimizing the root mean square of diffusion coefficient evaluated at discreet values of normalized wavenumber. MATLAB MultiStart solver combined with parallel computing along with global optimization toolboxes is used to enhance the modeling for optimizing for both scenarios due to its ability to evaluate multiple starting points in parallel, hence being able to find the global optimum. A wide array of metadiffusers is optimized using MATLAB MultiStart and fmincon solvers with the sequential quadratic programming and genetic algorithm for a comparison of performance of these algorithms.

10:05

1aAA3. Experiences with industrial application of wave-based architectural acoustics simulations. Jesper Pedersen (Treble Technologies, Asparhvarf 9, Kópavogur 203, Iceland, jp@treble.ac) and Finnur Pind (Treble Technologies, Reykjavik, Iceland)

Current state-of-the-art tools for simulation of acoustics in the built environment largely utilize geometrical acoustics technology, such as ray-tracing. Wave-based methods are known to be much more accurate than that of geometrical acoustics methods with the accurate inclusion of wave-effects such as resonant behavior, diffraction, focusing, and interference, but the computational burden has been the roadblock preventing the practical commercial application. However, recent advancements in both numerical methodology and cloud computing are now enabling the industry to explore the benefits of this technology. In this talk, we will present the findings from multiple case-studies of practical application of a cloud-based wave-based acoustics simulation tool. The case-studies include several real-world industrial projects, but a study of the scenes provided in "GRAS—Ground truth for room acoustical simulation" is also presented. The results are compared to traditional modelling approaches and measurement where available. It is found that there are significant accuracy improvements to be gained from shifting towards the use of wave-based acoustical simulation tools, and with the lower levels of uncertainty, it is assessed that the new methods can enable more efficient and robust design processes in building design.

10:20–10:35 Break

10:35

1aAA4. Optimizing well-depth sequences for Schroeder diffusers using machine learning. Priyam Selugar (Comput. and Information Sci., Univ. of Florida, 3800 SW, 34th St., Stoneridge Appt Bldg. #W 222, Gainesville, FL 32608, priyamselugar@ufl.edu) and Hassan Azad (Architecture, Univ. of Florida, Gainesville, FL)

Around mid-1970, Schroeder introduced a mathematical theory to generate sequences, which can compute the "depth of the Schroeder diffuser". A Schroeder diffuser is a design consisting of a number of wells of different "depths," which propagates sound energy in different directions. The Schroeder diffuser provides the ability to create an optimal scattering of the same sound energy in different diffraction lobes. This paper aims to exploit

this property and optimize well-depth sequences from Schroeder diffuser using machine learning techniques. With the advent of machine learning and parallel computing, the optimization of sequences and the iterative process to select the optimal pattern of sequence can be done more efficiently. Hence, the primary focus of this paper is to come up with a machine learning model that predicts the scattered reflections from a random well-depth sequence surface and evaluates the quality of the scattered reflections using a diffusion coefficient. The model tries to achieve optimum diffuser properties by adjusting the sequence. The boundary element method can be used for computing the diffusion coefficient. The diffusion coefficient parameter determines the quality of the diffuser and can be calculated at $^1/_3$ Octave frequency bands.

10:50

1aAA5. Acoustical transmission of face coverings used to reduce coronavirus transmission in a classroom environment. Laura A. Ruhala (Mech. Eng., Kennesaw State Univ., 840 Polytechnic State University, Rm. Q319, MD 9075, Marietta, GA 30060, lruhala@kennesaw.edu), Richard J. Ruhala, Anaheeta Hadjimirzaei, Danny Hernandez-Borjas, Andrew P. Pierce (Mech. Eng., Kennesaw State Univ., Marietta, GA), and Lance Crimm (Elec. and Comput. Eng., Kennesaw State Univ., Marietta, GA)

The COVID-19 pandemic has caused many communities to require the wearing of face coverings, masks, and/or shields indoors to reduce the transmission rate of the virus, which includes educators and students in classroom settings. Several types of face coverings are studied, including standardized N95 and KN95, assorted cloth, and clear plastic face shields. They are evaluated on an acoustical head and torso simulator (HATS) setup in a classroom with two different locations for monitoring via a sound level meter. The HATS is used as a controlled and repeatable artificial voice or sound source, which creates white noise, artificial speech, and real speech signals. Sound levels throughout the classroom are measured to determine the direct field and reverberant field regions, and they are compared to a room acoustics model. Attenuation at octave band frequencies due to the face coverings are evaluated at a location of 2.0 m from the HATS, which is within the direct field to reduce the room acoustical effects, with evaluations repeated at a location near the back of the classroom (6.2 m) to include those room acoustical effects. The acoustic effects of the face coverings are compared to reported droplet transmission rates.

11:05–11:30 Discussion

TUESDAY MORNING, 8 JUNE 2021 — 9:30 A.M. TO 11:05 A.M.

Session 1aABa

Animal Bioacoustics: Fish Bioacoustics: The Past, Present, and Future

Nora Carlson, Chair
P.O. Box 11590, Bainbridge Island, WA 98110

Chair's Introduction—9:30

Contributed Papers

9:35

1aABa1. Ending the day with a song: Patterns of calling behavior in a species of rockfish. Annebelle Kok (Scripps Inst. of Oceanogr., 9500 Gilman Dr., La Jolla, CA 92093, akok@ucsd.edu), Kelly M. Bishop (Univ. of California Santa Barbara, Santa Barbara, CA), Ella B. Kim (Scripps Inst. of Oceanogr., La Jolla, CA), Tetyana Margolina, John E. Joseph (Naval Postgrad. School, Monterey, CA), Lindsey Peavey Reeves (Channel Islands National Marine Sanctuary, Silver Spring, MD), Leila Hatch (NOAA Office of National Marine Sanctuaries, Scituate, MA), and Simone Baumann-Pickering (Scripps Inst. of Oceanogr., San Diego, CA)

Similar to birds, fish produce sound to attract mates and repel rivals. At the height of the mating season, these calls form a significant part of the marine soundscape. Even though this phenomenon is widespread in fish species, not much is known about fish calling behavior. We investigated the seasonal, lunar and diel patterns of calling behavior of bocaccio (*Sebastes paucispinis*), a species of rockfish, in the Channel Islands National Marine Sanctuary, on the west coast of the United States. We deployed acoustic recorders at five sites in the Sanctuary, at depths of 21–156 m, for a period of a year. We extracted bocaccio calls using a detection algorithm and related calling patterns to time of day, lunar illumination and time of year. Besides showing correlations with season and lunar illumination, bocaccio calls were mostly produced at night, with clear peaks at crepuscular time periods. The diel calling pattern showed correlations with site depth, possibly due to vertical migration of fish through the course of the night. Describing and understanding patterns of fish calling behavior can provide insight into communication, habitat preference, mating behavior, or animal density of these species as well as help characterize the acoustic environment that sustains them.

9:50

1aABa2. Grouper source levels and aggregation dynamics inferred from passive acoustic localization at a multispecies spawning site. Katherine Wilson (NOAA AFSC, 7600 Sand Point Way N.E., Bldg. 4, Seattle, WA 98115, katherine.wilson@noaa.gov), Ana Širović (Texas A&M Univ. Galveston, Galveston, TX), Brice X. Semmens (Scripps Inst. of Oceanogr., San Diego, CA), Stephen Gittings (NOAA Office of National Marine Sanctuaries, Silver Spring, MD), Christy Pattengill-Semmens (Reef Environ. Education Foundation, Key Largo, FL), and Croy McCoy (Cayman Islands Dept. of Environment, Grand Cayman, Cayman Islands)

Red hind *(Epinephelus guttatus)* and Nassau (*E. striatus*), black (*Mycteroperca bonaci*), and yellowfin grouper (*M. venenosa*) form spawning aggregations in Little Cayman, Cayman Islands and produce sound during these aggregations. Continuous observation of these aggregations is challenging because traditional methods are limited in time and space. Passive acoustic localization can overcome some of these challenges in case of sound-producing species, allowing observations over long durations and fine spatial scales. A hydrophone array was deployed in February 2017 over a nine-day period that included Nassau grouper spawning. Hyperbolic localization was used to find positions of the grouper producing calls during this time, to measure call source levels, and evaluate spatiotemporal aspects of calling. During the days Nassau grouper spawned, calling peaked after sunset from 19:00 to 21:00. Similarly, when red hind calls were most abundant, they peaked from 16:00 to 21:00. The mean peak-to-peak source levels of calls was 143.7 dB for yellowfin grouper and 154.9 dB for Nassau grouper (*re*: 1 μPa at 1 m for 70 to 170 Hz). The measured source levels can be used to determine communication and detection ranges and develop passive acoustic density estimation methods for these fishes.

Invited Papers

10:05

1aABa3. Building fish sound libraries, measuring aquatic soundscapes and quantifying the effects of noise. Francis Juanes (Dept. of Biology, Univ. of Victoria, 3800 Finnerty Rd., Victoria, BC V8P 5C2, Canada, juanes@uvic.ca)

Sound is a fundamental component of the sensory environment of many aquatic animals. Despite its importance, the effects of noise on aquatic organisms, particularly fishes, is not well studied nor is underwater noise regulated by most legislation. As the world has got noisier, the range and intensity of underwater anthropogenic noise continues to increase. Intense short-term noise can permanently alter auditory thresholds and lead to mortality for some organisms, while long-term chronic noise such as that produced by vessels, can lead to physiological and behavioural changes. Noise pollution can also mask environmental cues, vocalizations, or dampen the ability to hear conspecifics, prey or predators. Here, I will summarize our work developing quantitative descriptions of marine soundscapes and use our results to better understand the effects of noise on sound production and behaviour of fishes. Specifically, we are quantifying the known soniferous fish species to better understand taxonomic and geographic distribution patterns; developing inexpensive, novel, long-term, field-based methodological and statistical tools to localize and automatically detect vocalizing species; and quantifying and modeling the effects of noise on fish ecology in natural systems.

10:20

1aABa4. Unravelling the sound-induced motion of fish auditory structures: A non-invasive synchrotron radiation-based approach. Tanja Schulz-Mirbach (Biology II, Ludwig-Maximilians-Univ., Großhaderner Strasse 2, Planegg-Martinsried 82152, Germany, schulz-mirbach@biologie.uni-muenchen.de), Friedrich Ladich (Behavioral and Cognit. Biology, Univ. of Vienna, Vienna, Austria), Christian M. Schlepütz (Swiss Light Source, Paul Scherrer Inst., Villigen, Switzerland), Alberto Mittone (ALBA Synchrotron Light Source, Barcelona, Spain), Margie Olbinado (Swiss Light Source, Paul Scherrer Inst., Villigen, Switzerland), Alberto Bravin (ID17, European Synchrotron Radiation Facility, Grenoble, France), Isabelle P. Maiditsch (Behavioral and Cognit. Biology, Univ. of Vienna, Vienna, Austria), Roland Melzer (Bavarian State Collection of Zoology, Munich, Germany), Petr Krysl (Structural Eng., Univ. of California, San Diego, San Diego, CA), and Martin Heß (Biology II, Ludwig-Maximilians-Univ., Martinsried-Planegg, Germany)

Modern bony fishes display a high morphological diversity in their auditory structures. Yet, unraveling the sound-induced *in situ* interaction of the auditory structures has been challenging. Synchrotron radiation-based imaging techniques with high spatial and temporal resolutions now provide a powerful tool to study the functional morphology of such structures in a non-invasive way. We investigated two species representing two types of otophysic connections, namely, goldfish (*Weberian apparatus*) and *Etroplus canarensis* (swimbladder extensions contacting the inner ears) asking how different ancillary auditory structures affect otolith motion. Fishes were subjected to a 200 Hz pure tone in a 2L-standing wave tube-like setup while performing 2D radiography based on hard x-ray phase-contrast imaging. The shakers at each end of the tube were either driven 0° in-phase or 180° out-of-phase resulting in maximized sound pressure or sound-induced particle motion in the tube center, respectively. In both species, saccular otolith motion was more pronounced when the swimbladder walls oscillated under 0° in-phase condition and the motion patterns mainly matched the respective orientation patterns of ciliary bundles on the sensory epithelia. In future, we will quantify the motion patterns of fish auditory structures by applying “sound tomography” to cover the three-dimensional aspect of the moving structures.

1a TUE. AM

Contributed Paper

10:35

1aABa5. Automatic detection and classification of fish calls in the Northern Gulf of Mexico using energy detectors and a convolutional neural network. Emily Waddell (Marine Biology, Texas A&M Univ. Galveston, 200 Seawolf Parkway, P.O. Box 1675; Bldg 3029 Rm 130, Galveston, TX 77554, ewaddell@tamu.edu), Kait Frasier (Scripps Inst. of Oceanogr., Univ. of California San Diego, La Jolla, CA), John Hildebrand (Scripps Inst. of Oceanogr., Univ. of California San Diego, La Jolla, CA), and Ana Sirovic (Marine Biology, Texas A&M Univ. Galveston, La Jolla, CA)

Long-term passive acoustic monitoring datasets can require substantial effort for manual analysis; therefore, automatic methods are a more effective way to conduct these analyses and extract calls of interest. In this study, acoustic recordings from the northern Gulf of Mexico, about 60 km north of the 2010 Deepwater Horizon oil spill location, collected between July 2010 and May 2017 were analyzed to determine if fish call abundance has changed after the oil spill. An energy detector was created to extract six likely fish calls found in these data and a neural network was subsequently applied to classify the detections into different call categories. Data augmentation and iterative training were used to optimize classification and compensate for the low number of training images for a couple call types. Daily, monthly, and yearly patterns in calls were investigated and a hypothesis was tested that there was an increase in call abundance over time, indicating recovery of fish populations since the oil spill. Such long-term studies demonstrate that PAM can be used as a population assessment tool for fisheries management.

10:50–11:05 Discussion

TUESDAY MORNING, 8 JUNE 2021 — 11:20 A.M. TO 12:20 P.M.

Session 1aABb

Animal Bioacoustics, Acoustical Oceanography and Underwater Acoustics: Session in Memory of Thomas F. Norris I

Kerri D. Seger, Cochair
Applied Ocean Sciences, 11006 Clara Barton Dr., Fairfax Station, VA 22039

Ann Zoidis, Cochair
Cetos Research Organization, Bar Harbor, ME 04609

Chair's Introduction—11:20

Contributed Paper

11:35

1aABb1. Tom and Thode's excellent adventure: Practical guidance on surviving seedy bars, preparing for a DJ career, dismantling the U.S. Panama Canal zone, and other useful tips when working with towed acoustic arrays in the Eastern Tropical Pacific. Aaron M. Thode (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 9500 Gilman Dr., MC 0206, La Jolla, CA 92093, athode@ucsd.edu)

Tom Norris used many acoustic tools in his research career, but it is safe to say that towed passive acoustic arrays were one of his specialties. In 1998 the National Marine Fisheries Service conducted the Stenella Population and Abundance Monitoring (SPAM) cruise**.** The NOAA ship *Endeavor* was to survey enormous dolphin populations in the Eastern Tropical Pacific (ETP), starting from Lima, Peru, and ending in Panama City, Panama. Jay Barlow, one of my PhD thesis committee members, permitted me to participate in the cruise as a member of his towed array passive acoustic monitoring team. The first time I ever met Tom, the acoustics team leader, was when he was carrying a surfboard into his cabin, and I wondered how in the world he had managed to ship a surfboard into Peru. It was the first of many times I have enjoyed both working with and wondering about Tom, and our first trip together taught me practical things they forgot to teach in graduate school. Here, I will review Tom's tips on Mackie mixer boards, buying drinks in dangerous bars, tracking dolphin whistles, not antagonizing visual observers, and liberating furniture from the U.S. Panama canal zone.

Invited Paper

11:50

1aABb2. Tom Norris's contributions to the acoustic density estimation of minke whales near Kauai, Hawaii. Stephen W. Martin (National Marine Mammal Foundation, 2240 Shelter Island Dr., Ste. 200, San Diego, CA 92016, steve.martin@nmmf.org)

Tom Norris was involved in many collaborative efforts involving passive acoustic monitoring to study marine mammals. In the spring of 2010, he and his team conducted 1520 km of acoustic/visual line-transect surveys over 13 days of effort for minke whales (*Balaenoptera acutorostrata*) using the R/V Dariabar towing multiple hydrophones. The surveys were performed at the U.S. Navy Pacific Missile Range Facility's offshore underwater range located north-west of Kauai, Hawaii. Minke whales have low observables and are rarely sighted in the Hawaii area which limits the available knowledge on their ecology. However they produce the distinctive boing vocalizations in the winter and spring seasons in the area, presumably for breeding purposes, which makes PAM methods attractive. Simultaneous with the acoustic line-transect surveys, the PMRF hydrophone data were also collected to estimate the boing vocalization density in a collaborative effort. Combining the minke whale density from the acoustic line-transect survey with the minke whale boing vocalization density provided an estimate for the call rate for boing calling minke whales which was a major accomplishment at the time.

Contributed Paper

12:05

1aABb3. Automated tracking of multiple acoustic sources with towed hydrophone arrays. Pina Gruden (Joint Inst. for Marine and Atmospheric Res., Res. Corp. of the Univ. of Hawai'i, 2525 Correa Rd., Hawai'i Inst. of Geophys. 414, Honolulu, HI 96822, pgruden@hawaii.edu), Eva-Marie Nosal (Ocean & Resources Eng., Univ. of Hawaii, Honolulu, HI), and Erin M. Oleson (NOAA Pacific Islands Fisheries Sci. Ctr., Honolulu, HI)

Line transect surveys often incorporate a towed hydrophone array to detect and localize marine mammals. The animals are typically tracked based on the estimated time difference of arrivals (TDOAs) of their calls between pairs of hydrophones. The estimated TDOAs or bearings are then tracked through time to obtain animal or group positions, a process often performed manually. This process can be especially challenging in the presence of multiple animal groups that are vocalizing simultaneously, but at the same time do not emit signals consistently through time. In addition, the process is hindered by missed detections and false alarms (false TDOAs). Here, an automated approach to TDOA tracking is outlined, based on a multi-target Bayesian framework, that incorporates target appearance, disappearance, missed detections and false alarms. The method is demonstrated on examples of line transect surveys from Western Canada [Norris *et al.*, *J. Acoust. Soc. Am.***146**, 2805 (2019)] and from Hawaii, USA. [In memory of Thomas F. Norris.]

TUESDAY MORNING, 8 JUNE 2021 9:30 A.M. TO 10:15 A.M.

Session 1aBAa

Biomedical Acoustics: Pre-Clinical Models for Therapeutic Ultrasound

Julianna Simon, Chair
Pennsylvania State Univeristy, State College, PA 16802

Chair's Introduction—9:30

Invited Papers

9:35

1aBAa1. Pre-clinical models for therapeutic ultrasound. Julianna Simon (Graduate Program in Acoust., Pennsylvania State Univ., 201e Appl. Sci. Bldg., State College, PA 16802, jcs516@psu.edu)

Before clinical translation, all therapeutic ultrasound therapies require testing in pre-clinical models that can be broadly categorized as *in vitro* (cells), tissue-mimicking phantoms, *ex vivo* (tissues), and *in vivo* (animals) to establish safety and effectiveness. Choice of pre-clinical models is governed by the target application, the desired bioeffect, and the types of data that can be collected; other considerations include cost, access, and time. In this tutorial session, an overview of the four main pre-clinical categories will be presented, including common formulations used for therapeutic ultrasound. Within each category, experimental design considerations as well as the relative advantages and disadvantages to each will be discussed.

10:00–10:15 Discussion

Session 1aBAb

Biomedical Acoustics: Instrumentation and Simulation in Biomedical Acoustics

Virginie Papadopoulou, Chair
Univ. of North Carolina, Chapel Hill, NC 27599

Chair's Introduction—9:30

Contributed Papers

9:35

1aBAb1. Considerations for neuronavigation-guided blood–brain barrier opening in humans. Antonios Pouliopoulos (Columbia Univ., New York, NY, ap3623@columbia.edu), Omid Yousefian, Sua Bae, Hermes Kamimura, Robin Ji, Maria Murillo, Rachel Weber, Alec Batts, Rebecca Lynn Noel, and Elisa Konofagou (Columbia Univ., New York, NY)

In this talk, I will discuss the challenges of performing neuronavigation-guided blood–brain barrier opening in human subjects. I will describe the simulation framework required for treatment planning and the hardware needed to achieve targeted therapies.

9:40

1aBAb2. Transcranial radiation characteristics of leaky Lamb waves in different regions of a human skull. Eetu Kohtanen (Georgia Tech, Atlanta, GA, ekohtanen3@gatech.edu), Matteo Mazzotti (CU Boulder, CO), Massimo Ruzzene (CU Boulder, CO), and Alper Erturk (Georgia Tech, Atlanta, GA)

Guided (Lamb) waves in the human skull have received attention as a promising alternative to conventional ultrasound techniques for transcranial transmission, especially to access the brain periphery efficiently and thereby to increase the treatment envelope. We present detailed investigations of transcranial leaky Lamb waves and their radiation characteristics for degassed slices of a human skull through finite-element simulations based on microcomputed tomography scans (that account for high resolution diploë porosity) as well as rigorous experiments to extract the radiation angle dispersion spectra.

9:45

1aBAb3. Reconstruction of arrays of acoustic vortices using holograms for multiple particle trapping. Noé Jiménez (Universitat Politècnica de València, Valencia, Spain, nojigon@upv.es), Gabriela Sánchez-Rodríguez, Sergio Jiménez-Gambín, Diana Andrés, and Francisco Camarena (Universitat Politècnica de València, Valencia, Spain)

Arrays of acoustic vortices are synthesised using 3D printed holograms in the ultrasound regime. This technique paves the way for simultaneous trapping of multiple particles and such as arrays of cells, microbubbles or drug-delivery carriers using a low-cost device.

9:50

1aBAb4. Broad depth-of-field Bessel beams using acoustic holograms. Sergio Jiménez-Gambín (Universitat Politècnica de València, Valencia, Spain, serjigam@upv.es), Diana Andrés, Noé Jiménez, José M. Benlloch, and Francisco Camarena (Universitat Politècnica de València, Valencia, Spain)

Ideal Bessel beams can be useful for ultrasound imaging, biomedical ultrasound and particle manipulation. Since traditional passive methods to generate these beams are not capable of achieving a flat-intensity beam along the axial coordinate, we use acoustic holograms to produce ideal broad depth-of-field Bessel beams at zero-th and high-order topological charges.

9:55

1aBAb5. Ultrasound imaging simulations using Fullwave. Gianmarco Pinton (Joint Dept. of Biomedical Engineering, Univ. of North Carolina at Chapel Hill, NC, gia@email.unc.edu)

The latest advancements in diagnostic ultrasound imaging simulations based on the first principles of nonlinear attenuating propagation and reflection in the human body are presented.

10:00–10:15 Discussion

Contributed Papers

10:15

1aBAb6. 3-D ultrasound elasticity imaging for targeted prostate biopsy guidance. Derek Chan (Duke Univ., Durham, NC, derek.chan@duke.edu), D. Cody Morris (Duke Univ., Durham, NC), Thomas J. Polascik (Duke Univ., Durham, NC), Mark L. Palmeri, and Kathryn R. Nightingale (Duke Univ., Durham, NC)

We will present a recent work on the development of an ultrasound system that provides co-registered 3-D acoustic radiation force impulse (ARFI) imaging, shear wave elasticity imaging (SWEI), and B-mode imaging volumes to guide a targeted biopsy of prostate cancer.

10:20

1aBAb7. Transmission-reflection optoacoustic ultrasound (TROPUS) computed tomography of whole mice. Daniel Razansky (Univ., and ETH Zurich, Switzerland, danir@ethz.ch), Berkan Lafci, and Xose Luis Dean-Ben

We present a hybrid transmission-reflection optoacoustic ultrasound (TROPUS) small animal imaging platform that combines optoacoustic tomography with both reflection- and transmission-mode ultrasound computed tomography. The system features full-view cross-sectional tomographic imaging geometry for concomitant noninvasive mapping of the absorbed optical energy, acoustic reflectivity, speed of sound and acoustic attenuation in whole live mice with submillimeter resolution and unrivaled image quality.

10:25

1aBAb8. Sound out the hidden colors: Photoacoustic imaging in deep tissues. Junjie Yao (Duke Univ., Durham, NC, junjie.yao@duke.edu)

Acoustically detecting the optical absorption contrast, photoacoustic imaging can overcome the penetration limit of traditional optical imaging and can provide rich functional and molecular information at large depths.

10:30

1aBAb9. A robotic ultrasound system for multi-modality widefield preclinical imaging. TomekCzernuszewicz (SonoVol, Inc., Durham, NC, tomekc@sonovol.com), Juan Rojas (SonoVol), Paul Dayton, and Virginie Papadopoulou (UNC Chapel Hill, Chapel Hill, NC)

We will give an overview of the technology, and present results showing the robotic ultrasound system's use in a variety of use cases, including dual-imaging aligned with bioluminescence data for oncology studies, therapeutic ultrasound delivery, and multi-modality ultrasound imaging for liver disease.

10:35–10:50 Discussion

10:50–11:05 Break

Contributed Papers

11:05

1aBAb10. Consequences of power law scattering from soft tissues. Kevin Parker (Univ. of Rochester, Rochester, NY, kevin.parker@rochester.edu)

A recent series of theoretical and experimental results support the hypothesis that ultrasound speckle statistics and backscatter are deeply rooted in power law behaviors. The implications for the tissue characterization are direct and lead to Burr distributions for speckle analysis and the H-scan analysis for the tissue characterization.

11:10

1aBAb11. Photoacoustic impulse response of lipid-coated ultrasound contrast agents. Marco Inzunza (Univ. of Colorado Boulder, CO, marco.inzunza@colorado.edu), Mark Borden, and Todd Murray

An optical technique to excite and detect linear microbubble radial oscillations as a response of a photoacoustic impulse is presented. The radial oscillation information of the microbubble is then used to determine the viscoelastic properties of the lipid shell.

11:15

1aBAb12. Hearables for managing auditory sensitivities using heart rate variability. Danielle Benesch (Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT), McGill University, Montréal QC, Canada, danielle.benesch.1@ens.etsmtl.ca), Rachel Bouserhal, and Jérémie Voix Benesch (NSERC-EERS Industrial Research Chair in In-Ear Technologies (CRITIAS), Montreal, QC, Canada)

In-ear heartbeat sounds were recorded while participants were exposed to affective auditory stimuli with the aim of adapting a hearable to infer sound-induced distress.

11:20–11:35 Discussion

Additional Lightning Round presentations and discussion may be added

Session 1aCA

Computational Acoustics: Computational Methods for Complex Media and Geometries I

D. Keith Wilson, Cochair
Cold Regions Research and Engineering Laboratory, U.S. Army Engineer Research and Development Center, U.S. Army ERDC-CRREL, 72 Lyme Rd., Hanover, NH 03755-1290

Kuangcheng Wu, Cochair
Naval Surface Warfare Center - Carderock Division, 9500 MacArthur Blvd, West Bethesda, MD 20817

Chair's Introduction—9:30

Invited Paper

9:35

1aCA1. An immersed-boundary approach to time-domain simulation of acoustic propagation in complex geometries and media. Zhongquan C. Zheng (Mech. and Aerosp. Eng., Utah State Univ., 4130 Old Main Hill, Logan, UT 84322, zzheng@usu.edu) and Jiacheng Hou (Mech. and Aerosp. Eng., Utah State Univ., Logan, UT)

With the advent of computing power in recent decades, time-domain simulation of acoustic propagation has become practically feasible. In this presentation, we present an immersed-boundary approach implemented in TSPACE, a simulation for time-domain acoustic propagation in complex geometries. Because TSPACE is based on conservation laws in the physical domain (both time and space), the primary advantage is its ability to accommodate a wide spectrum of realistic physics in the ambient of acoustic propagation, including complex geometries, media, and environmental conditions. The immersed-boundary approach in TSPCE is to use simple structured Cartesian grid mesh to simulate acoustic propagations, where the time-domain simulation is coupled with the immersed-boundary method to accommodate complicated geometries. Properties such as interface between different acoustic propagation media can be effectively modeled. In the presentation, the mathematical formulation and numerical algorithm of TSPACE will be explained, followed by several examples of simulation including sound propagation around arbitrary-shaped porous barriers, noise from unmanned aerial vehicles, diffractions near buildings, array arrangements in sonic crystals in both two and three dimensions, ultrasonic wave propagation in a lossy medium, and acoustic scattering around bubbles. It will also be demonstrated that the simulation results are verified/validated by comparisons to the analytical solutions and measured data in the literature.

Contributed Papers

9:50

1aCA2. Modeling the extended reaction of porous absorbers in time-domain wave-based room acoustic simulations. Finnur Pind (Dept. of Industrial Eng., Mech. Eng. and Comput. Sci., Univ. of Iceland, Sæmundargata 2, Reykjavík 102, Iceland, finnurpind@hi.is), Cheol-Ho Jeong (Dept. of Elec. Eng., Tech. Univ. of Denmark, Lyngby, Denmark), Allan P. Engsig-Karup (Dept. of Appl. Mathematics and Comput. Sci., Tech. Univ. of Denmark, Kgs.-Lyngby, Denmark), Jan S. Hesthaven (Chair of Computational Mathematics and Simulation Sci., Ecole Polytechnique Federale de Lausanne, Lausanne, Switzerland), and Jakob Strømann-Andersen (Henning Larsen, Copenhagen, Denmark)

The absorption properties of room surfaces have a major influence on the acoustics of rooms. In wave-based room acoustic simulations it is common practice to model room surfaces using a local-reaction approximation, instead of modeling the full extended-reaction behavior. However, previous research has indicated that the local-reaction assumption is not appropriate for surfaces that have elastic properties or fluid layers, such as soft porous materials, porous materials backed by an air cavity and airtight membranes. In this talk we present a method for incorporating the extended-reaction behavior of porous absorbers into a time-domain discontinuous Galerkin (dG) based room acoustic simulation scheme. The dG method is attractive for room acoustic simulations due to its flexibility and cost-efficiency. The porous material is modeled using an equivalent fluid model (EFM). The EFM formulation is validated analytically and experimentally, and it is shown that using the EFM leads to significant and perceptually noticeable improvements in simulation accuracy, when modeling single reflections and full room simulations with various types of porous absorbers.

10:05

1aCA3. Binaural reproduction of time-domain spectral element method simulations using spherical harmonic spatial encoding. Anastasios Galanopoulos (Acoust. Technol. Group, Dept. of Elec. Eng., Tech. Univ. of Denmark, Lærkevej 11, Copenhagen 2400, Denmark, anstragal@gmail.com), Finnur Pind (Acoust. and Tactile Eng. group, Dept. of Industrial Eng., Mech. Eng. and Comput. Sci., Univ. of Iceland, Reykjavik, Iceland), Hermes Sampedro Llopis, and Cheol-Ho Jeong (Acoust. Technol. Group, Dept. of Elec. Eng., Tech. Univ. of Denmark, Lyngby, Denmark)

In room acoustic simulations and virtual acoustics, incorporating listener's directivity is crucial for achieving listener's immersion into the simulated sound field and enabling sound localization. Two techniques are presented for extracting spatially encoded signals around a receiver location in a wave-based spectral element method (SEM) numerical scheme. Both are based on the relation between spherical harmonic encoding and the sound field's local pressure gradients. In the first technique, the encoding

equations are solved by employing local finite differences incorporated into the SEM scheme. In the second, an SEM numerical discretization of the encoding equations is derived through the weak formulation of the encoding equations and solved inherently in the SEM scheme. Binaural responses are produced by convolving the computed wave amplitude density with a head-related transfer function. Numerical results from the two techniques are presented, and an excellent agreement is found with finite-difference time-domain simulations. The encoded signal's accuracy in the two SEM techniques is analyzed in terms of the resolution of the numerical discretization. The receiver directivity models run locally, in the time domain, and support interactive auralization with moving and rotating receivers.

10:20

1aCA4. Enhanced modal matching formulation for a cost-efficient computation of the acoustical properties of multi-layer perforated and micro-perforated partitions. Cedric Maury (Lab. of Mech. and Acoust., Ecole Centrale Marseille, Lab. of Mech. and Acoust. (LMA), Marseille 13013, France, cedric.maury@centrale-marseille.fr) and Teresa Bravo (Instituto de Tecnologias Fisicas y de la Informacion, Consejo Superior de Investigaciones Cientificas, Madrid, Spain)

As rigidly backed micro-perforated panels (MPPs) are Helmholtz-type absorbers, their performance is typically limited to narrow frequency bands. The use of multi-layer or multi-array partitions has been widely studied to extend their absorption over a broader range. Optimal selection often requires combination of macro and micro-perforated panels constitutive of the overall partition. However, it is difficult to find a unified impedance model that may account for the whole range of hole diameters variations encountered in an optimization process. In this study, an enhanced multi-modal (EMM) formulation is developed that overcomes limitations for the domain of validity of the MPP parameters. It provides a unit cell transfer impedance that accounts for visco-thermal dissipation and high-order evanescent modes both within the perforation and at the panel walls. It can be used as a Robin-type visco-thermal boundary condition in a pure Acoustic finite element model (FEM) of a complex micro-/macro-perforated structure. This approach leads to a mixed analytical-numerical approach with a much lower computational cost than a full visco-thermal Acoustic FEM model. The inclusion of hole or panel interaction effects is then achieved through the acoustic or structural FEM parts.

10:35

1aCA5. Model order reduction for efficient numerical room acoustic simulations with parametrized boundaries. Hermes Sampedro Llopis (Acoust. & Noise, Rambøll, Lyngby, Denmark, hsllo@elektro.dtu.dk), Allan P. Engsig-Karup (DTU Compute, Tech. Univ. of Denmark, Kgs.-Lyngby, Denmark), Finnur Pind (Acoust. and Tactile Eng., Dept. of Industrial Eng., Mech. Eng. and Comput. Sci., Univ. of Iceland, Reykjavik, Iceland), Cheol-Ho Jeong (Dept. of Elec. Eng. Acoust. Technol., Tech. Univ. of Denmark, Lyngby, Denmark), and Jan S. Hesthaven (Chair of Computational Mathematics and Simulation Sci. (MCSS), Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland)

This study presents a new model order reduction technique applied to room acoustic simulations using a high-order numerical scheme based on the spectral element method. The goal is to efficiently simulate iterative design processes in room acoustics, where the room acoustics with different boundary absorption properties are evaluated much quickly without solving the full wave equation. The wave-based methods are highly accurate but expensive when simulating high-frequencies and long simulation times in large and complex geometries, which are needed for industrial applications. Hence, it remains a key challenge to improve the computational performance of room acoustics simulations with different boundary material possibilities. With model order reduction, the boundary condition can be parametrized in the subsequent modelling. This allows to reduce the dimensionality of a wave-based simulator without compromising the transient wave propagation accuracy while enabling significant reductions of computational costs after initial training using proper orthogonal decomposition. We provide evidence that the combination of the high-order numerical scheme with model order reduction has significant potential value for building acoustics in terms of computational efficiency and accuracy.

10:50–11:00 Discussion

11:00–11:15 Break

Invited Papers

11:15

1aCA6. Boundary element methods based nearfield acoustic holography for fluids with constant flow. Nicolas P. Valdivia (Acoust. Div., Naval Res. Lab., Code 7130, Washington, DC 20375, nicolas.valdivia@nrl.navy.mil)

In this work, we present integral formulations to recover an arbitrarily shaped structure's vibrations from nearfield pressure measurements when the medium contains constant flow. This problem is central to the application of the Nearfield Acoustic Holography (NAH) technique. The classical application of the NAH for arbitrarily shaped geometries utilizes an integral formulation that not includes flow information. In many instances, we can argue that the classical application of NAH will be appropriate for a small subsonic flow instead of the more complicated integral formulations that contain the flow information. The main question that we should ask is how large the flow should be to impact the classical NAH reconstruction. Similarly, we want to quantify the advantage of using the integral formulations with flow information for these conditions. We intend to address these questions using numerically simulated data from point sources. [This work has been supported by the Office of Naval Research.]

11:30

1aCA7. Developing efficient finite element techniques for atmospheric sound propagation. Ray Kirby (Ctr. for Audio, Acoust. and Vib., Univ. of Technol., Broadway, Ultimo, New South Wales 2007, Australia, ray.kirby@uts.edu.au)

Applying the finite element method to problems in atmospheric sound propagation is challenging because the use of a standard approach, such as meshing the entire domain, quickly delivers a prohibitive problem size. The finite element method does, however, offer many advantages such as the ability to accommodate continuous variations in fluid properties, as well as scattering from obstacles of complex geometry. This means the method is ideally placed to provide benchmark solutions for more popular approaches. Accordingly, ideas for developing more efficient versions of the finite element method suitable for atmospheric sound propagation are explored here for two dimensional problems. These are based on the use of one dimensional normal mode expansions, and then mapping these on

to two dimensional solutions for non-uniform obstacles. The normal mode solution for a range independent inhomogenous moving fluid is presented, and numerical mode matching techniques are introduced to demonstrate the inclusion of a point source. The extension of these mode matching methods to accommodate scattering from obstacles is then discussed, and the conditions necessary to deliver efficient finite element solutions are reviewed.

Contributed Papers

11:45

1aCA8. Rough seafloor and target far-field scattering prediction using numerically determined Green's functions. Aaron M. Gunderson (Appl. Res. Labs., The Univ. of Texas at Austin, 10,000 Burnet Rd., Austin, TX 78758, aaron.gunderson01@gmail.com)

Acoustic scattering from rough seafloor, and from targets on and buried within rough seafloor interfaces, is modeled using 3D finite elements to capture the effect of seafloor roughness and variability upon the far-field scattering. Though the model is necessarily small, far-field scattering prediction is achieved using Green's functions determined numerically within the model. Comparisons to experimental measurements and between models demonstrate the effect that seafloor roughness and variation, as well as target orientation, burial, and asymmetry have upon the measured scattering. Numerically determined Green's functions are an efficient method for obtaining long-range scattering prediction out of small, localized models, and are practical for complex geometry situations in which the exact Green's function is difficult to estimate analytically. Best practice techniques for domain truncation in complex environments are also explored and compared in this work. [This work was supported by the Office of Naval Research and by the Strategic Environmental Research and Development Program.]

12:00

1aCA9. Mode coupling and sound field variability in near-coastal area in the presence of internal Kelwin waves. Ernest Uzhansky (Marine Geosciences, Univ. of Haifa, 199 Abba Khouchy Ave. Haifa 3498838, Israel, ernsruzhansky@gmail.com), Andrey Lunkov (General Phys. Inst., Moscow, Russian Federation), and Boris Katsnelson (Marine Geosciences, Univ. of Haifa, Haifa, Israel)

In this paper, propagation of the sound waves in near-coastal wedge-like area is studied in the presence of Internal Kelwin waves (IKW), which cause periodic changes of the thermocline level with daily period. These oscillations initiate variation of the sound field interference structure at the receiving system. In the paper theoretical analysis and numerical modeling of these fluctuations are carried out, it is shown that physical reason of variability of the sound field is specific mode coupling in area where time and range depending eigen values of adiabatic modes are closing to each other (quasi-crossection) in a wedge-like waveguide, periodical displacement of place of this quasi-crossection initiates fluctuations of the sound field. Calculations of modal amplitudes and in turn structure and spatio-temporal variability of the sound field in a waveguide was carried out within the framework of parabolic equation and solution of system of equations of mode coupling. Results are compared with experimental data. [Work was supported by RFBR, Grant 20-05-00119.]

12:15–12:30 Discussion

TUESDAY MORNING, 8 JUNE 2021 — 9:30 A.M. TO 11:15 A.M.

Session 1aEA

Engineering Acoustics: Emerging Topics in Engineering Acoustics I

Thomas E. Blanford, Cochair
The Pennsylvania State University, State College, PA 16804

Caleb F. Sieck, Cochair
Code 7160, U.S. Naval Research Laboratory, 4555 Overlook Ave. SW, Washington, D.C. 20375

Chair's Introduction—9:30

Invited Papers

9:35

1aEA1. Manufacturing and uniformity of grain textured piezoelectric ceramics. Mark Fanton (Appl. Res. Lab., Penn State Univ., 559A Freeport Rd., Freeport, PA 16229, maf146@arl.psu.edu), Beecher Watson (Appl. Res. Lab., Penn State Univ., Freeport, PA), Richard J. Meyer (Appl. Res. Lab., Penn State Univ., State College, PA), and Christopher Eadie (Appl. Res. Lab., Penn State Univ., University Park, PA)

Directional tailoring of performance for ceramic materials has been largely limited to taking advantage of anisotropies in single crystal or composite materials. This presentation outlines the process technology and scale up considerations for tailoring directionally

oriented ceramic microstructures, with a focus on achieving near single crystal performance from highly oriented ceramic piezoelectric materials in the PIN-PMN-PT, and PMN-PZT families of materials. The engineering challenges associated with scaling each step of the manufacturing process for both tape cast approaches and additive manufacturing approaches will be outlined as will observations regarding process variability. In addition, we will discuss modifications to these textured compositions and processes to control performance characteristics such as loss factor and coercive field. The electro-mechanical performance and performance trade-offs of materials for acoustic applications will be discussed.

9:50

1aEA2. Additive manufacturing of textured ceramics. Matthew Michie (NSWC Crane, 300 Hwy. 361, Crane, IN 47522, matthew.michie@navy.mil)

The study of tailoring crystallographic gain orientation has been an area of great interest due to the ability to enhance specific material properties. Bulk textured ceramics are commonly manufactured by aligning seed grains in a polycrystalline material through tape casting. This talk will explore the idea of transitioning this technology into an additive manufacturing process. Discussing the unique challenges of 3D printing ceramic materials and obtaining proper alignment of seed gains while flowing through a nozzle. This talk will detail current efforts to model alignment of seed grains through a nozzles and create new nozzle geometry optimized for aligning particles in a ceramic slurry. This discussion will entail the current prototype materials being created and the final goal of creating textured piezoelectric material to be used in transducer applications.

10:05

1aEA3. The electromomentum coupling in generalized Willis media. Gal Shmuel (Mech. Eng., Technion, Technion City, Haofa 32000, Israel, meshmuel@technion.ac.il), René Pernas-Salomón, Alan Muhafra, Majd Kosta (Mech. Eng., Technion, Haifa, Israel), Daniel Torrent (Institut de Noves Tecnologies de la Imatge, Universitat Jaume I, Castello, Spain), Michael R. Haberman (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), and Andrew N. Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ)

By developing and applying a homogenization scheme for elastodynamics, Willis discovered that the momentum of composite materials is macroscopically coupled with their strain through a constitutive tensor. This now-termed Willis tensor not only enlarges the design space of metamaterials, but is also necessary for obtaining a meaningful effective description that respects basic physical laws. In this talk, I will show how additional tensors of Willis type emerge by generalizing the homogenization theory of Willis to thermoelastic-, piezomagnetic- or piezoelectric media. I will provide examples for the latter case that exhibit an electromomentum coupling. I will show that this coupling is necessary for describing the effective properties of asymmetric piezoelectric media using a homogenized description that respects reciprocity and energy conservation. Finally, I will demonstrate how this coupling can be used to realize a device that actively control the phase of elastic waves.

10:20

1aEA4. Evaluating the impact of acoustic impedance matching on the airborne noise rejection and sensitivity of an electrostatic transducer. Valerie Rennoll (Elec. and Comput. Eng., Johns Hopkins Univ., 3400 N. Charles St., Baltimore, MD 21218, vrennol1@jhu.edu), Ian M. McLane, Adebayo Eisape, Mounya Elhilali, and James West (Elec. and Comput. Eng., Johns Hopkins Univ., Baltimore, MD)

To capture sound from solid mediums, such as the human body or musical instruments, transducers designed for airborne sound pickup are typically used. Acoustic impedance mismatches between the medium and transducer decrease the energy captured and increase noise corruption. Here, we demonstrate the improved sensitivity and airborne noise rejection of an electrostatic transducer with an acoustic impedance matched to the medium of interest. The transducer produces an electrical response when mechanical vibrations compress the distance between an elastomer with patterned microstructures and a charged electret film. Using a statistical model generated through an I-optimal design of experiments, the elastomer is fabricated with a specific polymer and concentration of nanoparticles to possess a targeted acoustic impedance. Transducers containing elastomers with impedances in the range of 1 to 2.2 MRayls are assembled and characterized on simulators emulating the human body and a wooden instrument. The noise rejection is quantified using the coherence between the captured transducer signal and the simulated ambient noise. Sensitivities are similarly characterized by comparing the transducer signal and input simulator signal. With an impedance closely matched to the medium of interest, the transducer demonstrates a 2V/N sensitivity and 35 dB SNR improvement compared to an airborne transducer.

10:35

1aEA5. Engineering acoustic reflections with programmable metasurfaces. Bogdan-Ioan Popa (Univ. of Michigan, Ann Arbor, MI 48109, bipopa@umich.edu)

Acoustic anomalous reflectors have recently drawn intense attention due to their ability to reflect impinging waves in non-specular directions. However, virtually all previously analyzed anomalous reflectors are passive structures with high spatial and/or temporal dispersion. Therefore, they are typically narrowband and unidirectional, namely they operate in the desired manner for only one direction of incidence. We discuss here a method to design quasi-omnidirectional and broadband anomalous metasurface reflectors composed of programmable non-resonant scatterers capable to manipulate the in-plane wave vector component in prescribed ways. We illustrate the method in 3D experiments in which the incident waves undergo negative reflections and show that the desired effect does not depend on the direction of incidence and has a bandwidth an order of magnitude larger than passive designs. Furthermore, we show experimentally that anomalous reflectors of various geometries can be realized by simply rearranging the active scatterers to fill-in the desired geometries as long as the periodicity of the scatterer lattice remains subwavelength. This is direct evidence that the presented metasurfaces behave like continuous materials rather than gratings or phonic crystal. The implications of this finding on the design of future sound manipulation devices will be discussed.

10:50–11:15 Discussion

TUESDAY MORNING, 8 JUNE 2021 9:30 A.M. TO 12:10 P.M.

Session 1aMU

Musical Acoustics, Computational Acoustics and Structural Acoustics and Vibration: Guitar Acoustics

Mark Rau, Cochair
Music, Stanford University, 660 Lomita Court, Stanford, CA 94305

Jonas Braasch, Cochair
School of Architecture, Rensselaer Polytechnic Institute, School of Architecture, 110 8th Street, Troy, NY 12180

Chair's Introduction—9:30

Invited Papers

9:35

1aMU1. Tuning signature modes in guitars—A lesson by Faustino Conde. Robert Mores (Hamburg Univ. of Appl. Sci., Finkenau 35, Hamburg, Deutschland 22081, Germany, robert.mores@haw-hamburg.de)

The low-frequency range strongly determines sound quality in a classical Spanish guitar. In the range above the fundamental air mode *A0* at roughly 100 Hz and below 400 Hz, most guitars reveal one or two main plate/body resonances. A progressive construction from Faustino Conde in 1964 was meant to leverage versatility across classical and flamenco guitar styles, and it reveals four distinct and well-balanced resonances in the mentioned range. Related modes have intensely been discussed for the violin, the so-called signature modes, but not necessarily for the guitar. This contribution points at constructive reasons behind the multiple resonances, identifies related tuning parameters which are finally part of a general analytical model. Analytical results deliver related eigenfrequencies while numerical analyses yield the modes' relative mobility, in agreement with both, an experimental set-up and diverse measurements at the guitar. In conclusion, all guitars could have more than two resonances, but the parametrical space of the four related parameters is wide and the tuning is delicate.

9:50

1aMU2. Measurements and analysis of acoustic guitars during various stages of their construction. Mark Rau (Music, Stanford Univ., 660 Lomita Court, Stanford, CA 94305, mrau@ccrma.stanford.edu)

Vibration measurements were taken at various stages of the construction of three steel-string acoustic guitars. The construction stages include: the unaltered top plate, braced top plate at multiple steps during the brace carving, glued guitar body before and after sanding, and the completed guitar. Measurements were taken with a laser Doppler vibrometer and force hammer to analyze the mode frequencies, damping, and amplitudes, and track how they evolve. The motivation is to investigate which building steps create the most significant vibrational changes and gain insight into the significance of each change. This knowledge can be used to help instrument builders know at which stage they can make specific alterations, and how much variation they can expect to see during the remainder of the construction.

10:05

1aMU3. Reverse-engineering a digital twin of a classical guitar using the finite element method and experimental modal analysis. Alexander Brauchler (Inst. of Eng. and Computational Mech., Univ. of Stuttgart, Pfaffenwaldring 9, Stuttgart 70569, Germany, alexander.brauchler@itm.uni-stuttgart.de), Pascal Ziegler, and Peter Eberhard (Inst. of Eng. and Computational Mech., Univ. of Stuttgart, Stuttgart, Germany)

The classical guitar is not only delighting musicians and audiences worldwide but also scientists are interested in the interplay of the coupled oscillatory systems that constitute the instrument. The bridge couples the plucked strings with the guitar body, which acts as an amplifier to radiate the guitar's sound while being, additionally, coupled strongly with the enclosed air volume. In this contribution, a numerical finite element model of a classical guitar body is presented and compared to experimental data. The guitar's geometry is reverse-engineered from computed tomography scans to a very high level of detail, and care is taken for including all necessary physical influences. Five different sorts of wood used in the guitar are modeled with their corresponding orthotropic material properties, and the fluid–structure interaction between the guitar body and the enclosed air is taken into account in the coupled finite element model. To substantiate the quality of the numerical model, the numerically calculated modal parameters are compared to experimentally identified ones. For this reason, an experimental modal analysis setup employing a scanning laser Doppler vibrometer is proposed, and modal parameters are identified utilizing the complex mode indicator function and enhanced frequency response functions.

10:20–10:45 Discussion

10:45–11:00 Break

Invited Papers

11:00

1aMU4. Numerical and experimental assessment of string gauge influence on guitar tone. Pawel M. Bielski (Faculty of Mech. Eng. and Ship Technol., Gdansk Univ. of Technol., Startowa 21B/14, Gdansk 80-461, Poland, pawbiels@pg.edu.pl), Tomasz Mikulski, and Hanna Pruszko (Faculty of Mech. Eng. and Ship Technol., Gdansk Univ. of Technol., Gdansk, Poland)

String gauge is known for affecting a guitar's tone, playability and volume. It is often a subject of debate between younger players and becomes a staple and signature of older ones. The choice between the heavier or lighter strings is usually made based on personal taste and practical reasons. Although string gauge is intuitively associated with fatter or thinner sound, physics behind string vibration do not necessarily confirm this assumption. In the study, the impact of string gauge on the guitar's tone is assessed in several ways. A numerical study is carried out, introducing a time-domain dynamic analysis of a coupled string-structure system. A basic experimental study is also performed to validate the numerical results. The study is focused on estimation of the three aspects of sound—harmonic composition, sustain and volume—and how they are affected by the guitar's string gauge.

11:15

1aMU5. Virtual strings filter design revisited. Julius O. Smith (Music, CCRMA, Stanford Univ., Stanford, CA 94305, AbstractCentral@w3k.org)

Digital filters have been used for decades to simulate losses and dispersion in real-time vibrating-string models for musical sound synthesis. String-loop filters in digital-waveguide models have generally been very low-order due to CPU limitations on typical available devices. In recent years, CPU speeds have increased so dramatically that very realistic string models can easily run in real time. This presentation revisits filter design for real-time musical string modeling.

11:30

1aMU6. Psychoacoustic phenomena in electric-guitar performance. Jonas Braasch (School of Architecture, Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180, braasj@rpi.edu), Joshua L. Braasch (Trans-genre Studio, Latham, NY), and M. Torben Pastore (College of Health Solutions, Arizona State Univ., Tempe, AZ)

Early prototypes of the electric guitar were created at about the time public address systems were invented in the 1930s, with the pure intention of making the instrument louder. However, it was not until the 1950s when artists like Link Wray, Chuck Berry, and Ike Turner used non-linear distortion as the first electronic effect to transform the electric guitar into a fundamentally new instrument. The effect adds higher harmonics and improves sustain, allowing for long notes and spectral presence. Several other effects and techniques followed (*e.g.*, delay, chorus, flanger, phaser, tremolo, equalization, and compression), which were often used to blend the electric guitar into a band mix or to help it sonically stand out. Interestingly, the apparatus used for psychoacoustic research stems from the same electronic-circuit innovations that founded the electric guitar's electronic-effect industry. This presentation will focus on computational auditory scene analysis of variously effected guitar tracks embedded in a whole band mix to determine how these effects are used to make the guitar blend in (fusion) or stand out (transparency). To investigate this, model parameters related to loudness, masking, spaciousness, and modulation detection will be computed from audio tracks.

11:45–12:10 Discussion

TUESDAY MORNING, 8 JUNE 2021 9:30 A.M. TO 12:20 P.M.

Session 1aNS

Noise: Pandemic Noise Reduction/Impact I

Kirill V. Horoshenkov, Cochair
Department of Mechanical Engineering, University of Sheffield, Sheffield S10 2TN, United Kingdom

Abigail Bristow, Cochair
Department of Civil and Environmental Engineering, University of Surrey, Guildford GU2, United Kingdom

Chair's Introduction—9:30

Invited Papers

9:35

1aNS1. COVID-19 related sound reduction. Soundscape changes during Peruvian de-escalation and "abnormal" opening. Walter A. Montano (Tech., ARQUICUST, #1227 Luis Clavarino St., Gualeguaychu, Entre Rios 2820, Argentina, montano_walter@yahoo.com.ar)

The COVID-19 outbreak has changed the worldwide way of life. In March 2020, Peru declared a State of Emergency and defined different phases to control the virus spreading, and as a result of the lockdown, Peruvian cities sound levels were reduced as never before imagined. The author installed a noise sensor before the pandemic on a rooftop to record the overflights sound levels, since the office building is in a residential area, which is near to the aircraft climbing curve towards the ocean on departure from Lima. The author published in *JASA* an article with the soundscape analysis of Lima, Peru, registered by the device between March through June 2020, so all soundscape changes have been measured as a consequence of flight suppression (due to the airport lockdown) and also because of a ban on traffic circulation in streets and curfew to reduce social distancing. In this paper, the author will analyze the sound levels registered from July through December 2020, which includes all de-escalation stages, the restart of non-essential activities and the partial opening of Lima international airport. The most important result of this survey is to have been able to measure the nighttime aircraft noise impact, in order to assess their noise annoyance, mainly from those which overflight at dawn that they are capable of producing sleep interruption.

9:50

1aNS2. Drop and restoration of noise levels in Madrid during the first year of the COVID-19 pandemic. César Asensio (Universidad Politécnica de Madrid, c/ Mercator 2, Madrid 28031, Spain, c.asensio@upm.es), Ignacio Pavón, and Guillermo de Arcas (Universidad Politécnica de Madrid, Madrid, Spain)

From 12 March to 7 June 2020, the Madrid region experienced one of the most severe lockdowns in Europe, to contain the advance and consequences of COVID-19. The closure of schools, the cancellation of crowded events, the closure of bars and restaurants, and the regional closure, together with the strong encouragement to stay home and to telework, led to a very strong reduction of traffic levels in the city and an absence of people on the streets. As a result, noise levels in the region were dramatically reduced for a few months. After the end of the most severe phases of confinement, activity in Madrid is still recovering, and with it, noise levels are returning to pre-covid values. In this video I will show the acoustic effect of the lockdown registered by the noise monitoring networks of the city of Madrid and Madrid's airport, and I will discuss the relationship that has been observed between acoustic and health variables in the region.

10:05

1aNS3. Acoustic environments and Soundscapes in London during the Spring 2020 Lockdown. Jian Kang (UCL Inst. for Environ. Design and Eng., Univ. College London, Central House, 14 Upper Woburn Pl., London WC1H 0NN, United Kingdom, j.kang@ucl.ac.uk), Francesco Aletta, Tin Oberman, Andrew Mitchell, and Huan Tong (Univ. College London, London, United Kingdom)

Three studies in London are presented about the changes of the acoustic environment and its perception, triggered by the first lockdown measures imposed during Spring 2020 because of the COVID-19 outbreak. The first study compared short-term binaural recordings performed pre- and during-lockdown at 11 public locations. Results revealed the decreases in sound levels varied from 1.2 to 10.7 dB(A) depending on the urban setting type. The second study made use of soundscape data gathered from users on site for the pre-lockdown survey to construct a model to predict how the lockdown soundscapes of the same locations (which were impossible to assess due to lack of people) would be experienced. A further validation listening experiment confirmed that lowering levels was not always followed up by improved experience. The third study looked at changes in noise complaints reported by residents to local authorities across the London boroughs and highlighted an increase of 47.5%, with neighborhood noise being the most relevant category. Taken together, the results from these studies demonstrate reduced urban activity leads to uneven sound level reduction across urban spaces and that significant sound level reductions do not universally result in improvements to the soundscape, whether in public spaces or at home.

10:20

1aNS4. Noise and air pollution during lockdown around a school site in the UK. Prashant Kumar, Hamid Omidvarborna, Abhijith Kooloth Valappil (Civil and Environ. Eng., Univ. of Surrey, Guildford, United Kingdom), and Abigail Bristow (Dept. of Civil and Environ. Eng., Univ. of Surrey, Guildford GU2, United Kingdom, a.l.bristow@surrey.ac.uk)

Noise and air pollutants share many common sources including traffic volume. Noise pollution causes annoyance and disturbs sleep and it is the second risk factor, after air pollution, to the estimated environmental burden of disease in Europe. It can also act as a proxy for some of the air pollutants, to allow building of holistic view of environmental pollution. During the pandemic and the resulting lockdowns in cities across the world, traffic volumes reduced significantly, leading to reduced pollutant concentrations and noise levels. In this work, we present an analysis of the multiple pollutants (*e.g.*, fine particulate matter, nitrogen oxide) and noise data that are monitored continuously during the lockdown at 15-minute resolution at a school site in the UK, which is situated next to a busy road. This talk will present trends of noise and the air pollutants during the lockdown period, explore possible relationship of noise as a proxy for air pollutants; variations between pollutants and the underlining reasons explaining the temporal variations. [This work is supported by Guildford Living Lab and INHALE (EP/T003189/1). We thank the Sandfields Primary school, its governors and the parent group for supporting this work.]

1a TUE. AM

10:35–10:50 Discussion

10:50–11:05 Break

Invited Paper

11:05

1aNS5. The quiet project-UK acoustic community's response to COVID-19. Stephen Dance (School of the Built Environment and Architecture, London South Bank Univ., Borough Rd., Torquay Rd., London SE1 0AA, United Kingdom, dances@lsbu.ac.uk) and Lindsay McIntyre (Acoust., KSGroup, Glasgow, United Kingdom)

The COVID-19 Lockdown created a new kind of environment both in the UK and globally, never experienced before or likely to occur again. A vital and time-critical working group was formed with the aim of gathering crowd-source high quality baseline noise levels and other supporting information across the UK during the lockdown and subsequent recovery period. The acoustic community were mobilised through existing networks engaging private companies, public organisations, and academics to gather data in accessible places. A website was designed and developed to advertise the project, provide instructions and to formalise the uploading of noise data, observations, and Soundscape feedback. In addition, pre-existing on-going measurements from major infrastructure projects, airport, and planning applications were gathered to create a data repository of 1.6 GB. The plan was to have regular 6 monthly national noise surveys, which turned into multiple Lockdown surveys. Noise data has been compared to the traffic flow data from the TRIS national wide permanent monitoring system. Ultimately, the databank will be used to establish the relation to other impacts such as air quality, air traffic, economic, and health and wellbeing. As publicly funded research the databank will be made publicly available to assist future research.

Contributed Paper

11:20

1aNS6. Changes in statistical traffic noise descriptors during COVID-19. McCall Edwards (Veneklasen Assoc., 1711 16th St., Santa Monica, CA 90404, medwards@veneklasen.com), Wayland Dong, John Lo Verde, and Samantha Rawlings (Veneklasen Assoc., Santa Monica, CA)

Road traffic noise assessments are based on noise indicators, which were traditionally based on long-term average levels such as L_{dn} and L_{night}. Newer regulations also include the "loudest" hourly L_{eq}, although the loudest hour is not defined nor is any guidance provided for determining it. Previous work has focused on methods for estimating these noise indicators from short-duration measurements and determining the uncertainty and reliability of those estimates. The analyses were based on statistical analyses of time history noise levels recorded at various cities across Connecticut and California as well as Dublin, Ireland [King *et al.*, in Noise-con (2016)]. Preliminary analysis of the changes in traffic patterns during to the COVID-19 pandemic showed that the hourly and daily variability increased significantly, with implications for the uncertainty of noise descriptors estimated from measurements. In this paper, an additional six months of traffic data are presented. The analysis presented looks at how the increased variability affects the definition and measurement of both average and loudest hourly levels and the uncertainties of the measurements.

Invited Papers

11:35

1aNS7. Impact of United Kingdom lockdown on subsea noise from vessel propulsion. Jeffrey Neasham (School of Eng., Newcastle Univ., Merz Court, Holystone, Newcastle upon Tyne NE17RU, United Kingdom, jeff.neasham@ncl.ac.uk) and Gavin Lowes (School of Eng., Newcastle Univ., Newcastle upon Tyne, United Kingdom)

As part of the EPSRC funded project Smart Dust for Large Scale Underwater Wireless Sensing (USMART) autonomous subsea vessel detectors have been developed which use passive acoustic sensing to detect the signature of cavitation noise from vessel propellers. These are low cost, low energy devices capable of long deployments of 6 + months which deliver near real time data on vessel detections via an acoustic/RF communication network. Since they are capable of detecting vessels that have no AIS or similar transponder, they provide a more complete picture of vessel traffic including unauthorised/illegal activity. An experimental deployment of a device off the Northumberland Coast spanned the enforcement of lockdown in the UK on 23rd March 2020. This led to an immediate reduction in marine traffic, especially fishing boats and other small vessels, which was clearly measured by the vessel detector. In this presentation we will briefly describe the acoustic technology, the results obtained and show how simple power spectral analysis of nearby hydrophone recordings was barely able to measure this difference. This leads to the conclusion that detecting vessel signature noise is a more effective way of quantifying the impact on anthropogenic noise.

11:50

1aNS8. Increasing Intensity: the sounds of church bells in Australia one year after COVID-19. Dirk H. Spennemann (Inst. for Land, Water and Society, Charles Sturt Univ., P.O. Box 789, Albury, New South Wales 2640, Australia, dspennemann@csu.edu.au) and Murray Parker (School of Environ. Sci., Charles Sturt Univ., Albury, New South Wales, Australia)

The COVID-19 pandemic has demonstrated how a stochastic disruptive event can dramatically alter community soundscapes. Whilst religious bells are symbolic in rituals in many faiths worldwide, the sound emanating from church bells can be by nature considered public domain and are therefore not exclusive to the church. Pandemic-related interruption of these sounds impacts not only the church involved, but both the surrounding soundscape and any members of the community who ascribe value to these sounds. We examine the soundscape of Christian churches in New South Wales, to give an Australian perspective one year on from the declaration of the COVID-19 pandemic. We provide an update of the situation in Australia, building on our previous work from August 2020. In doing so, we explore two different patterns of church bell ringing; change ringing and directed calling, and how each of these "non-essential" activities have been affected, both during and subsequent to the heavy community restrictions applied in Australia. We also explore to what lengths bell-ringers have undertaken to be permitted to conduct such activities, such as the use of protective equipment and/or "social distancing," and consider what projections could be applied to similar soundscapes elsewhere in the world.

12:05–12:20 Discussion

Session 1aPA

Physical Acoustics, Computational Acoustics, Biomedical Acoustics, Structural Acoustics and Vibration, and Signal Processing in Acoustics: Acoustic Wave Propagation Through Polydisperse Scatterers I

Nicholas Ovenden, Cochair
Dept. of Mathematics, University College London, London WC1E 6BT, United Kingdom

Eleanor P. Stride, Cochair
Institute of Biomedical Engineering, University of Oxford, Oxford OX3 7DQ, United Kingdom

Chair's Introduction—9:50

Invited Papers

9:55

1aPA1. Contrast agent microbubble scattering in response to sub-resonant ultrasonic driving. Paul Prentice (Univ. of Glasgow, James Watt South Bldg., Glasgow G12 8QQ, United Kingdom, paul.prentice@glasgow.ac.uk)

Much of the literature describing contrast agent microbubble response to ultrasound, details exposure to frequencies of 1 MHz, or above. The application of microbubble-mediated and transcranial focused ultrasound therapy of the brain, however, is clinically administered at 220 kHz to achieve adequate transmission across the skull. This excitation frequency is an order of magnitude below accepted values for microbubble resonances, yet fundamental studies of such sub-resonantly driven microbubble activity have only recently started to emerge. In this presentation our recent high-speed imaging-based investigations of single and multiple clinically approved microbubbles, exposed to sub-MHz focused ultrasound, will be reviewed. The observations indicate that the well documented microbubble response to higher frequencies, may not be applicable to lower frequency therapeutic driving. Specifically, periodic bubble-collapse generated pressure impulses are shown to account for all non-linear scattering, including subharmonics, harmonics and broadband noise, dependent on the amplitude of the driving [Song *et al.*, in UMB (2019)]. A new mechanism for microbubble-jetting, which occurs spontaneously on interaction between the microbubble at first inflation, and the pressure gradients within the initial cycles of a burst of sub-MHz focused ultrasound, will also be described [Cleve *et al.*, in UMB (2019)].

10:10

1aPA2. Pulsed ultrasound propagation through polydisperse contrast agent suspensions. Nicholas Ovenden (Dept. of Mathematics, Univ. College London, London WC1E 6BT, United Kingdom, n.ovenden@ucl.ac.uk), Eleanor P. Stride (Univ. of Oxford, Oxford, United Kingdom), and Jean-Pierre O'Brien (Mathematics, Univ. College London, London, United Kingdom)

Gas microbubbles stabilised by a surfactant or polymer coating are widely used in echocardiography and, increasingly, for quantitative studies of tissue perfusion. It is their highly nonlinear response to ultrasound excitation that makes them such effective contrast agents. It is this property also, however, that leads to image artefacts and difficulties in obtaining accurate quantitative information. There are few theoretical models describing the response of a contrast agent population that take into account both nonlinear behaviour and multiple bubble interactions. Computational complexity arises when the medium contains a polydisperse bubble population because a nonlinear ordinary differential equation (ODE) governing the bubble response must be computed for the current radius of each bubble size R_0 present at each spatial location at every time step, which unfortunately makes the numerical model impractical for real-time clinical use. Further complexity occurs when near-resonant microbubbles shed their lipid coating drastically transforming the suspension's acoustic response to subsequent pulses. In this work, we investigate approximations that can significantly reduce the computational complexity and demonstrate that, under certain parameter regimes, these approximations can simulate the nonlinear propagation of a repeated ultrasound pulses through a polydisperse contrast agent suspension to reasonably high accuracy.

10:25

1aPA3. A statistics-based model for cavitating polydisperse bubble clouds and their two-way-flow coupling. Spencer H. Bryngelson (California Inst. of Technol., 1200 E California Ave., MC104-44, Pasadena, CA 91125, spencer@caltech.edu) and Tim Colonius (California Inst. of Technol., Pasadena, CA)

Phase-averaged bubbly flow models require statistical moments of the evolving bubble dynamics distributions. Under step forcing, these moments reach a statistical equilibrium in finite time. However, actual flows entail time-dependent pressure forcing and equilibrium is generally not reached. In such cases, the statistics of the evolving bubble population must be represented and evolved. Since phase-averaged models compute these moments point-wise, a low-cost algorithm for this evolution is of particular significance for large-scale simulations. We present a population-balance-based method for this purpose. The bubble dynamic coordinates are treated via

a quadrature moment method and conditioned on the equilibrium bubble size. Statistics in the equilibrium bubble size coordinate are computed using a fixed quadrature rule and averaged over the period of bubble oscillation. Results show that two quadrature points in each of the bubble dynamic coordinates are sufficient to quantitatively reproduce key statistics. Further, averaging is shown to remove oscillatory behaviors that do not contribute to the moments. Together, this results in a method capable of tracking the bubble population statistics with significantly less computational expense than Monte Carlo approaches. The generality introduced by including statistics in the bubble dynamics coordinates is explored via acoustically excited bubble screen problems.

10:40

1aPA4. The iterative nonlinear contrast source method for simulating ultrasound propagation through a polydisperse microbubble population. Agisilaos Matalliotakis (Medical Imaging, Imaging Phys., Delft Univ. of Technol., Lorentzweg 1, Delft 2628 CJ, the Netherlands, a.matalliotakis@tudelft.nl) and Martin D. Verweij (Medical Imaging, Imaging Phys., Delft Univ. of Technol., Delft, the Netherlands)

Multiple scattering of sound by a population of particles attracts scientific interest for many decades. In contrast-enhanced echography, the simulation of ultrasound propagation through a dense cloud of nonlinearly oscillating microbubbles imposes a numerical challenge. This is particularly the case for polydisperse concentrations in which each scatterer has individual and independent properties. To address this problem, the Iterative Nonlinear Contrast Source (INCS) method has been adapted. Originally, this solved the Westervelt equation by letting its nonlinear term represent a contrast source in a "linearized" medium, and iteratively updating the pressure by computing the 4D spatiotemporal convolution between this source and the Green's function. Because convolution allows a coarse discretization, INCS is suitable to deal with large-scale problems. In this talk, microbubbles are regarded as nonlinearly responding point sources that act as contrast sources. The total scattered pressure is computed iteratively, as in the original method, but now in each iteration the temporal signature of the contrast sources is calculated by solving every bubble's own Marmottant equation. Physically, each iteration accounts for an order of multiple scattering. Numerical results will also be presented, demonstrating that INCS can accurately and efficiently simulate ultrasound propagation through a 3D population of polydisperse nonlinear microbubbles.

10:55–11:10 Break

Contributed Papers

11:10

1aPA5. Weakly nonlinear evolution of pressure waves in a polydisperse bubbly liquid. Takuma Kawame (Univ. of Tsukuba, Tennoudai 1-1-1, Tsukuba City 305-0006, Japan, kawame.takuma.ta@alumni.tsukuba.ac.jp) and Tetsuya Kanagawa (Eng. Mech. and Energy, Univ. of Tsukuba, Tsukuba, Ibaraki, Japan)

Weakly nonlinear propagation of plane pressure waves in initially quiescent liquids containing spherical bubbles with a small initial polydispersity of the bubble radius and bubble number density is theoretically studied to clarify the effect of the polydispersity on wave propagation. The wavelength is comparable with the bubble radius and the incident frequency of waves is with an eigenfrequency of the bubble. We consider two different cases of the size of the polydispersity (*i.e.*, small and large polydispersities) and assume that the polydispersity appears at a field far from a sound source. The polydispersity is formulated into a set of perturbation expansions. Bubble oscillations are spherically symmetric, and bubbles do not coalesce, break up, appear, and disappear. The basic set is composed of the conservation laws of mass and momentum for gas and liquid phases based on a two-fluid model, equation of motion for bubble wall, and so on. From the perturbation analysis up to the third order of approximation, two cases of nonlinear wave equation for a long-range propagation of waves were derived. We concluded that the polydispersity affects the advection of waves and is expressed as a variable coefficient.

11:25

1aPA6. Theoretical analysis on thermal effect of weakly nonlinear propagation of focused ultrasound toward medical applications. Shunsuke Kagami (Eng. Mech. and Energy, Univ. of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8573, Japan, kagami.shunsuke.sw@alumni.tsukuba.ac.jp) and Tetsuya Kanagawa (Eng. Mech. and Energy, Univ. of Tsukuba, Tsukuba, Ibaraki, Japan)

Toward medical applications such as a tumor ablation therapy by High-Intensity Focused Ultrasound (HIFU), weakly nonlinear propagation of quasi-planar focused ultrasound in a liquid containing many spherical microbubbles is theoretically investigated, especially focusing on thermal effects of microbubble oscillations. We shall derive a Khokhlov–Zabolotskaya–Kuznetsov (KZK) type equation incorporating the thermal effects of the microbubble oscillations by introducing the energy equation proposed by Prosperetti [*J. Fluid Mech.* (1991)] into the set of basic equations based on mixture and two-fluid models. Moreover, the phase difference between the temperature gradient and the average temperature inside bubble is considered in the energy equation. As a result, we found that (i) the thermal conduction of gas inside bubbles strongly affects the dissipation of ultrasound and (ii) the phase difference affects the advection of ultrasound.

11:40–12:05 Discussion

Session 1aPP

Psychological and Physiological Acoustics: Open Source Audio Processing Platform—Live Workshop!

Odile Clavier, Chair
Creare, Hanover, NH

Chair's Introduction—9:30

This workshop introduces the Tympan Open Source Audio Processing and Hearing Aid Platform (www.tympan.org), which wraps powerful audio hardware and software tools in a user-friendly app and novice programming environment. The workshop will feature live virtual tutorials and four short presentations on four different ways the tympan has been used before: (1) as a sound level meter for impulsive noise environments; (2) as a device to communicate using the ultrasonic frequency range; (3) as a way to conduct hearing aid research; and (4) a presentation on performance metrics for sound processing. We will follow these presentations with an open Q&A, and an invitation to participate in a hackathon challenge. Participants to the hackathon will be invited to present their results at the Fall 2021 ASA meeting. Participants may come from all ASA committees and are not limited to Physiological and Psychological Acoustics or hearing aid research.

Panelists include: Christopher Smalt, MIT Lincoln Lab.; Daniel Rasetschwane, Boys Town National Research Hospital; Eric Yuan, Creare LLC; Joel Murphy, Tympan.org; Joshua Alexander, Purdue Univ.; Marc Brennan, Univ. of Nebraska; Odile Clavier, Creare LLC; William (Chip) Audette, Creare LLC

Session 1aSC

Speech Communication and Psychological and Physiological Acoustics: Ideas Worth Reconsidering in Speech Perception and Production I

Matthew B. Winn, Cochair
Speech-Language-Hearing Sciences, University of Minnesota, 164 Pillsbury Dr. SE, Shevlin Hall Rm 115, Minneapolis, MN 55455

Richard A. Wright, Cochair
Department of Linguistics, University of Washington, Box 352425, Seattle, WA 98195-2425

Chair's Introduction—9:30

Invited Papers

9:35

1aSC1. Reconsidering reading span as the sole measure of working memory in speech recognition research. Adam K. Bosen (Boys Town National Res. Hospital, 555 North 30th St., Omaha, NE 68131, adam.bosen@boystown.org)

Although it is generally accepted that speech recognition depends on working memory, it can be difficult to delineate the roles of different aspects of working memory in speech recognition. A limitation of many studies relating speech recognition and working memory is the reliance on a single measure of working memory, often reading span. While reading span is a valuable assessment of working memory, its association with several aspects of cognition makes its connection to speech recognition difficult to interpret when used in isolation. Here, we present the benefits of using a combination of different stimuli, listening conditions, and tasks to assess working memory. By varying the stimuli and listening conditions in a serial recall task we isolated serial recall ability from difficulty identifying words in adverse listening conditions. Separating these aspects allowed us to characterize their relationship with vocoded sentence recognition. We also found that recognition of vocoded speech in the presence of two-talker competing speech was precited to the same extent by serial recall, free recall, and reading span tasks, which indicates that alternative tasks are viable for assessing the aspects of working memory which support speech recognition. We encourage assessing working memory ability with multiple short memory tasks.

9:50

1aSC2. The McGurk illusion. Kristin J. Van Engen (Psychol. and Brain Sci., Washington Univ. in St. Louis, One Brookings Pl, Campus Box 1125, St. Louis, MO 63130, kvanengen@wustl.edu)

In 1976, Harry McGurk and John MacDonald published their now-famous article, "Hearing Lips and Seeing Voices." The study was a remarkable demonstration of visual influence on auditory speech perception: when an auditory stimulus (*e.g.*, /ba/) was presented with the face of a talker articulating a different syllable (*e.g.*, /ga/), listeners experienced an illusory percept distinct from both sources (*e.g.*, /da/). In the subsequent 45 years, this effect has been used in countless studies of audiovisual processing in humans. It is typically assumed that people who are more susceptible to the illusion are better audiovisual integrators. However, when it comes to understanding multisensory speech perception, there are several reasons to argue that McGurk stimuli are poorly suited to the task. Most problematic is the fact that McGurk stimuli rely on audiovisual incongruence that never occurs in real-life audiovisual speech perception. Furthermore, recent studies show that susceptibility to the effect does not correlate with performance during audiovisual speech perception tasks. This presentation will review these issues, arguing that, while the McGurk effect is a fascinating illusion, it is the wrong tool for understanding the combined use of auditory and visual information during speech perception.

10:05

1aSC3. A review of the effect of musical training on neural and perceptual coding of speech. Kelly L. Whiteford (Psych., Univ. of Minnesota, N218 Elliott Hall, 75 East River Parkway, Minneapolis, MN 55414, whit1945@umn.edu), Angela Sim, and Andrew J. Oxenham (Psych., Univ. of Minnesota, Minneapolis, MN)

Several studies have reported enhanced neural coding of stimulus periodicity (frequency following response; FFR) and/or shorter neural response latencies to speech sounds in musicians than in non-musicians. Such enhanced early encoding may underlie the reported musician advantage for perceiving speech in noise. If such perceptual benefits are confirmed, it is possible that musical training may be an effective intervention for offsetting the decline of this important skill with age. This presentation will review evidence for and against the musician advantage in the neural coding and perception of speech, and will highlight several reasons to be cautious of the generalizability of the musician advantage in the published literature, including (1) small sample sizes, (2) varying definitions of musician and non-musician, (3) dichotomous between-group comparisons (*e.g.*, comparing professional musicians to non-musicians), (4) possible

speech-corpus specific effects, and (5) the multitude of degrees of freedom in FFR analyses. Efforts towards large-sample replications that use open science techniques, including preregistered hypotheses, methods and analyses, as well as open source data, should bring clarity to the association between musical expertise and the neural coding and perception of speech in noise. [Work supported by NIH under Grant R01 DC005216 and NSF-BCS under Grant 1840818.]

10:20

1aSC4. Categorical perception: Lessons from an enduring myth. Bob McMurray (Psychol. and Brain Sci., Univ. of Iowa, 278 PBSB, Iowa City, IA 52245, bob-mcmurray@uiowa.edu)

Categorical perception holds a unique place in cognitive science. In terms of its impact on other fields, it is likely the most impactful finding in speech perception over the last 60 years. However, within speech perception, it is widely known to be largely an artifact of task demands. Categorical perception is empirically defined as a relationship between phoneme identification and discrimination. As discrimination tasks do not appear to require categorization, such linkage violates psychophysical laws and was thought to support the claim that listeners perceive speech solely in terms of linguistic categories. However, 50 years of work using a variety of discrimination tasks, priming, the visual world paradigm, and event related potentials has roundly rejected this account. In this talk, I explore the origins and impact of this scientific meme and the work challenging it. This leads to a new understanding of how to use and interpret some of the most basic techniques of speech—phoneme identification along a continuum—and to new ways of understanding the role of sensitivity to withing category variation. This has major implications for understanding language and hearing disorders and development.

10:35

1aSC5. A critical look at commonly used stimuli in speech perception experiments. Matthew Winn (Speech-Language-Hearing Sci., Univ. of Minnesota, 164 Pillsbury Dr. SE, Minneapolis, MN 55455, mwinn83@gmail.com) and Richard A. Wright (Linguist, Univ. of Washington, Seattle, WA)

Speech is an attractive stimulus to use for testing the auditory system because it is both highly relevant to everyday life and also replete with acoustic complexity that can test a variety of auditory skills. This presentation shines a light on some commonly used test stimuli or stimulus practices and raises questions about their use, or the interpretations of previous results. For example, the vowel acoustic data published by Hillenbrand *et al.* (1995) has been adopted as a de facto gold standard even though it was intended as a snapshot of a single dialect at a particular point in time. In that paper, the dynamics of vowel spectra were emphasized, though this aspect of vowels has been often overlooked. In consonant testing, the use of the /a/ context is pervasive, and yet this consonant environment is far from "neutral," especially in situations where perception of voicing/voice onset time is measured. Perception of consonants and words will be examined with regard to their generalization to perception of longer utterances. Finally, we will examine the balance between convenience and generalizability, including strengths and weaknesses of closed-set speech stimuli.

10:50–11:05 Break

11:05

1aSC6. Words matter: Analyzing lexical effects on recognition and effort using normed word stimuli. Stefanie E. Kuchinsky (Univ. of Maryland, 7005 52nd Ave., College Park, MD 20742, skuchins@umd.edu), Niki Razeghi, and Nick B. Pandza (Univ. of Maryland, College Park, MD)

Clinical assessments of speech-perception difficulties involve speech-in-noise tests in which individuals recognize words (or sentences) at varying signal-to-noise ratios (SNRs). Words are presented in lists that have been balanced based on their phonetic properties or on their average intelligibility in quiet from norming studies. Such list-wise balancing presumably allows for generalizations to be drawn about the difficulty of an SNR irrespective of word-level difficulty. However, differences in the lexical properties of items (*e.g.*, lexical frequency) may yield substantial variability in how hard individuals work to recognize each word, especially in poorer SNRs. To demonstrate the impact of word-level factors on assessments of listening difficulty, I will present the results of a study with 26 younger, normal-hearing adults. Participants recognized 160 monosyllabic words in noise from the Northwestern University Auditory Test Number Six (NU-6) in acoustically and cognitively demanding conditions. Multilevel models simultaneously assessed word-level (lexical frequency) and participant-level effects on a dual-task measure of listening effort. Results revealed interactions among acoustic, lexical, and cognitive demands on effort, even for items that were correctly identified. These findings highlight the importance of considering item-level difficulty on speech recognition tests even when using normed speech materials. [This work is supported by NIH/NIDCD R03DC015059.]

11:20

1aSC7. Is speech perception what speech perception tests test? Timothy Beechey (Speech-Language-Hearing Sci., Univ. of Minnesota, 115 Shevlin Hall, 164 Pillsbury Dr. SE, Minneapolis, MN 55455, tbeechey@umn.edu)

Speech signals employed in clinical and research contexts are thought to be realistic or representative to the extent that they consist of phonetic, lexical, and morphosyntactic content. These characteristics may be assumed to ensure that speech perception tests are representative of the demands of real-world speech perception and understanding, and therefore that these tests are predictive of real-world speech understanding. However, there are numerous reports of discrepancies between the results of speech perception tests and real-world speech understanding and hearing device benefit. To make optimal use of existing speech tests, and to design more predictive speech tests in the future, it is important to consider how clinical and research speech tests do and do not represent the process and demands of everyday speech understanding. Speech and language examples from a single talker engaged in conversation with a hearing-impaired interlocutor in a range of realistic acoustic environments will be contrasted with widely used recordings of BKB sentences produced by the same talker. The absence of much natural variation in standard speech test materials, as well as a failure to quantify perception of information which cannot be captured orthographically, will be discussed as limitations to the generalizability of standard speech test results.

11:35

1aSC8. Reconsidering variability in child speech production. Margaret Cychosz (Hearing and Speech Sci., Univ. of Maryland, 7251 Preinkert Dr., College Park, MD 20742, mcychosz@umd.edu)

Child speech is highly variable between and within speakers. This pattern has traditionally been explained by a lack of motor routine and articulatory control in the developing speech-motor apparatus. But the assumption that child speech is inherently variable—and the result of motor development and control—may be premature. Recent work suggests that some child speech variation may instead be attributable to errors in measurement: children's high fundamental frequencies make many traditional acoustic measures, such as formant tracking, unreliable and variable. Additionally, child speech variation can often be explained by experiential factors, such as the size of the lexicon or the type and quantity of language exposure. This talk will report on these and other recent findings that suggest a need to reconsider the prevalence of, and reasons for, variability in young children's speech.

11:50

1aSC9. Reconsidering "articulatory effort" as an explanatory force. Sarah Bakst (SRI Int., 333 Ravenswood Ave., Menlo Park, CA 94025, sarah.bakst@sri.com)

Phoneticians and phonologists have long appealed to the concept of "articulatory effort" to explain various phenomena. Oxygen consumption has been measured as a proxy for articulatory effort, and indeed, increased consumption has been observed for louder or faster articulatory movements (Moon and Lindblom, 2003). Other work has relied on the intuition that changing the position or shape of the articulators requires effort, and the speech production system seeks to minimize that effort expenditure. However, this effort minimization is constrained by the need to maintain phonetic contrasts. This talk will present recent work on individual differences in articulatory variability in reconsideration of the explanatory power of the concept of articulatory effort.

12:05–12:30 Discussion

TUESDAY MORNING, 8 JUNE 2021 9:30 A.M. TO 11:15 A.M.

Session 1aSPa

Signal Processing in Acoustics, Engineering Acoustics, Underwater Acoustics, Physical Acoustics, and Structural Acoustics and Vibration: Signal Processing Methods and Applications for Autonomous Vehicles

Amanda Lind, Cochair
Hardware Sensors, Acoustics, San Francisco, CA

George Sklivanitis, Cochair
Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431

Chair's Introduction—9:30

Contributed Papers

9:35

1aSPa1. Passive acoustic detection and tracking of an unmanned underwater vehicle from motor noise. Kristen Railey (MIT/ WHOI, 77 Massachusetts Ave., Cambridge, MA 02139, krailey@mit.edu), Dino Dibiaso (Draper, Cambridge, MA), and Henrik Schmidt (MIT/ WHOI, Cambridge, MA)

Using passive acoustics to distinguish unmanned underwater vehicles from other marine traffic in a complex environment and tracking a vehicle to understand its intent is critical for harbor security. Ships and boats can be classified by their unique acoustic signature due to machinery vibration and detection of envelope modulation on (cavitation) noise. However, cavitation noise of unmanned underwater vehicles is quieter than these vessels, and bearing-only measurements using a stationary array are insufficient for tracking. Tracking accuracy depends on the quality of acoustic measurements, such as high SNR, and observability, estimating vehicle state from the data available. In this work, we demonstrate that it is possible to passively track a vehicle from high-frequency motor noise using a stationary array in a shallow water experiment with passing boats. Motor noise provides high SNR measurements of bearing, bearing rate, propeller rotation, and range rate that are combined in an Unscented Kalman Filter to track the vehicle. First, receiver operating characteristic curves are generated to evaluate detection and false alarms. Conventional beamforming is applied to estimate bearing and bearing rate. Range rate is calculated from the Doppler effect of the motor noise. Propeller rotation is estimated from sideband spacings in the motor signature. [Work supported by Draper, ONR, and DARPA.]

9:50

1aSPa2. Glider-based passive bottom reflection-loss estimation: Proof of concept. Lanfranco Muzi (Ocean Networks Canada, Univ. of Victoria, 2474 Arbutus Rd., 100, Victoria, BC V8N 1V8, Canada, muzi@oceannetworks.ca), Scott Schecklman (Adv. Mathematics Applications Div., Metron, Inc., Portland, OR), Martin Siderius (Elec. and Comput. Eng., Portland State Univ., Portland, OR), and Peter L. Nielsen (Int. Data Ctr., Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Vienna, Austria)

This study presents the proof of concept, based on data collected by a flying glider, for extending the capabilities of autonomous underwater vehicles to the passive measurement of the seabed reflection loss, an important contributor to the transmission loss in shallow water scenarios. During the GLISTEN 15 experiment, a Slocum glider was equipped with an advanced acoustic multi-channel payload coupled with a nose-mounted eight-element vertical line array of hydrophones. By processing the ambient-noise field generated by wind and breaking waves at the surface, recorded while the glider is quietly hovering over the seabed, the system provides an entirely passive, *in situ* measurement of the bottom power reflection coefficient as a function of frequency and grazing angle. The theoretical foundations and the algorithms for processing the data are summarized and applied for the first time to data collected by a linear array mounted on a flying glider. The results are compared to those obtained by arrays moored in the vicinity of the glider during the same experimental campaign. The possibility of recovering the layering structure of the bottom by passive fathometry is also discussed.

10:05

1aSPa3. Underwater navigation via spiral wave front beacon. Benjamin Dzikowicz (Naval Res. Lab., 4555 Overlook Ave. SW, Washington, DC 20375, ben.dzikowicz@nrl.navy.mil), John Yoritomo (Naval Res. Lab., Washington, DC), Brian T. Hefner (Appl. Phys. Lab., Univ. of Washington, Seattle, WA), David A. Brown (ECE, Univ. Massachusetts Dartmouth, Fall River, MA), and Corey L. Bachand (BTech Acoust. LLC, Fall River, MA)

Experiments carried out at NUWC's Seneca Lake facility in the summer of 2020 demonstrate the efficacy of navigating via a single spiral wave front (SWF) beacon. A set of experiments were performed where an Unmanned Underwater Vehicle (UUV) operating in Seneca Lake under various channel conditions receives a regular signal from a single SWF beacon. The UUV's aspect relative to the beacon and its radial velocity can be determined by comparing the phase of a specially generated spiral wave front signal to that of an omnidirectional reference signal. Comparison of the SWF navigation solutions to the UUVs inertial/GPS navigation solutions will be presented for various geometries. This talk will also discuss how this technology can be used to navigate the UUV in GPS denied environments, how it compares to other acoustic navigation systems, and its robust operation in multipath environments. (Work sponsored by the Office of Naval Research.)

10:20

1aSPa4. Acoustic fields of unmanned aerial vehicles in the tasks of passive detection. Valentin V. Gravirov (Lab. 703, IPE RAS, B. Gruzinskaya ul, 10, str.1, Moscow 123242, Russian Federation, vvg@ifz.ru), Ruslan A. Zhostkov, and Dmitriy A. Presnov (Lab. 703, IPE RAS, Moscow, Russian Federation)

The increasingly widespread use of unmanned aerial vehicles (UAVs) requires improved methods of their detection. In some cases, this is only possible by analyzing the physical fields created by the UAV. This work is dedicated to the study of the UAV's acoustic field as applied to the problem of passive detection. In the laboratory, the acoustic fields of the most popular quadcopters were studied, as well as the properties of individual propellers of various designs. The influence of blade defects on the resulting spectral portrait was analyzed. Based on the results of numerical simulations in the COMSOL Multiphysics software package, directional patterns and pressure variations caused by a rotating propeller are obtained. A neural network has been trained to analyze the kepstrum coefficients calculated from acoustic records. The neural network allows monitoring and recognizing the presence of a quadrocopter in an area of interest, taking into account natural and anthropogenic noises. Field experiments carried out in urban conditions made it possible to estimate the range of possible passive detection of an unmanned aerial vehicle. [This work was financially supported by the Russian Foundation for Basic Research (Project No. 19-29-06062).]

10:35

1aSPa5. Bearing estimation of screams using a volumetric microphone array mounted on a UAV. Macarena Varela (Sensor and Data Fusion, Fraunhofer FKIE, Fraunhoferstr. 20, Wachtberg, NRW 53111, Germany, macarena.varela@fkie.fraunhofer.de) and Wulf-Dieter Wirth (Sensor and Data Fusion, Fraunhofer FKIE, Wachtberg, NRW, Germany)

The use of Unmanned Aerial Vehicles (UAVs), also called drones, is increasing for emergency and rescue operations. UAVs can be equipped with state-of-the-art technology to enable surveillance and provide quick situational awareness. Considering that UAVs better reach inaccessible and larger areas than other types of vehicles, such as Unmanned Ground Vehicles (UGVs), they could be used to locate people during catastrophes, and support the rescue team. For this purpose, an automatic and accurate detection, bearing estimation, and source localization system focused on specific audio events, such as persons' screams, is being developed at Fraunhofer FKIE. The solve those tasks, the system uses a particular volumetric array of MEMS microphones, called "Crow's Nest Array," combined with advanced array processing techniques, such as beamforming. The spatial distribution and number of microphones in arrays have a crucial influence on the bearing estimation of audio events; therefore, in this paper, microphone array configurations are described, and their performance in different open field experiments is presented.

10:50–11:15 Discussion

Session 1aSPb

Signal Processing in Acoustics and Animal Bioacoustics: Signal Processing for Environmental Sensing I

Ananya Sen Gupta, Cochair
Department of Electrical and Computer Engineering, University of Iowa, 103 S Capitol Street, Iowa City, IA 52242

Kainam T. Wong, Cochair
School of General Engineering, Beihang University, New Main Building D-1107, 37 Xueyuan Road, Beijing 100083, China

Chair's Introduction—11:30

Invited Papers

11:35

1aSPb1. Extrapolation of Green's functions using the waveguide invariant theory. Hee-Chun Song (Scripps Inst. of Oceanogr., Univ. of California, San Diego, 8820 Shellback Way, Spiess Hall, Rm 448, La Jolla, CA 92093-0238, hcsong@ucsd.edu) and Gihoon Byun (Scripps Inst. of Oceanogr., Univ. of California, San Diego, CA)

The broadband interference structure of sound propagation in a waveguide can be described by the waveguide invariant, β, that manifests itself as striations in the frequency-range plane. At any given range (r) there is a striation pattern in frequency (ω), which is the Fourier transform of multipath impulse response (or Green's function). Moving to a different range (r+Δr), the same pattern is retained but either stretched or shrunken in ω in proportion to Δr, according to $\Delta\omega/\omega=\beta(\Delta r/r)$. The waveguide invariant property allows a time-domain Green's function observed at one location, g(r,t), to be extrapolated into adjacent ranges with a simple analytic relation: $g(r+\Delta r, t) \approx g(r,\alpha(t-\Delta r/c))$ where $\alpha = 1+\beta(\Delta r/r)$ and c is the nominal sound speed of 1500 m/s. The relationship is verified in terms of range variation of the eigenray arrival times via simulations and using real data from a ship of opportunity radiating broadband noise (200–900 Hz) in a shallow-water environment, where the steep-angle arrivals contributing to the acoustic field have $\beta \approx 0.92$.

11:50

1aSPb2. Long-term variations in calls produced by a potential blue whale species from the central Indian Ocean. Nikita R. Pinto (Dept. of Ocean Eng., Indian Inst. of Technol. Madras, Chennai, Tamil Nadu 600036, India, nikitapinto8@gmail.com) and Tarun K. Chandrayadula (Dept. of Ocean Eng., Indian Inst. of Technol. Madras, Chennai, Tamil Nadu, India)

The Comprehensive Nuclear-Test-Ban Treaty Organization hydrophones at Diego Garcia record many marine mammal sounds from the central Indian Ocean. A peculiar call between 20 and 40 Hz from a potential blue whale species, referred to as the Diego Garcia Downsweep (DGD), is regularly recorded in the dataset. The call consists of a set of tones that resemble a comb, followed by a downsweep. Long term spectral averages suggest that the call frequencies are drifting. Tracking the change in frequencies by mere visual observations from the spectrograms is however challenging because of interference from anthropogenic noises and other biophony. This talk presents signal processing methods to track the call-frequencies, across years 2002 to 2019. Energy detectors are initially used to identify, and then exclude acoustic interference from shipping and outliers from electronics. Following that, to isolate the DGDs, and cancel other biophony, the presentation constructs subspace detectors. Finally, the talk uses the spectrograms of the detections to track the change in frequencies for each day. The observations show that while the frequencies of the comb steadily increase, the downsweep decrease. There are new frequencies that appear, and some disappear. These changes are unlike behavior observed from other whales in the region.

12:05

1aSPb3. Explainable artificial intelligence: Linking domain knowledge and machine interpretation using cognitive sampling of acoustical datasets. Ananya Sen Gupta (Dept. of Elec. and Comput. Eng., Univ. of Iowa, 103 S. Capitol St., Iowa City, IA 52242, ananya-sengupta@uiowa.edu), Bernice Kubicek, Ryan A. McCarthy, Timothy Linhardt, Luke Hermann, and Madison Kemerling (Dept. of Elec. and Comput. Eng., Univ. of Iowa, Iowa City, IA)

Explainable artificial intelligence is gaining wider traction within the machine learning community and its application domains at large for its inherent motivation to explain and interpret large-scale machine interpretation of experimental datasets. We will present cognitive sampling as new way to implement explainable AI for acoustical signal processing. In particular, methods based on geometric signal processing and sparse sensing will be harnessed with machine cognition to interpret, classify and predict information autonomously from large-scale acoustic datasets spanning a wide variety of applications. We will compare the difference in performance between traditional supervised and semi-supervised learning architectures such as deep learning, and ensemble approaches, unsupervised learning networks. We will also present preliminary research on implementing cognitive sampling in machine-directed inverse problem-

solving techniques such as autoencoders. The end goal is to discover efficient data encodings that enable hitherto unforeseen feature spaces using optimal or close to optimal sampling strategies. Specific applications will include a variety of acoustical environmental sensing applications involving spectral feature generation and interpretation such as sonar signal processing, undersea multipath channel sensing, as well as feature extraction in complex melodic structures in Indian classical music. [Work funded partially by ONR under Grants N00014-19-1-2436, N00014-19-1-2609, N00174-20-1-0016 and N00014-20-1-2626.]

TUESDAY AFTERNOON, 8 JUNE 2021 12:55 P.M. TO 2:30 P.M.

Session 1pAA

Architectural Acoustics: Noise and Vibration Control in 2021

Christopher Barnobi, Cochair
Coffman Engineers, Inc., 1939 Harrison St. #320, Oakland, CA 94612

Edgar Olvera, Cochair
1939 Harrison Ave. Suite 320, Oakland, CA 94612

Chair's Introduction—12:55

Invited Paper

This panel will discuss emerging trends that acoustical consultants are seeing. Topics covered will include architectural acoustics shifts due to people's patterns and habits shifting over the past year. General discussion of major markets such as residential, commercial, and energy sectors and how these sectors have shifted recently. For residential and commercial, some shifting to mass timber or hybrid timber buildings has been observed and will be discussed. In the energy sector, alternative energies have been growing in popularity. We will discuss implications of diversifying energy sources.

Panelists include: Christopher Barnobi, Coffman Engineers, Inc.; Dennis Paoletti, Paoletti Consulting; Edgar Olvera, Coffman Engineers, Inc.; Joseph Bridger, Stewart Acoustical Consultants.

1p TUE. PM

Session 1pAB

Animal Bioacoustics, Acoustical Oceanography and Underwater Acoustics: Session in Memory of Thomas F. Norris II

Kerri D. Seger, Cochair
Applied Ocean Sciences, 11006 Clara Barton Dr., Fairfax Station, VA 22039

Ann Zoidis, Cochair
Cetos Research Organization, Bar Harbor, ME 04609

Chair's Introduction—12:55

Invited Papers

1:00

1pAB1. Deriving an acoustic-based abundance estimate for porpoise species in Pacific Canadian waters. Elizabeth Ferguson (Ocean Sci. Analytics, 13328 Sparren Ave., San Diego, CA 92129, eferguson@oceanscienceanalytics.com), Thomas Doniol-Valcroze, and Linda Nichol (Fisheries and Oceans Canada, Nanaimo, BC, Canada)

The Pacific Region International Survey of Marine Megafauna was conducted in the summer of 2018 to determine the distribution and abundance of cetaceans within the coastal and offshore waters of Canada. Tom Norris led the passive acoustic monitoring operations for this survey, and his Bio-Waves team of bioacousticians conducted 24-hour linear towed hydrophone array monitoring. Ocean Science Analytics worked in partnership with Bio-Waves, Inc. to conduct a post-processing analysis of this dataset and obtain an acoustic-based abundance estimate of porpoises by localizing individual click trains. Data were first re-processed in PAMGuard to reduce confounding noise and improve click classification. High-pass filters were used to reduce noise, and narrow-band, high-frequency (NBHF) echolocation clicks were up-sampled to improve the time delay measurement. The average peak frequency of clicks was used to determine their likely categorization as Dall's (*Phocoenoides dalli*) or harbour (*Phocoena phocoena*) porpoise. Of the 90 NBHF clicks trains detected, 78 were categorized as Dall's porpoise, and 56 yielded localizations. The resulting acoustic-based Dall's porpoise abundance estimate (3967, CV 29%) was considerably lower than the visual-based estimate (27 002, CV 23%). We discuss possible reasons for this discrepancy and new insights into porpoise occurrence and distribution within the study area.

1:15

1pAB2. Autonomous towed hydrophone system detects many beaked whales and other cetacean species in waters of the Southern Ocean. Jay Barlow (NOAA Southwest Fisheries Sci. Ctr., 8901 La Jolla Shores Dr., La Jolla, CA 92037, jay.barlow@noaa.gov), Ted Cheeseman (Happywhale, Santa Cruz, CA), and Jenny S. Trickey (Scripps Inst. of Oceanogr., UCSD, La Jolla, CA)

A SoundTrap ST300HF hydrophone recorder in a streamlined, flooded towbody was towed behind expeditionary tourism vessels on trips to South Georgia and the South Sandwich Islands and to the Antarctic Peninsula in December 2019—February 2020. Recordings were analyzed to identify acoustic detections of cetacean species. Identified species included sperm whales (*Physeter macrocephalus*) and southern bottlenose whales (*Hyperoodon planifrons*). Acoustic detections also included echolocation pulses from several previously described beaked whale pulse types (BW37 and BW58) as well as a possibly new type of beaked whale echolocation pulse. Narrow-band high-frequency (NBHF) echolocation signals (typical of porpoises and some dolphin species) were detected at several locations, and one of these coincided with a sighting of hourglass dolphins (*Lagenorhynchus cruciger*). Unidentified large delphinids were also detected several times. This study shows the utility of a simple towed hydrophone system on a vessel of opportunity to study the distribution of cetaceans in rough seas that are difficult to study by visual survey methods. Additional research is needed to link the unidentified echolocation signals to known species throughout waters of the Southern Ocean.

Contributed Paper

1:30

1pAB3. The development and use of towed hydrophone arrays to inform Southern Resident killer whale Critical Habitat in outer coastal waters. M. Bradley Hanson (Conservation Biology Div., NOAA/NMFS Northwest Fisheries Sci. Ctr., Seattle, WA 98112, Brad.Hanson@noaa.gov), Marla M. Holt, Candice Emmons, Dawn P. Noren (Conservation Biology Div., NOAA/NMFS Northwest Fisheries Sci. Ctr., Seattle, WA), Elizabeth L. Ferguson (Bio-Waves, Inc., San Diego, CA), Shannon Coates, Kerry Dunleavy, Corry Hom-Weaver, and Jeff Jacobsen (Bio-Waves, Inc., Encinitas, CA)

Southern Resident killer whales (SRKW) were listed as endangered in 2005, requiring designation of Critical Habitat. At that time little was known about SRKW distribution in winter/spring along the outer coast. From 2004 to 2016, we conducted nine winter/spring surveys aboard NOAA ocean-class vessels to locate and follow SRKW pods using visual sightings, satellite telemetry, and passive acoustic monitoring using towed hydrophone arrays. We present information on the evolution of the towed hydrophone array system, and insights gained on the movements and acoustic behavior of this population. Beginning with a linear two-element hydrophone array system, operations evolved to include a secondary, five-element array towed in parallel, to resolve left-right bearing ambiguity to vocalizing animals. Acoustic localization allowed tracking of vocalizing whales when visual surveys were not possible (*e.g.*, nighttime/inclement weather). When visual and/or satellite tag position data indicated whales were within acoustic range, vocalizations were detected only 45% of the time, a result that has implications for other PAM efforts. These surveys helped fill important gaps in our understanding of SRKW occurrence to inform Critical Habitat in the outer coastal portion of their range. Despite limited monitoring, we established the importance of this key portion of their range in winter/spring.

Invited Papers

1:45

1pAB4. Visualizing how anthropogenic noise affects the Good Environmental Status of the North Sea. Emily T. Griffiths (Dept. of Bioscience, Aarhus Univ., C.F. Møller's Allé 3, Bldg. 1131, Aarhus 8000, Denmark, emilytgriffiths@bios.au.dk), Jakob Tougaard (Dept. of Bioscience, Aarhus Univ., Aarhus, Denmark), Christ de Jong (Netherlands Organisation for Appl. Sci. Res., The Hague, The Netherlands), Michael Carder (Michael Carder, London, United Kingdom), Mathias Andersson (FOI, the Swedish Defence Res. Agency, Stockholm, Sweden), Nathan D. Merchant (Cefas Noise and Bioacoustics Team, Ctr. for Environment, Fisheries and Aquaculture Sci., Lowestoft, United Kingdom), Jens-Georg Fischer, Dennis Kühnel (Bundesamt fuer Seeschifffahrt und Hydrographie (BSH), Hamburg, Germany), Alain Norro (Underwater Acoust., Royal Belgian Inst. of Natural Sci., Bernissart, Belgium), and Niels A. Kinneging (Water, Rijkswaterstaat Water Verkeer en Leefomgeving, Amsterdam, The Netherlands)

The Joint Monitoring Programme for Ambient Noise North Sea (JOMOPANS) aimed to develop a framework for managers, planners and other stakeholders to incorporate the effects of ambient noise in their Good Environmental Status (GES) assessment of the North Sea. This was accomplished by generating spatial maps of the anthropogenic and natural soundscapes, modelled from ambient noise measurements collected around the North Sea by the different member states in 2018 and 2019. We focused on the depth-averaged sound pressure level (SPL) of the one-third octave (base-10) bands between 10 Hz to 20 kHz in one second snapshots, viewed in monthly percentiles. From these data, we can better understand the criteria and noise thresholds necessary to achieve GES in the North Sea. Part of this effort was to develop a GES Tool, which would allow users to view the modelled noise maps by noise type (ship type, weather, etc.), protected areas designated by various EU agencies, and habitats used by soniferous or sound sensitive species. The tool computes and displays areas where there is a large overlap between anthropogenic noise and key marine species. This tool aims to help policy makers evaluate measures and thresholds put forward to achieve GES.

2:00–2:20 Discussion

2:20–2:35 Break

Invited Papers

2:35

1pAB5. FindPorpoises: Deep learning for detection of harbor porpoise echolocation clicks. David K. Mellinger (Coop. Inst. for Marine Resources Studies, Oregon State Univ., 2030 SE Marine Sci. Dr., Newport, OR 97365, David.Mellinger@oregonstate.edu) and Selene Fregosi (Coop. Inst.for Marine Resources Studies, Oregon State Univ., Newport, OR)

Tom Norris expressed conservation concern for the vaquita, a close relative of harbor porpoises; here we report on a harbor porpoise (*Phocoena phocoena*) conservation effort. Tidal energy devices are installed in high-flow estuaries that are also prime harbor porpoise habitat. To study tidal energy device impacts on porpoises, sound was recorded in Minas Passage, Bay of Fundy, Canada. Analysis aimed to distinguish harbor porpoises from noise sources. "Click candidate" sounds were detected using the ratio between the harbor porpoise frequency band and lower guard band, then reviewed by humans to label which were correct. Because more "correct" instances were needed, data were augmented by mixing porpoise clicks with known noise, producing 20,000 "click present" labeled instances. Additionally, 20 000 "non-click" instances were extracted from noise recordings. Labeled instances were made into a 0.5-s equalized spectrograms for training deep-learning networks. Of the network architectures tried, the best was a convolutional neural network with pooling and fully connected layers, achieving 99.1% accuracy. User-friendly "FindPorpoises" software was made to pre-process raw files, detect candidate clicks, use the trained network to sort candidate clicks into correct and incorrect instances, and plot and tabulate the results by time of day, tide cycle, and month. [Work supported by OERA.]

2:50

1pAB6. Oscillatory whistles—The ups and downs of identifying species in passive acoustic recordings. Julie N. Oswald (Univ. of St Andrews, Scottish Oceans Inst., St. Andrews, Fife KY16 8LB, United Kingdom, jno@st-andrews.ac.uk), Sam F. Walmsley (Univ. of St Andrews, St Andrews, United Kingdom), Caroline Casey (SEA, Inc., Aptos, CA), Selene Fregosi (SEA, Inc., Newport, OR), Brandon Southall (SEA, Inc., Santa Cruz, CA), and Vincent M. Janik (Univ. of St. Andrews, St. Andrews, United Kingdom)

Sympatric short- and long-beaked common dolphins in the Southern California Bight (*Delphinus delphis* and *D. delphis bairdii*) are challenging to identify acoustically because their whistles overlap in many time-frequency characteristics. We therefore asked whether frequency modulation patterns can help with species identification. Whistle contours from single-species encounters (short-beaked = 902 whistles, 14 schools, long-beaked = 872 whistles, 10 schools) were extracted and categorized based on frequency content and shape using dynamic time warping and artificial neural networks. This analysis resulted in 447 whistle types with 38% being produced by both species. Of the remaining species-specific whistle types, 22% (n = 60) were recorded from more than one school. Thirty-two of these were specific to short-beaked common dolphins and 28 were specific to long-beaked common dolphins. Almost half of the short-beaked common dolphin species-specific whistle types (47%) were oscillatory (contour shape containing at least two cycles with the maximum and minimum of each cycle separated by at least 1 kHz), while only 3% of long-beaked common dolphin species-specific types were oscillatory. Thus, oscillatory whistles appear to be diagnostic of short-beaked common dolphins in this area. More broadly, our findings suggest that repertoire-wide comparisons of acoustic features may overlook possible species recognition via specific signals.

3:05

1pAB7. Tom Norris: One scientist can make a lasting difference. Anurag Kumar (NAVFAC EXWC, 1000 23rd Ave., Port Hueneme, CA 93043, anurag.kumar@navy.mil)

Most of us in our youth have never heard of the term bioacoustics, let alone knew this could be a possible career option. Yet almost all of us in our youth have heard the fascinating sounds humpback whales make. Early on, it took an adventurous spirit, inquisitive mind, and perseverance to learn a wide variety of disciplines to study marine mammal bioacoustics. Even today, bioacoustics it typically a college course and not a full degree. Tom Norris was one of the few early scientists that helped shape what it takes to study bioacoustics and paved the way for others. With increasing concern about the potential impacts to marine mammals from noise in the ocean, there has been greater demand for those with a background in bioacoustics. Part of that overall interest has been using acoustics to passively listen and monitor marine mammal sounds, to learn more about the occurrence and distribution of these animals. Tom Norris's efforts to create a better, more cost effective approach, helped shape the way that we use passive acoustic monitoring to study marine mammals today.

3:20–3:40 Discussion

TUESDAY AFTERNOON, 8 JUNE 2021 — 12:55 P.M. TO 3:45 P.M.

Session 1pBA

Biomedical Acoustics: Instrumentation and Simulation in Biomedical Acoustics: Using k-Wave for Simulation of Ultrasound Pulses

Bradley Treeby, Cochair
Department of Medical Physics and Biomedical Engineering, University College London, London WC1E 6BT, United Kingdom

Ben Cox, Cochair
Dept. of Medical Physics and Biomedical Engineering, Univ. College London, London WC1E 6BT, United Kingdom

Chair's Introduction—12:55

In this tutorial, instruction in the use of k-Wave to simulate acoustic fields will be provided. A brief overview of the toolbox will be given, followed by hands-on demonstrations of how to set up and run simulations. In particular, the new kWaveArray class for simulating arbitrary transducer geometries will be demonstrated. Code will be provided to participants to work in sync during instruction.

Session 1pCA

Computational Acoustics and Computational Acoustics: Computational Methods for Complex Media and Geometries II

D. Keith Wilson, Cochair
Cold Regions Research and Engineering Laboratory, U.S. Army Engineer Research and Development Center, U.S Army ERDC-CRREL, 72 Lyme Rd., Hanover, NH 03755-1290

Kuangcheng Wu, Cochair
Naval Surface Warfare Center-Carderock Division, 9500 MacArthur Blvd, West Bethesda, MD 20817

Chair's Introduction—12:55

Invited Papers

1:00

1pCA1. Theoretical analysis of acoustic pulse propagation through forest edges. Michael B. Muhlestein (Cold Regions Res. and Eng. Lab., US Army ERDC, 72 Lyme Rd., Hanover, NH 03755, Michael.B.Muhlestein@usace.army.mil) and Michelle E. Swearingen (Construction Eng. Res. Lab., US Army ERDC, Champaign, IL)

Sound propagation through forest edges can be complicated due to the sudden and significant change in propagation environment. One approach to estimating the coherent and diffuse sound fields due to an acoustic pulse in or near a forest boundary is to use the energy-based radiative transfer (RT) theory [Muhlestein *et al.*, *J. Acoust. Soc. Am.* **143** (2018)]. This technique accounts for propagation from the source to scattering locations through an effective medium, single scattering, and propagation from the scattering locations to the measurement site. This paper applies the RT theory to two cases: an acoustic pulse source located within a forest and a receiver located outside, and vice versa. The results are compared with experimental data.

1:15

1pCA2. Modelling statistics of sonic boom parameters in turbulent media using nonlinear parabolic equation. Petr V. Yuldashev (Lomonosov Moscow State Univ., Leninskie Gory, Moscow 119991, Russian Federation, petr@acs366.phys.msu.ru), Maria M. Karzova, Vera Khokhlova (Lomonosov Moscow State Univ., Moscow, Russian Federation), and Philippe Blanc-Benon (Université de Lyon, Ecole Centrale de Lyon, Université Claude Bernard Lyon I, Institut National des Sci. Appliquées de Lyon, Ctr. National de la Recherche Scientifique, Laboratoire de Mécanique des Fluides et d'Acoustique, Unité Mixte de Recherche 5509, Ecully, France)

Over the past decade, plans to develop a new generation of supersonic passenger aircrafts have spurred interest in sonic boom propagation in the atmosphere. New designs are focused on reducing its loudness on the ground. Sonic boom waves are affected by propagation in turbulence of the planetary boundary layer occurring in few kilometers above the ground. Therefore, sonic boom wave parameters such as peak pressure and rise time, as well as corresponding noise levels, become random, which requires statistical characterization. Theoretical analysis of the effects of the presence of turbulent layer is frequently based on one-way model equations of different complexity, of which the basic equation is the nonlinear parabolic Khokhlov-Zabolotskaya-Kuznetsov-type (KZK) equation. Here, sonic boom propagation through homogeneous isotropic turbulence is simulated using the KZK equation. Classical N-waves with different amplitudes and several examples of low-boom waveforms are considered as input waveforms at the entrance to turbulent layer. Statistical data of the peak pressure, shock front steepness, and perceived loudness metric are analyzed. It is shown than unless sonic boom amplitude exceeds a certain threshold, perceived loudness variability is mainly determined by waveform spectral components at mid-range frequencies around 100 Hz. [Work supported by RSF-18-72-00196 and ANR-10-LABX-0060/ANR-16-IDEX-0005.]

Contributed Papers

1:30

1pCA3. Automated regularization parameters method for the inverse problem in ultrasound tomography. Anita Carević (FESB, Univ. of Split, Ruđera Boškovića 32, Split 21000, Croatia, carevica@fesb.hr), Ivan Slapničar (FESB, Univ. of Split, Split, Croatia), and Mohamed Almekkawy (School of Elec. Eng. and Comput. Sci., Penn State Univ., Univ. Park, State College, PA)

Ultrasound tomography (UT) is an emerging technology that has been applied for the detection of breast cancer. It is safe and cost effective medical imaging modality that can provide a high-quality image and is free from patient constraint of magnetic resonance imaging (MRI) and computed tomography (CT). One of the methods to solve the problem of UT is to model it as an integral form and apply the distorted Born iterative method. This method needs a regularization parameter in each iteration to solve the inverse problem. We developed a new algorithm to automatically choose the regularization parameters needed by balancing the signal loss and the scaled noise error. We applied our new algorithm with Tikhonov regularization in general form to regularize the inverse problem to reconstruct a simulated breast phantom image. The performance of our algorithm is compared to those of L-curve, GCV and the projection based total least squares methods. Our proposed algorithm provides the highest reconstructed image quality with the lowest relative error in all tested cases with different frequencies and noise levels.

1:45–1:55 Discussion

1:55–2:10 Break

Contributed Papers

2:10

1pCA4. Experimental and numerical analysis of Lamb wave transmission through the coronal suture of a dry human skull. Matteo Mazzotti (Dept. of Mech. Eng., CU Boulder, 1111 Eng. Dr., UCB 427, Boulder, CO 80309, matteo.mazzotti@colorado.edu), Eetu Kohtanen, Alper Erturk (Dept. of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA), and Massimo Ruzzene (Dept. of Mech. Eng., CU Boulder, Boulder, CO)

Cranial Lamb waves have recently gained attention as potential means for ultrasound imaging and diagnostics of the skull. The inherent capability of these waves to travel for long distances across the cranial vault requires the understanding of transmission mechanisms across cranial sutures, which remain mostly unexplored. This work investigates such mechanism in the coronal suture of a dry human skull. The transmission analysis is performed experimentally by recording velocity arrays induced by short tone-bursts along curvilinear paths that intercept the suture at different locations. For each path, the experimental frequency-wavenumber spectrum of the incident wave indicates the presence of fundamental and higher order Lamb modes, with transmission being mainly associated with the fundamental antisymmetric Lamb mode. By calculating the corresponding transmission coefficients and comparing them with those obtained from a semi-analytical multilayered model of the cranial bone, we demonstrate that the coronal suture can be described by a simplified constitutive law defined by distributed shear and compressional stiffness coefficients. The experimental results and the estimated suture constitutive parameters provide the basis for a comparative analysis of the suture mechanical properties at different spatial locations, which may be employed for suture characterization and imaging.

2:25

1pCA5. One-dimensional harmonic scattering from a localized damage modeled as symmetric and asymmetric hysteretic nonlinearity. Pravinkumar R. Ghodake (Mech. Eng., Indian Inst. of Technol., Bombay, IIT Bombay, Mumbai, Maharashtra 400076, India, mech7pkumar@gmail.com)

A monochromatic ultrasonic wave propagating in damaged material modeled as quadratic, cubic, and hysteretic nonlinearities generates higher harmonics as reported in various theoretical, computational, and experimental studies. In metals under fatigue, certain grains get plastically deformed due to their preferentially oriented slip planes in certain regions and form localized damages like slip bands and micro-cracks. To capture the complex nature of the locally damaged material, local damage is modeled as symmetric and asymmetric hysteretic nonlinearity in this study. A one-dimensional domain is discretized as a long spring-mass chain with few spring-mass elements at the center of a domain modeled as hysteretic elements. Both the back and forward scattered waves from the symmetric hysteretic model contain only odd harmonics and in an asymmetric hysteretic model, both the odd and even harmonics observed. The amplitude of fundamental harmonics of the forward scattered wave decreases with an increase in local damage size and the amplitudes of higher harmonics increases due to an energy transfer from fundamental harmonics in both symmetric and asymmetric hysteretic models. Due to interference of backscatterd waves from two interfaces of local damage, backscattered higher harmonics amplitudes shows increasing and decreasing nature with an increase in local damage size.

2:40

1pCA6. The influence of relief on the amplitude and velocity of acoustic surface waves as applied to the tasks of passive seismic prospecting. Ruslan A. Zhostkov (Lab. 703, IPE RAS, Profsouznaya str., 31-4-14, Moscow 117418, Russian Federation, shageraxcom@yandex.ru)

Today, in geophysics, passive technologies of surface-wave tomography and methods that analyze the amplitude characteristics of surface waves are widely used. Unfortunately, the issues of taking into account the influence of the relief on the results of these methods have not yet been given due attention. The existing solutions are poorly corresponding to the real tasks of geophysics. Numerical models have been created for the study of surface waves. Their correctness is confirmed by comparison with the results of laboratory experiments. A study of the scattering of surface waves on the features of the relief of various shapes and sizes, including for the seabed and ice-covered water, has been carried out. It is shown that the effect of the relief at certain parameters can change the structure of the field more strongly than local inhomogeneities of the medium. A positive relief can lead to a significant change in the effective velocity of surface waves due to the effect of splitting of these waves discovered both by numerical simulation and laboratory experiment. [This work was financially supported by the Russian Foundation for Basic Research (Project No. 18-05-70034).]

2:55–3:15 Discussion

Session 1pEA

Engineering Acoustics and Engineering Acoustics: Emerging Topics in Engineering Acoustics II

Thomas E. Blanford, Cochair
The Pennsylvania State University, State College, PA 16804

Caleb F. Sieck, Cochair
Code 7160, U.S. Naval Research Laboratory, 4555 Overlook Ave SW, Washington, D.C. 20375

Chair's Introduction—12:55

Contributed Papers

1:00

1pEA1. Broadband global acoustic cloaking experiments. Theodor S. Becker (Earth Sci., ETH Zurich, Sonneggstrasse 5, Inst. of Geophys., NO H 41.1, Zürich 8092, Switzerland, theodor.becker@erdw.ethz.ch), Johan O. Robertsson, and Dirk-Jan van Manen (Earth Sci., ETH Zurich, Zürich, Switzerland)

Rendering objects invisible to impinging acoustic waves (*i.e.*, acoustic cloaking), is a mature topic in the acoustic community and has diverse applications. Nevertheless, existing approaches and physical demonstrations still exhibit a large range of assumptions and limitations. Passive approaches, which surround the scattering object with a suitable (meta-)material, are usually only effective in a narrow frequency-band and cannot adapt to changing incident fields. Active approaches, which rely on the emission of a secondary wavefield that destructively interferes with the scattered field, have the potential to respond dynamically and be broad band. However, without knowledge of the primary or scattered field, the signals for the secondary sources need to be estimated from wavefield measurements in real-time. To our knowledge, this was never demonstrated beyond 1D acoustic experiments to achieve global broadband control of forward- and backscattered waves. Here, we present experimental results of active, broadband 2D acoustic cloaking without any assumptions of the primary or scattered wavefields. Using a low-latency control system and a dense array of control microphones, the signals for 20 control sources surrounding the scatterer are estimated and applied in real-time to achieve fully deterministic, global acoustic cloaking.

1:15

1pEA2. High-frequency single beam acoustical tweezers for 3D trapping and dynamic axial manipulation of cells and microparticles. Zhixiong Gong (CNRS UMR8520 IEMN, IEMN, Cité Scientifique Ave. Henri Poincaré CS 60069, Lille 59652, France, zhixiong.gong@iemn.fr) and Michael Baudoin (Univ. of Lille, Lille, France)

The 2D trapping and manipulation capabilities of acoustical tweezers based on focused acoustical vortices and Spiraling InterDigitated Transducers (S-IDTs) have been demonstrated both experimentally and numerically {see [Baudoin *et al.*, *Sci. Adv.***5**, eaav1967 (2019)] for microparticles and [Baudoin *et al.*, *Nat. Commun.*, **11**, 4244 (2020)] for cells}. Compared to other technologies, S-IDTs have the advantage to enable the synthesis of high-frequency vortices with trap lateral extension comparable to the cell scale (typically from 5 to 20 μm), which is a necessary condition for selectivity. However, our previous work based on the S-IDTs only demonstrated 2D trapping. Here we investigate numerically the feasibility of 3D trapping of cells and microparticles with a focused vortex beam with large aperture and axial motion of the trapped object by tuning the excitation frequency. This work opens perspectives for 3D advanced cells and microparticles manipulation.

1:30

1pEA3. Automatic differentiation approach for acoustic holograms: Performance and potential applications. Tatsuki Fushimi (R&D Ctr. for Digital Nature, Univ. of Tsukuba, 1-2 Kasuga, TsukubaIbaraki 305-0821, Japan, tfushimi@slis.tsukuba.ac.jp), Kenta Yamamoto, and Yoichi Ochiai (R&D Ctr. for Digital Nature, Univ. of Tsukuba, Tsukuba, Ibaraki, Japan)

Acoustic holography underpins the number of modern acoustics applications. The usage of multi-focal acoustic holograms with phased array transducers (PATs) in ultrasonic tactile displays and acoustic levitation are increasing, and achieving a high-quality hologram are of significant interest. Inspired by the latest optical hologram optimizer, we developed a novel acoustic hologram optimizer for PATs called Diff-PAT [T. Fushimi, K. Yamamoto, and Y. Ochiai, "Acoustic hologram optimisation using automatic differentiation"]. Diff-PAT is based on a gradient-descent algorithm and automatic differentiation. The performance of Diff-PAT was numerically evaluated using three array configurations and it achieved superior accuracy over the conventional optimizers. For example, when two focal points are generated with 196 ultrasonic (40 kHz) transducers; the state of art optimizer (with phase and amplitude modulation) based on Eigensolver has an average error of 4.07 % where Diff-PAT (with only phase modulation) achieve average error of 0.0174%. These results show that amplitude and phase modulation may not be necessary for PATs to be successful. Furthermore, we demonstrate the versatility of Diff-PAT by applying it to binary acoustic holograms, simultaneous modulation of acoustic amplitude and phase at the target plane, and phase plates. [Work supported by Pixie Dust Technologies, Inc., Diff-PAT is patent pending (JP2020-167367A).]

1:45

1pEA4. Utilizing laser distance sensors for audio recovery and acoustic source localization. Kanad Sarkar (Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, B10 Coordinated Sci. Lab, 1308 West Main St., Urbana, IL 61801-2447, kanads2@illinois.edu), Ryan M. Corey (Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, Urbana, IL), Sri Vuppala (Univ. of Illinois at Urbana-Champaign, Urbana, IL), and Andrew C. Singer (Elec. and Comput. Eng., Univ. of Illinois at Urbana-Champaign, Urbana, IL)

Previous research has shown that we can measure the acoustic displacement of a surface with a laser to recover audio inside a room, but these were not done with modern laser distance measurement methods. One such method, LIDAR, has the potential for acoustic recovery, allowing for a room's visual and auditory mapping to be done with one device. With audio

recovery through an ideal spinning LIDAR, we would not only obtain the sound inside the room, but we should be able to localize an acoustic source through sampling points around a room. We define the parameters required for a single-point light distance sensor to record audio and compare our results to a light distance sensor used in manufacturing. We also show the parameters that a spinning LIDAR device needs for acoustic source localization and draw a comparison to what is currently available today.

2:00

1pEA5. Ceramic additive manufacturing for enhanced piezocomposite transducers. Justin Tufariello (MITRE, 202 Burlington Rd., Bedford, MA 01730, jtufariello@mitre.org), Shawn Allan (Lithoz America, LLC, Troy, NY), Barry Robinson (MSI Transducers Corp., Littleton, MA), Brian Pazol (MSI Transducers Corp., Littleton, MA), Leslie Riesenhuber (MITRE, McLean, VA), Alex Angilella, and Casey Corrado (MITRE, Bedford, MA)

Ceramic Additive Manufacturing (AM) offers the potential to create piezocomposite structures with refined and customizable features that result in augmented performance for underwater acoustic transduction. Novel geometries that would otherwise be impossible to fabricate with conventional manufacturing methods may be efficiently created through AM processes to invoke increased sensitivity and improved directionality. These favorable characteristics promise enhanced sensing performance on compact and autonomous Navy platforms where efficiency is critical and spatial aperture may be limited. To date, Lithoz-America, LLC (Lithoz), The MITRE Corporation (MITRE), and MSI Transducers Corp. (MSI) have entered a Collaborative Research Agreement that has been successful in utilizing Lithoz's patented lithography-based ceramic manufacturing (LCM) process to create innovative PZT-5H (DoD Type VI) structures. MSI has applied broad material knowledge to create ceramic powders for slurry creation and refine post-processing procedures for repeatable sintered material properties equivalent to bulk ceramic. Through the process, an AM 1-3 piezocomposite transducer, resonant at 71 kHz, was compared against a replica conventionally manufactured transducer with excellent measured acoustic response agreement. MITRE has utilized coupled-acoustic finite element analysis (FEA) to design and evaluate distributed composite apertures and auxetic structures with improved performance and only feasible to manufacture with AM.

2:15

1pEA6. Thermoacoustic Instability in the flexural motion of a bilayer beam. Haitian Hao (Mech. Eng., Purdue Univ., 177 S. Russel St., 1007, West Lafayette, IN 47907, haoh@purdue.edu), Carlo Scalo, and Fabio Semperlotti (Mech. Eng., Purdue Univ., West Lafayette, IN)

Recent studies have shown that axial waves in a one-dimensional solid rod can become thermoacoustically unstable in presence of a spatial temperature gradient [Hao *et al.*, *J. Appl. Phys.***123**(2), 024903 (2018)]. It is well-known that elastic waves in solids can occur in a variety of mode types dominated by different displacement profiles. This study presents the theory of flexural-mode solid-state thermoacoustics (F-SSTAs) according to which flexural waves in a bilayer slender beam subject to a spatial thermal gradient can become thermoacoustically unstable. The instability in F-SSTA was linked to three factors: (1) the asymmetric distribution of the temperature fluctuation in the cross-section, (2) the non-uniform thermal moment in the axial direction, and (3) the spatial thermal gradient. The criterion for the occurrence of flexural instability in bilayer beams was identified by exploring both the mechanics and the thermodynamics of the system. The existence of a thermally induced unstable response was further substantiated by direct numerical simulations. Finally, although the experimental investigation was not able to achieve a fully sustained instability, data showed clear evidence of thermal-to-mechanical energy conversion in the F-SSTA process.

2:30–2:55 Discussion

Session 1pED

Education in Acoustics and Education in Acoustics: Reflections on Teaching Acoustics During a Pandemic

Daniel A. Russell, Cochair
Graduate Program in Acoustics, Pennsylvania State University, 201 Applied Science Bldg, University Park, PA 16802

John R. Buck, Cochair
ECE, University of Massachusetts Dartmouth, 285 Old Westport Rd., Dartmouth, MA 02747

Chair's Introduction—12:55

Contributed Papers

1:00

1pED1. Musical acoustics video demonstrations for online classes. William Hartmann (Michigan State Univ., 749 Beech St., East Lansing, MI 48823, wmh@msu.edu)

Forty high-resolution (3480×2160) video presentations were created in an attempt to replace in-person demonstrations for teaching elementary musical acoustics. Demonstrations were selected to accompany the author's textbook, *Principles of Musical Acoustics* (W. M. Hartmann, Springer, NY, 2013). Mean duration of the demonstrations was 4.1 min, though one was as long as 17 min while another lasted only 30 s. Demonstrations were devoted to physical principles of vibrations and waves (13), musical instruments and other sound making devices (20), and signal processing (3). Electronic instrumentation appeared somehow in almost all the demonstrations with (4) devoted specifically to instrumentation itself. Attempts were made to evaluate the effectiveness of the demonstrations through questions on the weekly quizzes. In any case, the demonstrations provided a welcome relief from a straightforward power-point lecture. A second form of relief presented some topics, especially mathematical topics, using pen and paper together with a document camera. Evaluations of the methods will be complete before the June meeting.

1:15

1pED2. Supporting hyflex acoustics laboratory exercises. Scott H. Hawley (Dept. of Chemistry and Phys., Belmont Univ., 1900 Belmont Blvd, Nashville, TN 37212, scott.hawley@belmont.edu)

Challenges for laboratory instruction due to COVID include lab room occupancy being cut in half, the prohibition of lab partner arrangements, and students (or instructors) who, on any given day, might be unable to attend lab in person. To allow students to perform laboratory exercises at home requires accounting for a heterogeneous set of available equipment (typically of low-precision) and a multiplicity of computing platforms. The author's Mac-only software suite "SHAART Acoustic Tools" needed porting to Windows and Linux executables so students could measure reverberation times at home. In this talk, we share some experiments, apps, and cross-platform tricks that enabled students to have a reasonably uniform experience that was also manageable for the instructor.

1:30

1pED3. Teaching underwater acoustics and sonar during the COVID pandemic. Murray S. Korman (Phys. Dept., U.S. Naval Acad., 572 C Holloway Road572 C Holloway Rd., Annapolis, MD 21402, korman@usna.edu) and Leah E. Burge (Phys., U.S. Naval Acad., Annapolis, MD)

USNA's Underwater Acoustics and Sonar (SP411) course, taught in a studio classroom, can seat 36 students with 5 experimental/computer workstations on each side of the classroom. This non-laboratory course relies on hands-on demos and in-class mini-laboratory experiences bringing theoretical concepts and experimental aspects of sound propagation and detection theory to life. Experiments include: (a) sound speed versus temperature in water, (b) beam pattern functions versus angle for multi-element arrays, (c) Fourier analysis of periodic waveforms including rectangular pulses, and (d) square law detection of signals plus noise—generating receiving operating characteristic ROC curves. Computer visualizations using Mathematica included phasor addition of signals, N-element array superposition for directivity analysis and a user friendly ray tracing program implementing any sound speed versus depth profile. On 20 March, 2020, the USNA entered the pandemic era by requiring remote learning for all 4100 midshipman, commencing shortly after spring break. Remote learning in SP411 was asynchronous, devoid of lectures, including handouts and videos of wave effects and worked examples. Mathematica visualizations replaced experiments and extra instruction (in different time zones) was always available. Coauthor LEB's photoacoustic imaging experiments, done remotely, used homemade electronics (pulsed LED driver and low-noise amplifiers)—keeping future midshipmen research going.

1:45

1pED4. Lessons learned teaching through a pandemic and looking forward to a post-COVID-19 classroom. Andrew C. Morrison (Natural Sci., Joliet Junior College, 1215 Houbolt Dr., Joliet, IL 60431, amorriso@jjc.edu)

Many educators have faced the challenge of teaching in a world with COVID-19. Not everyone has the same amount of difficulties to work through, but each of us has the pandemic's unspoken weight affecting our daily life and work. After teaching for over a year through the pandemic, several lessons have shaped my approach to this time of emergency remote teaching. Some adaptations made to course delivery will survive in a post-COVID classroom if not entirely intact, at least with a considerable influence from the current situation. The variety of teaching modalities that have emerged have shown the possibilities of how courses can be delivered. Although there are aspects of online courses which we may never wish to

repeat post-COVID, some aspects of our current situation could be useful in the future. We can continue to use remote collaboration tools when being together in a room is not an absolute necessity. We can help our students develop collaborations using these same technologies. Forming positive relationships with students and supporting how students work with their classmates has never been more important than during the pandemic. We should continue to prioritize relationship-building in a post-COVID future.

2:00

1pED5. Aspects of teaching online during COVID-19 that I want to retain when returning to a "normal" classroom environment. Daniel A. Russell (Graduate Program in Acoust., Penn State Univ., 201 Appl. Sci. Bldg, University Park, PA 16802, dar119@psu.edu)

For ten years I have been teaching graduate level acoustics courses simultaneously to 15–20 resident students and 20–25 distance education students. Prior to COVID-19, I live-streamed my lectures from a specially equipped multimedia classroom, but my attention during any given class period was primarily focused on the resident students sitting in the classroom. Any interaction with the 5–8 distance students attending my "live" lectures was limited to sporadic short questions posted to a chat window. During COVID-19, I have been teaching entirely online from my home and all 25-30 students (both resident and distance) who attend "live" class meetings participate in the same way: online through Zoom. As I reflect on 2.5 semesters of teaching acoustics to both resident and distant graduate students entirely online, there are several positive aspects of my online interactions with students that I hope to retain when I return to a "normal" classroom environment. In this presentation I will share several of the ways I successfully engaged and interacted with students while teaching online, both during and outside of class meetings. I will also discuss possible challenges of bringing some of those positive online interactions back into a "normal" classroom setting.

2:15

1pED6. Sharing physics through sound: Undergraduate outreach. Holly Fortener (American Inst. of Phys. (AIP), Society of Phys. Students (SPS), 3300 Cummins St., Houston, TX 77027, holly.fortener@rice.edu) and Brad Conrad (American Inst. of Phys. (AIP), Society of Phys. Students (SPS), Washington DC, MD)

The Society of Physics Students values opportunities in physics and astronomy for undergraduates and places global science outreach for younger generations at its core. Science Outreach Catalyst Kits (SOCKs) are free to SPS chapters while supplies last and contain an exploratory physics and science activity. SOCKs are specifically designed for SPS chapters to use in outreach presentations for elementary, middle, and high school students. Each SOCK comes with the essential materials to conduct a set of demonstrations, a comprehensive manual, and instructions on how to expand the demonstration to become a tried-and-true outreach activity. The 2020–2021 SOCK celebrated the international year of sound by theming its demonstrations around acoustics and expanding availability to both SPS and Acoustic Society of America (ASA) chapters. Come learn about the 2020–2021 SOCK if you are interested in creating acoustic-themed demonstrations for ASA outreach events!

2:30–3:00 Discussion

Session 1pID

Interdisciplinary: Excellence in Acoustics Around the World

Brigitte Schulte-Fortkamp, Cochair
HEAD Genuit Foundation, Ebert Straße 30 a, Herzogenrath 52134, Germany

Andy W. Chung, Cochair
ASA ESEA Regional Chapter, Macao, Macao

Chair's Introduction—12:55

Invited Papers

1:00

1pID1. International collaboration on acoustics Orchestrating five essential elements.— Andy W. Chung (ASA ESEA Regional Chapter, Macao, Macao, ac@smartcitymaker.com) and Brigitte Schulte-Fortkamp (HEAD Genuit Foundation, Herzogenrath, Germany)

E—empowering knowledge transfer X—eXtending application of acoustics to other sectors C—capacity building "rethink" E—engaging stakeholders & community L—long term strategic management towards healthy and harmonised cities/societies

1:15

1pID2. Acoustics development in China and path of collaborations with US. Likun Zhang (National Ctr. for Physical Acoust. and Dept. of Phys. and Astronomy, Univ. of MS, 1032 NCPA, TUniversity, MS 38677, zhang@olemiss.edu) and Xiuming Wang (Res. Ctr. for Ultrason. and Technologies and School of Phys. Sci., Inst. of Acoust., Chinese Acad. of Sci. and Univ. of Chinese Acad. of Sci., Beijing, China)

This talk will start out by reviewing some of the current situations of acoustics research and education in China. There are mutual interests between the acoustical societies of both sides to maintain international communications and collaborations in acoustics research and education. Specific topics of these interests include, but not limited to, joint conferences, funding to support scholars of both sides to attend joint conferences, and acoustics journals for exchange publications. Some of these topics have been initiated and proceeded in past years. For example, the *Journal of Applied Acoustics* and the *Chinese Journal of Acoustics* published the greetings from the Editor-in-Chief of *ASA* journals in both Chinese and English. More work need to be done in the future. There are some existing opportunities that encourage international education and research communications. While there are so many opportunities for communications and collaborations, it can be difficult to start up. The talk will address some of these matters relating to the collaborations, including the mutual interests, existing opportunities, current status, future efforts, and potential difficulties.

1:30

1pID3. The past, the present, and the future of acoustics in Hong Kong. Maurice YEUNG (Hong Kong Inst. of Acoust., 26/F, 130, Hennessy Rd., Wanchai, Hong Kong, China, mklyeung@yahoo.com)

Accommodating over 7 million population in about 1100 km^2 area, Hong Kong is truly a densely populated city. Also, with its almost 24-hour non-stop activities, Hong Kong is a vibrant and dynamic city. These two factors undoubtedly put environmental noise like traffic noise and neighborhood noise center of public concerns. Hence, combating environmental noise became the top priority in the development of acoustics in Hong Kong. With further developing into an international finance center in which luxurious hotels plus sophistically designed performance centers were planned and built, excellent knowledge and experience of indoor acoustics and architectural acoustics became mostly needed. These spectacular demands set path for collaborations for local and overseas acoustic researchers, academia and professionals in spearheading initiatives like a noise-heath study associated with over 10,000 household surveys; the world first ever three-dimensional traffic noise mapping; the largest theatre for Xiqu (the Chinese traditional opera) and currently the largest number of residential developments applying open-typed windows for noise amelioration. This paper gives a summary of the developments of acoustics in Hong Kong, reviews its current status and portrays its future including the discussion of how the acoustical professionals and academics in Hong Kong would benefit from international collaborations and educations in acoustics in the years to come.

1:45

1pID4. Excellence of acoustics in India—Its heritage and recent research. Shyam S. Agrawal (Electronics and Commun., KIIT Group of College, KIIT Campus, Maruti Kunj Rd., near Bhondsi, Sohna Rd., Gurugram, Haryana 122102, India, ss_agrawal@hotmail.com)

Acoustics research and its applications have been an age-old tradition in India. In ancient times it has marvelous examples of achievement particularly in the areas of production of sounds, vocal recitations, musical instruments and in architectural acoustics. Rules for production of sounds, chanting Vedas, and methods of playing instruments were well designed. Similarly, the forts and temples were designed with great mathematical accuracy from the acoustics points of view. In recent times acoustic research have been pursued in several areas in R&D laboratories, educational institutions and in industries. Some of these include research in physical acoustics, ultrasonic, non-linear acoustics, transducers, material characterization, NDT, etc. Underwater and sonar acoustics; Speech processing and hearing, acoustic phonetics and development of Indian speech and language resources, etc.; Study on Indian classical music and musical instruments; Environmental and Noise control including industrial noise control; vibro- and aero-acoustics for acoustic protection systems; Building and architectural acoustics are getting great attention. Many projects are carried out with international collaboration. The standards in acoustic measurements, calibration are maintained and updated at the National level. AI and digital technologies play a vital role in development of Acoustical systems. This paper describes technologies and status of research in acoustics in India.

2:00–2:15 Break

2:15

1pID5. Ocean acoustics research in India: Potential for collaborations. Gopu R. Potty (Dept. of Ocean Eng., Univ. of Rhode Island, 215 South Ferry Rd., Narragansett, RI 02882, gpotty@uri.edu), Latha Ganesan (National Inst. of Ocean Technol., Chennai, Tamil Nadu, India), and Tarun K. Chandrayadula (Dept. of Ocean Eng., Indian Inst. of Technol., Madras, Chennai, Tamil Nadu, India)

This talk will provide an overview of the research carried out in ocean acoustics in India. The topics of special interest for international collaboration identified by some of the institutions involved in ocean acoustics research will be highlighted. The status of underwater acoustics education in India will be reviewed. Two institutions located in Chennai, India (National Institute of Ocean Technology (NIOT) and Indian Institute of Technology (IIT), Madras) are heavily involved in ocean acoustics research and their research activities will be discussed in detail. The ocean acoustics research at these two institutions has a strong field experimental component involving international collaboration. Past and ongoing research with international collaboration will be highlighted. Challenges faced by these and other institutions in fostering collaboration with international counterparts will be discussed. The scenario of ocean acoustics education and training in India will be surveyed and outlook for the future will be discussed.

2:30

1pID6. Creation of acoustic environment from the viewpoint of perception and cognition. Takeshi Akita (Dept. of Sci. and Technol. for Future Life, Tokyo Denki Univ., 5 Senju-Asahi-cho Adachi-ku, Tokyo 1208551, Japan, akita@cck.dendai.ac.jp)

The investigations of our research team are generally carried out for the purpose of creating good acoustic environment from the perspective of person's perception and cognition. The concept of the researches is supported by the framework of soundscape that is defined in ISO 12913-1. It shows that soundscape that is perceived by a person is affected by the context that is different among individuals. Among the context that is illustrated by many examples in ISO, the background systems of perception and cognition like attention to the acoustic environment, forepast experience of soundscape, person's sense of value, and effects of vision on perception of soundscape are mainly paid attention to in our researches. In contrast, there are little researches about perception and cognition of sonic environment or evaluation of it that is associated with ISO 12913-1 in Japan. It seems that such situation makes it difficult to discuss about good acoustic environment consistently. In the future, it is considered as an important way to try to create good acoustic environment involving the viewpoint of the context that has significant effect on perception and cognition not only in our country but also worldwide.

2:45

1pID7. Making acoustics visible in the Philippines. Jose Francisco L. Hermano (Acoust. Anal., Inc., 1850 E. Rodriguez Sr. Blvd., Cubao, Quezon City, Metro Manila 1109, Philippines, jhermano@acoustics.com.ph) and Martin C. Galan (Acoust. Anal., Inc., Quezon City, Metro Manila, Philippines)

The Philippines presents itself as an ideal country to test methods of making acoustics visible in developing and underdeveloped countries. This report will first give a historical overview of the country's acoustic environment in its 7000 + islands. 300 years of Spanish rule and 50 years of American colonial culture are acoustically visible in its public spaces, churches, buildings, schools and rural life. The first country in South East Asia to gain its independence, it is now a developing country that is the most fluent in the English language. It is known for its love for music and world class talents, onstage and backstage. It is presented that this gives the Filipino an inert advantage in understanding, expressing, good sound. Problems do abound, recent decades of economic strife have allowed the appreciation of good and safe sound to take a back seat. Lack of education, legislation, and the general misunderstanding of the basic principles of sound is the norm. The challenge of education and sharing the knowledge is urgent as the country progresses, so is the preservation of its rich multicultural acoustic heritage. Suggested solutions to remedy this will be presented.

3:00

1pID8. Acoustic research at the National University of Singapore. Heow Pueh Lee (Dept. of Mech. Eng., National Univ. of Singapore, 9 Eng. Dr. 1, Singapore 117575, Singapore, mpeleehp@nus.edu.sg)

Noise pollution is a major problem in many major cities in particular a small island state like Singapore with residential buildings very close to the major trunk roads and expressways. There are therefore increased interest in designs and solutions that will contribute to better sonic ambience. In this presentation, I will focus on the recent research and investigation in related to sonic crystals, acoustic metamaterials, noise barriers, and soundscape. The focus on sonic crystal research is on the use of sonic crystals in the form of sonic windows and sonic cage that would provide noise mitigation in addition to natural ventilation and day light. The design would also include the incorporation of Helmholtz's resonators, labyrinth and micro-perforated features into the sonic crystal structures. The focus on acoustic metamaterials would be on ventilated acoustic meta-structures incorporating Helmholtz's resonators and labyrinth or coiled-up space features. For soundscape research, a novel calibration method has been put forward for making the typical smartphone to be accurate enough as a sound level meter for the measurement of environmental noise. Some studies in terms of cabin noise of subway systems, aircraft cabins, high speed trains would be presented.

3:15

1pID9. Excellent acoustic development in Taiwan. Shiang-I Juan (Dept. of Architecture, National Taiwan Univ. of Sci. and Tech., 43 Keelung Rd. Sec. 4, Taipei 10607, Taiwan, ukla2005@hotmail.com) and Lucky S. Tsaih (Dept. of Architecture, National Taiwan Univ. of Sci. and Tech., Taipei, Taiwan)

Development of acoustics in research and field applications in Taiwan has been well established and aligned with developed countries world-wide. Taiwan has comprehensive acoustic regulations and standards for residential and hospitality building types and stringent environmental noise protection ordinances. It is the only country that has specific noise regulation for 20 Hz to 200 Hz. The Taiwan Acoustical Association (TAA) was established on 1987. Since then, thirty-two biannual meetings have been successfully held. Auditory and speech communication, building acoustics, mechanical acoustics, ultrasound, underwater acoustics, noise and vibration, as well as bio-acoustics and other related acoustic topics were covered in these meetings. According to the Taiwan Patent Search System (English version), about 187 acoustic related patents have been granted since 2004. In terms of research institutes, at least 14 top universities in Taiwan have specific major for acoustic studies. At National Taiwan University of Science and Technology, there is an architectural acoustics program under the Department of Architecture. Its team has been involved in the world-renowned performing arts center projects such as Taichung Metropolitan Opera House, Weiwuying National Kaohsiung Center for the Arts, Taipei Performing Arts Center and Taipei Pop Music Center. It can be concluded that research and field applications of acoustics in Taiwan has been valued by the people and will be continued and tuned to world-wide standards!

3:30–3:55 Discussion

Session 1pNS

Noise: Pandemic Noise Reduction/Impact II

Kirill V. Horoshenkov, Cochair
Department of Mechanical Engineering, University of Sheffield, Sheffield S10 2TN, United Kingdom

Abigail Bristow, Cochair
Civil and Environmental Engineering, University of Surrey, Department of Civil and Environmental Engineering, University of Surrey, Guildford, GU2, United Kingdom

Chair's Introduction—12:55

Invited Paper

1:00

1pNS1. More noise nuisance by Covid-19 Compared to 2019, the Dutch Noise Abatement Society (NSG) received 25% more questions about noise in 2020. These were mainly about living noises and environmental noise. Erik Roelofsen (Dutch Noise Abatement Society, P.O. Box 381, Delft 2600AJ, The Netherlands, erik.roelofsen@nsg.nl)

Survey The NSG conducted a survey of more than 5,000 people and it was completed by some 1200 respondents aged 21 to 88 living across the country. This shows, among other things, that the noise from vehicles (road traffic) and aviation is perceived as significantly less present and noise from neighborhood and nature sounds as more present in the local noise landscape. Respondents perceived the composition of the sound as changed. Natural sounds and sounds from the immediate living environment are more pronounced than before the lockdown. Noise from vehicles, aviation and nightlife noise is perceived as considerably less. Because of the disappearance of the masking effect of these "unnatural" ambient sounds, nature and neighborhood noise came more to the foreground, as it were. Although a characterization / evaluation of the noise is not available before the lockdown, it may be assumed that respondents consider the acoustic environment on site to be more pleasant during the lockdown. Respondents perceive the noise situation as calm, calming, pleasant and pleasant. It can be assumed that the appreciation that many respondents gave to the noise during the lockdown is changing now that the old situation is returning.

Contributed Papers

1:15

1pNS2. COVID-19 and self-reported noise reports: A comparative study. Yalcin Yildirim (Landscape Architecture, Univ. of Texas at Arlington/Bursa Tech. Univ., 601 W Nedderman Dr. #203, Arlington, TX 76019-0001, yalcin.yildirim@mavs.uta.edu)

COVID-19 has affected people's lives differently, from mobility concerns and staying-at-home orders to all life routines. These changes have, in turn, affected daily life in urban environments based on different factors, including air quality and noise. For example, COVID-19 has resulted in quieter environments due to less mobility on streets and less anthropogenic activities. On the other hand, staying-at-home orders promote more activities to occur at the building scale, *i.e.*, individual stay at home and produce more noise for neighbors. This study examines the noise complaints data in Dallas, USA, to understand this association by comparing the noise complaints during the COVID-19 period and the same data period in 2019. Findings surprisingly show reduced noise complaints during the COVID-19 time frame by about 14% compared to the pre-COVID-19 period. The study then performed spatial and statistical analyses, and findings show that the majority of noise reduction occurred in the city center. In other words, the noise complaints were more spatially dispersed at the outskirts of the city during the COVID-19 period. To identify specific factors, there is a need for some other techniques and studies.

1:30

1pNS3. Noise complaints in New York City and their relationship with housing cost—Before and after COVID. Martin Schiff (611 Broadway #806, New York, NY 10012, schiff@gmail.com)

This work explores how escalating New York City rent and noise dissatisfaction may interrelate, and whether pre-pandemic trends held up during 2020 and beyond. Are there parts of town that combine affordable rent and low noise complaint rates? Can past complaints and housing trends predict when and where noise complaints are most likely, and does this hold up in a city on lockdown? Using eleven years of New York City "311" hotline noise complaint records (over three million individual complaints) and combining these with neighborhood rent statistics, comparisons can be made on a local level. A positive correlation is apparent between monthly median rent and monthly noise complaint rate in every borough and sub-district in the city. Whether this is causal or inflationary coincidence is uncertain, and massively increased complaint rates during lockdown defy past trends.

Invited Papers

1:45

1pNS4. Noise annoyance in dwellings during the first wave of Covid-19. Ayca Sentop Dümen (Turkish Acoust. Society, Ibrahimkaraoglanoglu cad. 105 / 2368 Kagithane, Istanbul 34418, Turkey, ayca.sentop@bilgi.edu.tr) and Konca Saher (Turkish Acoust. Society, Istanbul, Turkey)

In March 2020, strict lock-down measures were imposed in response to COVID-19 pandemic. These restrictions greatly affected our lives together with our environment. While indoor activities increased, streets got tranquil. On Noise Awareness Day 2020, Turkish Acoustical Society started an online survey on noise annoyance in dwellings. 1053 People responded questions on perceived noisiness, dwelling satisfaction, and noise annoyance for two time periods: (1) before and (2) during the pandemic. Stress and anxiety at the time was also evaluated. The results showed that traffic noise annoyance decreased while annoyance due to own-dwelling noises increased. Although being higher than both, neighbor noise annoyance did not change significantly. People who perceived their environment as "noisy" were more satisfied with their dwelling during COVID-19, and those who perceived as "quiet" were less satisfied. Noise sensitivity and annoyance were positively correlated with stress and anxiety while individual changes in annoyance (A_{during}–A_{before}) were independent. Finally, environmental noise levels (1) before COVID-19, (2) during total lock-down and (3) partial lock-down were measured at two locations. During total lock-down noise levels dropped 7.8dB near a main road while it increased 5 dB near greenery due to human activities. During partial lock-down the levels dropped 2.4 dB and 2.1 dB respectively.

2:00–2:15 Discussion

TUESDAY AFTERNOON, 8 JUNE 2021 — 12:55 P.M. TO 2:40 P.M.

Session 1pPA

Physical Acoustics, Computational Acoustics, Biomedical Acoustics, Structural Acoustics and Vibration, and Signal Processing in Acoustics: Acoustic Wave Propagation Through Polydisperse Scatterers II

Nicholas Ovenden, Cochair
Dept of Mathematics, University College London, London WC1E 6BT, United Kingdom

Eleanor P. Stride, Cochair
Institute of Biomedical Engineering, University of Oxford, Oxford OX3 7DQ, United Kingdom

Chair's Introduction—12:55

Invited Papers

1:00

1pPA1. Ensemble average waves in random materials of any geometry. Artur L. Gower (Mech. Eng., Univ. of Sheffield, RD08, Mappin Mining Block, Sheffield S1 3JD, United Kingdom, arturgower@gmail.com) and Gerhard Kristensson (Lund Univ., Lund, Sweden)

Suppose we measure the scattered field from a material with an assortment of randomly placed particles of different sizes. To get a repeatable measurement, we may need to perform the experiment many times and average over time (or space). This talk focuses on how to calculate and understand this average field. For instance, from this average field we could then calculate what effective properties, filling a homogeneous material, would lead to the same scattered field we measured. However, these effective properties are only useful if they can tell us something about the microstructure and the particles. In this talk I will show how these effective properties depend on the geometry of the material, and not just the microstructure. On the other hand, the effective wavenumbers are inherently related to only the material microstructure and not its geometry. This result comes from a framework which was deduced from first principles, using only minimal statistical assumptions. Using this framework we will also show how to calculate the average scattered field, and specialise to a sphere filled with particles. [1] A. L. Gower and G. Kristensson, "Effective waves for random three-dimensional particulate materials." *New J. Phys.* (2021).

1:15

1pPA2. Multiple scattering effects for polydisperse scatterers in soft media. Valerie J. Pinfield (Chemical Eng. Dept., Loughborough Univ., Loughborough LE11 3TU, United Kingdom, V.Pinfield@lboro.ac.uk) and Megan J. Povey (School of Food Sci. and Nutrition, Univ. of Leeds, Leeds, West Yorkshire, United Kingdom)

We explore the effects of polydispersity in 3D heterogeneous media consisting of scattering species (*e.g.*, droplets, particles) in viscous liquids using a multiple scattering formulation to define effective speed and attenuation spectra. We adopt a published formulation [A. L. Gower, M. J. A. Smith, W. J. Parnell, and I. D. Abrahams, in Proceedings of the Royal Society of America (2018), p. 474] that rigorously extends multiple scattering theory to multi-component systems and show that in the long wavelength region it is consistent with a previous heuristic methodology applied to polydisperse scatterers. We investigate cases of a monomodal size distribution of finite width, and multi-modal size distributions with similar species. Further, systems of *mixed* scatterer species (*i.e.*, different types of scatterer) with different sizes and distributions are considered. We will discuss the implications for inversion of ultrasonic spectra to determine particle size distributions and for the design of materials with targeted properties by varying composition (concentrations of different scatterer species) and scatterer properties.

1:30

1pPA3. Von Karman spatial correlation functions for modeling ultrasonic scattering in metallic media. Andrea P. Arguelles (Eng. Sci. and Mech., Penn State Univ., 212 Earth-Engr Sci. Bldg, University Park, PA 16802, aza821@psu.edu)

In recent years, ultrasonic scattering has been studied as a potential method for nondestructive microstructure characterization in polycrystalline media. In order to invert microstructural data from ultrasonic data, analytical models of wave propagation and material statistics are generally employed. The microstructure statistics are frequently represented by spatial correlation functions (SCFs), which describe how microscopic variables at random positions are correlated (e.g., elastic stiffness). In polycrystalline media with statistically isometric crystallites, SCFs are defined as the probability that two randomly chosen points lie within a single crystallite (or grain). This work reviews common forms of the SCF in the context of ultrasonic scattering measurements. In addition, we introduce the von Karman SCF, frequently used in seismic wave propagation studies, as a potential alternative for metallic components with increased microstructural complexity. In the macroscale, the material systems are assumed to be statistically isotropic, and the microstructural differences focus on the morphology of the grain structure.

1:45

1pPA4. Agglomeration of particles by a converging ultrasound field and their quantitative assessments. Tianquan Tang (Dept. of Mech. Eng., The University of Hong Kong, Pokfulam Rd., Hong Kong and Lab. for Aerodynamics and Acoust., Zhejiang Inst. of Res. and Innovation, The University of Hong Kong, Hong Kong 999077, Hong Kong, tianquan@connect.hku.hk) and Lixi Huang (Mech. Eng., The Univ. of Hong Kong, Hong Kong, Hong Kong)

The acoustic radiation force resulting from acoustic waves has been extensively studied for the contact-free generation of organized patterns. Microscopic objects normally cluster at pressure nodes, but the size of the clusters is restricted by the saturation limit. Here, we present a two-dimensional bulk acoustic wave (BAW) device to propel particles of various sizes. It is shown experimentally that, when particles are large, significant acoustic energy is scattered and is partly absorbed by the matched layers in front of the sensors. The acoustic radiation force then forms a convergent acoustic pressure field which agglomerates the large polystyrene (PS) particles towards the central region instead of the pressure nodes. The transition from the nodal-array patterns to the central agglomeration depends on particle size, particle concentration, and load voltage. A parametric study reveals that the particles can agglomerate with a cluster ratio greater than 70%, and this ratio can be improved by increasing the load power/voltage supplied to the transducers. With its ability to perform biocompatible, label-free, and contact-free self-assembly, the device introduced offers a new possibility in the fabrication of colloidal layers, the recreation of tissue microstructure, the development of organoid spheroid cultures, the migration of microorganisms, and the assembly of bioprinting materials.

2:00

1pPA5. What does multiple scattering tell us about rheology? Professor M. Povey (School of Food Sci. and Nutrition, Univ. of Leeds, Willow Terrace Rd., Leeds ls2 9jt, United Kingdom, m.j.w.povey@leeds.ac.uk)

Longitudinal viscosity can be obtained at all frequencies directly from measurements of ultrasound/acoustic attenuation and sound velocity. The bulk viscosity can then be obtained from the longitudinal viscosity provided a measure of the shear viscosity is available. Unfortunately, the shear viscosity values chosen may be entirely inappropriate because the viscosity experienced by an oscillating particle need not be the same as that determined by low frequency oscillatory rheology. The relationships between acoustical/ultrasound parameters such as attenuation and sound velocity, bulk and shear viscosity will be presented and the role of multiple scattering in these measurements discussed. The use of dispersed phase particles, visco-inertial scattering and multiple scattering will then be considered as a possible way of determining high frequency shear viscosity.

2:15–2:40 Discussion

Session 1pSCa

Speech Communication and Psychological and Physiological Acoustics: Ideas Worth Reconsidering in Speech Perception and Production II

Matthew B. Winn, Cochair
Speech-Language-Hearing Sciences, University of Minnesota, 164 Pillsbury Dr SE, Shevlin Hall Rm 115, Minneapolis, MN 55455

Richard A. Wright, Cochair
Department of Linguistics, University of Washington, Box 352425, Seattle, WA 98195-2425

Chair's Introduction—12:55

Invited Papers

1:00

1pSCa1. Reconsidering methods for automatic speech processing: The case of the Language ENvironment Analysis (LENA) system. Laura Dilley (Communicative Sci. and Disord., Michigan State Univ., 1026 Red Cedar Rd., East Lansing, MI 48824, ldilley@msu.edu)

Starting around a decade ago, the Language Environment Analysis (LENA) system for automatic speech processing began to be used widely by both researchers and clinicians in order to derive estimates of numbers of adult words or child vocalizations during day-long audio recordings in naturalistic environments. Widespread adoption was spurred in part by a number of studies of correlational evidence of LENA's reliability. However, confidence in reliable and valid measurement of metrics of conversational interactions entails consideration of both true accuracy (cf. false positive and false negative rates) for frame-based classification, as well as variability in error rates in counts of communicative vocalizations. This talk reviews evidence indicating highly variable error rates across naturalistic recordings for both frame-based classification and counts of communicative vocalizations. Such findings prompt reconsideration of conditions under which LENA can be used with confidence of both high reliability and high validity for measuring communicative interactions.

1:15

1pSCa2. Phones in larger inventories are not (necessarily) less variable. Ivy Hauser (Linguist, Univ. of Texas Arlington, 701 Planetarium Pl., Box 19559—132 Hammond Hall, Arlington, TX 76019, ivy.hauser@uta.edu)

It is often assumed that there should be relatively less within-category phonetic variability in production in languages which have larger phonemic inventories (Lindblom, 1986 on Dispersion Theory). Although this hypothesis is intuitive, existing evidence in the literature is mixed and suggests the need to modulate the hypothesis according to phonological context (*e.g.*, Renwick, 2012) and individual cues (Recasens and Espinosa, 2006). In this paper, we examine this prediction using data from sibilant fricatives in French, Polish, and Mandarin. A direct implementation of Lindblom (1986) predicts more variation in French (2 sibilants) relative to Polish and Mandarin (3 sibilants). We obtained data from these languages in a speech production experiment, analyzing within-category variability in sibilant center of gravity and onset of the second formant of the following vowel. We observed no language-specific differences in extent of within-category variability on either phonetic dimension. We did, however, observe systematic individual differences in extent of within-category variability among speakers of the same language, which were correlated with individual differences in production cue weight. We interpret these results as evidence that extent of variation is related to phonological contrast, but contrast must be quantified in terms of cue weight, rather than phoneme inventory size.

1:30–1:45 Discussion

Session 1pSCb

Speech Communication and Psychological and Physiological Acoustics: Ideas Worth Reconsidering in Speech Perception and Production III

Matthew B. Winn, Cochair
Speech-Language-Hearing Sciences, University of Minnesota, 164 Pillsbury Dr. SE, Shevlin Hall Rm. 115, Minneapolis, MN 55455

Richard A. Wright, Cochair
Department of Linguistics, University of Washington, Box 352425, Seattle, WA 98195-2425

Chair's Introduction—2:00

Contributed Papers

2:05

1pSCb1. Mobile voice recording and analysis: Uncertainty and reproducibility. Eric J. Hunter (Michigan State Univ., MI, ejhunter@msu.edu)

Mobile voice recording has been a staple of voice research, providing an authentic representation of speech outside a controlled environment; however, mobile recordings increase uncertainty with potential environmental sound contamination, as well as speech production differences due to variations in environment, purpose, or communication partner. Several studies will be reviewed to give context to uncertainty and reproducibility issues to be considered when conducting mobile voice recording.

2:10

1pSCb2. Individual differences in speech perception: Evidence for gradiency in the face of category-driven perceptual warping. Efthymia C. Kapnoula (Basque Center on Cognition, Brain and Language, Donostia-San Sebastián, Gipuzkoa, Spain, kapnoula@gmail.com) and and Bob McMurray (Univ. of Iowa Iowa City, IA)

In contrast to the long-running debates around universally categorical vs. gradient speech perception, we find individual differences in listeners' sensitivity to subtle acoustic differences between speech sounds (within and between phoneme categories). Here, we used an EEG measure of listeners' early perceptual encoding of a primary acoustic cue and found that categorical listeners showed stronger perceptual warping around the boundary, even as sensitivity to within-category differences was present across the board.

2:15

1pSCb3. New methodologies for research in bilingual speech processing. Laura Spinu (City Univ. of New York—Kingsborough Community College, NY, lspinu@kbcc.cuny.edu)

Findings in bilingual cognition have long been undermined by conflicting results attributed, among others, to our inability to adequately describe and quantify bilingual knowledge in the context of experimental work. In this presentation, I will discuss the necessity of standardizing experimental paradigms involving bilinguals through the collaborative development of partly automated proficiency testing tools for a variety of languages.

2:20

1pSCb4. Transient speech processing costs depend on accent type and talker variability. Madeleine E. Yu (Univ. of Toronto Mississauga, Mississauga, ON, Canada, madeleine, yu@mail.utoronto.ca) and and Craig Chambers (Univ. of Toronto Mississauga Mississauga, ON, Canada)

In a dual-task paradigm, native English-speaking listeners (N=55) made judgments about visually presented digits while simultaneously listening to speech that varied by talkers-per-accent (between-subjects: 1 vs 3) and accent type (within-subjects: native[Canadian]/regional[Australian]/nonnative[Mandarin]). Adaptation occurred within only six exposures but was only observed for nonnative and native-accented speech ($p < 0.05$) and was also dependent on talkers-per-accent, indicating that transient speech processing demands are uniquely impacted by the interactions between accent type and talker variability.

2:25–2:40 Discussion

2:40

1pSCb5. Articulatory and acoustic phonetics of voice actors. Colette Feehan (Indiana Univ., Bloomington, IN, cmfeehan@iu.edu)

Looking at voice actors' novel productions of typical speech sounds can tell us more about over which muscles we have volitional control. This can help us to test models of speech production, inform speech therapy, and create better pedagogy for teaching vocal performance.

2:45

1pSCb6. Labiodentalization of Korean bilabials. Elisabeth Kang (Univ. of Brit. Columbia Interdisciplinary Speech Research Lab, Canada, eliskang@gmail.com), Linda Wu, Melissa Wang, Alexandria Brady, Grace Purnomo, Yadong Liu, and Bryan Gick (UBC Interdisciplinary Speech Research Lab)

The present study examines the interaction of Korean bilabials in natural speech during neutral and smiling conditions to determine whether labiodentalization occurs and, if it does, how the body resolves the conflict between lip spreading and lip compression in smiled speech. Results from various Korean YouTube videos indicate that despite the absence of labiodental tokens in the Korean language inventory, bilabial stops are compromised in smiled speech in being realized as labiodental tokens.

2:50

1pSCb7. Are there no back vowels? Angela Xu (UCLA, Los Angeles, CA, angelaxusc@gmail.com), Dylan Ross, and Z.L. Zhou (UCLA, Los Angeles, CA)

Esling (2005)'s Laryngeal Articulator model of vowels and the traditional grouping of vowels make different predictions for the effects of front and back vowels on non-contrastive rounding in adjacent [ʃ]. We experimentally measured the rounding of [ʃ] (operationalized as center of gravity) neighboring different vowels and compared two mixed error-component models representing the theories; we find no significant evidence favoring the retraction model over the traditional model.

2:55

1pSCb8. Social priming or not? Investigating generalizability via individual variation. Lauretta S. P. Cheng (Univ. of Michigan, Ann Arbor, MI, lspcheng@umich.edu)

Although the effects of social priming-where social information about a speaker influences linguistic decisions-have long been accepted (e.g., Niedzielski, 1999; Strand, 1999; Hay et al., 2006), recent studies call attention to a lack of generalizability across contexts (e.g., Lawrence, 2015; Chang, 2017; Walker et al., 2019). The current study finds that social priming, in the case of /aʊ/-raising in Michigan and Canadian English, is primarily observed for individuals who scored high on both stereotype awareness and cognitive perspective-taking, suggesting that aspects of both the sociolinguistic context and participant sampling can impact when and why social priming effects do not occur.

3:00 - 3:15 Discussion

Additional presentations and discussions may be added

TUESDAY AFTERNOON, 8 JUNE 2021 12:55 P.M. TO 4:00 P.M.

Session 1pSP

Signal Processing in Acoustics and Animal Bioacoustics: Signal Processing for Environmental Sensing II

Ananya Sen Gupta, Cochair
Department of Electrical and Computer Engineering, University of Iowa, 103 S Capitol Street, Iowa City, IA 52242

Kainam T. Wong, Cochair
School of General Engineering, Beihang University, New Main Building D-1107, 37 Xueyuan Road, Beijing 100083, China

Chair's Introduction—12:55

Contributed Papers

1:00

1pSP1. Improving data labeling efficiency for deep learning-facilitated bioacoustics monitoring. Mallory Morgan (Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180, morgam11@rpi.edu) and Jonas Braasch (Rensselaer Polytechnic Inst., Troy, NY)

Over the last decade, deep learning has proven invaluable for classifying data with complex spatial and temporal relationships. Unfortunately, its utility in the context of bioacoustics monitoring has been limited by the unavailability of large, labeled datasets of species vocalizations. To explore solutions to this problem, various deep learning architectures and techniques were evaluated for their ability to reduce the data labeling efforts required to characterize the distinct sound stimuli present in two different acoustic environments. Located around Lake George, NY, these sites were acoustically monitored nearly continuously for 12 months. Commonly employed techniques such as transfer and semi-supervised learning were then analyzed for their ability to reduce the amount of labeled data necessary to achieve state-of-the-art classification results. Meanwhile, cross-corpus training was used to provide automatic "pre-labels" for these datasets, reducing the amount of total time associated with data labeling efforts. A hierarchical neural network was also implemented in order to reduce the performance costs associated with encountering sound stimuli in the test dataset that was not captured in the training dataset, perhaps as a result of the reduction techniques outlined.

1:15

1pSP2. Active sonar target classification using a physics-cognizant feature representation. Bernice Kubicek (Dept. of Elec. and Comput. Eng., Univ. of Iowa, 103 South Capitol St., Iowa City, IA 52242, bernice-kubicek@uiowa.edu), Ananya Sen Gupta (Dept. of Elec. and Comput. Eng., Univ. of Iowa, Iowa City, IA), and Ivars Kirsteins (Naval Undersea Warfare Ctr., Newport, RI)

Active sonar target classification is challenging due to the non-linear overlap of changing oceanic and target parameters, creating entangled acoustic color spectra that should be disentangled prior to classification. A physics-cognizant feature extraction algorithm, used before interfacing with three machine learning techniques for active sonar target classification of experimental field data, is presented. The feature extraction algorithm convolves a two-dimensional Gabor wavelet across acoustic color spectra prior to threshold-based binarization, feature culling, and dimensional reduction.

The optimal two-dimensional Gabor wavelet parameters are chosen through sensitivity analysis by a support vector machine (SVM) on a disjoint subset of data. Classification is performed on the second subset of data with an SVM, random forest tree, and neural network on the Gabor filtered spectra and unfiltered spectra to show the increased classification accuracy of the application of the geometric wavelet. Classification results are presented as confusion matrices for four targets of two public domain experiments. Ongoing and future work will include extending this feature extraction technique using various geometric feature representations to capture and describe far-field large scattering mechanisms from targets such as oil rigs, tankers, and shipwrecks. [This research is funded by the Office of Naval Research under Grant No. N00014-19-1-2436.]

1:30

1pSP3. Representation of bioacoustic sound data through graphical similarities to enhance knowledge discovery. Ryan A. McCarthy (Elec. and Comput. Eng., Univ. of Iowa, 103 S. Capitol St., Iowa City, IA 52242, ryan-mccarthy-1@uiowa.edu)

Autonomous detection and classification of species through bioacoustics sound has been an ongoing and challenging problem due to noise, overlapping sound, and varying frequency components. This work assesses bioacoustic sound data through speech patterns similarities by utilizing graphical representations of features found in spectrograms. Speech within the received sound can be characterized as individual components within the spectrogram that can be used to identify species. In this work, individual components are connected high PSD dB values in the spectrogram that form unique shapes. By representing these components through graphical representations, similarities of speech can be seen as repeating patterns across larger collected data sets that can be associated with certain behaviors of species. An example resulting graphical representation is presented through a sample humpback whale speech collected. [This research is funded by the Office of Naval Research under Grant No. N00014-19-1-2609.]

1:45

1pSP4. Tracking multiple humpback whales simultaneously using time-frequency representations of active intensity on DIFAR acoustic vector sensors. Aaron M. Thode (Scripps Inst. of Oceanogr., Univ. of California, San Diego, La Jolla, CA), Alexander Conrad (Greeneridge Sci., 90 Arnold Pl., Ste. D, Santa Barbara, CA, conrad@greeneridge.com), Marc Lammers (Hawaiian Islands Humpback Whale National Marine Sanctuary, NOAA, Kīhei, HI), and Katherine Kim (Greeneridge Sci., San Diego, CA)

Humpback whale song consists of sequences of frequency-modulated sounds whose exact purpose remains unknown. Tracking multiple individuals simultaneously may provide insights into song function and assist in population estimation; unfortunately, during the winter breeding season off Hawaii so many whales produce overlapping songs that identifying the same individual becomes challenging on underwater sensors spaced a few kilometers apart. Here we present a triangulation technique using three bottom-mounted DIFAR acoustic vector sensors for tracking multiple animals simultaneously. A time-frequency representation of the dominant azimuth ("azigram") of the acoustic energy is computed from estimates of the active intensity, (*i.e.*, the conjugate product of pressure and particle velocity). By defining a set of azimuthal sectors, azigrams from each sensor can be subdivided into a series of binary images, with each image associated with energy propagating from a particular azimuthal sector. Spectrogram correlation methods applied to binary images from different sensors yield individual song fragments that can be used to mask the original azigram, yielding the azimuth of the fragment from each sensor, and thus the singer's position. The technique, which has also been demonstrated on coral reef fish, is illustrated using singer data collected in 2020 off Maui, Hawaii.

2:00–2:15 Discussion

2:15–2:30 Break

Contributed Papers

2:30

1pSP5. Green's functions extraction between ships of opportunity using a vertical array. Gihoon Byun (Marine Physical Lab., Scripps Inst. of Oceanogr., 5260 Fiore Terrace, San Diego, CA 92122, gbyun@ucsd.edu) and Hee-Chun Song (Marine Physical Lab., Scripps Inst. of Oceanogr., La Jolla, CA)

This work describes a method for extracting the time-domain Green's function between two ships in a shallow-water environment. First, the individual Green's functions from each ship are estimated along the vertical receiver array using blind deconvolution. Then, the Green's function between two ships is obtained simply by either correlation or convolution of the individual Green's functions, depending on the array position with respect to the ships. Simulation and experimental results are presented and discussed to demonstrate the feasibility of extracting the Green's functions between ships radiating random broadband noise (100–500 Hz), using a 56.25 m long vertical array in about 100-m deep shallow water.

2:45

1pSP6. Correlation signal processing for determination of the spatial distributions of temperature and acoustic characteristics of the medium. Konstantin Dmitriev (Acoust., Moscow State Univ., Leninskie Gory, 1, 2, Moscow 119992, Russian Federation, presentatio@mail.ru), Olga Rumyantseva, and Sergey A. Yurchenko (Acoust., Moscow State Univ., Moscow, Russian Federation)

It is required in some applications to determine spatial temperature distribution inside investigated object, when direct measurement is impossible, and IR and microwave methods do not provide acceptable spatial resolution. For example, such problems arise in diagnostics of soft biological tissues lying at a depth of about 10 cm or more, and in hyperthermia. To do this, thermal acoustic radiation of the object can be used, which is similar to thermal electromagnetic radiation. It is required to solve the complicated inverse radiation-scattering problem. The intensiometric approach allows determining temperature by signal power measuring at each receiver and by subsequent processing. The correlation processing approach involves calculating the cross correlation functions for each pair of receivers. This approach improves the resolution. The acoustic field focusing is used to further improve the sensitivity and resolution. Moreover, the receiver system can be supplemented with transmitters creating a controlled noise field that is similar to the thermal acoustic field of the object. In this case, the algorithm is proposed that uses three data sets obtained under different experimental conditions. This algorithm allows to separately reconstruct the spatial distributions of temperature, absorption coefficient, and sound speed. [This study was supported by RFBR under Grant No. 21-32-70003]

3:00

1pSP7. Tracking surface waves in bi-static geometries with Doppler sensitive probe signals. Edward Richards (Ocean Sci., UC Santa Cruz, 532 Meder St., Santa Cruz, CA 95060, edwardlrichards@gmail.com)

This talk describes a method of estimating the position and velocity of surface waves that uses the delay and Doppler shift of observed scatter arrivals, and does not need a receiving array with high spatial resolution. This method is demonstrated using data collected during the at-sea KAM11 experiment, similar to data that has been previously analyzed using Doppler insensitive linear frequency modulated waveforms [*e.g.*, M. Badiey, A. Song, and K. Smith, *J. Acoust. Soc. Am.* **132**(4), EL290–EL295 (2012)]. An analysis of Doppler sensitive maximum length sequence transmissions is presented for the same experimental geometry as the previous studies. The Doppler sensitive analysis shows additional scatter arrivals previously not reported with distinct Doppler shifts. A simple travel time argument is then used to explain the observed Doppler of the scatter arrivals, and infer the time-varying position of waves traveling along the sea surface.

3:15

1pSP8. A hydroacoustic approach to oil detection in ice covered water. Veronica Shull (Eng., Lake Superior State Univ., 1110 Meridian St., Sault Sainte Marie, MI 49783, sags@lssu.edu), Lauren Niemiec, Bryan Wertz, Brennan Suddon, Robert Hildebrand, David Baumann, and Edoardo Sarda (Eng., Lake Superior State Univ., Sault Ste. Marie, MI)

A method of detecting oil spills in ice-covered lakes and seas, by observing changes in underwater acoustic reverberation time, had earlier been proposed; testing in a small tank environment showed it to hold some promise. Work now continues to improve the method, to further validate it, and to extend it to large bodies of water. The current work carries such scale testing further, establishing, by hypothesis testing, the level of confidence with which the presence of an oil layer underlying the ice can be discerned. Moreover, it expands the study to full scale experimentation in lakes and seas, including a portion of the Great Lakes across which a pipeline lies. These experiments seek to determine representative reverberation times (albeit without oil contamination, for obvious ethical reasons), and to explore whether natural impulsive sounds from ice fissuring may serve as a basis for passive hydroacoustic monitoring. The experiments at both scales are mutually complementary; while the tank tests serve to more rigorously validate that reverberation time is measurably affected by an oil layer, the lake-scale tests suggest those frequency bands an eventual passive monitoring using naturally arising sound would actually use, and establish the "control case" (oil-free) reverberation times.

3:30

1pSP9. Acoustic analysis of an actively controlled pipe subject to vortex induced vibration. Hui Li (Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton SO17 1BJ, United Kingdom, hl1u20@soton.ac.uk), Jordan Cheer, Stephen Daley (Inst. of Sound and Vib. Res., Univ. of Southampton, Southampton, United Kingdom), and Stephen Turnock (Dept. of Civil, Maritime and Environ. Eng., Univ. of Southampton, Southampton, United Kingdom)

Pipe-like structures are utilised in a wide variety of engineering applications, which must often consider the impact of noise and vibration. This paper presents a numerical study into the Vortex Induced Vibration (VIV) of a flexible pipe in laminar flow and the resulting acoustic radiation, and explores the potential of an active vibration control strategy. The VIV is solved using a commercial CFD code, coupled with a finite element model (FEM) to obtain the pipe displacement. The hydrodynamic noise is solved using the FW-H equation based on the acoustic analogy and the vibrational noise is calculated by an acoustic FEM in the time-domain. Without control, when the vortex shedding frequency is approximately equal to the first structural natural frequency of the pipe, large amplitude vibration is induced. The fluid-pipe interaction causes hydrodynamic noise and the vibration of the pipe generates significant vibroacoustic noise. The simulations show that when the first mode of the pipe is well excited, the vibroacoustic noise dominates the sound radiation. A velocity feedback controller is then utilised to control the VIV of the pipe, which reduces both the vibrational and hydrodynamic noise, with the latter reduced to about the same level as a rigid stationary pipe.

3:45–4:00 Discussion

Session 1pUW

Underwater Acoustics: Underwater Sound Modeling: Comprehensive Environmental Descriptions

Timothy Duda, Cochair
Woods Hole Oceanographic Inst., 86 Water Street, Woods Hole, MA 02543

Bruce Cornuelle, Cochair
San Diego, CA

Chair's Introduction—12:55

Invited Paper

Valid environmental information is critical for effective modeling and simulation of underwater sound. Subject matter centers on the latest methods for best describing water, seabed and surface conditions in models. A wide-ranging discussion of how to effectively determine the necessary information and how to represent it in computations is planned. Panelists include oceanographers, acousticians, and signal processors. Scheduled panelists include Anatoliy Ivakin, Megan Ballard, Martin Siderius, Pierre Lermusiaux, Paolo Oddo, Tim Duda and Lora Van Uffelen.

Session 1pID

Keynote Lecture

Maureen L. Stone, Chair
Department of Neural and Pain Sciences and Department of Orthodontics and Pediatrics, University of Maryland School of Dentistry, Baltimore, MD 21201

Chair's Introduction—4:00

4:05

1pID. Speech acoustics and mental health assessment. Carol Espy-Wilson (Electr. and Computer Eng. (ECE) Dept. and the Inst. for Systems Research (ISR), Univ. of Maryland, College Park, MD 20740)

According to the World Health Organization, more than 264 million people worldwide suffer from Major Depression Disorder (MDD) and another 20 million have schizophrenia. MDD and schizophrenia are among the most common precursors to suicide and, according to a 2018 CDC report, suicidality is the second leading cause of death in youth and young adults between 10 and 34 years of age. While suicidality has historically been at low rates in the black community, it has recently become a crisis for black youth. It is the second leading cause for the death of black children between 10 and 14 years of age, and it is the third leading cause of death for black adolescents between 15 and 19 years of age. Our work is focused on understanding how a person's mental health status is reflected in their coordination of speech gestures. Speech articulation is a complex activity that requires finely timed coordination across articulators, i.e., tongue, jaw, lips, velum, and larynx. In a depressed or a psychotic state, this coordination changes and, in turn, modifies the perceived speech signal. In this talk, I will discuss a speech inversion system we developed that maps the acoustic signal to vocal tract variables (TVs). The trajectories of the TVs show the timing and spatial movement of speech gestures. Next, I will discuss how we use machine learning techniques to compute articulatory coordination features (ACFs) from the TVs. The ACFs serve as an input into a deep learning model for mental health classification. Finally, I will illustrate the key acoustic differences between speech produced by subjects when they are mentally ill relative to when they are in remission and relative to healthy controls. The ultimate goal of this research is the development of a technology (perhaps an app) for patients that can help them, their therapists and caregivers monitor their mental health status between therapy sessions.

Q&A will follow the presentation

OPEN MEETINGS OF TECHNICAL COMMITTEES

The Technical Committees of the Acoustical Society of America will hold open meetings on Tuesday and Thursday evenings. Meetings will begin at 6:00 p.m. on Tuesday and 5:00 p.m. on Thursday, except for Noise and Speech Communication as noted in the list below.

These are working, collegial meetings. Much of the work of the Society is accomplished by actions that originate and are taken in these meetings including proposals for special sessions, workshops, and technical initiatives. All meeting participants are cordially invited to attend these meetings and to participate actively in the discussion.

Committees meeting on Tuesday are as follows:

Acoustical Oceanography
Animal Bioacoustics
Architectural Acoustics
Engineering Acoustics
Physical Acoustics
Psychological and Physiological Acoustics
Signal Processing in Acoustics
Structural Acoustics and Vibration

Committees meeting on Thursday are as follows:

Biomedical Acoustics
Computational Acoustics
Musical Acoustics
Noise 4:30 p.m.
Speech Communication 5:30 p.m.
Underwater Acoustics

See the Acoustics in Focus webpage for open meeting zoom links at acousticalsociety.org/asa-meetings/

Session 2aAO

Acoustical Oceanography, Animal Bioacoustics and Underwater Acoustics: Long Term Acoustic Time Series in the Ocean I

Jennifer Miksis-Olds, Cochair
University of New Hampshire, 24 Colovos Rd., Durham, NH 03824

Joseph Warren, Cochair
School of Marine and Atmospheric Sciences, Stony Brook University, 239 Montauk Hwy, Southampton, NY 11968

Chair's Introduction—9:30

Invited Paper

9:35

2aAO1. What can you do with twenty years of water column sonar data? Plenty!. J Michael Jech (NEFSC, 166 Water St., Woods Hole, MA 02543, michael.jech@noaa.gov)

Collection of multifrequency fisheries acoustic data began at the NOAA Northeast Fisheries Science Center (NEFSC) in 1998. Over the past 20 + years, data have been collected on the NOAA fisheries survey vessels as well as commercial vessels during numerous surveys and research cruises. Many lessons in cooperation, initiative, persistence, and compromise have been learned, resulting in data sets with plenty of potential. Some of these data have been rejected and then resuscitated for stock assessments, used to estimate biomass of undersampled biota, and used to study catchability of commercial species. Until recently, data were limited to those at the NEFSC with sufficient expertise and access to the data—*i.e.*, me, which has restricted application of the data. But now the data are searchable and available to the world via NOAA's National Center for Environmental Information (NCEI). The evolution of acoustic technology and software from costly and proprietary to inexpensive and open-source has expanded the utility of these, and other long-term, data sets to the broader scientific community. An overarching goal has been to collect consistently high-quality data, yet only through incorporating innovation can long-term data collection survive in a dynamic environment and ever-changing scientific landscape.

Contributed Papers

9:50

2aAO2. Seasonal variations in multi-year active acoustic surveys of fish and zooplankton in the New York Bight. Brandyn M. Lucca (School of Marine and Atmospheric Sci., Stony Brook Univ., 239 Montauk Hwy., Southampton, NY 11968, brandyn.lucca@stonybrook.edu), Hannah Blair, and Joseph Warren (School of Marine and Atmospheric Sci., Stony Brook Univ., Southampton, NY)

Active acoustic surveys provide fine-scale measurements over broad spatial and temporal scales of organism abundance in the water column which can be useful as ecosystem indicators. As part of a long-term time series monitoring program, we conducted seasonal surveys within the New York Bight beginning in 2017. The survey comprises eight transects that extend from near-shore to the continental shelf break, and include multiple stations within each transect where net tows and CTD casts are conducted. Acoustic backscatter measurements at 38, 70, 120, and 200 kHz from the water column were integrated (NASC, m^2 nmi^{-2}) to examine the distribution and relative abundance of pelagic scatterers. Generally, NASC was highest during the summer and fall surveys, which corresponds to expected seasonal migrations of fish and squid in this area. Winter NASC distributions were highest in waters deeper than 50 m, but increased nearshore during the summer and fall surveys. Backscatter also appeared to be associated with bathymetric features, such as the shelfbreak and the Hudson Canyon, and in some cases with hydrographic fronts and gradients. These data are the first steps in a longer-term monitoring program of pelagic organisms in the New York Bight.

10:05

2aAO3. Spatial variability of epi- and mesopelagic backscattering layers remains relatively constant over multi-year monitoring across the southeastern U.S. shelf break. Hannah Blair (School of Marine and Atmospheric Sci., Stony Brook Univ., 39 Tuckahoe Rd., Southampton, NY 11968, hannah.blair@stonybrook.edu), Jennifer Miksis-Olds (Univ. of New Hampshire, Durham, NH), and Joseph Warren (School of Marine and Atmospheric Sci., Stony Brook Univ., Southampton, NY)

Acoustic echosounders can measure the distribution and abundance of pelagic organisms over varying spatial and temporal scales. The spatial variability of 38 kHz backscatter along the U.S. Mid- and South Atlantic continental slope was measured from ship-based surveys (50–100 km^2) at seven sites over a four year period. We used variogram analysis to estimate the horizontal spatial structure of backscatter measurements and examined how these varied among sites, across years, and with environmental factors. Average patch sizes were consistently between 2 and 4 km for surveys across time and location. Modeled variogram range varied significantly with the depth of the backscatter layer, but linear effect sizes were negligible ($<$1 m). Chlorophyll *a* (chl-*a*) concentration had a significant positive effect on range (95 m), suggesting patch sizes are slightly larger in the epipelagic where chl-*a* concentration is higher. Incorporating variogram range, sill, and

nugget produced some clustering of backscatter spatial autocorrelation with depth, particularly for the deepest sites assessed. These results offer insight into nekton and macrozooplankton backscatter patterns in important shelf slope systems, and provide needed information to design accurate long-term monitoring programs for offshore marine habitats. [Work supported by BOEM/ONR/NOAA under NOPP]

10:20

2aAO4. Atlantic deepwater ecosystem observatory network: Patterns of acoustic backscatter and community structure of the U.S. Outer Continental Shelf. Jennifer Miksis-Olds (Ctr. for Acoust. Res. & Education, Univ. of New Hampshire, 24 Colovos Rd., Durham, NH 03824, j.miksisolds@unh.edu), Joseph Warren, Hannah Blair, and Brandyn M. Lucca (School of Marine and Atmospheric Sci., Stony Brook Univ., Southampton, NY)

Three nodes in the Atlantic Deepwater Ecosystem Observatory Network (ADEON) network on the U.S. Mid- and South Atlantic Outer Continental Shelf (OCS) contain an upward looking, multi-frequency echosounder system. Data was collected from November 2017–December 2020 at these sites extending from the OCS waters of Virginia down to Florida. Along shelf backscatter comparisons were made for general scattering groups related to fish and zooplankton across time and latitude. Unique seasonal patterns were observed across sites both in terms of volume backscatter magnitude and community structure. Measurements made within this research program will serve as a baseline for pattern and trend analyses of acoustic backscatter related to ecosystem components of this traditionally under sampled, offshore region. Study concept, oversight, and funding were provided by BOEM under Contract No. M16PC00003, in partnership with ONR and NOAA. Funding for ship time was provided under separate contracts by ONR, Code 32.

10:35

2aAO5. Long-term acoustic monitoring and tracking of natural hydrocarbon seeps from an offshore oil platform in the Coal Oil Point seep field. Alexandra M. Padilla (CCOM/JHC, Univ. of New Hampshire, 24 Colovos Rd., Durham, NH 03824, apadilla@ccom.unh.edu), Franklin Kinnaman, David Valentine (Earth Sci., Univ. of California, Santa Barbara, CA), and Thomas C. Weber (CCOM/JHC, Univ. of New Hampshire, Durham, NH)

The Coal Oil Point (COP) seep field, located offshore of Santa Barbara, California, is known for its prolific, natural hydrocarbon seepage activity. The COP seep field has been active for decades and previous research indicates both spatial and temporal variability in seep activity across the area. An offshore oil platform within the COP seep field, known as Platform Holly, has extracted oil and gas in the area since the late 1960s, which has been linked to a reduction in natural seep activity. In recent years, Platform Holly has been decommissioned, and anecdotal observations indicate a subsequent resurgence in natural seep activity in the vicinity. In early September 2019, a Simrad ES200 split-beam echosounder was mounted to one of the cross-members of the platform to collect acoustic measurements of the seepage activity west of the platform. This long-term time series of acoustic measurements will provide insight on the spatial and temporal variability of seepage activity in the region and how said variability is affected by external physical processes such as atmospheric pressure, currents, and tides.

10:50–11:10 Discussion

11:10–11:25 Break

Invited Papers

11:25

2aAO6. Web-based visualization of long-term ocean acoustic observations and modelled soundscapes. Thomas Butkiewicz (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Chase Ocean Lab, 24 Colovos Rd., Durham, NH 03824, tbutkiewicz@ccom.unh.edu), Colin Ware, Jennifer Miksis-Olds, Anthony P. Lyons, and Ilya Atkin (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH)

The Atlantic Deepwater Ecosystem Observatory Network (ADEON) is an array of hydrophones deployed along the U.S. Mid- and South Atlantic Outer Continental Shelf, that has been collecting long-term measurements of natural and human sounds in the region since 2017. This presentation focuses on the design and implementation of a web-based geospatial visualization interface that allows anyone to easily explore the massive datasets being generated in order to gain insight about the ecology and soundscape of the region. Visitors to the public website can use an interactive map of the ADEON project region to see the locations of the hydrophone deployments, 2D overlays of contextual data such as sea surface temperature and chlorophyll levels, and 3D modelled soundscapes. Selecting individual deployment stations brings up visualization interfaces that provide multiple ways to explore the data that has been collected there. A perceptually optimized tri-level spectrogram viewer permits rapid exploration of multiple years of raw recordings, and a similar deviations viewer reveals times when the ocean was unusually loud (or quiet) at various frequencies. An interactive heat map visualization presents the results of marine mammal detection algorithms, providing insight into migration behaviors, relationships with surrounding conditions such as temperature and chlorophyll, and cyclical patterns.

11:40

2aAO7. Centralized repositories and cloud-based access: How ocean acoustic archives add value and enhance science. Carrie Wall (Univ. of Colorado, 216 UCB, Boulder, CO 80309, carrie.bell@colorado.edu), Charles Anderson, and Veronica Martinez (Univ. of Colorado, Boulder, CO)

The NOAA National Centers for Environmental Information has developed two ocean acoustic archives for long-term stewardship, discovery and access to water-column sonar and passive acoustic data. These vast datasets are collected across NOAA, other government agencies, and academia for a wide range of scientific objectives. Through free and global access, users can discover, query, and analyze the data for new research and add value to the data by using it beyond its original collection purpose. NCEI has partnered with Google and Amazon Web Services to facilitate cloud-based access to 200 + TB of archived ocean acoustic data. Users can listen to the sound files from their browser, immediately download the desired data, and—most importantly—bring processing routines to large volumes of data from simple statistical analyses to artificial intelligence. The strength of the archives, the challenges faced by the impending tsunami of data, and how to tap into the archives for current and future acoustic research will be discussed.

Contributed Paper

11:55

2aAO8. Echopype: Enhancing the interoperability and scalability of ocean sonar data processing. Wu-Jung Lee (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98105, wjlee@apl.washington.edu), Valentina Staneva (Univ. of Washington, Seattle, WA), Emilio Mayorga, Kavin Nguyen (Appl. Phys. Lab., Univ. of Washington, Seattle, WA), Landung Satiewan, and Imran Majeed (Univ. of Washington, Seattle, WA)

The recent expanded availability of autonomous ocean sonar systems has created a data deluge. Despite their potential in advancing our understanding of the marine ecosystems, a large proportion of these new data remains significantly under-utilized. Specifically, the sheer tedium in data wrangling has significantly diverted efforts of the research community away from answering scientific questions. One of the root causes of this problem is the lack of an interoperable and scalable analysis workflow that adapts well with the rapidly increasing data volume and can be easily integrated with other oceanographic observations. To address this challenge, we developed an open-source software package "Echopype" that leverages the power of existing distributed computing libraries in the scientific Python ecosystem to directly interface data storage and computation on the cloud. Echopype provides tools to convert manufacturer-specific data files to a standardized, labeled multi-dimensional format that is familiar to the wider oceanography and geoscience communities, and offers a uniform computational interface for data originating from heterogeneous instrument sources. We envision that the continued development of Echopype will catalyze broader use of sonar data in oceanographic studies.

12:10–12:30 Discussion

WEDNESDAY MORNING, 9 JUNE 2021 9:30 A.M. TO 12:15 P.M.

Session 2aBAa

Biomedical Acoustics: Advances in Ultrasound Imaging: Novel Imaging Methods

Libertario Demi, Chair
Information Engineering and Computer Science, University of Trento, Via Sommarive 9, Trento 38123, Italy

Chair's Introduction—9:30

In recent years, medical ultrasound imaging technology has gone through important transformations: from the advances in the field of lung ultrasound, to the introduction of artificial intelligence, the continuous progress made with programmable research platforms, the improvements in high frame rate cardiac imaging, the growth in photoacoustics applications, as well as in the field of tissue mechanics estimation. During this panel discussion, international experts in these areas will give their overview of the most recent developments in their fields as well as a forward looking view of what awaits us in the future. The discussion features Libertario Demi from The University of Trento, Yonina Eldar from the Weizmann Institute, Piero Tortoli from the University of Florence, Ron Daigle CTO of Verasonics, Jan D'Hooge from The Katholieke Universiteit Leuven, Srirang Manohar from Twente University, and Elisa Konofagou from Columbia University.

Session 2aBAb

Biomedical Acoustics: Advances in Ultrasound Imaging

Karla Mercado-Shekhar, Chair
Indian Institute Of Technology Gandhinagar, Ab 5/317a, 382355, India

Chair's Introduction—9:30

Contributed Papers

9:35

2aBAb1. A Hybrid magnetic-ultrasonic technique for spectral viscoelastic characterization of soft solids. Rafael Tarazona (Universitat Politècnica de València, València, Spain, ratatar@ibv.upv.es), Alejandro Cebrecos, Noé Jiménez, and Francisco Camarena (i3M, CSIC, Universitat Politècnica de València, València, Spain)

We present a hybrid technique that combines magnetic forces and ultrasonic waves (MMUS based) to explicitly characterize the complex elastic modulus of soft-solids in the frequency domain. The results show the dependence of the viscoelastic properties with the frequency content of the applied magnetic impulse.

9:40

2aBAb2. Effect of retraction time and thrombin concentration on porcine whole blood clot elasticity and rt-PA susceptibility. Chadi Zemzemi (Univ. of Cincinnati, Cincinnati, OH, zemzemci@uc.edu), Matthew Phillips (Univ. of Cincinnati, Cincinnati, OH), Kenneth B. Bader (Univ. of Chicago, Chicago, IL), Kevin J. Haworth, and Christy K. Holland (Univ. of Cincinnati, Cincinnati, Ohio)

In vitro porcine blood clots mimicking deep vein thrombosis were formed in glass pipettes using 2.5 U/ml or 15 U/ml bovine thrombin and incubated at 37°C for 15, 30, 60, or 120 min. Clot stiffness, measured by shear wave elastography, increased and rt-PA susceptibility decreased with incubation time until 3-day old highly retracted clot characteristics were recapitulated.

9:45

2aBAb3. Arterial stiffness estimation with shear wave elastography. Tuhin Roy (Civil Eng., North Carolina State Univ., Raleigh, NC, troy@ncsu.edu)

In arterial shear wave elastography, the arterial wall is excited with acoustic radiation force and the resulting wave propagation through the arterial wall is analyzed to estimate the wall modulus. In this talk, we present a guided wave inversion framework not only to estimate elastic modulus but also the viscoelasticity, which is often considered an important additional biomarker.

9:50

2aBAb4. Ultrasound measurement of transmural fiber orientation and 3D tissue strain in excised myocardium under uniaxial loading. John M Cormack (Medicine, Univ. of Pittsburgh, Pittsburgh, PA, jmc345@pitt.edu)

The noninvasive measurement with ultrasound of myofiber orientation and 3D tissue strain through the tissue thickness during the application of uniaxial tension is demonstrated on porcine myocardium. Complex tissue deformation, including rotation of myofiber sheets, during the application of stretch is observed.

9:55–10:10 Discussion

10:10

2aBAb5. H-scan analysis of subtle changes in scattering. Kevin J. Parker (Electr. & Computer Eng., Univ. of Rochester, Rochester, NY, kevin.parker@rochester.edu)

The H-scan analysis provides a matched filter approach to quantifying the scattering transfer function of tissue, at high resolution, in medical ultrasound. The approach yields quantitative estimates and high resolution images where color encodes the scattering information, and the results on normal and diseased tissues will be presented.

10:15

2aBAb6. Evaluation of H-scan imaging in phantoms and *ex vivo* tissue. Anushka Yadav (Electr. Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, Gujarat, India, yadav_anushka@iitgn.ac.in)

H-scan ultrasound imaging is a recently reported technique for tissue characterization. In this study, we report on the evaluation of H-scan imaging in hydrogel phantoms with scatterers of different sizes and in *ex vivo* tissue.

10:20

2aBAb7. Towards real-time super-resolution imaging with fast-AWSALM. Kai Riemer (Imperial Coll. London, London, UK, Kr616@ic.ac.uk), M. Toulemonde, M. Lerendegui, K. Christensen-Jeffries, S. Harput, G. Zhang, C. Dunsby, and M-X Tang

Localization-based ultrasound super-resolution imaging can visualize the microvascular structure beyond the diffraction limit but is sensitive to contrast concentration and requires acquisition for seconds. Low-boiling-point phase-change nanodroplets achieve super-resolved images with sub-second temporal resolution through activation and destruction with high frame rate plane waves in real-time.

10:25

2aBAb8. Alleviating the tradeoffs between spatial and temporal resolution in super-resolution ultrasound. Costas Arvanitis (School of Mech. Eng., Dept. of Biomedical Eng., Georgia Inst. of Technol., Atlanta, GA, costas.arvanitis@gatech.edu) and Scott D. Schoen (Georgia Inst. of Technol., Atlanta, GA)

Despite the rapid progress of super-resolution ultrasound, tradeoffs between spatial and temporal resolution may challenge the translation of this promising technology to the clinic. To temper these tradeoffs, we propose a new and computationally efficient method that can extract hundreds

of micro-bubble peaks from ultra-fast contrast-enhanced US images and demonstrate its potential to augment the abilities of SR-US in imaging micro-vascular structure and function.

10:30–10:45 Discussion

10:45–11:00 Break

11:00

2aBAb9. Image compositing for simultaneous passive imaging of stable and inertial cavitation. Maxime Lafond (INSERM, Lyon, France, maxime.lafond@gmail.com), Sonya Kennedy, Nuria G. Salido, Kevin J. Haworth (INSERM, Lyon, France), Alexander S. Hannah (Boston Scientific, Arden Hills, MN), Gregory P. Macke (INSERM, Lyon, France), Curtis Genstler (Boston Scientific, Arden Hills, MN), and Christy K. Holland (INSERM, Lyon, France)

For image guidance of ultrasound-mediated drug delivery using Definity® infusions through the Ekosonic Endovascular System (Boston Scientific, Arden Hills, MN), composite cavitation images were formed using ultraharmonic and inharmonic energy values in the green and red channels, respectively, and overlayed on B-mode images. The extension of the traditional 1D color bar to a 2D color map enabled simultaneous display of ultraharmonic and inharmonic energy, coupled with B-mode imaging for spatial localization.

11:05

2aBAb10. Acoustic emissions from echocontrast agents infused through an EkoSonic endovascular system *in vitro*. Sonya Kennedy (Univ. of Cincinnati, Cincinnati, OH, kennesy@mail.uc.edu), Maxime Lafond, Kevin J. Haworth (Univ. of Cincinnati, Cincinnati, OH), Shao-Ling Huang, Tao Peng, David D. McPherson (Univ. of Texas, Houston, TX), Curtis Genstler (Boston Scientific, Arden Hills, MN), and Christy K. Holland (Univ. of Cincinnati, Cincinnati, OH)

The objective of this study was to explore the location and amount of cavitation nucleation from DefinityÛ or drug-loaded echogenic liposomes infused through the EkoSonic endovascular system (Boston Scientific, Arden Hills, MN) in an in vitro model mimicking porcine femoral arterial flow. Passive cavitation images were acquired during echocontrast agent infusion and 2.2 MHz EkoSonic ultrasound exposure over a range of ultrasound drive powers (4 W-47 W), and the ultraharmonic and inharmonic energy patterns were compared.

11:10

2aBAb11. The role of bubbles in twinkling on pathological mineralizations. Eric Rokni (Penn State, State College, PA, ezr144@psu.edu) and Julianna C. Simon (The Pennsylvania State Univ., State College, PA)

The Doppler ultrasound twinkling artifact has been attributed to scattering off microbubbles on and within kidney stones; however, it is not clear if microbubbles are also present on other pathological mineralizations. Uric acid, cholesterol, calcium oxalate, and calcium phosphate crystals ($n = 5$/type) were grown in the lab and imaged with Doppler ultrasound in ambient and hyperbaric conditions to show that microbubbles are present and cause twinkling on mineralizations other than kidney stones. [Work supported by NSF CAREER Grant No. 1943937 and NSF GRFP Grant No. DGE1255832.]

11:15

2aBAb12. High-frame rate cavitation observation of a blunt impact on a hydrogel cranial phantom. Eric Galindo (Materials Eng., New Mexico Tech, Socorro, NM, Eric.Galindo@student.nmt.edu), Kiri J. Welsh (Materials Eng., New Mexico Tech, Socorro, NM), and Michaelann Tartis (Chemical Eng., New Mexico Tech, Socorro, NM)

In order to better understand the damage mechanisms involved in traumatic brain injury (TBI) due to blunt and blast impacts, high frame rate ultrasound was used in conjunction with high speed-optical imaging to observe potential cavitation, deformation, and shear wave propagation. We present early findings using a cranial phantom with hydrogels tuned to represent grey and white matter tissue during high-rate blunt loading. Ultimately, the developed techniques could be employed in blast chambers to understand the differences between blast- and blunt-TBI.

11:20–11:35 Discussion

Additional presentations and discussions may be added

Session 2aCA

Computational Acoustics, Physical Acoustics, Biomedical Acoustics, and Underwater Acoustics: Normal Mode Methods Across Acoustics

Jennifer Cooper, Cochair
Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Rd., M.S. 8-220, Laurel, MD 20723

Michelle E. Swearingen, Cochair
Construction Engineering Research Laboratory, US Army ERDC, P.O. Box 9005, Champaign, IL 61826

Subha Maruvada, Cochair
U.S. Food and Drug Administration, 10903 New Hampshire Ave., Bldg. WO 62-2222, Silver Spring, MD 20993

Chair's Introduction—9:30

Invited Paper

9:35

2aCA1. The use of (bi-)normal modal expansions for modeling sound propagation in the atmosphere. Roger M. Waxler (Univ. of MS, P.O. Box 1848, University, MS 38677, rwax@olemiss.edu)

One method for solving the equations of sound propagation in the atmosphere is to expand the propagating acoustic pressure with respect to the eigenfunctions (or modes) of the vertical part of the equations in the frequency domain. In the approximation that the atmosphere is vertically stratified, using an expansion in vertical modes is an implementation of seperation of variables. In the simplest case, the propagation is described by a wave equation with the sound speed depending on altitude. Finding the vertical modes requires that one solve the eigenvalue problem for the resulting vertical operator. When attenuation is included, this operator is not self-adjoint, increasing the complexity of the problem and leading to modes which are not orthogonal, but rather bi-orthogonal: that is, orthogonal to the corresponding modes of the adjoint operator. The use of and methods for obtaining modal expansions for sound propagation in the atmosphere will be discussed, ranging from low frequency audible sound propagating in the nocturnal boundary layer to infrasound propagating in the global atmosphere. If the number of modes required is small, the modes provide a compelling physical picture complimentary to that provided by geometrical acoustics.

Contributed Papers

9:50

2aCA2. A mode based broadband scattering model for deep water sound propagation. Sivaselvi Periyasamy (Dept. of Ocean Eng., Indian Inst. of Technol. Madras, Chennai, Tamil Nadu 600036, India, oe15d008@smail.iitm.ac.in), Tarun K Chandrayadula (Ocean Eng., IIT Madras, Chennai, Tamil Nadu, India), John A. Colosi (Dept. of Oceanogr., Naval Postgrad. School, Monterey, CA), Peter F. Worcester, and Matthew A. Dzieciuch (Scripps Inst. of Oceanogr., Univ. of California, San Diego, San Diego, CA)

Internal-wave induced sound-speed perturbations cause phase and intensity fluctuations of time-fronts. This paper focuses on predictions for broadband Transmission Losses (TL), time wander, and Scintillation Index (SI), along various sections of a typical deep water time-front. These statistics are usually predicted using Monte-Carlo Parabolic Equation (PE) simulations, or the high frequency based path-integral method. A physics based model that fully connects the wave-field statistics, and the internal wave spectrum, to the broadband statistics is not yet available. This paper uses the mode-based transport theory approach to predict the pressure field scattering at different frequencies, and from that the broadband statistics. This requires calculations for cross-modal correlations over mode number and frequency, which becomes computationally intensive for large bandwidths. This paper considers the adiabatic phase coherence to simplify the computations, and tests the final predictions against PE simulations and observations from the Philippine Sea 2010 experiment.

10:05

2aCA3. Separation of acoustic normal modes in shallow water. Sergei Sergeev (Acoust. Dept., Phys. Faculty, Moscow State Univ., Leninskie Gory, Moscow 119991, Russian Federation, sergeev@aesc.msu.ru), Konstantin Dmitriev, and Andrey Shurup (Acoust. Dept., Phys. Faculty, Moscow State Univ., Moscow, Russian Federation)

The normal mode method is widely used for the acoustic field presentation in the deep ocean. In shallow water, the advantages of the mode description are not obvious, since in this case the mode structure is determined by the boundary conditions at the bottom and the surface, the properties of which are most often unknown, and are also nonstationary in space and time. Under such conditions, it is not clear to what extent the mode representation obtained in numerical models corresponds to reality. The authors studied the mode structure of several shallow water bodies and the coastal shelf of the White Sea. In the case when it was possible to measure the

vertical profile of the field at the receiving point, the mode profiles are easily distinguished and can be used, for example, to determine unknown boundary conditions at the bottom and surface, including in the presence of ice cover. A method has been developed for identifying modes in the case of field reception by single spaced hydrophones; the difficulty in this case is that at each moment of time the received signal contains all propagating modes that have to be selected in subsequent processing.

10:20–10:35 Break

10:35

2aCA4. Modeling time reversal focusing amplitudes in a reverberation chamber using a modal summation approach. Brian D. Patchett (Phys. and Astronomy, Brigham Young Univ., 800 W University Pkwy, MS-179, Orem, UT 84058, brian.d.patchett@gmail.com), Brian E. Anderson, and Adam D. Kingsley (Phys. & Astronomy, Brigham Young Univ., Provo, UT)

Time reversal (TR) is a signal processing technique often used to generate focusing at selected positions within reverberant environments. This study looks at the effect of the location of the focusing, with respect to the room wall boundaries, on the amplitude of the focusing and the uniformity of this amplitude at various room locations. A numerical model based on the summation of room modes was created to simulated the TR process in a large reverberation chamber. This model returned results that showed the peak amplitude of the focusing is quite uniform, and that there is also a notable increase in amplitude for each additional surface that is adjacent to the modeled focal location. With spatial uniformity of focusing within the room and uniform increases when the focusing is near adjacent walls. An experiment was conducted that verified the numerical findings, resulting in the confirmation of both the uniformity and uniform increases as the focusing position is moved near an adjacent wall.

10:50

2aCA5. Computation of normal modes based on a coupled finite/infinite element formulation. Felix Kronowetter (Mech. Eng., TUM, Boltzmannstrasse 15, Garching near Munich 85748, Germany, felix.kronowetter@tum.de), Eser Martin (Mech. Eng., TUM, Garching near Munich, Germany), and Suhaib K. Baydoun (Chair of Vibroacoustics of Vehicles and Machines, Tech. Univ. of Munich, Garching bei München, Germany)

The computation of eigenfrequencies and corresponding normal modes in exterior acoustic domains is presented based on a coupled finite/infinite element approach. First, the eigenvalue problem is solved in 2D elliptical domains. The applicability of normal modes is discussed in the example of sonic crystals. It can be shown that the sound-insulating effect of sonic crystals and individual meta-atoms in the free field can be related to certain normal modes in exterior acoustics. The numerical results provide a new point of view and physical insights into the effects and underlying physics of sound insulation by finite periodic sonic crystals and acoustic meta-atoms in the free field. Second, the quadratic eigenvalue problem of a hollow sphere submerged in water is addressed by a contour integral method based on resolvent moments. The accuracy of the proposed numerical framework is shown by comparing the eigenfrequencies to those obtained by boundary element discretization as well as finite element discretization in combination with perfectly matched layers. Extensive parameter studies demonstrate the performance of the method with regard to both projection and discretization parameters. The contour integral method is compared to the Rayleigh-Ritz procedure with second-order Krylov subspaces via the residuals of the computed eigenpairs.

11:05–11:30 Discussion

Session 2aMU

Musical Acoustics: Numerical Methods for Musical Acoustics

Nicholas Giordano, Cochair
Auburn Univ., Auburn, AL 36849

Vasileios Chatziioannou, Cochair
Department of Music Acoustics, University of Music and Performing Arts Vienna, Anton-von-Webern-Platz 1, Vienna 1030, Austria

Mark Rau, Cochair
Music, Stanford University, 660 Lomita Court, Stanford, CA 94305

Chair's Introduction—9:30

Invited Papers

9:35

2aMU1. Numerical investigation of effects of lip stiffness on reed oscillation in a single-reed instrument. Tsukasa Yoshinaga (Toyohashi Univ. of Technol., 1-1 Tempaku, Hibarigaoka, Toyohashi 441-8580, Japan, yoshinaga@me.tut.ac.jp), Hiroshi Yokoyama (Toyohashi Univ. of Technol., Toyohashi, Aichi, Japan), Tetsuro Shoji, Akira Miki (Yamaha Corp., Shizuoka, Japan), and Akiyoshi Iida (Toyohashi Univ. of Technol., Toyohashi, Japan)

The sound of a single-reed instrument is produced by the interactions among flow, reed oscillation, and acoustic resonance in the resonator. To investigate the effects of lip stiffness on the reed oscillation and acoustic propagation in the single-reed instrument, we conduct a flow simulation coupled with a dynamic beam analysis. The flow and acoustic fields are simulated by solving the three-dimensional Navier–Stokes equations, while the geometry of the instrument is expressed by the volume penalization method in the computational grids. The lip force on the reed is modeled as a function proportional to the distance between the lip position and reed surface, and the coefficient of lip stiffness was changed in the simulation. The mouthpiece of the instrument was set in the pressure chamber. The results showed that the self-sustained oscillation of reed started by adjusting the initial pressure condition of the chamber without the lip force, and amplitudes of the reed displacement decreased until a stable condition by adding the lip force. The lip stiffness was found to affect the amplitude of reed displacement, indicating the necessity of controlling the lip force to obtain stable oscillation.

9:50

2aMU2. Three-dimensional numerical analysis of acoustic energy transfer in air-jet instrument. Ryoya Tabata (kyushu Inst. of Technol., 680-4 Kawazu, Iizuka-shi, Fukuoka 8208502, Japan, tabata@chaos.mse.kyutech.ac.jp), Hiroko Midorikawa (Dept. of Comput. and Information Sci., Seikei Univ., Tokyo, Japan), Taizo Kobayashi (Res. Inst. for Information Technol., Kyushu Univ., Fukuoka, Japan), and Ki'nya Takahashi (Dept. of Phys. and Information Technol., Kyushu Inst. of Technol., Fukuoka, Japan)

In this presentation, we will discuss acoustic energy transfer in a recorder-like air-jet instrument at a low Strouhal number. We will share the methods and results for a three-dimensional numerical analysis of acoustic energy transfer estimated using Howe's energy corollary, based on the results of a large eddy simulation. The results are remarkably stable compared with previous two-dimensional numerical results, allowing us to consider the relative timing of the energy transfer with respect to the jet displacement. We will show that three-dimensional analysis is essential, especially when considering the energy transfer due to vortex shedding above and below the pipe edge (labium).

Contributed Papers

10:05

2aMU3. Using Navier–Stokes modeling to design a better recorder. Jared W. Thacker (Phys., Auburn Univ., 155 Havenbrooke Court, Fayetteville, GA 30214, jwt0024@auburn.edu)

The recorder family consists of several instruments of varying musical compasses. A musical tone is established by blowing into the mouthpiece of the instrument and a standing pressure wave is formed in the resonator of the instrument. Blowing harder into the instrument can cause a transition from the original (lower frequency) note to a higher (frequency) note. This transition is often referred to as "regime-change." Recorder players have told us that regime-change in the bass recorder can happen at significantly lower blowing speeds for notes at the lower end of its musical compass. In this talk, regime-change is studied using Navier–Stokes based modeling in simplified models of sopranino and bass recorders. We show how the geometry beneath the labium of the recorder can be modified in order to alter regime-change behavior and extend the blowing range of the lowest notes in the bass recorder. In addition, these computational results are verified

through experimental studies using 3D printed recorders and dimensions inspired by the modeling results.

10:20

2aMU4. Tuning idiophone bar torsional modes with three-dimensional cutaway geometries. Douglas Beaton (Music Res., McGill Univ., 555 Sherbrooke St. West, Montreal, QC H3A 1E3, Canada, douglas.beaton@mail.mcgill.ca) and Gary Scavone (Music Res., McGill Univ., Montreal, QC, Canada)

The bars of marimbas, vibraphones and similar idiophones are tuned by shaping their "cutaway" or "undercut" geometries. Makers commonly shape bar cutaways to tune three flexural modes of vibration. The first flexural mode is tuned to the fundamental frequency of the bar's musical note. Two other flexural modes are tuned such that their frequencies become specific multiples of the fundamental. The remaining flexural modes and all other modes are left untuned. Makers have complained of untuned torsional modes polluting bar timbre over specific sections of the keyboard. In wooden marimba bars this problem has proven difficult to predict, filling reject bins with valuable tonewood. This work investigates tuning these torsional modes by varying bar cutaway geometry in three dimensions. No additional mass or heterogeneous materials are employed. Modal frequencies are determined via finite element analysis. Mode shapes are identified algorithmically, enabling analyses to explore the parameter space unsupervised. Geometries are tuned using a gradient-based search method. The approach, designed to efficiently solve underdetermined systems with multiple objectives, is readily applicable to other problems. A selection of tuned example models will be showcased, including rosewood and aluminum bars with common and uncommon tuning ratios.

10:35–10:55 Discussion

10:55–11:10 Break

Contributed Paper

11:10

2aMU5. Evaluation of individual differences of vibration duration of tuning forks. Kyota Nomizu (Ctr. for Frontier Medical Eng., Faculty of Eng., Chiba Univ., 1-33, Nakagawa&Otsuka Lab., Yayoi-cho,Inage-ku, Chiba 263-8522, Japan, k-nomizu@chiba-u.jp), Sho Otsuka, and Seiji Nakagawa (Ctr. for Frontier Medical Eng., Chiba Univ., Chiba, Japan)

Tuning forks are used in the fields of music, clinical tests of vibrotactile sensation/audition, and healing. For the tuning fork, longer duration of the fundamental tone is required as well as accuracy of the frequency of the fundamental tone. Additionally, it is desirable that the harmonic tone decreased immediately after the stroke. However, in the manufacturing process of the tuning forks, only the fundamental frequency is tuned and durations of tones have not been evaluated. In this study, we evaluated the effective durations of fundamental and harmonic tones generated from several kinds of tuning forks in order to clarify the parameters that affect them. Measurements of sounds generated from individual tuning forks were repeated with several holding pressures and individual differences among tuning forks and effect of the holding pressure were examined. As results, significant individual differences in the effective duration of fundamental and harmonic tones were observed. In addition, the durations of the fundamental and harmonic tones varied with change of the holding pressure, however, the holding pressures showing the longest duration were different between the fundamental and harmonic tones and also different among individual tuning forks.

Invited Paper

11:25

2aMU6. Analyzing spectral envelope position and shape in a large set of sustained musical instrument sounds. Kai Siedenburg (Dept. of Medical Phys. and Acoust., Univ. of Oldenburg, Küpkersweg 74, Oldenburg 26129, Germany, kai.siedenburg@uol.de), Simon Jacobsen (Dept. of Medical Phys. and Acoust., Univ. of Oldenburg, Oldenburg, Germany), and Christoph Reuter (Dept. of Musicology, Univ. of Vienna, Vienna, Austria)

It has been argued that the relative position of spectral envelopes along the frequency axis serves as a cue for musical instrument size (*e.g.*, violin versus viola) and that the shape of the spectral envelope encodes family identity (violin versus flute). However, the extent to which spectral envelope position and shape are affected by fundamental frequency (F0), F0- register within instruments, and dynamic level has never been rigorously quantified across a representative set of musical instrument sounds. Here, we analyzed sounds from 50 sustained orchestral instruments sampled across their entire range of F0s at three dynamic levels. Linear regression of spectral centroid (SC) values that index envelope position indicated that smaller instruments possessed higher SC values in most instrument classes, but SC also correlated with F0 and was strongly and consistently affected by the dynamic level. Instrument classification using relatively low-dimensional cepstral audio descriptors allowed for discrimination between instrument classes with accuracies beyond 80%. Envelope shape became much less indicative of instrument class whenever the classification problem involved generalization across dynamic levels or F0-registers. These analyses confirm that the spectral envelope encodes information about instrument size and family identity and highlight its strong dependence on F0 (-register) and dynamic level.

Contributed Paper

11:40

2aMU7. An investigation of sound radiation from the double bass using acoustical holography. Samuel D. Bellows (Phys. and Astronomy, Brigham Young Univ., N247 ESC Provo, UT 84602, sbellows@byu.edu) and Timothy W. Leishman (Phys. and Astronomy, Brigham Young Univ., Provo, UT)

Studying radiation from musical instruments helps increase understanding and improve applications in auralizations, room acoustics, and microphone placement techniques. This work reviews a string bass's directivity measurements and demonstrates how numerical techniques such as spherical near-field acoustical holography enhance understanding of both the instrument's near-field and far-field radiation. The technique also allows calculation of the sound intensity field around the instrument, providing additional insights.

Invited Papers

11:55

2aMU8. State-space simulation of sound source directivity for interactive geometric acoustics. Esteban Maestre (Music Res., McGill Univ., 555 Sherbrooke St. W, Montreal, QC H3A 1E3, Canada, esteban.maestre@mcgill.ca), Gary Scavone (Music Res., McGill Univ., Montreal, QC, Canada), and Julius O. Smith (Music, CCRMA, Stanford, CA)

A method is proposed for simulating the frequency-dependent directivity of sound sources for use in interactive geometric acoustic rendering applications. The method is based on using measurements to design a state-space filter allowing the interactive simulation of a time-varying number of radiated sound wavefronts, each towards a time-varying direction. With applicability in sound synthesis or auralization within virtual environments where sound sources dynamically change position and orientation, techniques are proposed for modeling and simulating directivity profiles on perceptually motivated warped frequency axes, along with alternatives for representing directivity on a per-vibration-mode basis or by reduced-order efficient representations. We demonstrate the method by using experimental acoustic data to simulate the directivity of a violin body and a clarinet air column.

12:10–12:30 Discussion

WEDNESDAY MORNING, 9 JUNE 2021 — 9:30 A.M. TO 12:20 P.M.

Session 2aNS

Noise, Animal Bioacoustics, Psychological and Physiological Acoustics, and Architectural Acoustics: Soundscape Projects: Networking, Participation, and New Technology I

Antonella Radicchi, Cochair
TU Berlin, Hardenbergstr. 40a, Sekt. B4, Berlin 10623, Germany

Brigitte Schulte-Fortkamp, Cochair
HEAD Genuit Foundation, Ebert Straße 30 a, Herzogenrath 52134, Germany

Chair's Introduction—9:30

Invited Papers

9:35

2aNS1. Soundscape design for people with dementia; The correlation between psychoacoustic parameter and human perception of safety and mood. Arezoo Talebzadeh (Faculty of Eng. and Architecture, Ghent Univ., 8 The Esplanade, Suit 2403, Toronto, ON M5E 0A6, Canada, Arezoo.talebzadeh@ugent.be) and Dick Botteldooren (Dept. of Information Technol., Ghent Univ., Gent, Belgium)

In its base, soundscape design has a human-centred approach to the acoustic environment by putting a person's perception at the heart of the design process. The goal is to improve people's quality of life and well-being through sonic environments. The soundscape approach becomes complex when designing for people with cognitive complexities. It is critical to find ways to understand the connection between soundscape and people's responses. In this research, a personalized soundscape is designed based on recognizable sounds that give persons with dementia clues regarding time and place. Research has shown the positive effect of natural and non-natural soundscape on people with cognitive difficulties. Adding recognizable sounds to the soundscape gives people a feeling of safety, elevates their mood and activates them. The soundscape then will be evaluated by persons with dementia or their caregivers for necessary adjustment. The sound's evaluation process depends on the sound's physical characteristics, the psychoacoustic parameter of sound, and the person's cognition and psychological state. The research looks at the psychoacoustic parameter of evaluated sounds (sharpness, loudness, and roughness) concerning a sense of safety and improving the mood. The goal is to find a correlation between these parameters and sound selection to improve the process and enhance people's quality of life through soundscape design.

9:50

2aNS2. Recognition of sound source components in soundscape based on deep learning. Ming Yang (HEAD Acoust. GmbH, Herzogenrath 52134, Germany, mingkateyang@163.com)

Sound source components are a crucially important aspect in soundscape, since humans' perception and evaluation of soundscape strongly depend on the recognition of the constituent sound sources of the acoustic environment. Over the last few years, numbers of studies examined the methods of automated recognition of environmental sound sources/events using machine learning technology. However, the recognition of sound source components in soundscapes remains a challenge for real applications. This present study utilizes the deep learning, a latest developed and advanced machine learning technology, to develop an algorithm to solve this challenge. Without manually extracted acoustic or psychoacoustic features based on expertise, this algorithm automatically extracts features from the spectrogram representation of the sound signals and makes the recognition. It produces the sound source components recognized in the acoustic environment and their respective present time. The algorithm achieves high recognition accuracy, based on binaural recordings of outdoor acoustic environment. For new recordings, *i.e.*, test samples, the recognition accuracies vary from 81.3% to 100%, depending on the specific sound source. This algorithm developed can greatly help soundscape research, and can be applied in automatic soundscape description of sound source components, prediction of soundscape perception and evaluation, and soundscape management.

10:05

2aNS3. A socio-technical model for soundmapping community airplane noise. Tae Hong Park (Music, New York Univ., 33 WASH SQ W, Apt. 1010, New York, NY 10011, thp1@nyu.edu)

Modern megacities around the world are exemplified by extraordinary population densities, ground transportation omnipresence, and breathtakingly busy airports that operate day and night. And while airports act as critical city infrastructures from economic, employment, and transportation perspectives, assessing noise resulting from the constancy of flyover aircraft is challenging, in part due to the lack of noise measurements. Additionally, community noise reporting yield mostly qualitative data which further renders community noise assessment difficult. Citygram, in partnership with GetNoisy, employs a socio-technical model to enable the creation of data-driven, community-accessible spatio-temporally granular airplane noise maps. The technology layer is comprised of edge compute sensor devices, cloud server, and web-based user dashboard that automatically identifies, tracks, and tags airplane events with time-stamps, decibel levels, 3D positions, tail numbers, and speed. The social layer enables community engagement and facilitates rapid sensor network scaling. This socio-technical airplane soundmapping model, we believe, can be applied to practically any neighborhood as it harnesses and integrates state-of-the-art smart noise sensing technologies, environmentally incentivized communities, existing community resources, and participation workflows that are necessary in rendering a scalable and cost-effective airplane noise soundmapping system.

10:20

2aNS4. The role of technology in creating community participation in soundscape projects. Eric Leonardson (Sound, School of the Art Inst. of Chicago, 112 S. Michigan Ave., Chicago, IL 60603, eleona@saic.edu)

For those who seek to engage diverse, multi-generational communities in urban soundscape awareness, this paper examines the social and creative roles of technology and collaborators in fostering networks and participation in public projects. The author— an experimental improvised music performer, sound artist/designer, and educator—explores models for social practice and public engagement in acoustic ecology as introduced through soundwalks, handmade electronic instruments, and field recording. The importance of inclusive approaches to programming, access to recording and other technologies, attraction through thematically focused events, listening as somatic process, and the role of institutional support, are described. Underlying these topics is a "do it yourself" (DIY) ethic of equity and collaboration with neighborhood community leaders as catalysts for using the power of narrative to build and influence soundscape awareness, thereby creating agency for local residents in shaping their own acoustic environments. Informed by Leonardson's extensive firsthand experience, the importance of art and science collaboration, balanced and informed use of new mobile technologies, the challenges of grassroots volunteer organizing, teaching in higher education and designing youth workshops, are among other ear-minded points and pursuits to be discussed.

10:35–10:50 Break

10:50

2aNS5. Sound walking Chicago's waterways. Linda N. Keane (Architecture, Interior Architecture, Designed Objects, School of the Art Inst. of Chicago, 36 S. Wabash AIADO 14th Fl., Chicago, IL 60603, lkeane@saic.edu)

What are the creative possibilities of studying soundscape ecology as citizen scientists for raising engagement with and stewardship of urban health and freshwater? Utilizing everyday technology of sound walks and recordings of Chicago's waterways, students explore sonic layers of interconnections between life in the atmosphere, geosphere, lithosphere, and hydrosphere. Citizen scientists open noise and liquid definitions of health, learning the history of Chicago's development and imagining the past, present, and future biodiversity of life. Sound walking and analysis of various Chicago sites in the loop, along the river, in parks, at the world's largest filtration plant, and along the lakefront, change understanding and begin new strategies of stewardship. Public and private partnerships with college students, Chicago public school students, Friends of the Chicago River, Chicago Line Cruises, and architectural and ecological researchers share advocacy with diverse audiences through exhibits, installation proposals, water workshops, and field trips. Hush City recordings, Radio Aporee Chicago Maps, sound emporiums, water workshops, tender house Installations, and Eco-Cruises on the river connect the public with the criticality of listening to the health of the city.

11:05

2aNS6. The implementation of a soundscape approach and methodologies in an acoustic consulting context. Mitchell Allen (Arup, 151 Clarence St., Barrack Pl. Level 5, Sydney, New South Wales, Australia, Mitchell.Allen@arup.com), Terence Caulkins (Arup, New York, NY), Brendan Smith (Oceanogr., Dalhousie Univ., Halifax, NS, Canada), and Raj Patel (Arup, New York, NY)

Acoustic engineering practice in the built environment increasingly aims to implement a soundscape approach as a base offering rather than supplementary to traditional noise control engineering. With the recent introduction of parts 1, 2, and 3 of ISO 12913, a suite of new resources has become available to apply a soundscape design approach within the built environment. There are various opportunities and obstacles associated with implementing the theory and standards as a built environment consultancy for clients on real world projects. This presentation discusses some examples and approaches adopted by Arup across the globe and highlights successes and barriers experienced along the way. Specific Arup project case studies of different scales are included where a shift towards adopting a soundscape design approach has been utilized in the broadest sense. Additionally, the role of acoustic consultants as a connection between theory, standards, and implementation is discussed.

Contributed Papers

11:20

2aNS7. Towards a new understanding of the concept of quietness. Aggelos Tsaligopoulos (Dept. of Environment, Univ. of the Aegean, University Hill, Mytilene 81100, Greece, tsaligopoulos@env.aegean.gr), Stella Kyvelou (Dept. of Economics and Regional Development, Univ. of Social and Political Sci., Athens, Greece), Nefta E. Votsi (Inst. for Environ. Res. & Sustainable Development, National Observatory of Athens, Athens, Greece), Aimilia Karapostoli (School of Architectural Eng., Democritus Univ. of Thrace, Xanthi, Greece), Chris Economou, and Yiannis Matsinos (Dept. of Environment, Univ. of the Aegean, Mytilene, Greece)

Sound is an inseparable part of the living environment and the liveability of the city, whilst environmental noise is a major stressor affecting the urban environment. Several approaches have been applied for its mitigation and the goal of several strategy plans regards the creation of quietness. "Quietness" as a term retains an ambiguity and it can be described, so far, as the lack of noise that is portrayed by means of intensity. The concept of quietness in the urban environment is revisited, in an attempt to reveal a new understanding of the specific phenomena. In this research, the focus is on setting aside all indicators either measuring intensity or contextual ones and use quantifiable metrics regarding the acoustic environment, thus introducing a new composite index called the Composite Urban Quietness Index (CUQI). CUQI comprises two sub-indicators, the Acoustic Complexity Index and the Normalized Difference Soundscape Index. CUQI was tested in order to verify the results of previous research regarding the identification of Quiet Areas in the city of Mytilene. It was concluded that CUQI is effective even in this early stage of development.

11:35

2aNS8. Introduction and application of a proposed method for quantitative soundscape analysis: The soundscape code. Dylan Wilford (Univ. of New Hampshire, 24 colovos Rd., Durham, NH 03824, dcw1017@wildcats.unh.edu), Jennifer Miksis-Olds (School of Marine Sci. and Ocean Eng., UNH, Ctr. for Acoust. Res. and Education (CARE), Durham, NH), Bruce Martin (JASCO Appl. Sci., Halifax, NS, Canada), and Kim Lowell (School of Marine Sci. and Ocean Eng., UNH, Ctr. for Coastal and Ocean Mapping (CCOM), Durham, NH)

A novel methodology for the analysis of soundscapes was developed in an attempt to facilitate quick and accurate soundscape comparisons across time and space. The methodology, proposed here for the first time, consists of a collection of traditional soundscape metrics, statistical measures, and acoustic indices that were selected to quantify several salient properties of marine soundscapes: amplitude, impulsiveness, periodicity, and uniformity. The metrics were calculated over approximately 30 h of semi-continuous passive acoustic data gathered in seven unique acoustic environments. The resultant metric values were analyzed and cross-examined to determine which combination most effectively captured the characteristics of the respective soundscapes. The best measures of amplitude, impulsiveness, periodicity, and uniformity were combined to form the proposed "Soundscape Code," which allows for rapid multidimensional and direct comparisons of salient soundscape properties across time and space. The soundscape code methodology was then applied at three deep-sea habitats located in the Mid- South Atlantic Outer Continental Shelf (OCS) region that varied in depth, substrate, proximity to shore, and community structure. Soundscape code metrics highlighted nuanced differences in the acoustic environments and allowed for rapid, direct, quantitative comparisons to be made between the sites.

11:50–12:20 Discussion

Session 2aPA

Physical Acoustics, Structural Acoustics and Vibration, Noise, and Computational Acoustics: Sonic Boom: Modeling, Measurement, Annoyance and Standards Development I

Joel B. Lonzaga, Cochair
Structural Acoustics Branch, National Aeronautics and Space Administration, 2 N. Dryden St. (MS 463), Hampton, VA 23681

Alexandra Loubeau, Cochair
NASA Langley Research Center, MS 463, Hampton, VA 23681

Chair's Introduction—9:30

Invited Papers

9:35

2aPA1. Simulation of the propagation of classical and low booms through turbulent wind fluctuations. Roman Leconte (75, Sorbonne Université, 4 Pl. Jussieu, 75005 Paris, France, roman.leconte@sorbonne-universite.fr), Jean-Camille Chassaing (75, Sorbonne Université, Paris, France), François Coulouvrat (Ctr. National de la Recherche Scientifique, Paris, France), and Régis Marchiano (75, Sorbonne Université, Paris, France)

The present revival of supersonic civil aviation outlines the need to study the propagation of sonic boom through turbulent wind fluctuations known to have an important impact on the noise perceived at the ground. Numerous physical phenomena must be considered: diffraction, non-linearity, absorption, relaxation and turbulence effects. A recent numerical method called FLHOWARD3D is used to simulate the propagation of classical and low-boom wave-forms in a three-dimensional domain of (1 km $\times$ 1 km $\times$ 1 km) representing a portion of the planetary boundary layer. Wind field is synthesized following a von Kármán energy spectrum. It is found that simulated wave-forms on the ground are close to experimental observations. Low-boom wave-forms show less sensitivity to turbulence. Comparisons between 2D and 3D simulations for peak overpressure statistical distribution show that, in 3D, results are closer to flight tests data than in 2D. Nevertheless the 2D levels are consistent with the experimental levels for around 98% of the cases, and only slightly underestimate the rarest events of highest amplification. Therefore, for this configuration, 2D simulations, though slightly less accurate than 3D ones, are computationally much less intensive and can be used for statistical analysis. [This research was conducted as a part of Rumble—EU Grant Agreement 769896.]

9:50

2aPA2. Probability distributions of sonic boom noise metrics in isotropic turbulent fields. Alexander N. Carr (Mech. and Aerosp. Eng., Univ. of Florida, P.O. Box 116250, 939 Sweetwater Dr., Gainesville, FL 32611, alexcarr.1721@gmail.com), Joel B. Lonzaga (Structural Acoust. Branch, National Aeronautics and Space Administration, Hampton, VA), and Steven A. Miller (Mech. and Aerosp. Eng., Univ. of Florida, Gainesville, FL)

Sonic boom waveform distortion caused by isotropic turbulence is examined with numerical simulations of acoustic propagation through randomly generated 3D turbulent fields. A recently developed planar, one way acoustic propagation code is used in this study to simulate the propagation of sonic boom waveforms. Computations of the signal account for diffraction, signal scattering by turbulence, nonlinear distortion, and absorption. Two types of waveforms are considered, one type is an N-wave and the other is a shaped boom. The intensity of the turbulent field is systematically varied for each set of simulations. For each condition, simulations through hundreds of randomly generated fields are conducted to obtain the statistical means and variances of PL, ISBAP, and select weighted SEL metrics. The computational results provide insight on the dependence of the probability distribution of each metric on the turbulence intensity and propagation distance. The data is further examined to compute probability density functions for each metric as a function of the turbulence intensity at different propagation distances. These functions provide insight on the effects of turbulence on the loudness levels of sonic booms. Future work and applicability of the results to atmospheric boundary layer turbulence is considered. [NASA Fellowship Activity Grant No. 80NSSC19K1685.]

10:05

2aPA3. Distortion and losses of sonic booms through turbulent fields. Joel B. Lonzaga (Langley Res. Ctr., National Aeronautics and Space Administration, 2 N. Dryden St. (MS 463), Hampton, VA 23681, joel.b.lonzaga@nasa.gov)

Distortion and losses due to scattering of sonic booms propagating through turbulent fields are investigated using an extended Burgers equation that incorporates an extinction coefficient model previously reported by the author. The extinction coefficient, induced by turbulence, is modeled as a correction to the free field wavenumber using multiple scattering theory. It is a complex-valued function whose real part leads to a frequency dependent attenuation while the imaginary part results in additional dispersion of sonic booms. Numerical calculation of the extinction coefficient is validated using an exact solution derived for a turbulent field with an exponentially decaying correlation function. The model is suitable for direct integration into any Burgers equation that only accounts for geometrical spreading, nonlinear, and atmospheric absorption effects. The extended Burgers equation lends itself to a very efficient algorithm compared to other sonic boom numerical models developed to account for turbulent fields. The algorithm is then used to model sonic boom waveform distortion and loudness variability through randomly generated, realistic turbulent fields. The effects of the intensity and correlation length of the turbulence on the loudness of N-waves and shaped booms are examined and will be presented.

Contributed Paper

10:20

2aPA4. Development of analytical models for calculating the characteristics of intense acoustic waves propagating in a stratified atmosphere. Vladimir A. Gusev (Physical Faculty, Dept. of Acoust., Lomonosov Moscow State Univ., Leninsky Gory, Moscow 119991, Russian Federation, vgusev@bk.ru) and Denis A. Zharkov (Physical Faculty, Dept. of Acoust., Lomonosov Moscow State Univ., Moscow, Russian Federation)

The time profiles and characteristics of sonic boom waves during propagation in a density-stratified atmosphere are calculated. It is shown that this stratification leads to a significant change in wave parameters: the wave amplitude, the characteristic distances at which the wave transformation is manifested, the width of the shock front. It is shown that the effective role of viscosity decreases when the shock wave propagates down to the earth's surface. So the width of the shock front decreases. Two methods are being developed for analytical calculation. The first one, the nonlinear geometric acoustics approximation, allows obtaining the Burgers equation with a variable viscosity to describe the wave field along the ray. Some exact solutions and asymptotic solution for low viscosity are obtained. This method is not applicable in focusing regions. The second method is based on the application of a modular nonlinearity model. Replacing the quadratic nonlinearity with a modular one allows obtaining a system of linear equations, the solution of which is possible. The difficulty lies in the correct construction of the discontinuity in the profile and subsequent stitching of solutions for different polarities. [This study was supported by the Russian Foundation for Basic Research (Project No. 20-02-00493-a).]

10:35–10:50 Break

Invited Papers

10:50

2aPA5. An extension of the geometrical-acoustic model near a caustic with application to off-track sonic boom focusing. Luke A. Wade (Graduate Program in Acoust., Penn State, 201 Appl. Sci. Bldg., University Park, PA 16802, law591@psu.edu) and Victor W. Sparrow (Penn State, University Park, PA)

A focused sonic boom or "superboom" is caused by the convergence of acoustic energy generated by a passing supersonic aircraft; this occurs along a surface known as a caustic. The term "superboom" is fitting, as the resulting ground pressure signature is invariably louder than any other boom event associated with the given aircraft configuration. Unfortunately, when an aircraft accelerates to supersonic speeds, boom focusing is unavoidable. Although previous research has modeled the focus boom expected under the flight track, relatively little is known about noise experienced away from the flight track. The most popular model for sonic boom focusing, the lossy nonlinear Tricomi equation (LNTE), breaks down when an observer is not directly undertrack. This presentation will recount recent work aimed at augmenting the LNTE model such that it remains accurate over the lateral extent of the boom carpet during focusing. Emphasis will be placed on the extension of the geometrical-acoustic approximation used above the boundary layer of the caustic via analysis of new expressions resulting from the addition of the off-track component to the problem. [This material was based upon work supported by the National Aeronautics and Space Administration under Grant No. 80NSSC19K1684 issued through the NASA Fellowship Activity.]

11:05

2aPA6. Sonic boom simulation for boom carpet determination. Jacob J. Jäschke (Hamburg Tech. Univ., Blohmstrasse 20, Hamburg 21079, Germany, jacob.jaeschke@tuhh.de) and Bernd Liebhardt (German Aerosp. Ctr. (DLR), Hamburg, Germany)

The Institute of Air Transportation Systems in Hamburg, Germany, researches methodologies for optimized supersonic flight routing that prevents the (primary) sonic boom from reaching the ground. The sonic boom shall either be cut off vertically or laterally. In initial trials, lateral cutoff positions of the sonic boom carpet were searched geometrically by ray tracing. Thereby, it was found that smooth interpolation of atmospheric data is necessary for geometrical convergence of different ray tracing methods, and that determining the marginal ray was oftentimes virtually impossible leeward. (These findings will be elaborated in more detail.) For those reasons, acoustic propagation has been introduced based on the Augmented Burgers equation, and implementing the Tricomi equation for covering flight maneuvers is planned in the short term. Our main research goal is finding numerical methods for determining the acoustic sonic boom

cutoff that are first and foremost practical, *i.e*., fast, accurate, and robust. In this respect, we will discuss different termination conditions in signature propagation for the purpose of sonic boom carpet computation.

11:20

2aPA7. Sonic boom reflection over irregular terrain. Ariane Emmanuelli (LMFA, Ecole Centrale de Lyon, Lyon, France), Didier Dragna (LMFA, Ecole Centrale de Lyon, 36, Ave. Guy de Collongue, Ecully 69134, France, didier.dragna@ec-lyon.fr), Sebastien Ollivier (LMFA, Ecole Centrale de Lyon, Lyon, France), and Philippe Blanc-Benon (LMFA, Ecole Centrale de Lyon, Ecully, France)

An overview of recent studies on sonic boom reflection over irregular terrain is presented. Numerical simulations based on the two-dimensional Euler equations are performed using high-order finite-difference time-domain techniques, allowing for an accurate prediction of diffraction. Studies are done for two sonic boom waves: a conventional N-wave and a low-boom wave. First, ground elevation effects on sonic boom are examined. An academic ground profile, corresponding to a terrain depression, is considered to highlight mechanisms at play. In particular, caustics due to ground elevation variations induce another contribution at the ground level, in the form of a U-wave. Results for real ground profiles are then presented and cumulative effects, due to the succession of terrain irregularities, are shown. Second, propagation of sonic boom over an urban profile is investigated. Possible resonance effects inside street canyons are discussed. For all cases, statistics of noise metrics are examined. [This work was performed within the framework of the LabexCeLyA of the University of Lyon, within the program ‘‘Investissements d'Avenir" (ANR-10-LABX-0060/ANR-16-IDEX-0005) operated by the French National Research Agency and has received funding from the European Union's Horizon 2020 research and innovation programme (Grant Agreement No. 769896 (RUMBLE).]

11:35

2aPA8. Complex ray tracing algorithm for infrasound propagation in the atmosphere. Annie Zelias (CEA/DAM/DIF, Arpajon 91297, France, annie.zelias@gmail.com), François Coulouvrat (Institut Jean le Rond d'Alembert, Sorbonne Universite, Paris, France), and Olaf Gainville (CEA/DAM/DIF, Arpajon, France)

A classical long standing challenge for the infrasound research community is explaining frequently observed infrasound arrivals into shadow zones. This arrivals can be obtained by generalising standard ray method to complex ray tracing, which takes into account diffraction effects. This method is applied to long range infrasound propagation in a stratified and moving atmosphere by a three step numerical algorithm computing both real and complex eigenrays. First, real rays shooting allows to locate caustics and shadow zones. Second, extrapolation around caustics provides real and complex rays initial guesses. Third, their optimisation is performed using an adaptive algorithm. This process provides wave arrival times, azimuths, apparent velocities and over-pressures at a set of stations. Algorithm efficiency and robustness are illustrated by numerical examples: the ground sonic boom of a slightly supersonic aircraft (Mach cut-off problem), explosion at a ground-based point source, and the sonic boom from a meteorite atmospheric entry. In this last case, a 2D model has been developed inspired by the well-documented Carancas meteorite. Finally, comparisons are performed with other numerical methods.

11:50

2aPA9. The analysis of west coast arrivals for secondary sonic booms. Kimberly A. Riegel (Phys., Queensborough Community College, 652 Timpson St., Pelham, NY 10803, kriegel@qcc.cuny.edu) and Victor W. Sparrow (Penn State, University Park, PA)

During certain atmospheric conditions, sonic boom noise that normally would travel away from the ground is refracted back down toward the ground. This occurs for booms that have been emitted from the top of a supersonic aircraft or already bounced off the ground. These types of sonic boom arrivals are called secondary sonic booms or Over The Top (OTT) booms and can be audible more than 100 km away from the flight path. It is expected that these secondary sonic booms will impact the coastline even for flights that are only flying over water. Therefore, these OTT booms need to be well understood for future supersonic aircraft approaching coastal airports. Previous work by the authors has confirmed the findings of Rickley and Pierce for OTT booms of Concorde approaching the U.S. east coast. The present work employs the PCBoom software and will provide simulations of aircraft approaching U.S. west coast airports during all seasons to predict areas where noise may be heard. [Work supported by the FAA. The opinions, findings, conclusions and recommendations expressed in this material are those of the authors and do not necessarily reflect the views of ASCENT FAA Center of Excellence sponsor organizations.]

12:05–12:30 Discussion

Session 2aPP

Psychological and Physiological Acoustics: Linking Psychological and Physiological Acoustics I

Frederick J. Gallun, Cochair
Oregon Hearing Research Center, Oregon Health and Science University, 3181 Sam Jackson Park Road, Portland, OR 97239

Virginia Best, Cochair
Speech, Language and Hearing Sciences, Boston University, 635 Commonwealth Ave., Boston, MA 02215

Chair's Introduction—9:30

Contributed Papers

9:35

2aPP1. Investigation of distortion product otoacoustic emission in humans using a nonlinear mechano-electro-acoustic model of the cochlea. Naman Agarwal (Dept. of Mech. Eng., Indian Inst. of Technol. Bombay, Mumbai, Maharastra 400076, India, 154100025@iitb.ac.in) and Sripriya Ramamoorthy (Dept. of Mech. Eng., Indian Inst. of Technol. Bombay, Mumbai, Maharastra, India)

Nonlinear response component ($2f_1$-f_2) measured in the ear canal when two primary tones at f_1 and f_2 are presented to the mammalian cochlea, is termed as distortion product otoacoustic emission (DPOAE). Whether the mechanism of propagation of distortion product (DP) from the cochlea toward the middle ear, via fast compression waves in fluid or via slow traveling waves on the basilar membrane, is still being debated. In the current study, the computational mechano-electro-acoustic nonlinear cochlea model is used to predict the location and propagation of DP. The three-dimensional model has two fluid-filled ducts coupled with BM and OHC somatic feedback motility coupled to nonlinear HB mechanotransduction, which is the source of nonlinear distortion in the model. The Puria-Allen transmission line model is used for the middle ear. For solving the nonlinear cochlea model dynamics, the alternating time-frequency method is used. The model parameters are adapted to the human cochlea to help understand DPOAE in humans. Preliminary results based on the model will be discussed.

9:50

2aPP2. Minimal time to determine moving sound source direction in patients with sensorineural hearing loss. Evgenia Klishova (Lab. of Comparative Sensory Physiol., Sechenov Inst. of Evolutionary Physiol. and Biochemistry RAS, St. Petersburg, Russian Federation), Alisa Gvozdeva (Lab. of Comparative Sensory Physiol., Sechenov Inst. of Evolutionary Physiol. and Biochemistry RAS, Torez, 44, St. Petersburg 194223, Russian Federation, kukumalu@mail.ru), Vladimir Sitdikov (Lab. of Comparative Sensory Physiol., Sechenov Inst. of Evolutionary Physiol. and Biochemistry RAS, St. Petersburg, Russian Federation), Larisa Golovanova (I.I. Mechnikov North-Western State Medical Univ., St. Petersburg, Russian Federation), and Irina Andreeva (Lab. of Comparative Sensory Physiol., Sechenov Inst. of Evolutionary Physiol. and Biochemistry RAS, St. Petersburg, Russian Federation)

Minimal time to determine the direction of azimuthal motion was measured in normally hearing subjects and in patients with sensorineural hearing loss (SNHL). A moving sound image was formed by counter-directional change of the amplitude on two loudspeakers placed at 1.1 m in front of the listener by azimuthal angles of $\pm 30°$ in a sound-treated room. The sound image moved from the central position to the left or to the right, or in the opposite direction along 24.2° arc. An adaptive psychoacoustic procedure was used in a diapason of sound images durations from 0.1 to 1.5 s with 0.1 s step. All subjects with normal hearing ($N = 11$) had the minimal time of 0.1 s or lower. Patients demonstrated significantly higher minimal time: 0.4, 0.5 and 0.9 s in case of mild ($N = 16$), moderate ($N = 16$) and moderately severe ($N = 12$) SNHL, respectively ($p < 0.001$, $p < 0.0001$, and $p < 0.00001$, Mann-Whitney U Test). Patients were divided into groups in accordance with the WHO classification. Minimal times in patients with mild and moderate SNHL did not differ ($p = 0.18$, Mann-Whitney U Test), but both were lower than in patients with moderately severe SNHL ($p < 0.01$, Mann-Whitney U Test). [This work was supported by means of the State assignment (AAAA-A18-118013090245-6).]

10:05

2aPP3. Ripple density resolution in the presence of an additional rippled pattern. Marina Tomozova (Inst. of Ecology and Evolution, Inst. of Ecology and Evolution, 33 Leninsky Prospect, Moscow 119071, Russian Federation, m.tomozova86@mail.ru), Alexander Supin, Dmitry I. Nechaev, and Olga N. Milekhina (Inst. of Ecology and Evolution, Moscow, Russian Federation)

Rippled-spectrum signals are known for measurements of ripple density resolution. Such signals used previously had uniform ripple patterns across the entire signal's frequency band. In the present study, signals consisted of two overlapping test and additional patterns with different ripple densities. Ripple density resolution in the test signal was measured as a function of ripple density in the additional pattern. Two discrimination tasks were conducted: either discrimination between a rippled test signal and rippled reference signal or a non-rippled reference signal. The additional pattern reduced the resolution of the test signal in general. For a rippled reference signal, the effect of the additional pattern could be explained by decreased ripple depth in the test signal. For a non-rippled reference signal, the resolution of the test signal was lower for a rippled than for a non-rippled additional pattern. In such a case, there was no dependence on the density of ripples in the additional pattern. The last cannot be explained by a decrease of the ripple depth and was interpreted as a manifestation of temporal processing equivalent to the reveal of a delayed segment of the autocorrelation function of the test signal. [This study was supported by Russian Foundation for Basic research, Grant No. 20-015-00054.]

10:20

2aPP4. Eye-movement patterns of hearing-impaired listeners measure comprehension of a multitalker conversation. Martha M Shiell (Eriksholm Res. Ctr., Rørtangvej 20, Snekkersten 3070, Denmark, mrhs@eriksholm.com), Teresa Cabella, Gitte Keidser (Eriksholm Res. Ctr., Snekkersten, Denmark), Diederick C. Niehorster, Marcus Nyström (Humanities Lab, Lund Univ., Lund, Sweden), Martin Skoglund (Eriksholm Res. Ctr., Linköping, Sweden), Simon With, Johannes Zaar, and Sergi Rotger-Griful (Eriksholm Res. Ctr., Snekkersten, Denmark)

The ability to understand speech in complex listening environments reflects an interaction of cognitive and sensory capacities that are difficult to capture with behavioural tests. The study of natural listening behaviours may lead to the development of new metrics that better reflect real-life communication abilities. To this end, we investigated the relationship between speech comprehension and eye-movements among hearing-impaired people in a challenging listening situation. While previous research has investigated the effect of background noise on listeners' gaze patterns with single talkers, the effect of noise in multitalker conversations remains unknown. We tracked eye-movements of seven aided hearing-impaired adults while they viewed video recordings of two life-sized talkers engaged in an unscripted dialogue. Hearing loss ranged from moderate to severe. We used multiple-choice questions to measure participants' comprehension of the conversation in multitalker babble noise at three different signal-to-noise ratios. All participants made saccades between the two talkers more frequently than the talkers' conversational turns. This measure tended to correlate positively with participants' comprehension scores, but the effect was significant in only one signal-to-noise ratio condition. Post-hoc investigation suggests that intertalker saccade rate is driven by an interaction of hearing ability and conversational turn-taking events, which will be further discussed.

10:35–10:50 Discussion

10:50–11:05 Break

Contributed Papers

11:05

2aPP5. Cues to monaural edge pitch in single auditory nerve fibers. Yi-Hsuan Li (KU Leuven, Campus Gasthuisberg, O&N 2 Herestraat 49 - bus 102, Leuven 3000, Belgium, yihsuan.li@kuleuven.be) and Philip X. Joris (KU Leuven, Leuven, Belgium)

The spectral edge of a bandlimited noise can create a pitch sensation, called "edge pitch," which is slightly mismatched to the edge frequency. This pitch is usually speculated to reflect neural lateral inhibition but could also reflect temporal cues. We looked for such cues recording responses of single auditory nerve fibers in the anesthetized chinchilla to edge pitch stimuli. For every stimulus, we compute shuffled autocorrelograms for all recorded fibers and pool them in a population interval distribution (PID) from which we obtain the most common interval. We also quantify the slower "envelope" fluctuations in firing resulting from cochlear bandpass filtering of the bandlimited noise stimulus. Single fibers shows systematic temporal changes related to the spectral edge of the stimulus when it does not cover the fiber's frequency filter. Across the population of fibers, the estimated pitch based on the dominant interspike interval shows trends that are similar, qualitatively and quantitatively, to those observed behaviorally. Slower envelope fluctuations also systematically vary with the relationship of edge frequency to fiber CF, and are another potential temporal cue to the presence of the edge frequency. We conclude that temporal cues to edge-pitch are present in the auditory nerve at multiple time scales.

11:20

2aPP6. A model of cortical timbre classification using spike latency coding. David A. Dahlbom (School of Architecture, Rensselaer Polytechnic Inst., 96 11th St., Fl 1, Troy, NY 12180, dahlbd@rpi.edu) and Jonas Braasch (School of Architecture, Rensselaer Polytechnic Inst., Troy, NY)

Earlier modeling studies of spiking neural networks with conduction delays have shown that temporally precise, distributed spike patterns (polychronous groups) contain more information about timbral distinctions than firing rates. Additionally, experimental work in auditory cortex has suggested that the initial onset of firing activity is especially important for encoding timbre, an observation that is in accordance with psychoacoustical evidence that the onset characteristics of a stimulus can have a profound effect on the perception of timbre. These observations are combined in a model that uses spike latency to make timbral classifications. A simplified spiking model of the subcortical auditory system is connected to a reservoir of spiking point neurons with cortex-like connectivity statistics and conduction delays. Stimuli are presented to the model in an unsupervised manner, and synaptic strengths are adapted via a spike-timing-dependent plasticity mechanism. After training, a stochastic search algorithm is used to find stimulus-triggered firing patterns generated in the reservoir, the firing latency of which can be used to make accurate timbral categorizations of novel stimuli. The stimuli consist of FM-synthesized instrument sounds (two categories) with varying pitches, demonstrating the model's ability to learn timbral distinctions in a manner invariant with respect to changes of pitch.

11:35

2aPP7. Controlled cortical impact-induced brain injury alters auditory sensitivity in laboratory mice. Kali Burke (Otolaryngol.—Head and Neck Surgery, Johns Hopkins Univ. School of Medicine, 515 Traylor, Baltimore, MD 21205, kaliburk@buffalo.edu), Athanasios S. Alexandris, Vassilis Koliatsos (Pathol.—Neuropathology, Johns Hopkins Univ. School of Medicine, Baltimore, MD), and Amanda M. Lauer (Otolaryngol.—Head and Neck Surgery, Johns Hopkins Univ. School of Medicine, Balitmore, MD)

Individuals who have sustained a traumatic brain injury (TBI) often report auditory dysfunction including changes to their hearing sensitivity, tinnitus, and hyperacusis. One factor that may have a significant contribution to a person's post-injury outcomes is whether the TBI occurred in combination with a high intensity noise exposure (*e.g.*, as in the case of a car accident). To date, no study has examined the combined effects of a brain injury and high intensity noise exposure to evaluate whether this would lead to worse overall auditory outcomes than either trauma in isolation. In this study we tested the auditory sensitivity of male and female CBA/CaJ laboratory mice before and 3, 7, 14, 30, 60, and 90 days after acoustic (noise exposure), physical (controlled cortical impact), and combined acoustic and physical injuries. Following completion of the experiment, cochlear and brain tissue was fixed with paraformaldehyde and central and peripheral auditory structures were examined for damage. Our preliminary results show that physical injuries alone cause damage to the auditory sensitivity of mice measured using the auditory brainstem response, reduced acoustic startle responses in quiet and noise, yet hair cells remain intact. Long-term consequences on auditory perception are being tracked in these mice.

11:50

2aPP8. Grasshopper mice alter vocalizations with age-related and noise-induced hearing loss. Anastasiya Kobrina (Dept. of Biological Sci., Northern Arizona Univ., 617 S. Beaver St., Flagstaff, AZ 86001, anastasiya.kobrina@gmail.com), Mahendra Hidau (Dept. of Biomedical Eng., Wayne State Univ., Detroit, MI), Tobias Riede (Dept. of Physiol., Midwestern Univ., Glendale, AZ), O'Neil Guthrie (Dept. of Commun. Sci. and Disord., Northern Arizona Univ., Flagstaff, AZ), and Bret Pasch (Biological Sci., Northern Arizona Univ., Flagstaff, AZ)

Age-related and noise-induced hearing loss disorders are among the most common pathologies affecting Americans across their lifespans. Loss of auditory feedback due to hearing disorders is correlated with changes in voice and speech-motor control in humans. Although rodents are increasingly used to model human age- and noise-induced hearing pathologies, few studies have assessed vocal changes that co-occur with hearing deterioration. Northern grasshopper mice represent a candidate model because their hearing sensitivity is matched to the frequencies of long-distance vocalizations that are produced using vocal fold vibrations similar to human speech. In this study, we quantified changes in auditory brainstem responses and vocalizations related to aging and noise-induced acoustic trauma. Mice showed a progressive decrease in hearing sensitivity for pure tone stimuli, with males losing hearing more rapidly than females. Mice experienced severe hearing loss across all frequencies after exposure to noise. Frequency and duration of long-distance vocalizations were affected by hearing loss similar to findings in other mammals. Our findings indicate that grasshopper mice experience age- and noise- induced hearing loss and concomitant changes in vocal output, making them a promising model for hearing and communication disorders.

12:05–12:20 Discussion

WEDNESDAY MORNING, 9 JUNE 2021 — 9:30 A.M. TO 12:15 P.M.

Session 2aSA

Structural Acoustics and Vibration, Physical Acoustics and Engineering Acoustics: Acoustic Metamaterials I

Christina J. Naify, Cochair
Naval Research Lab, 4555 Overlook Ave. SW, Washington, D.C. 20375

Alexey Titovich, Cochair
Carderock Div., Naval Undersea Warfare Center, 9500 MacArthur Blvd, West Bethesda, MD 20817-5700

Bogdan-Ioan Popa, Cochair
Univ. of Michigan, 2350 Hayward St., Ann Arbor, MI 48109

Chair's Introduction—9:30

Invited Papers

9:35

2aSA1. Transformable topological mechanical metamaterials based on Maxwell lattices. Xiaoming Mao (Phys., Univ. of Michigan, 450 Church St., Ann Arbor, MI 48108, maox@umich.edu)

Maxwell lattices are mechanical networks on the verge of instability and feature convenient mechanisms of transformation. They exhibit topologically protected floppy modes and states of self-stress, offering an excellent platform for topologically robust and yet transformable mechanical and acoustic properties. In this talk, we will discuss recent progress in developing topological mechanical metamaterials based on Maxwell lattices, from dramatic changes of surface stiffness upon a small stimuli, to programmable stress distribution for fracturing protection, and nonreciprocal propagation for nonlinear waves. These results reveal great potential for Maxwell lattices as a new class of topological mechanical metamaterials with emerging applications.

9:50

2aSA2. Phononic crystals as a platform for experimental physics: The direct observation of Klein tunneling. Chengzhi Shi (School of Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr. NW, Atlanta, GA 30332, chengzhi.shi@gatech.edu), Xue Jiang (Fudan Univ., Shanghai, China), Zhenglu Li (Dept. of Phys., Univ. of California, Berkeley, Berkeley, CA), Siqi Wang, Yuan Wang, Sui Yang (Nano-Scale Sci. and Eng. Ctr., Univ. of California, Berkeley, Berkeley, CA), Steven G. Louie (Dept. of Phys., Univ. of California, Berkeley, Berkeley, CA), and Xiang Zhang (Nano-Scale Sci. and Eng. Ctr., Univ. of California, Berkeley, Berkeley, CA)

Phononic crystals consist of periodic Mie scatterers that modulate the band structure through multi-scattering to control acoustic wave propagation. Recently, the Dirac cone dispersion of phononic crystals with triangular or hexagonal lattices has been used to demonstrate interesting physics such as topologically protected edge states and Zitterbewegung effects. In this work, we present phononic crystals with triangular lattices that can be used as a platform to directly observe Klein tunneling. Klein tunneling is an important quantum mechanical physics proposed in 1929 for high-energy electrons. Klein suggested that electrons that are accelerated to the relativistic regime will tunnel through potential barriers with 100% probability regardless the width and height of the potential barrier. However, Klein tunneling has never been directly observed in quantum mechanics and solid state physics due to the difficulties in satisfying the stringent requirements. Here, we designed phononic crystals with Dirac cone dispersion at which the phonons behave as quasi-particles in the relativistic regime. Near total transmissions of the phonons through potential barriers were measured that are independent from the width and height of the potential barrier. Our results provide the first direct observation of Klein tunneling. This work will inspire a new type of applications that uses phononic crystals as a platform for the experimental studies of wave mechanics and quantum physics.

10:05

2aSA3. The influence of spatially varying materials and buckling instabilities on elastic band gaps. Stephanie G. Konarski (US Naval Res. Lab., 4555 Overlook Ave. SW, Washington, DC 20375, stephanie.konarski@nrl.navy.mil) and Christina J. Naify (US Naval Res. Lab., Washington, DC)

The behavior of band gaps is often important to the design of architected materials. One aspect of interest is the ability to tune the band gap via an external stimulus. The use of elastic deformation is a popular method within the field of mechanical metamaterials to achieve band gap switching. Another design feature is the width of the band gap. Structures with variations in the physical or geometric properties may exhibit wider band gaps than uniform designs. This work combines the study of lattices that achieve buckling induced band gaps with spatially varying material properties to leverage both effects. The example lattice design contains super-unit cells of circular voids within a soft elastomeric matrix arranged with different combinations of discrete material properties. The present numerical study compares the simulated transmission through several example designs and demonstrates both band gap widening due to the multiple materials and switching as a function of mechanical deformation.

Contributed Papers

10:20

2aSA4. Analysis of the interaction of Helmholtz resonators in periodic acoustic metamaterials depending on its orientation with the acoustic source. David R. Solana (Universitat Politècnica de Valencia, Paranimf, 1, Grao de Gandía, Gandía, Valencia 46730, Spain, d.ramirezsolana@gmail.com), Sergio Castiñeira-Ibáñez (Centro de Tecnologías Físicas: Acústica, Materiales y Astrofísica, Valencia, Spain), Javier Redondo (Instituto de Investigación para la Gestión Integrada de zonas Costeras, Gandia, Spain), Jose María Bravo-Plana-Sala (Centro de Tecnologías Físicas: Acústica, Materiales y Astrofísica, Valencia, Spain), Rubén Picó (Instituto de Investigación para la Gestión Integrada de zonas Costeras, Gandía, Spain), and Juan Vicente Sánchez-Pérez (Centro de Tecnologías Físicas: Acústica, Materiales y Astrofísica, Valencia, Spain)

Acoustic screens based on sonic crystals constitute one of the most promising technological bets of recent years in the field of environmental acoustics. Sonic crystals are defined as new materials formed by arrays of acoustic scatterers embedded in air. The design of these screens is made using powerful simulation models that provide reliable results without the need of expensive experimental testing. This project applies the finite elements method in order to analyse an acoustic barrier that includes (Helmholtz) resonators in its scatterers, and studies the interference of the sonic crystal with the effect of the Helmholtz resonator, depending on its orientation with the acoustic source.

10:35–10:50 Break

10:50

2aSA5. Imaging through an imperfect skull with non-Hermitian complementary acoustic metamaterials. Steven R. Craig (School of Mech. Eng., Georgia Inst. of Technol., Atlanta, Georgia), Phoebe Welch (School of Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr., NW, Atlanta, GA 30318, pwelch8@gatech.edu), and Chengzhi Shi (School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA)

Biomedical ultrasound is a proficient tool for diagnostic imaging and a wide variety of non-invasive medical procedures due to its high spatial resolution and biocompatibility. While high frequency ultrasound is highly sought after for use in the brain, the skull acts as a highly mismatched and lossy impedance barrier that scatters and damps the energy delivered to a targeted region. This limits the usefulness of ultrasound for brain imaging and brain therapies. Non-Hermitian complementary metamaterials (NHCMM) use transformation acoustics to overcome the impedance mismatch and intrinsic loss of the skull to enable bidirectional acoustic transmission into the brain. Here, we apply the NHCMM to skulls with curved geometries, varying thicknesses, and irregularities to evaluate the performance of NHCMMs in near realistic circumstances. We customize the metamaterial shape for each unique skull geometry to maximize the bidirectional transmission through the skull to better identify internal acoustic scatters. The NHCMM manages to preserve the imaging information of an acoustic tumor embedded in the brain with multiple imperfections present. The evaluation of NHCMMs for skulls with imperfections is vital to gauge its effectiveness for real-world applications as the proposed NHCMM establishes a noninvasive technique for ultrasonic brain imaging through skull and ultrasound diagnostics for neurological disorders.

11:05

2aSA6. Transformation acoustics for beamforming in anisotropic media. Steven R. Craig (School of Mech. Eng., Georgia Inst. of Technol., 771 Ferst Dr., NW, Atlanta 30318, Georgia, scraig32@gatech.edu), Jeonghun Lee, and Chengzhi Shi (School of Mech. Eng., Georgia Inst. of Technol., Atlanta, GA)

Acoustic wave propagation in anisotropic media like tissue and other biomaterials is important for biomedical acoustics, as ultrasound is commonly used as a technique for non-invasive surgeries and diagnostic imaging purposes. These ultrasound applications require beamformed signals to target specific regions of the body. However, the anisotropic properties of the body (*e.g.*, muscle fibers) distort the beamformed wavefronts, detrimental to the performance of ultrasound therapies and imaging. Here, we propose and experimentally demonstrate a unique transformation acoustic technique that corrects the anisotropic distortive effects to beamform an arbitrarily desired propagation pattern. The experimental measurements demonstrate the effectiveness of this transformation acoustic correction for arbitrary focusing and selfbending beams. Our work provides an important method to suppress undesired anisotropic effects on beamformed waves, to improve upon the precision and effectiveness of medical treatments and diagnostics facilitated by noninvasive ultrasound therapies and imaging.

11:20

2aSA7. Unit cell interactions of non-local active acoustic media. Nathan Geib (Mech. Eng., Univ. of Michigan, 1587 Beal Ave. Apt 13, Ann Arbor, MI 48105, geib@umich.edu), Bogdan-Ioan Popa, and Karl Grosh (Mech. Eng., Univ. of Michigan, Ann Arbor, MI)

Active acoustic metamaterials have greatly expanded upon the unique and unusual ways that passive metamaterials manipulate sound. Previously, we have shown how spatially non-local forces in an acoustic system can create band gaps and break acoustic reciprocity, and how such effects can be realized in practice using a non-local active acoustic metamaterial (NAM). We demonstrated experimentally the remarkable ability of a single NAM unit cell to generate large, subwavelength, broadband nonreciprocity using an open loop feedforward control mechanism where a measured local pressure is transmitted by an electronic controller downstream to actuate an acoustic source. In NAM systems with multiple unit cells, this control scheme strongly couples each cell with every other cell, and thus requires special design considerations. Here, we discuss the advantages and challenges of developing NAM systems with multiple unit cells by first considering a system with two cells, detailing the impacts of their complex interaction on both performance and stability. We validate model predictions with experiments and highlight the exciting prospects offered by larger multi-cell NAM arrays.

11:35

2aSA8. Reflective acoustic metamaterial for dynamic axial sub-wavelength field control in acoustic levitation. Yusuke Koroyasu (Univ. of Tsukuba, Res. and Development Ctr. for Digital Nature, Kasuga1-2, Tsukuba, Ibaraki 305-0821, Japan, koroyu@digitalnature.slis.tsukuba.ac.jp), Daichi Tagami (Tsukuba Univ., Tsukuba, Ibaaraki, Japan), Takayuki Hoshi, Yoshiki Nagatani (Pixie Dust Technologies, Inc., Tokyo, Tokyo, Japan), Ochiai Yoichi, and Tatsuki Fushimi (Faculty of Library, Information and Media Sci., Univ. of Tsukuba, TsukubaIbaraki, Japan)

Acoustic levitation is a non-contact manipulation techniques used in a wide range of fields from biology, physics to medical research. The manipulation of levitated objects can be achieved by controlling the phase of each transducer in a phased array or by using reflective metamaterial. Reflective metamaterial is the acoustic analogy of spatial light modulators, and horizontal movement of the levitated object may be achieved by physical translation of the metamaterial itself. However, axial movement relative to the reflective metamaterial has not been enabled. Here, we propose a reflective metamaterial for dynamic sub-wavelength field control to realize the axial movement of the levitated object, using the property that levitation points are created at distances multiple of half of a wavelength relative to the reflector in a sound field with sufficient sound pressure. It was shown that by mounting the triangular prisms with multiple of half of a wavelength on a reflector and moving them horizontally, the object would rise/fall by the height of the prism. The simple design of reflectors using the properties of acoustic levitation, paves the way to expand the capability of reflective acoustic metamaterial. [Funded by Strategic Research Platform towards Digital Nature Powered by Pixie Dust Technologies, Inc.]

11:50–12:15 Discussion

Session 2aSC

Speech Communication: Speech Studies Conducted Remotely: Methods and Examples I

Sandie Keerstock, Cochair
Psychological Sciences, University of Missouri, 124 Psychology Bld, Columbia, MO 65201

Pasquale Bottalico, Cochair
Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901 South Sixth Street, Champaign, IL 61820

Eric Hunter, Cochair
Com Sciences & Disorders, Michigan State University, 1026 Red Cedar Road, East Lansing, MI 48824

Chair's Introduction—9:30

Invited Papers

9:35

2aSC1. Collecting experimental data online: How to maintain data quality when you can't see your participants. Jennifer Rodd (Dept. of Experimental Psych., Univ. College London, 26 Bedford Way, London WC1H 0AP, United Kingdom, j.rodd@ucl.ac.uk)

Researchers are often nervous about collecting experimental data online because unlike lab-based experiments they cannot directly control their participants' hardware, software or their location. They also cannot directly observe participants' behaviour during the experiment. I will review the key issues that arise from using remote participants, and suggest a systematic approach to (i) participant recruitment, (ii) data collection and (iii) data analysis that ensures high levels of data quality. I will argue that it is inevitable that online recruitment will lead to the collection of unsuitable data, and that while we should do all we can to improve the quality of our collected data, it is perhaps more important to focus on ensuring that poor quality data is not included in our final analyses. A cornerstone of this approach is the careful pre-registration of exclusion criteria based on task piloting. I will also suggest that this principled approach to data quality control is often missing in lab-based settings and that the lessons learned due to running experiments online can be broadly applied to a range of experimental paradigms.

9:50

2aSC2. Remote collection of speech recognition data: Considerations for testing children. Lori Leibold (Hearing Res., Boys Town National Res. Hospital, 555 North 30th St., 555 N. 30th St., Omaha, NE 68131, lori.leibold@boystown.org), Heather Porter, Kaylah Lalonde, Gabrielle R. Merchant, Margaret K. Miller (Hearing Res., Boys Town National Res. Hospital, Omaha, NE), and Emily Buss (Univ. of North Carolina, Chapel Hill, NC)

This talk will provide an overview of the methods and lessons learned over the course of three studies in which children's masked speech recognition performance was assessed remotely. The first study evaluated the binaural intelligibility level difference in typically developing children using families' personal computers and headphones. The second study examined the impact of face coverings on consonant identification in noise with and without access to visual cues. Participants were children with and without hearing loss. The third experiment evaluated the feasibility of remote speech recognition testing for children with Down syndrome. The latter two experiments entailed providing families with laboratory hardware, following appropriate social distancing and infection control measures. Findings from all three studies will be discussed, highlighting comparisons with data obtained in the laboratory. Recommendations for remote studies involving children will be provided, based on our experiences and the resultant data.

10:05

2aSC3. Testing performance in complex listening tasks with primary school children in remote settings. Chiara Visentin (Dept. of Eng., Univ. of Ferrara, via Saragat, Ferrara 44122, Italy, chiara.visentin@unife.it), Matteo Pellegatti, and Nicola Prodi (Dept. of Eng., Univ. of Ferrara, Ferrara, Italy)

When assessing the impact of the classroom sound environment on students' learning an approach as much ecological as possible is needed. Tasks should be presented collectively to the entire class in real-life scenarios, as during regular school-day activities, thus preserving self- and mutual perception of the students. However, in this specific era of pandemic, such an ecological approach cannot be pursued and new ways for testing students are necessary. In this study, the method used to present two experiments remotely to primary school children (8 to 10 year olds) is described. Online platforms with specific design tools and touch-screen devices were used to build and administer the tasks. Auditory stimuli were presented via headphones, whose effect was compensated by filtering. In the sound

stimuli the typical reverberant environment of the classroom was simulated by auralization. Aiming to improve as much as possible the face validity of the experiments, the tests were presented collectively to the students in their classrooms even though each children performed the task individually and at his/her own pace. Moreover, the tasks were presented and explained by the experimenters by using interactive whiteboards, as during distance learning.

10:20

2aSC4. Effect of voice problems on vowel identifications in different acoustics environments. Pasquale Bottalico (Dept. of Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, 901 South Sixth St., Champaign, IL 61820, pb81@illinois.edu), Silvia Murgia, and Keiko Ishikawa (Speech and Hearing Sci., Univ. of Illinois, Urbana-Champaign, Champaign, IL)

Voice disorders can reduce speech intelligibility. This study evaluated the effect of noise, voice disorders, and room acoustics on vowel intelligibility. College students listened to 9 vowels in /h/-V-/d/ format. The speech was recorded by three adult females with dysphonia and three adult females with normal voice quality. The recordings were convolved with three oral-binaural impulse responses with 0.4 s, 0.7 s, and 3.1 s of reverberation time. The test was performed online. The intelligibility and the listening easiness were significantly higher when the speakers had normal voice quality and in low reverberated environments.

10:35–10:50 Break

10:50

2aSC5. Running voice identity perception studies online. Nadine Lavan (Dept. of Psych., Queen Mary, Univ. of London, Mile End Rd., Bethnal Green, London E1 4NS, United Kingdom, n.lavan@qmul.ac.uk)

In this presentation, I will give a broad overview of my experience running voice identity perception studies online. I will give examples of the kinds of perceptual studies I have run online using testing platforms, such as Qualtrics and Gorilla, paired with the online recruitment service Prolific. As part of this overview, I will discuss some ways to ensure and improve data quality, such as adding vigilance trials, limiting the duration of the online experiments, and including other checks that enable researchers to assess whether a participant's data is useable. Finally, I will highlight some of the advantages and considerations that are specific to online testing. For example, it is possible to test hundreds of participants in one afternoon using online testing, thus dramatically speeding up data collection. However, it is very difficult to tightly control the participant's listening environment and the use of hardware (*e.g.*, type of speakers or headphones used).

11:05

2aSC6. Experiences on voice assessment and voice intervention programs implemented remotely among college professors. Lady Catherine Cantor-Cutiva (Universidad Nacional de Colombia, Carrera 30 Calle 45, CiudadelaI Universitaria, Bogota 110110, Colombia, lccantorc@unal.edu.co)

This is a meta-analysis of two longitudinal studies and one cross-sectional study with the aim of analyzing the response rate and adherence to voice programs implemented remotely. In the cross-sectional study, we collected responses of around 150 college professors, for 2 weeks, by means of a Google form. Around 30% of participants reported voice symptoms. In the longitudinal studies, we recruited around 50 college professors, who were followed between 15 days and 5 weeks. In the first study, college professors met (in Zoom meetings) with a Speech-language pathologist every day to fill-in a short questionnaire and to record two voice samples. The main result was that sleep quality was associated with reductions in the maximum sound pressure level for vowel /i/. In the second study, college professors had meetings (in a Moodle platform), where they discuss about vocal hygiene practices, voice training exercises and adjustments of teaching-learning process to avoid voice misuse inside the classrooms. The main result was an improvement in vocal quality, reduction in vocal fatigue, and reduction of 2.5% in time dose. In conclusion, voice assessments and voice intervention programs conducted remotely showed good performance and positive effect on voice functioning among college professors.

11:20

2aSC7. Using remotely collected voice recordings for clinical voice evaluation: A feasibility study. Keiko Ishikawa (Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, 901 S. 6th St., Champaign, IL 61820, ishikak@illinois.edu), Clarion Mendes, Grace Braden, Kelsey Libert, MariaElena Kouriabalis, and Lianna J. Yang (Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, Champaign, IL)

The COVID-19 pandemic underscored the importance of telepractice in the care of voice disorders. Acoustic analyses are routinely conducted for determining the presence and severity of voice disorders. In the in-person voice evaluation, the recording environment is carefully controlled as the recording's quality can affect the acoustic analyses' output. Telepractice environment does not allow such control, challenging this aspect of voice evaluation. In order to capture the nature of this challenge, this study examined the feasibility of using remotely collected voice recordings for the acoustic evaluation of disordered voice. Thirteen students in Vocal Performance and Theater studies were trained to perform individuals with voice disorders as standardized patients (SPs) and underwent a remote voice evaluation. Recordings of sustained vowels and sentences were collected via Zoom and the SP's personal computers. The fundamental frequency, cepstral peak prominence, and harmonic-to-noise ratio were calculated from these recordings. A listening experiment was also conducted to examine the perceptual similarity between the Zoom and computer recordings. The preliminary data analyses indicated that the mode of voice recording significantly affects the listener's perception and acoustic analyses of dysphonic voice. Clinical implications and possible strategies for future studies will be discussed.

11:35

2aSC8. Tips for collecting self-recordings on smartphones. Valerie Freeman (Commun. Sci. & Disord., Oklahoma State Univ., 042 Murray Hall, Stillwater, OK 74078, valerie.freeman@okstate.edu)

The COVID-19 pandemic has challenged phoneticians to adopt remote methods of collecting recorded speech. For many research questions, remote collection presents enough logistical benefits to balance the reduced control over recording conditions, allowing us to expand our toolkits and reach more participants quickly and cheaply, even after the pandemic subsides. A current study of multiple vowel mergers provides a successful example of collecting talker-supplied recordings on smartphones and laptops. In two months, over 90 talkers made good-quality 10-min recordings of read words and passages. The short procedure and $5 e-compensation bolstered this success, but smartphone familiarity skewed the sample toward young, educated respondents, necessitating adaptations for less tech-savvy older adults. These and other methodological challenges will be addressed with tips and lessons learned: simplifying task design for increased response rates and compliance, successful approaches to online recruiting and compensation, considerations for populations with poor tech access/skills, and maximizing audio quality within logistical constraints. Recent work will be referenced to support the quality of homemade recordings, with suggestions for determining their suitability for any acoustic measures. Throughout the talk, various tradeoffs will be highlighted: quality/quantity, breadth/depth, control/access, complexity, speed, cost.

11:50

2aSC9. Remotely collecting immediate voice production effects of semi-occluded vocal tract exercises. David S. Ford (Michigan State Univ., 1026 Red Cedar Rd., East Lansing, MI 48824, forddav5@msu.edu) and Dimitar Deliyski (Michigan State Univ., East Lansing, MI)

The purpose of this study was to evaluate the feasibility of remote collection of immediate vocal production effects of semi-occluded vocal tract exercises (SOVTs). Participants received a shipment of study equipment and materials with instructions on how to set-up and configure them. The collection protocol was conducted with remote guidance from the researcher via a Zoom session. The protocol included a double baseline voice recording, experimental tasks consisting of straw phonation and straw phonation into a cup of water, and a post-task recording. Audio recordings of sustained vowels, CAPE-V sentences, and the Rainbow Passage were analyzed for jitter, shimmer, harmonic-to-noise ratio, cepstral peak prominence, and presence of a singer's formant. Following the tasks, participants were asked to provide self-perceptual ratings of vocal quality and vocal effort. Auditory-perceptual analysis (CAPE-V) was also performed, in which expert listeners (speech-language pathologists with extensive voice backgrounds) rated differences following the SOVT tasks. Instrumentation and methodology will be discussed, with a focus on the strengths and weaknesses of remote data collection including which voice assessment metrics were still robust to immediate SOVT effects, even in a remote setting. While obtaining lab-quality audio recordings for acoustic analysis remotely is considered challenging, this study suggests that it is feasible to obtain high-quality data remotely.

12:05–12:30 Discussion

Session 2aSP

Signal Processing in Acoustics and Computational Acoustics: Bayesian Signal Processing and Machine Learning I

Ning Xiang, Cochair
School of Architecture, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY 12180

Peter Gerstoft, Chair
Scripps Inst. of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093

Stan Dosso, Cochair
School of Earth and Ocean Sciences, University of Victoria, Victoria, V8W 2Y2, Canada

Chair's Introduction—9:30

Invited Papers

9:35

2aSP1. Bayesian signal processing: A practical guide to particle filtering design and performance. James V. Candy (ENGR, LLNL, P.O. Box 283, Danville, CA 94526, tsoftware@aol.com)

When uncertain acoustic processes can no longer be characterized by Gaussian or for that matter unimodal (single peak) distributions along with the fact that the underlying phenomenology is nonstationary (time-varying) and nonlinear, then more general Bayesian processors must be applied to solve the underlying signal enhancement/extraction problem. A particle filter provides a solution to this multimodal (multiple peaks) posterior distribution estimation problem in noisy acoustic environments. A particle filter is a sequential Markov chain Monte Carlo processor capable of providing reasonable performance for data evolving from a multimodal distribution by estimating a nonparametric representation of the posterior distribution from which a multitude of meaningful statistics can be retrieved. However, the question of evaluating its performance can be challenging even for the simplest of processes. For instance, it is well-known that Kalman filter optimality can be obtained only when the resulting error residuals (innovations) are zero-mean and white. It is not that simple for the particle filter. Once characterized, the performance of the particle filter must be analyzed for it to be of practical value. Here a set of design and analysis criteria is discussed and applied to demonstrate their ability to quantify particle filtering performance.

9:50

2aSP2. Source detection and localization in the ocean with a Bayesian approach. Zoi-Heleni Michalopoulou (Dept. of Mathematical Sci., New Jersey Inst. of Technol., 323 M. L. King Boulevard, Newark, NJ 07102, michalop@njit.edu), Andrew Pole (Dept. of Mathematical Sci., New Jersey Inst. of Technol., Newark, NJ), and Ali Abdi (Dept. of Elec. and Comput. Eng., New Jersey Inst. of Technol., Newark, NJ)

Source localization and detection of sound sources in the ocean are investigated from a Bayesian Matched Field Processing perspective. Unknown parameters comprise the source spectrum along with source location; the spectrum is estimated within the localization and detection process. We develop incoherent and coherent processors, integrating the source spectrum estimation employing a Gibbs sampler. Using synthetic data we find that the coherent processor is superior to the incoherent processor and the standard Matched Field approach both in terms of source location estimates and uncertainty. The coherent and incoherent techniques are also applied to real data from the Hudson Canyon experiment with the same conclusion. Employing Receiver Operating Characteristic (ROC) curves, the coherent and incoherent processors are evaluated and compared in the task of joint detection and localization as well. The coherent detector/localization processor is superior to the incoherent one. Joint detection and localization performance is evaluated with Localization-ROC curves. [Work supported by ONR.]

10:05

2aSP3. A computational Bayesian approach to machine learning of an acoustic scatterer's state of motion in a refractive propagation environment under a small aperture constraint. Paul J. Gendron (ECE, Univ. of Massachusetts Dartmouth, 285 Old Westport Rd., Dartmouth, MA 02747, gendronpauljohn@gmail.com) and Abner C. Barros (ECE, Univ. of Massachusetts Dartmouth, Dartmouth, MA)

A computational Bayesian method for inference regarding the size and state of motion of a submerged mobile object from narrow band transmissions and a small receiver aperture is presented. The challenge of attendant closely spaced multipath arrivals is addressed by taking advantage of knowledge of the refractive environment. Acoustic phase fronts, their angles and Doppler compressed wavelengths are jointly inferred. We take full advantage of the analytic conditional densities of eigenray amplitudes as well as ambient and reverberant power under the conventional Gaussian-Inverse Gamma model and focus computational resources on conditional densities for the frequency-angle dependent wave vectors via sampling from conditional quantile functions. Inversion of the posterior probability density of the wave vectors to the scatterer's state space is accomplished quickly via eigen-ray interpolation. Examples are given from real ocean sound speed profiles as well as the classic Munk profile.

10:20

2aSP4. Uncertainty and interdependence of localization parameters within Bayesian framework for near-field source localization. Thomas Metzger (School of Architecture, Rensselaer Polytechnic Inst., 121 4th St., Troy, NY 12180-3912, tommy.r.metzger@gmail.com) and Ning Xiang (School of Architecture, Rensselaer Polytechnic Inst., Troy, NY)

Localization of sound sources relative to a receiver is of great interest in many acoustical applications. In a recent study, a Bayesian framework was presented for the three-dimensional localization of an unknown number of sound sources within the near field of a spherical microphone array. Within this model-based probabilistic framework, the spherical beamforming model is formulated to include dependence on radial distances of potentially multiple sources in the near field. The focus of this work is threefold. First, to analyze the uncertainty and error of the localization results. The results provide estimates of the source distance(s) with increasing uncertainty at increased distances. Second, to analyze the interdependence of source distance and amplitude on the estimation results when multiple sources are present. Finally, this work discusses how mitigation of this interdependence affects the uncertainty and error for multiple sound sources.

10:35–10:55 Discussion

10:55–11:10 Break

Invited Papers

11:10

2aSP5. Sequential sparse Bayesian learning for beamforming. Yongsung Park (Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093-0238, yongsungpark@ucsd.edu), Florian Meyer, and Peter Gerstoft (Univ. of California, San Diego, La Jolla, CA)

A sequential Bayesian method for beamforming is presented for the estimation of the directions of arrivals (DOAs) of source signals which are varying over time. The sparse Bayesian learning (SBL) uses prior information of unknown source amplitudes as a multi-variate Gaussian with zero-mean and time-varying variance parameters. For sequential processing, we utilize the unknown variance as statistical information across time and propose a sequential SBL-based method to improve time-varying DOA estimation performance. The suggested method has two steps. A prediction step calculates the prior distribution of the current variance parameter from the variance parameter estimated at the previous time step, and an update step incorporates the current measurements. This SBL approach with sequential processing provides high-resolution for time-varying DOA tracking. We evaluate the proposed method using simulated data and real data from the SWellEx-96 experiment.

11:25

2aSP6. Spatio-temporal Gaussian process regression for room impulse response interpolation with acoustically informed priors. Diego Caviedes-Nozal (Acoust. Technol. Group, Tech. Univ. of Denmark, Ørsteds Plads, Bldg. 352, Lyngby 2800, Denmark, dicano@elektro.dtu.dk) and Efren Fernandez-Grande (Acoust. Technol. Group, Tech. Univ. of Denmark, Copenhagen, Denmark)

The reconstruction of sound fields in a room from a limited set of measurements is a central problem in acoustics, with relevant applications in *e.g.* acoustic analysis, audio, or sound field control. Conventional approaches rely on measuring the room impulse response (RIR) at several locations in the room, and fitting a wave model that enables to estimate the field at other locations—via solving an inverse problem. Previous studies have shown that the reconstruction of RIRs strongly depends on the regularization method used to solve the problem, and that enforcing sparsity is beneficial for the reconstruction of the early part of the RIR. This work studies Gaussian processes with time-dependent regularization in order to exploit the temporal properties of RIRs. The inverse problem is solved in the time domain, where hierarchical Bayes is applied in order to explicitly promote solutions where waves are more likely to propagate as time evolves. The model aims at reconstructing both the early part, and the late part of the RIRs. The performance of the proposed model is studied with experimental measurements, and compared to classical reconstruction methods with l1 and l2-norm regularization schemes

11:40

2aSP7. Basis function choice for trans-dimensional models in geophysical inference. Jan Dettmer (Dept. of Geoscience, Univ. of Calgary, 2500 University Dr. NW, Calgary, AB T2N 1N4, Canada, jan.dettmer@ucalgary.ca) and Emad Ghalenoei (Dept. of Geomatics Eng., Univ. of Calgary, Calgary, AB, Canada)

Inference methods depend on parametrization choices. Over-parametrized, under-parametrized, and trans-dimensional (trans-D) models are routinely chosen. Over-parametrization employs space discretization below the resolution power of the data and includes regularization (*e.g.* Tikhonov) to control the amount of model structure. Under-parametrized models employ fewer parameters, and practitioners choose model complexity (*e.g.* the number of seabed layers) that is consistent with data information, often based on incomplete prior information. Trans-D models assign model complexity based on data information in an automated, data-driven procedure. The success of trans-D models depends on the choice of basis function for space partitioning. We review existing trans-D approaches and present new ones for 2D and 3D Earth models. Existing approaches include Voronoi partitioning, wavelet decomposition, and polynomial shapes, which can produce inadequate results. New approaches use various degrees of prior information when assigning the basis. The approaches include multiple nested Voronoi diagrams, a combination of grid data and alpha shapes, and partitioning of Voronoi diagrams with horizontal and vertical lines and planes. Since the computational burden is significant for 2D and 3D Earth models, we study various algorithms to carry out partitioning and show that approximate nearest neighbours are sufficiently accurate and outperform other methods.

11:55

2aSP8. Unsupervised learning for seabed type and source parameters from surface ship spectrograms. Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., N251 ESC, Provo, UT 84602, tbn@byu.edu), Zhi-Hao Tsai (Phys. and Astronomy, Brigham Young Univ., Provo, UT), William Hodgkiss (Marine Physical Lab., Scripps Inst. of Oceanogr., San Diego, CA), and David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX)

Lack of labeled field data in ocean acoustics is a limitation for applying supervised machine learning techniques. Unsupervised techniques have shown potential for classifying signals, but questions remain as to how much additional information unsupervised techniques can learn from ocean acoustic data. This paper evaluates the ability of an unsupervised k-mean clustering algorithm to provide information about the seabed and location of a moving source. The training data are synthetic spectrograms from surface ships based on a wide variety of ship speeds, closest distance to the hydrophone, and seabed types. The resulting clusters are evaluated to discover trends into which types of spectrograms are in each cluster, and the characteristics of the cluster centroids are investigated. These studies highlight the speed-distance ambiguity seen in ship spectrograms as well as the ambiguity between distance and bottom loss of the seabed. The trained algorithm is tested on both synthetic spectrograms and ones from merchant and cargo ships recorded during the Seabed Characterization Experiment in 2017. The future of unsupervised machine learning in ocean acoustics depends on correctly interpreting the results and testing the ability of trained networks to generalize.

12:10–12:30 Discussion

Session 2aUW

Underwater Acoustics, Acoustical Oceanography and Animal Bioacoustics: The Effects of COVID-19 on Global Ocean Soundscapes

David R. Barclay, Chair
Department of Oceanography, Dalhousie University, P.O. Box 15000, Halifax B3H 4R2, Canada

Chair's Introduction—9:30

Invited Paper

9:35

2aUW1. Quiet oceans: United States Virgin Islands coral reef soundscapes in the age of coronavirus. Hadley G. Clark (Biology, Woods Hole Oceanographic Inst., 360 Woods Hole Rd., Woods Hole, MA 02543, hadleygtclark@gmail.com) and Nadège Aoki (Biology, Woods Hole Oceanographic Inst., Woods Hole, MA)

The COVID-19 pandemic has led to unprecedented changes in human behavior around the world. These changes have impacted local soundscapes in both terrestrial and marine environments resulting in a global 'quieting' event that has allowed for the opportunity to evaluate the activity of soniferous organisms in unique acoustic environments. Across the world's oceans, patterns of commercial, research, and recreational vessel traffic have all been altered, with corresponding alterations in the anthropogenic contribution to underwater noise. To assess these changes we used long-term acoustic recorders at three different coral reef sites on the Southern coast of the island of St. John in the United States Virgin Islands (USVI). We compared conditions pre-coronavirus outbreak (2019) and post-outbreak (2020) and found a decrease in the incidence of boat noise over the course of the pandemic. Because anthropogenic noise tends to overlap with the low frequencies used by marine fishes and invertebrates for sound production and detection, we predicted that changes in boat noise patterns would lead to concurrent changes in biological sound production of coral reef organisms. Understanding the impacts of this "quiet time" on marine organismal activity in the USVI could play a role in worldwide coral reef acoustic studies and conservation efforts.

Contributed Papers

9:50

2aUW2. Trends in low frequency ambient noise for a site 80 km off the Oregon coast over approximately four years ending August 2020. Peter H. Dahl (Appl. Phys. Lab. and Mech. Eng., Univ. of Washington, Seattle, WA), Michael Harrington (Appl. Phys. Lab. at Univ. of Washington, Seattle, WA), and David R. Dall'Osto (Acoust., Appl. Phys. Lab. at Univ. of Washington, 1013 N 40th St., Seattle, WA 98105, dallosto@apl.washington.edu)

Approximately 4 years of underwater noise data recorded from the Regional Cabled Array (RCA) network, at the site known as Hydrate Ridge, is studied for purposes of examining long term trends. The data originate from station HYS14 located on the seabed at a depth of approximately 800 m and 80 km offshore of Newport, OR. The sample rate is 200 Hz, setting to the analysis limit to less than 100 Hz. A distinctive feature of the data is the sound pressure level in the frequency range of 20 Hz that reflects the migratory timing of fin whales, which peaks near the start of the new year, and reaches a minimum around June. There is a suggestion that the level between 10 and 70 Hz attributable shipping activity, is reduced in the spring of 2020 by about 2 dB relative the three prior years, possibly owing reducing economic activity linked with Covid-19. At the time of this writing independent verification of with shipping data is ongoing. [This study was partially supported by U.S. Office of Naval Research and by the UW Cooperative Institute for Climate, Ocean and Ecosystem Studies (CICOES).]

10:05

2aUW3. Effect of COVID-19 spring lockdown on low-frequency ambient noise levels along the Brittany coast. Delphine Mathias (SOMME, 300 Rue Pierre Rivoallon, Brest 29200, France, mathias.somme@orange.fr), Julien Bonnel (Woods Hole Oceanographic Inst., Woods Hole, MA), and Laurent Chauvaud (CNRS (UMS3113), Institut Universitaire Européen de la Mer, Plouzané, France)

Shipping noise is a major source of ocean noise in Brest bay, and includes cargo vessels, navy ships, fishing boats and recreational vessels with frequencies overlapping the range of marine animal sound emission. Changes in vessel activity provide unique opportunities to quantify the relationship between traffic levels and soundscape conditions in biologically important habitats. Using an autonomous recorder deployed from March 20 to July 29 2019 inside Sainte-Anne harbor in Brest area we assessed the effect of the 2020 spring COVID-19 lockdown (March 17 to May 11) on ambient noise levels. We measured the mean power spectral density levels in different third-octave bands (including Marine Strategy Framework Directive bands centered on 63 Hz and 125 Hz). The March 20–May 15 (during lockdown) levels were up to 2.6 dB *re* 1 μPa^2/Hz below the May 15–July 28th (after lockdown) levels, corresponding to nearly a halving of acoustic power.

10:20

2aUW4. Long time-series analysis from a directional acoustic sensor near Monterey Bay. Kevin B. Smith (Dept. of Phys., Naval Postgrad. School, 833 Dyer Rd., Bldg 232, Rm 114, Monterey, CA 93943, kbsmith@nps.edu), Paul Leary (Dept. of Phys., Naval Postgrad. School, Monterey, CA), Thomas Deal (Naval Undersea Warfare Ctr. Div. Newport, Newport, RI), John E. Joseph, Chris Miller (Dept. of Oceanogr., Naval Postgrad. School, Monterey, CA), John P. Ryan, and Craig Dawe (Monterey Bay Aquarium Res. Inst., Moss Landing, CA)

A reduction in commercial shipping was reported during the first half of 2020 in response to the COVID-19 pandemic. The goal of this analysis is to determine if this impact on shipping resulted in a corresponding reduction in low-frequency ambient noise levels off the coast of Monterey Bay, California. Data presented here was collected on a Naval Postgraduate School directional acoustic sensor deployed on the Monterey Accelerated Research System's cabled observatory, managed by the Monterey Bay Aquarium Research Institute. The directional acoustic sensor was developed by GeoSpectrum Technologies, Inc for integration onto the observatory system, and was initially installed in February, 2019. Since then, the data has been continuously streaming to a server at the Naval Postgraduate School for subsequent processing. In this work, long time-series analysis is performed to compare year-to-year statistics of month-long data sets through the end of January, 2021. Spectral probability densities are computed for each month over the 1/3 octave band for both amplitude and direction. Annual variations of the 50th percentile statistics are evaluated to determine if the shipping reduction due to COVID-19 is a distinguishable feature in the data.

10:35–10:45 Discussion

10:45–11:00 Break

Contributed Papers

11:00

2aUW5. COVID-19 impact on the Northern Gulf of Mexico soundscapes. Natalia Sidorovskaia (Dept of Phys., Univ. of Louisiana at Lafayette, P.O. Box 43680, Lafayette, LA 70504, nas@louisiana.edu) and Naomi Mathew (Phys., Univ. of Louisiana at Lafayette, Lafayette, LA)

Changes in the Gulf of Mexico soundscapes due to COVID-19 are investigated. Baseline ambient noise recordings from five Environmental Acoustic Recording System buoys in the Mississippi Valley/Canyon region between May 2018 and June 2020, collected as a part of the collaborative efforts funded by BOEM, are analyzed. The statistical data processing is based on the standards developed for the previous large-scale ocean ambient noise monitoring projects; extracted acoustic metrics are directly comparable to the levels reported in the Baltic Sea, the North Atlantic, and the North Sea . The monthly medians of 1/3-octave band Sound Pressure Levels (SPLs) vary up to 15 dB *re* 1 μPa across sites depending on surrounding anthropogenic activities and local propagation conditions that makes it challenging to recognize the variations due to the pandemic. Overall, the deepest site appears to have the highest SPLs at the low frequency bands and the lowest SPLs at the mid-frequency bands. The mid-frequency band highest SPLs are observed at the shallow site and the site outside the canyon. Exploration surveys and industrial activities were present across all COVID-19 impacted months. More subtle changes in ambient levels due to the pandemic impact will be discussed in the presentation.

11:15

2aUW6. Global shipping soundscapes: A study of the COVID-19 impact. Chris Verlinden (Appl. Ocean Sci., 11006 Clara Barton Dr., Fairfax Station, VA 22039, Chris.verlinden@AppliedOceanSciences.com), Kevin D. Heaney (Appl. Ocean Sci., Fairfax Station, VA), Sarah Rosenthal (Appl. Ocean Sci., Honolulu, HI), and James J. Murray (Appl. Ocean Sci., Fairfax Station, VA)

The global ocean soundscape, at frequencies below 400 Hz, is dominated by shipping and at some select frequencies marine mammals and large storms. In this paper, we present a global model of the shipping and wind noise soundscape. The Parabolic Equation (PE) Model is used to compute the propagation loss from a grid of points through the dynamical ocean to a high resolution grid of receivers. Source depths of 5 m are used for ships and 1/4 wavelength are used surface wind. The combined wind/shipping soundscape can then be generated using satellite observations of the shipping positions via Automated Identification Services and the wind speed at 10 m. Both databases were provided by SPIRE Inc. SPIRE provided the shipping AIS for March/April 2018 and March/April 2020. The global shipping soundscape for these two time periods reveals a drop of 3-6 dB depending upon position at 50 Hz from the reduction in surface shipping traffic due to the COVID-19 global shut down.

11:30

2aUW7. An update to real-time observations of the impact of COVID-19 on underwater sound. David R. Barclay (Dept of Oceanogr., Dalhousie Univ., 1355 Oxford St., LSC Bldg., Halifax, NS B3H 4R2, Canada, dbarcl@gmail.com) and Dugald Thomson (Oceanogr., Dalhousie Univ., Halifax, NS, Canada)

A slowdown in global trade activity due to COVID-19 has led to a reduction in commercial shipping traffic into the Port of Vancouver. The Ocean Networks Canada observatory system provides researchers real-time access to oceanographic data from a wide range of instruments including hydrophones located along the offshore and inshore approaches to Vancouver. Power spectral density statistics at 100 Hz from four of these bottom mounted hydrophones were monitored, along with AIS data and shipping and trade statistics to assess to what extent the economic impact of COVID-19 can be observed acoustically and in near real-time. The quarterly trend in median weekly noise power in the shipping band of frequencies provides an early indicator that a reduction in noise commensurate with the economic slowdown occurred at two hydrophone stations. Time series of the median and 1st percentile weekly power provide a retrospective detail of the impact of the pandemic on underwater sound.

11:45–12:00 Discussion

Session 2pAA

Architectural Acoustics: Advances in Architectural Acoustics for Cultural Heritage Research and Preservation

David Lubman, Cochair

Miriam A. Kolar, Cochair
Amherst College, Ac#2258, Amherst, MA 01002

Chair's Introduction—12:55

Cultural heritage implies risk management entangled with politics of responsibility and access. We bring together leading researchers to discuss precedents, challenges and innovations in the documentation and preservation of architectural acoustics in heritage sites. Among the topics of particular interest to our discussion is the relating of acoustical data to human experience, and the strategies that panelists have used to document, estimate, and convey the perceptual significance of heritage acoustics. Panelists include ASA Fellow and archaeoacoustics pioneer David Lubman; audio engineers Brian F. G. Katz, Sungyoung Kim, Doyuen Ko; architect Pamela Jordan; soundscape researcher Francesco Aletta; and cultural acoustician Miriam Kolar, who will serve as the moderator.

WEDNESDAY AFTERNOON, 9 JUNE 2021 12:55 P.M. TO 3:30 P.M.

Session 2pAO

Acoustical Oceanography: Long Term Acoustic Time Series in the Ocean II

Jennifer Miksis-Olds, Cochair
University of New Hampshire, 24 Colovos Rd, Durham, NH 03824

Joseph Warren, Cochair
School of Marine and Atmospheric Sciences, Stony Brook University, 239 Montauk Hwy, Southampton, NY 11968

Chair's Introduction—12:55

Invited Paper

1:00

2pAO1. Multipurpose acoustic networks in the Arctic. Hanne Sagen (Nansen Environ. and Remote Sensing Ctr., Bergen, Norway, hanne.sagen@nersc.no), Matthew A. Dzieciuch, Peter F. Worcester (Scripps Inst. of Oceanogr., Univ. of California San Diego, San Diego, CA), Espen Storheim, and Florian Geyer (Nansen Environ. and Remote Sensing Ctr., Bergen, Norway)

To improve the Arctic Ocean observing capability, OceanObs19 recommends "to pilot a sustained multipurpose acoustic network for positioning, tomography, passive acoustics, and communication in an integrated Arctic Observing System, with eventual transition to global coverage." A multipurpose acoustic network will widen the wealth of observations of ocean and sea ice variables in the central Arctic. Several regional multipurpose acoustic experiments have been carried out in the Arctic, helping create the capability and experience to go basin wide. The CAATEX (Coordinated Arctic Acoustic Thermometry Experiment) is a first step towards a basin wide multipurpose acoustic system. CAATEX was a one-year limited experiment, but the experiences from the experiment are a forerunner for a sustained Pan Arctic Acoustic Observation Network. This presentation will focus on the planning of and first results from CAATEX and the role of acoustic networks in the future Arctic Ocean Observing System. [CAATEX is supported by Office of Naval Research through Grant No. N00014-18-1-2698 and the Research Council of Norway under Grant No. 280531.]

Contributed Papers

1:15

2pAO2. Sound field fluctuations in shallow water waveguide in the presence of nonlinear internal waves and estimation of their speed. ASIAEX experiment as a case study. Boris Katsnelson (Marine Geosciences, Univ. of Haifa, 199 Adda Khouchy Ave., Haifa 3498838, Israel, bkatsnels@univ.haifa.ac.il), Valery Grigorev (Phys. Dept, Voronezh State Univ., Voronezh, Russian Federation), and Yanyu Jiang (Marine Geosciences, Univ. of Haifa, Haifa, Israel)

Spectra of the sound field fluctuations in shallow water waveguide in the presence of nonlinear internal waves (NIW) are studied and used for solution of inverse problem: to estimate variability of speed of NIW using results of ASIAEX experiment. ASIAEX was carried out in the South China sea since April 29 until May 14, 2001, a few tens of solitary NIW with amplitude up to 100 m were registered, moving toward the beach. Sound pulses (M-sequences, frequency 224 Hz) from the source were propagating in narrowing channel (350 m–120 m, distance 30 km) toward the beach in the presence of NIW. It was shown earlier by authors that spectrum of fluctuations measured during NIW's motion contains peaks at frequencies F depending on speed v of NIW and scales of interference beating D of waveguide modes F $\sim$ v/D. D depends on bathymetry and sound speed profile in a waveguide. Using measurement of peak frequencies and known values of D, and using matching procedure between modeling and experimental data, variations of v were found for set of above mentioned events of NIW passing. Results were compared with direct measurements using satellite observations. [Work was supported by RFBR under Grant No. 20-55-S52005.]

1:30

2pAO3. Long-term analysis of ocean noise floor in the northeast Pacific Ocean. Felix Schwock (Elec. and Comput. Eng., Univ. of Washington, 185 Stevens Way, Paul Allen Ctr. – Rm. AE100R, Seattle, WA 98195, fschwock@uw.edu) and Shima Abadi (Elec. and Comput. Eng., Univ. of Washington, Seattle, WA)

Characterizing the ocean noise floor is important for tracking long-term acoustic changes and creating environmental regulations to mitigate the effects of human activities on the ocean soundscape. Underwater noise levels have been measured at two sites in the northeast Pacific off the coast of Oregon between 2015 and 2019. The acoustic data were recorded continuously at a sample rate of 64 kHz at 81 m depth and 581 m depth at the continental shelf and slope, respectively. Sequential one-minute power spectral density estimates are computed and used to calculate spectral probability density functions (SPDFs) for every month of the measurement period. The ocean noise floor is then defined as the 5th percentile of the SPDF. Multi-year data are used to compute time series of the ocean noise floor at various frequencies, which are then examined for long-term trends and seasonal patterns. The frequency dependence of the noise floor is analyzed and the results are compared between two measurement sites. Environmental data from surface buoys and Conductivity, Temperature, Depth (CTD) instruments collocated with the hydrophones are used to study how the ocean noise floor changes with wind, temperature, and sound speed. [Work supported by ONR.]

1:45

2pAO4. Long term very low frequency ambient noise: A window to the ocean and atmosphere. Anthony I. Eller (Appl. Ocean Sci., 11006 Clara Barton Dr., Fairfax Station, VA 22039, anthony.eller@appliedoceansciences.com), Kevin D. Heaney, James J. Murray (Appl. Ocean Sci., Fairfax Station, VA), and David L. Bradley (SERDP/ESTCP Program Office, Alexandria, VA)

Long term time series data of ambient noise in deep water from a site near Wake Island in the western Pacific provide a window into processes occurring in the ocean and in the atmosphere. Acoustic noise data in the Very Low and Ultra Low Frequency bands show strong frequency components at major tidal frequencies, are correlated with El Niño Sea Surface Temperature Anomaly time records, and correlate also with yearly wind fluctuations. Directional ambient noise data also allow tracking of distant storms. Noise at 1 Hz was chosen in particular for study because the noise sources are primarily environmental and, thus, the data may serve as a harbinger of pending environmental change.

2:00–2:15 Break

2:15

2pAO5. Long-term noise interferometry analysis in the northeast Pacific Ocean. John Ragland (Elec. Eng., Univ. of Washington, Seattle Main Campus, Seattle, WA 98195, jhrag@uw.edu) and Shima Abadi (Elec. Eng., Univ. of Washington, Seattle, WA)

Noise interferometry is the method of passively estimating acoustic propagation using ambient sound. It has been used for long-term ocean monitoring applications such as tomography, thermometry, and measuring flow velocity. Using noise interferometry, the time domain Greene's function (TDGF) between two locations can be estimated. In this talk, we use 6 years (2015–2020) of acoustic data recorded by two hydrophones in the northeast Pacific Ocean to analyze the long-term TDGF. The hydrophones are deployed at the Cabled Array which is maintained by the Ocean Observatories Initiative (OOI). They are separated by 3.2 km, located on the ocean floor at a depth of 1500 m, and have a sampling rate of 200 Hz. We calculate the signal-to-noise ratio (SNR) of the TDGF estimate for different propagation paths and study how it varies for different average times, local shipping densities, and oceanographic variables such as sound speed. [Work supported by ONR.]

2:30

2pAO6. Seasonal variations of ambient sound and ice draft in the Northwest Passage between 2018 and 2021. Emmanuelle Cook (Dalhousie Univ., 1355 Oxford St., Halifax, NS B3H 3Z1, Canada, emmanuellecook@dal.ca), David R. Barclay (Dalhousie Univ., Halifax, NS, Canada), Clark Richards, and Shannon Nudds (Bedford Inst. of Oceanogr., Dartmouth, NS, Canada)

The Barrow Straight Real-time Observatory is a cabled underwater monitoring station operated by Fisheries and Oceans Canada in the Tallurutiup Imanga National Marine Conservation Area. The observatory measures temperature, salinity, pressure, dissolved oxygen, currents, ambient noise and ice draft. Every 2 h a hydrophone records a 1-min pressure time series and generates a spectrogram with a frequency range of 10–6390 Hz and time resolution of 1 s. The IPS generates a histogram of ice draft measurements every 2 h. Data are sent in near real-time to the Bedford Institute of Oceanography via satellite. The average monthly sound levels follow seasonal ice variations with higher frequencies varying more strongly with season than the lower frequencies and depend on the timing of ice melt and freeze-up. Ambient levels are higher in the summer during open water and quieter in the winter during periods of pack ice and shore fast ice. An autocorrelation of weekly noise levels over the ice freeze-up and complete cover periods reveal a $\sim$24 h periodic trend in noise at high frequencies (>1000 Hz) which is caused by tidally driven surface currents in combination with increased ice block collisions or increased stress in the shore fast sea ice.

2:45

2pAO7. Assimilation of acoustic thermometry data in Fram Strait. Florian Geyer (Nansen Environ. and Remote Sensing Ctr., Nansen Environ. and Remote Sensing Ctr., Thormølens Gate 47, Bergen 5006, Norway, florian.geyer@nersc.no), Ganesh Gopalakrishnan (Scripps Inst. of Oceanogr., UCLD, San Diego, CA), Hanne Sagen (Nansen Environ. and Remote Sensing Ctr., Bergen, Norway), Bruce Cornuelle, and Matthew M. Mazloff (Scripps Inst. of Oceanogr., UCLD, San Diego, CA)

The 2010i–2012 ACOBAR acoustic thermometry experiment in Fram Strait resulted in 2-year-long timeseries of sound speed and temperature. These timeseries are section- and depth-average along 4 sections covering the deep part of Fram Strait (77.9°–78.9°N, 4.2°W–8.7°E). They were obtained by inversion from the acoustic travel times measured in the

thermometry experiment. Such large-scale average measurements in a highly turbulent environment at one of the important sites for ocean circulation in the Arctic are unique and will hopefully increase our understanding of volume and heat exchanges between the Arctic and Atlantic. A regional ocean model of Fram Strait was set up for the assimilation of the ACOBAR measurements using the 4-DVAR data assimilation technique. The forward model part was evaluated using both oceanographic and acoustic measurements (Geyer *et al.*, 2019). First assimilation results show a cost reduction of 85% after 10 iterations. The resulting ocean state estimate will be evaluated using the long-term oceanographic mooring section in Fram Strait at 78°50'N. The aim of this study is to use the ocean state estimate to facilitate the interpretation of the acoustic thermometry results and to investigate how the circulation dynamics in Fram Strait are influencing the volume and heat exchanges through the strait.

3:00–3:30 Discussion

WEDNESDAY AFTERNOON, 9 JUNE 2021 12:55 P.M. TO 2:55 P.M.

Session 2pBAa

Biomedical Acoustics: Advances in Ultrasound Imaging: Passive Cavitation Imaging/Mapping

Kevin J. Haworth, Cochair
Internal Medicine, University of Cincinnati, 231 Albert Sabin Way, CVC 3939, Cincinnati, OH 45267-0586

Michael Gray, Cochair
Institute of Biomedical Engineering, University of Oxford, Oxford, OX3 7DQ, United Kingdom

Chair's Introduction—12:55

Invited Paper

1:00

2pBAa1. Advances in ultrasound imaging: Passive cavitation imaging/mapping. Michael Gray (Inst. of Biomedical Eng., Univ. of Oxford, Oxford OX3 7DQ, United Kingdom, michael.gray@eng.ox.ac.uk) and Kevin J. Haworth (Internal Medicine, Univ. of Cincinnati, Cincinnati, OH)

Ultrasound-induced cavitation has been demonstrated to induce numerous bioeffects, including tissue ablation and drug delivery. Different types of cavitation activity (*e.g.*, inertial or stable) nucleate different bioeffects and are associated with distinct regimes of ultrasonic emissions. Thus decades of research have investigated the emission-bioeffect relationship. Since 2008, beamforming of cavitation emissions has been performed to provide images of cavitation activity. This enables the spatio-temporal localization, characterization, and quantification of cavitation activity, which has been shown to have utility in both image-guidance of therapies and basic science studies. The goal of this tutorial is to familiarize participants with the principles and implementation techniques for array-based passive cavitation monitoring. We will begin with a review the fundamentals of time-domain and frequency-domain beamforming, including an opportunity to form images during the tutorial using data and MATLAB code provided by the speakers. Next, we will discuss steps to correct for propagation path and hardware-specific effects in order to provide improved cavitation dose estimates. Display considerations and B-mode duplex imaging topics will follow. Finally, common hardware configurations, including benefits and limitations, will be covered to provide guidance for individuals considering a setup in their laboratory.

Session 2pBAb

Biomedical Acoustics: Advances in Ultrasound Contrast Agents and Bubble Nuclei

James Kwan, Chair
Nanyang Technological University, 62 Nanyang Drive, Singapore 637459, Singapore

Chair's Introduction—3:10

Perspectives on the state of the art for ultrasound contrast agents will be discussed from leaders in the academic and industry communities.

Panelists: Christy K. Holland, Univ. of Cincinnati, Eleanor Stride, Oxford Univ., Mark Borden, Univ. of Colorado, Tyrone Porter, Univ. of Texas at Austin, Jameel Feshitan, Advanced Microbubbles Inc., Thierry Bettinger, Bracco Research, Christian Coviello, OxSonics Inc.

WEDNESDAY AFTERNOON, 9 JUNE 2021 12:55 P.M. TO 4:10 P.M.

Session 2pCA

Computational Acoustics and Musical Acoustics: Tutorials on Computation Techniques and Best Practices

Kimberly A. Riegel, Cochair
Physics, Queensborough Community College, 652 Timpson Street, Pelham, NY 10803

Gary Scavone, Cochair
Music Research, McGill University, 555 Sherbrooke Street West, Montreal, H3A 1E3, Canada

Chair's Introduction—12:55

Invited Papers

1:00

2pCA1. A tutorial on the finite and boundary element methods in acoustics. Jonathan A. Hargreaves (Acoust. Res. Group, Univ. of Salford, Newton Bldg., Salford M5 4WT, United Kingdom, j.a.hargreaves@salford.ac.uk)

The Finite Element Method (FEM) and Boundary Element Method (BEM) are established numerical simulation techniques that are widely used in Engineering, including in Acoustics. This tutorial lecture will give a brief tour of both methods, some discussion of their pros and cons—including when to choose which, or when to use a coupled combination of both—and pointers to commercial and open-source software implementations.

1:30

2pCA2. Tutorial on finite-difference time-domain (FDTD) methods for room acoustics simulation. Brian Hamilton (Acoust. & Audio Group, Univ. of Edinburgh, 20/4 Rodney St., Edinburgh EH74EA, United Kingdom, brian.hamilton@ed.ac.uk)

Wave-based simulation models for acoustics have remained an active area of research and development for the past three decades. Wave-based methods aim to solve the 3D wave equation directly and therefore have large computational costs relative to conventional ray-based methods, which tend to simplify wave-diffraction effects. However, wave-based methods offer the potential of complete numerical solutions, including all wave-scattering and diffraction effects over the full audible bandwidth. Additionally, wave-based methods are highly parallelisable, making them amenable to parallel computing architectures such as graphics processing units, which can greatly cut down lengthy simulation times. This tutorial will give an introduction to wave-based methods for room acoustics with a focus on the finite-difference time-domain (FDTD) method. The basic concepts behind FDTD methods, along with practical implementation issues, will be discussed and illustrated with examples. The relationship of FDTD methods to other wave-based methods, along with differences to ray-based methods, will be explained. Also, the use of graphics processing units (GPUs) with freely available FDTD software will be discussed.

2:00

2pCA3. Parabolic equations in motionless and moving media. Vladimir Ostashev (U.S. Army Engineer Res. and Development Ctr., 72 Lyme Rd., Hanover, NH 03755, vladimir.ostashev@colorado.edu) and D. Keith Wilson (U.S. Army Engineer Res. and Development Ctr., Hanover, NH)

The narrow-angle parabolic equation (NAPE) provides a robust approach for sound propagation in inhomogeneous media such as the atmosphere and ocean. Several numerical methods for solving the NAPE in a motionless medium have been developed. The Crank-Nicholson finite-difference method is one of the simplest and readily supports range-dependent environmental processes such as turbulence. The NAPE, boundary condition, and artificial absorbing layer are discretized, and the solution is written in a matrix form. A starting field, which approximates the sound source, is marched forward by solving a matrix equation. Because the matrices involved are triagonal, the solution is highly efficient. For many applications in atmospheric and ocean acoustics, the NAPE needs to be generalized for wide-angle propagation and moving media (winds or currents). Recently derived wide-angle parabolic equations (WAPEs) in moving media are reviewed including the phase errors pertinent to the equations. In the Pade (1,1) and high-frequency approximations, the WAPE in a moving medium with arbitrary Mach numbers is surprisingly simple. It can be implemented numerically with minimal modifications to existing Crank-Nicholson NAPE solvers.

2:30–2:45 Discussion

2:45–3:00 Break

3:00

2pCA4. A tutorial on the transfer matrix method for acoustic modeling. Gary Scavone (Music Res., McGill Univ., 555 Sherbrooke St. West, Montreal, QC H3A 1E3, Canada, gary.scavone@mcgill.ca)

The transfer matrix method (TMM) is a common technique used to calculate the input impedance or reflectance for 1D acoustic systems that can be approximated in terms of concatenated cylindrical and/or conical sections, as well as side branches. Each section is represented by a transfer matrix that relates frequency-domain expressions of input to output in terms of pressure and volume velocity. This tutorial will provide a brief overview of the TMM formulation, followed by examples using an open-source implementation in Matlab. Methods to derive TMM characterizations for more arbitrarily shaped geometries and extensions for tonehole interactions will also be briefly discussed.

3:30

2pCA5. Uncertainty quantification in acoustics through generalized polynomial chaos expansions. Andrew S. Wixom (Appl. Res. Lab., Penn State Univ., P.O. Box 30, M.S. 3220B, State College, PA 16801, axw274@psu.edu) and Gage S. Walters (Appl. Phys. Lab., Johns Hopkins Univ., Laurel, MD)

Modeling and simulation has become increasingly important within acoustics to support system design and evaluation while reducing the need for expensive or sometimes unattainable field experiments. Much time and money has been invested in developing computational models that propagate known (deterministic) input data through a deterministic, and often very complex system to generate the relevant outputs of interest. System performance in real environments is, however, subject to uncertainties arising from incomplete knowledge of the input data as well as approximations made in generating the system model. In this tutorial talk, we will review the generalized polynomial chaos (GPC) method for propagating uncertainties through a deterministic computational acoustics model given probability distributions for the unknown quantities. Our approach uses stochastic collocation which permits reuse of deterministic acoustic codes so that the GPC is implemented as a wrapper code, rather than requiring a new complex model to be built. We then suggest a framework for general uncertainty quantification starting with informed probabilistic modeling of input, through interpretation of the GPC output, and illustrate with a structural acoustics example problem.

4:00–4:10 Discussion

Session 2pEA

Engineering Acoustics: Acoustic Transducers and Transduction Mechanisms

Vahid Naderyan, Cochair
University of Mississippi, 1151 Maplewood Drive, Itasca, IL 60143

Thomas E. Blanford, Cochair
The Pennsylvania State University, State College, PA 16804

Zane T. Rusk, Cochair
The Pennsylvania State University, 104 Engineering Unit A, University Park, PA 16802

Chair's Introduction—12:55

Invited Papers

1:00

2pEA1. An innovative MEMs peizo speaker. Mike Klasco (Menlo Sci., 5161 Rain Cloud Dr., Richmond, CA 94803, mike@menlo-scientific.com), Michael Ricci (xMEMS, Sant Clara, CA), and Neil A. Shaw (Menlo Sci., Topanga, CA)

MEMs micro-speaker development has trailed behind MEMs microphone development by over two decades due to fabrication and acoustical challenges. While MEMs microphones only need to respond to minuscule displacement, generating sound energy requires both motor force and far higher volume velocity of the transducer mechanism. Recent development of a full bandwidth piezo-MEMs micro-speaker with a silicon diaphragm creates a rigid, light, fast responding transducer with high resistance to humidity and low thermal expansion. Fabricated using a monolithic MEMS semiconductor process eliminates calibration and driver matching. 20 Hz to 20 kHz frequency response is delivered in occluded earbud, IEM, and hearing aid applications. The 20 kHz resonance peak provides a smoothly increasing response in the upper octaves. This extra amplitude allows for a significant increase in hearing aid gain and bandwidth over balanced armature transducers. The device is packaged in both top- and side-fire port configurations with earbud EVKs currently shipping. Integration of the amp, on the package substrate or SiP module, opens possibilities for more compact devices, longer battery life, lower cost, and more robust construction. The combination of audio fidelity, size, and speaker to speaker uniformity is not possible with traditional voice coil or hybrid MEMS approaches.

1:15

2pEA2. From single-ended to push-pull electrostatic MEMS speakers for in-ear audio applications. Lutz Ehrig (Arioso Systems GmbH, Maria-Reiche-Str. 2, Dresden 01109, Germany, Lutz.Ehrig@arioso-systems.com), Hermann A. G. Schenk (Arioso Systems GmbH, Dresden, Germany), Franziska Wall, Anton Melnikov, Bert Kaiser, Sergiu Langa, Michael Stolz, Jorge Mario Monsalve Guaracao, Andreas Mrosk (Fraunhofer Inst. for Photonic Microsystems, Dresden, Saxony, Germany), and Holger Conrad (Arioso Systems GmbH, Dresden, Germany)

Recently, a new approach for an all-silicon MEMS-based microspeaker has been presented for in-ear applications. The volume displacement is generated by multiple electrostatic actuated beams called "Nanoscopic Electrostatic Drives" (NED) that move in lateral direction between a top and a bottom silicon wafer. The top and the bottom wafers are provided with openings through which air can flow in and out. Two fundamentally different actuator designs have been realized: An asymmetric electrostatic pull-actuator and an electrostatic push-pull actuator. While the push-pull actuator can be actively displaced in both directions, the pull actuator can only be displaced actively in one direction and therefore requires an offset voltage to oscillate around a working point. These different driving schemes have a major impact on stability and harmonic distortions. In this presentation, MEMS speakers realized using both approaches will be compared and the impact on acoustic performance will be demonstrated.

1:30

2pEA3. FCS technology: A novel electrodynamic transducer architecture. Paul Vedier (R&D, Resonado Labs, 230 E Ohio St., Ste. 210, Chicago, IL 60611, pvedier@resonado.com)

For a century now, acoustic electrodynamic transducers have been bound by axisymmetric motor structures for high performance due to the assumption in transducer theory that the diaphragm moves pistonically for all operating frequencies. This is of course a flawed assumption, and results in much research and development being focused on the vibro-acoustic components of the driver to minimize cone breakup at higher frequencies.A new architecture for the electrodynamic motor has been developed which helps to address this inherent problem. Flat Core Speaker (FCS) technology presents an architecture that is a rearrangement of the conventional electrodynamic

motor structure with a planar voice coil and bobbin assembly that is situated between two parallel bar magnets. This results in a high aspect ratio design where the bobbin runs along the length of a flat diaphragm, leading to even force distribution, and therefore pistonic movement, while utilizing a thin profile with a flat diaphragm. COMSOL simulations and Klippel measurement data support these claims and show evidence of FCS technology having comparable performance to conventional drivers in a slimmer profile and blowing conventional high aspect ratio driver performance out of the water.

1:45

2pEA4. Performance and measurement of a bistable acoustic valve for earphones. Christopher Monti (Knowles, 1151 Maplewood Dr., Itasca, IL 60124, chris.monti@knowles.com), Charles King (Knowles, Oak Park, IL), Christopher Jones (Knowles, Carpentersville, IL), Thomas Miller (Knowles, Arlington Heights, IL), Shehab Albahri (Knowles, Hanover Park, IL), Jose Salazar (Knowles, Chicago, IL), and Mohammad Mohammadi (Knowles, Arlington Heights, IL)

Hearing devices often employ ear seals to optimize playback quality and reduce the leakage of low frequency signals. There are several downsides to having a fully blocked ear. One negative effect is the inability of the user to hear external sounds. Another downside of an ear seal is the introduction of occlusion effects, such as the amplification of the user's own voice. The ideal hearing device would have excellent sound reproduction but also avoid the negative effects of a sealed ear. One way to accomplish this goal is to have an earphone that can change states between being sealed and being open through a vent. An acoustic valve can be selectively opened and closed to change the state. Unlike active occlusion reduction and active pass through algorithms, a bistable valve will only consume power when transitioning between the open and closed states. In this talk, we present the important characteristics of an acoustic valve for battery-powered hearing devices. We explore the design and performance of one example acoustic valve. We discuss how to measure the acoustic performance of the valve and how the valve performs in real-world earphones. Practical considerations for in-ear valves are also examined.

2:00

2pEA5. Evaluating the depth capability of underwater thermophone projectors. Nathanael K. Mayo (Naval Undersea Warfare Center: Newport, Naval Undersea Warfare Ctr., Div. Newport, 1176 Howell St., Newport, RI 02841-1708, nathanael.mayo@navy.mil) and John Blottman (Naval Undersea Warfare Center: Newport, Newport, RI)

Thermophones are sound projectors which operate by producing thermally induced gas rarefaction and compression within a thin region adjacent to an electrically heated active element. To enable use underwater and provide protection, the active element can be encapsulated within a housing which is typically backfilled with either an inert gas or a liquid. Until recently, all characterization of underwater thermophones has been conducted at relatively low hydrostatic pressure, within 50 feet of the water's surface. Hydrostatic pressure tests, Multiphysics simulations, and methods of improving depth capability are discussed as well as an evaluation of the trade-offs and difficulties associated with improving the performance of these underwater projectors.

2:15

2pEA6. Flexoelectric barium strontium titanate (BST) hydrophones. Michael Hahn (Mater. Sci. and Eng., The Penn State Univ., University Park, PA), Thomas Blanford, Richard J. Meyer (Appl. Res. Lab., Penn State Univ., State College, PA), and Susan Trolier-McKinstry (Mater. Sci. and Eng., The Penn State Univ., N-227 Millennium Sci. Complex, University Park, PA 16802, stmckinstry@psu.edu)

Flexoelectric hydrophones offer the possibility of reasonable sensitivity in lead-free systems. Flexoelectricity utilizes strain gradients, rathan the strain, in the case of a piezoelectric. As a fourth rank tensor, flexoelectricity is shown by all solids; the magnitude of the flexoelectric coefficient scales with the relative permittivity, In this work, a $Ba_{0.7}Sr_{0.3}TiO_3$ ceramic with an effective flexoelectric coefficient, $\sim\mu_{12}$, of 105.6 ± 0.6 μC/m at room temperature was utilized in a prototype three-point bending hydrophone. Tap testing with a calibrated acoustic hammer showed a resonant frequency of 250 Hz and a maximum sensitivity of 80 pC/N. Finite element analysis (FEA) was employed to compare single and three bending point hydrophone designs. The results showed a 43% increase in charge output in the three bending point design versus the single bending point design despite an average strain decrease of 48% in each electrode pair. This design would lower the voltage output by 48% in a voltage-based design unless the voltages could be added in series.

2:30–2:45 Break

Contributed Papers

2:45

2pEA7. Laser-based comparison calibration of laboratory standard microphones. Randall Wagner (NIST, 100 Bureau Dr., MS 6833, Gaithersburg, MD 20899, randall.wagner@nist.gov), Richard A. Allen (NIST, Gaithersburg, MD), and Qian Dong (Dept. of Mech. Eng., Temple Univ., Philadelphia, PA)

Laboratory standard microphones, which have characteristics that are specified in international and U.S. national standards, are condenser microphones used for highly accurate sound pressure measurements and calibrations. A precision laser-based comparison calibration method for these microphones is described. This method uses laboratory standard microphones calibrated by the pressure reciprocity method as transfer standards, or reference microphones, to calibrate other laboratory standard microphones, or test microphones. Electrical drive current and microphone diaphragm velocity are measured while the microphones are driven as transmitters/sources of sound; the microphone diaphragm velocity is measured using scanning laser-Doppler vibrometry. The reference and test microphones are measured consecutively. Sensitivities determined using this method display very good agreement with those determined directly by the pressure reciprocity method for seven such test microphones at 250 Hz and 1000 Hz. At these frequencies of calibration, the expanded (coverage factor, $k = 2$) uncertainties of this comparison calibration method for these microphones are ± 0.05 dB at both frequencies. These expanded uncertainties compare favorably to those of the reciprocity-based comparison calibration service done with a large-volume acoustic coupler at the National Institute of Standards and Technology, which are ± 0.08 dB at 250 Hz and 1000 Hz.

3:00

2pEA8. Introduction to modeling and analysis of small, piezoelectrically excited bending-wave loudspeakers. David Anderson (Appl. Res. Assoc., 3415 E 29th Ave., Denver, CO 80205, danderson@ara.com)

Piezoelectric patches are used to excite panels into bending vibration, allowing the screens or cases of smartphones, tablets, laptops, and other small electronic devices to produce sound without traditional microspeakers. This paper presents an introduction to modeling and analyzing the acoustic response of such devices, assuming the use of a piezoelectric patch exciter driven with a 10 VRMS signal. Simulations are performed with respect to four design factors (piezoelectric patch size, piezoelectric patch location, panel material, and panel enclosure depth) as well as three performance metrics [low-frequency cutoff point, mean sound pressure level (SPL) above cutoff, and the standard deviation of SPL above cutoff]. Results demonstrate several key relationships, such as: larger patch sizes create higher mean SPLs, smaller enclosures create higher mean SPLs but also higher cutoff points, and larger enclosures create more deviation in the measured SPL. Additional design factors are identified and discussed which will impact practical designs.

3:15

2pEA9. Constant pressure decibel (A weighted) and decibel (C weighted) frequency response of microphones and the expanded uncertainties involved therein. Aruna Godase (Dept. of Phys., Nowrosjee Wadia College, Pune 411001, Maharashtra 411001, India, arunagodase@gmail.com) and Farhat Surve (Dept. of Phys., Nowrosjee Wadia College, Pune 411001, India)

In practice, a microphone is calibrated in a closed coupler, wherein sound pressure is distributed uniformly over the diaphragm. Nonetheless, in that case, the problem of sound reflection remains indispensable. A technique that overcomes this limitation and augments the coupler calibration method is offered. Also, the frequency response data provided by the manufacturer is always A-weighted. The A and C-weighted frequency response characteristics of a variety of microphones is studied using the testing and calibration suite in the direct field of the source which overcomes the problem of sound reflection. The frequency response in the 100 Hz to 16 kHz frequency range has been examined at constant SPL of 82 dB. The implementation and reliability of the technique is evaluated by examining the expanded uncertainties involved therein. Furthermore, the A-weighted and C-weighted constant pressure frequency response in case of each microphone is compared. A detailed description of the procedure is presented, along with assessments, wherein the reliability of the results is evaluated over Type-A and Type-B uncertainties.

3:30

2pEA10. Directional factors of radially polarized piezoceramic cylindrical transducers. Michael St. Pierre (ECE, Univ. Massachusetts Dartmouth, 151 Martine St., Ste. 123, Fall River, MA 02723, stpierremichael97@gmail.com), David A. Brown (ECE, Univ. Massachusetts Dartmouth, Fall River, MA), and Corey L. Bachand (BTech Acoust. LLC, Fall River, MA)

An experimental investigation on the directional factors of radially polarized piezoceramic cylindrical transducers as a function of aspect ratio and for different design boundary conditions (fluid-filled, air-backed, and open-closed squirter) is presented. Several prototypes were tested for their acoustic properties (impedance, transmit sensitivity, and directional factor). For the free-flooded designs, the directional factor radiation transitions from mainly axial to mainly radially (side walls) for increasing height-to-diameter. Also, a model of directional factor is presented using a coaxial array of toroids for the free-flooded transducer prototypes. [Research supported in part by ONR and the Marine and UnderSea Technology Research Program (MUST) at UMass Dartmouth.]

3:45

2pEA11. Effects of stress on properties of soft piezoelectric and single crystal elements under typical operational depth. Eric K. Aikins (Elec. and Comput., Univ. OF Massachusetts, 61 Stephanie Pl., New Bedford, MA 02745, aikinse@umich.edu), David A. Brown (ECE, Univ. Massachusetts Dartmouth, Fall River, MA), and Corey L. Bachand (BTech Acoust. LLC, Fall River, MA)

Electromechanical properties (coupling coefficient, dielectric constant, elastic compliance and piezoelectric constant) of piezoelectric ceramics are affected by exposure to compressive stress. This investigation explores the extent of changes in properties of spherical and tangentially polarized cylindrical transducers made of soft PZT-5 when exposed to pressure up to 1500 psi (equivalent to 1000 m) of water depth. Also, the pressure effect on Fully Active (FA) single crystal cylindrical transducer exposed to circumferential stress up to 380 psi (250 m depth) was investigated. In the spherical PZT-5, the planar coupling coefficient decreased by 15%, dielectric constant decreased by 40%, piezoelectric constant decreased by 35% and the elastic compliance decreased by about 10%. The single crystal transducer's effective coupling coefficient k_{32eff} increased by8%, dielectric constant by 90%, elastic compliance by 40% and the effective piezoelectric constant d_{32eff} by 75%. For the tangentially polarized cylindrical transducer, the sensitivity of dielectric constant and piezoelectric modulus to the compressive stress is shown to be less than radially polarized case. The setup of the experiment ensured the elimination of external effect due to loading on the transducers.

4:00–4:25 Discussion

Session 2pMU

Musical Acoustics and Structural Acoustics and Vibration: Acoustics of Harps and Zithers

Chris Waltham, Cochair
Department of Physics & Astronomy, U. British Columbia, Vancouver V6T 1Z1, Canada

James P. Cottingham, Cochair
Physics, Coe College, 1220 First Avenue NE, Cedar Rapids, IA 52402

Chair's Introduction—12:55

Invited Papers

1:00

2pMU1. The fretted zither and the influence of a supporting table on its initial transients—An impulse pattern formulation model. Simon Linke (Inst. of Systematic Musicology, Univ. of Hamburg, Finkenau 35, Hamburg 22081, Germany, simon.linke@haw-hamburg.de), Rolf Bader (Inst. of Systematic Musicology, Univ. of Hamburg, Hamburg, Germany), and Robert Mores (Hamburg Univ. of Appl. Sci., Hamburg, Deutschland, Germany)

Fretted zithers originate in the Alpine region and their adjacent countries. They consist of 5 fretted and 24-37 free vibrating strings stretched across a thin body. The instrument is usually played on a specific table, which is designed to amplify the sound. Thus, the table is crucial for the produced sound and must therefore be considered in respective acoustical analyses. This work explores the influence of various tables and other supporting material on the length and character of initial transients of a played zither tone. Measurements are performed while playing with differently designed tables, with a solid tabletop or with a hollow sound chamber, but while playing without a table, with the instrument placed on one's knees. As every part of the instrument is coupled to the table, the transients not only depend on the impedance of the support material but also on the plucked string itself. Thus, all components are modeled together. The method of choice is the Impulse Pattern Formulation (IPF) which assumes the zither to work with impulses traveling through the instrument body. During the transition from zither to the table, they get partly reflected, damped, and act back on the string, effectively co-defining the transient behavior.

1:15

2pMU2. Vibro-acoustics of Central Africa harps. François B. Fabre (Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, Equipe Lutheries-Acoustique-Musique, F-75005 Paris, 4 Pl. Jussieu, Paris 75252, France, francois.fabre@sorbonne-universite.fr), Jean-Loic Le Carrou (Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, Equipe Lutheries-Acoustique-Musique, F-75005 Paris, France), and Baptiste Chomette (Sorbonne Université, CNRS, Institut Jean Le Rond d'Alembert, Equipe MPIA, F-75005 Paris, France)

Central Africa harps are string instruments, often anthropomorphic, whose soundbox is built from a hollowed out tree trunk. There strings, usually 8 in number using nowadays fishing line, are wrapped to wooden tuning pegs on the neck and attached to a tailpiece placed under animal skin used as soundboard. Each instrument-making element can vary according to ethnic groups and material availability. This study aims at understanding the vibro-acoustic behavior of these instruments in order to determine relevant acoustic descriptors linked to there building process. Hence, a numerical model is developed based on the Udwadia-Kalaba modal formulation, relying on substructuring concepts. Each subsystem's dynamics is described by its modal parameters in terms of unconstrained modes and the coupling is enforced by boundary conditions. Strings displacement is described in two polarizations including geometrical nonlinear effects. Modal parameters are experimentally identified, on severa harps collected from different ethnic groups, and turn out to be discriminating descriptors. The reliability of the model is validated against laboratory measurements. Finally, sound syntheses based on the proposed approach are compared to experimental data, showing good agreement. [This work, part of the project NGombi, was funded by the Agence Nationale de la Recherche (French National research agency), Grant No. ANR-19-CE27-0013-01.]

1:30

2pMU3. String choice: Why do harpists still prefer gut? Jim Woodhouse (Dept. of Eng., Univ. of Cambridge, Trumpington St., Cambridge CB2 1PZ, United Kingdom, jw12@cam.ac.uk) and Nicolas Lynch-Aird (none, Stowmarket, United Kingdom)

There are three materials commonly used for non-metallic musical strings: nylon, fluorocarbon and natural gut. Classical guitarists have, almost universally, switched from gut to nylon or fluorocarbon, but many harpists still prefer gut. A design chart for string choice will be presented, and versions of it will be shown for the three materials. These will be used to demonstrate that harpists make a choice of gauges and tensions that contrasts dramatically with the practice of guitarists. This leads them to be interested in a different corner of the design chart, where gut indeed has an advantage over nylon in terms of the internal damping behaviour of bass strings. It will then be suggested that this advantage could be eliminated by the use of fluorocarbon strings, with appropriate gauges, in the lower register of plain strings (without over-winding).

1:45–2:10 Discussion

2:10–2:25 Break

Invited Papers

2:25

2pMU4. Effects of humidity on natural gut harp strings. Nicolas Lynch-Aird (none, The Old Forge, Burnt House Ln., Battisford, Stowmarket IP142ND, United Kingdom, lynchaird@yahoo.co.uk) and Jim Woodhouse (Eng., Univ. of Cambridge, Cambridge, United Kingdom)

Natural gut harp strings are notoriously sensitive to changes in humidity, but the nature of this sensitivity is poorly understood. The results of some recent measurements will be presented, in which a number of well-settled strings were held at constant temperature and subjected to changes in humidity. It will be shown that there appears to be some form of coupling between humidity-induced changes in the string linear density and its tension. Moreover, these changes in linear density and tension largely cancel out, with little net effect on the string frequency. It appears, instead, that the major effect of changes in humidity is to trigger episodes of additional string creep. The longevity of gut harp strings may therefore be determined as much by their propensity to creep as by their breaking strength.

2:40

2pMU5. Anomalous low frequencies in the Japanese koto. A. K. Coaldrake (Pan Pacific Technologies, 9 Church Rd., Apt. 3, Paradise, South Australia 5075, Australia, coaldrake@panpacific.com.au)

A finite element model based on a computed tomography (CT) scan of the Japanese koto, a 13-string plucked zither, was previously found to predict frequencies accurately above 100 Hz when compared to a range of physical experiments with the original instrument. Predictions for frequencies below 100 Hz were more ambiguous. Anomalous low frequency components, also known as phantom partials, have been observed in other zithers, notably the piano. The objective of this study was to assign meaning to all frequencies in general, but specifically as reported in this paper, to frequencies below 100 Hz. The results of the analysis using the CT model as an investigative tool in conjunction with the physical experiments results, identified three types of low frequencies in the sound spectra: (1) Frequencies which are air mediated frequencies and those which are wood mediated; (2) The different frequencies associated with instrument's wood grain orientation in the x-, y- and z-direction; and (3) Beating arising from the periodic interaction of two frequencies to produce a difference spectrum. These results help to expand the knowledge of the complex resonances in the koto's characteristic sound.

Contributed Papers

2:55

2pMU6. Inter-mode patterns in bundengan string vibrations. Gea O. Parikesit (Universitas Gadjah Mada, Jalan Grafika 2, Yogyakarta 55281, Indonesia, geaofp@yahoo.com)

The bundengan, a folk zither instrument from Indonesia, has a unique timbre because its strings are added with small bamboo clips. The non-homogeneous mass distributions allow the strings to imitate the sound of metal percussions in the gamelan ensemble. Moreover, the clever design of the bamboo clips allow the bundengan timbre to be controlled easily by sliding the clips along the strings. Using computer simulations, we have systematically varied both the position and the mass of the bamboo clips, resulting in a rich catalogue of vibration spectra. In these spectra, we have observed peculiar patterns in the graphs of vibration-frequency -vs- clip-position; see https://www.youtube.com/watch?v = 8kacF$_{\text{hICXs}}$ and https://www.youtube. com/watch?v = 1UdwGANtSAU for the shapes of the patterns. These patterns, which occur across different vibration modes, evolve as the mass of the bamboo clips are increased. In the extreme case where the bamboo clips are very heavy, these patterns can be explained by a modified version of the Mersenne's Law.

3:10–3:35 Discussion

Session 2pNS

Noise: Soundscape Projects: Networking, Participation, and New Technology II

Abigail Bristow, Cochair
Department of Civil and Environmental Engineering, University of Surrey, Guildford, GU2, United Kingdom

Brigitte Schulte-Fortkamp, Cochair
HEAD Genuit Foundation, Ebert Straße 30 a, Herzogenrath, 52134, Germany

Chair's Introduction—12:55

Contributed Papers

1:00

2pNS1. Exploring visualization techniques to enhance and inform soundscape analysis. Michael J. Smith (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, 24 Colovos Rd., Durham, NH 03839, msmith@ccom.unh.edu), Hilary S. Kates Varghese (Univ. of New Hampshire, Durham, NH), Xavier Lurton, Larry A. Mayer (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH), and Jennifer Miksis-Olds (Univ. of New Hampshire, Durham, NH)

Anthropogenic impact on soundscape dynamics is complex and often highly specific to the environment under investigation. As a result, rigorous qualitative and quantitative analyses are required to contextualize temporal, spatial, and spectral changes. As part of a multidisciplinary effort to study the acoustic characteristics of a deep-water multibeam echosounder and its impact on the local soundscape, continuous acoustic recordings were collected from an array of 89 seafloor mounted hydrophones off the coast of San Clemente, California during multibeam surveys in the area from January 4–8, 2017 and January 3–6, 2019. These datasets were used to calculate soundscape metrics including sound pressure level, sound exposure level, and decidecade band levels covering [50 Hz–48 kHz]. The remarkable density and resolution of these multi-receiver datasets posed significant and specific processing and display challenges with respect to understanding the micro- and macro-changes within the soundscape. This work presents several visualization approaches designed to exploit strong human visual perceptions skills to better understand changes in soundscape metrics, and to help quickly identify spatial/temporal periods for further quantitative analysis. Visualizations tracking the evolution of soundscape metrics through time, space, and frequency are presented here, illustrating their utility towards soundscape analysis.

1:15

2pNS2. Empirical probability density of sound levels to understand the contribution of mapping sonar to a soundscape. Hilary S. Kates Varghese (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, 24 Colovos Rd., Durham, NH 03824, hkatesvarghese@ccom.unh.edu), Michael J. Smith (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH), Jennifer Miksis-Olds (Ctr. for Acoust. Res. and Education, Univ. of New Hampshire, Durham, NH), Xavier Lurton, and Larry A. Mayer (Ctr. for Coastal and Ocean Mapping, Univ. of New Hampshire, Durham, NH)

Soundscapes—or the characterization of the temporal, spatial, and frequency attributes of the ambient sound and its sound sources—are commonly used to assess the impact of anthropogenic noise-generating events. Large-scale, cabled hydrophone arrays offer a unique opportunity for high-resolution temporal and spatial sampling, providing a comprehensive empirical understanding of the contribution of anthropogenic noise to a soundscape. The Southern California Antisubmarine Warfare Range hydrophone array, which spans 2000 km^2 and contains 89 bottom-mounted 50 Hz–48 kHz receivers, was used to characterize the marine soundscape during a mapping survey utilizing a hull-mounted 12 kHz multibeam echosounder (MBES). The acoustic data from the array were continuously recorded throughout the approximately two-day survey in January 2017 and used to calculate unweighted decidecade sound levels using standard temporal window lengths and weighted levels with non-standard window lengths motivated by their applicability to marine mammal hearing. The time-dependent contribution of the MBES survey to the unweighted and marine mammal-weighted soundscape was assessed by calculating the probability density of the decidecade sound levels and comparing them spatially for four analysis periods. The analysis periods were: (1) no mapping activity; (2) vessel-only; (3) vessel and MBES; and (4) vessel, MBES, and other active acoustic sources.

1:30

2pNS3. Quantifying ship noise in the marine soundscape of the western Canadian Arctic. William D. Halliday (Wildlife Conservation Society Canada, Wildlife Conservation Society, 169 Titanium Way, Whitehorse, YT Y1A 0E9, Canada, whalliday@wcs.org) and Stephen Insley (Wildlife Conservation Society Canada, Whitehorse, YT, Canada)

The Arctic soundscape is naturally quite complex, but many parts of the Arctic have also historically had very low levels of ship noise. However, ship traffic is increasing throughout the Arctic, which is likely leading to increased levels of underwater noise, causing changes in this soundscape. In this study, we thoroughly quantified ship noise in passive acoustic data collected at 10 sites in the western Canadian Arctic between 2014 and 2020, with data collected from between one and three years at each site. We paired the acoustic data with automatic identification system ship data to collect information on the individual ships creating noise. We quantified the presence of ship noise within all of the acoustic data, statistically examined the influence of different static and dynamic ship variables on sound levels, and estimated source levels of ships that traveled close to the acoustic recorder. These analyses represent the first detailed examination of ship noise in this region of the Arctic, and the results provide valuable information for future soundscape studies, as well as relevant information for the management of ship noise in the Arctic.

1:45

2pNS4. The soundscape of quarantine. Braxton Boren (Performing Arts, American Univ., 4400 Massachusetts Ave. NW, Washington, DC 20016, boren@american.edu)

Given the drastic effect of ongoing lockdowns during the COVID-19 pandemic of 2020–2021, many researchers in different fields found themselves learning the basics of epidemiology and public health. However, in the midst of such a crisis, it is incumbent for content experts to apply their own expertise to the problem at hand, no matter how marginal their contribution may be. It is argued that at the broadest level, acousticians may contribute to the mental and physical health of those undergoing pandemic lockdowns via soundscape analysis. Given the widespread lockdown fatigue of staying largely indoors for nearly a year, even small improvements in quality of life under lockdown may be help the wider crisis by helping people follow public health recommendations longer than they otherwise would. The first part of this analysis focuses on noise prevention, especially in multi-unit housing where sound transmission between units can exacerbate social ties. Second, this talk examines the role of acoustic simulation, spatial audio, and VR to open up larger worlds to those under prolonged confinement.

2:00–2:25 Discussion

WEDNESDAY AFTERNOON, 9 JUNE 2021 — 12:55 P.M. TO 4:30 P.M.

Session 2pPA

Physical Acoustics, Structural Acoustics and Vibration, Noise, and Computational Acoustics: Sonic Boom: Modeling, Measurement, Annoyance and Standards Development II

Joel B. Lonzaga, Cochair
Structural Acoustics Branch, National Aeronautics and Space Administration, 2 N. Dryden St. (MS 463), Hampton, VA 23681

Alexandra Loubeau, Cochair
NASA Langley Research Center, MS 463, Hampton, VA 23681

Chair's Introduction—12:55

Invited Papers

1:00

2pPA1. Building vibration due to sonic boom—Results from simulations and field measurements. Finn Løvholt (Geodynamics and Geohazards, Norwegian Geotechnical Inst., Sognsveien 72, Oslo 0806, Norway, finn.lovholt@ngi.no), Karin Noren-Cosgriff, Joonsang Park, and Jörgen Johansson (Geodynamics and Geohazards, Norwegian Geotechnical Inst., Oslo, Norway)

Sonic boom causing rattling and whole-body vibration in buildings can lead to human disturbance and annoyance. An overview of research on sonic boom vibration in the EU RUMBLE project is presented here. Numerical simulations are carried out for sets of buildings encompassing a variety of European building styles, and for different transmission situations such as with and without open windows. We calibrate the simulations with previous laboratory data and recorded sound and vibration data from field experiments in Tretyakov (Russia). We then use the simulation to understand how sensitive the vibrations are to various buildings and conditions. Moreover, correlations of sonic boom metrics to the measured and simulated vibrations are quantified. Two different types of vibration generation mechanisms are detected and analysed: The first one is floor vibrations being set up from the indoor sound transmitted from outdoor. The second is the horizontal motion of the whole building being set up by the outdoor sound at the lower overall resonance frequency of the building. It is found that both types of generation mechanisms can be important for sonic boom, and that they take place for different frequencies.

1:15

2pPA2. Relationships between ratings and calculated loudness values for sonic booms at low levels. Stephan Töpken (Acoust. Group, Dept. of Medical Phys. and Acoust., Cluster of Excellence Hearing4all, Oldenburg Univ., Germany, Carl-von-Ossietzky-Str. 9-11, Oldenburg 26129, Germany, stephan.toepken@uol.de) and Steven van de Par (Acoust. Group, Dept. of Medical Phys. and Acoust., Cluster of Excellence Hearing4all, Oldenburg Univ., Germany, Oldenburg, Germany)

Due to progress in aircraft design, the sonic boom produced by supersonic aircraft may be reduced considerably in the future and the subjective response of humans to future low sonic boom signatures is currently under investigation. In the frame of the RUMBLE project, loudness and short-term ratings of different recordings and simulations of classical booms and potential future boom sounds were collected. The time signals of the signatures were differing in shape but were confined in maximum overpressure and the A-weighted sound exposure level (ASEL) to the range foreseen for future low boom aircraft. Besides a high correlation with the ASEL, the short-term annoyance ratings were also highly correlated to the loudness ratings, suggesting that loudness was the underlying factor for short-term annoyance in the laboratory experiments. Therefore, loudness values were calculated with loudness models from the current ISO 532-1 and 532-2 standard in an attempt to predict the annoyance ratings. The correlation coefficients between short-term annoyance ratings and loudness model values are similar to those between ratings and level based measures (*e.g.*, weighted SELs). For the loudness model according to the ISO 532-1 standard, the correlation coefficient is even slightly higher that than for ASEL.

1:30

2pPA3. Impact of low sonic boom exposure on psychophysical and cognitive performance. Frédéric Marmel (Institut Jean Le Rond d'Alembert, Sorbonne Université & CNRS, Sorbonne Université - Institut Jean Le Rond d'Alembert, 4 Pl. Jussieu, Paris 75005, France, frederic.marmel@gmail.com), Léo Cretagne, Linh-Thao Thuong, Francois Coulouvrat (I), and Claudia Fritz (Institut Jean Le Rond d'Alembert, Sorbonne Université & CNRS, Paris, France)

The RUMBLE project aimed to quantify the effects of low sonic boom exposure on human responses, in situations representative of the daily life of European citizens, so as to inform policy, establish standards and develop protection concepts for a new generation of supersonic commercial aircraft that should emit a reduced but perceivable boom (a "low boom") while flying overland. Two low boom simulators were affixed to the bedrooms' windows of a house located on our university campus. The simulators allowed us to study indoor the participants' responses to realistic "outdoor" booms. Testing took place in both the living room and kitchen because the booms caused different intensities of rattle noise in those two rooms. Participants performed a communication task, a working memory task, a drawing task, and an automatic evaluation task. They also had three mandatory rests. We used questionnaires to assess the booms' perception and annoyance as well as their influence on participants' mood. The booms were rated unpleasant, especially with rattle, and more disturbing during the rests than during the tasks. The booms made the rests less relaxing and impaired short-term cognitive performance. [This research was conducted as a part of Rumble—EU Grant Agreement 769896.]

1:45

2pPA4. Concept for a study on community responses to low sonic boom in Europe. Dirk Schreckenberg (ZEUS GmbH, Sennbrink 46, Hagen, NRW 58093, Germany, schreckenberg@zeusgmbh.de), Stephan Grossarth (ZEUS GmbH, Hagen, Germany), Luis Meliveo, and Nico van Oosten (ANOTEC Eng., Motril, Spain)

In 2018, NASA was the first to assess noise annoyance by low-sonic booms among a population not used to hearing any of the acoustical phenomena associated with an aircraft flying at supersonic speeds (QSF18 study). Meanwhile, within the EU-project RUMBLE, data are collected, and literature reviewed used for research on community responses to low sonic boom demonstrator overflights. We present recommendations for such a field study, comprising NASA and RUMBLE studies' findings and other European efforts emphasizing items discussed by NASA and European researchers in the aftermaths of the first QSF18 results. We propose a study design for the CRLSB study in different European climate zones. A low-fidelity simulation model has been developed to pre-select test sites, supplemented by a more detailed impact model (NENA) for final site selection and preparation of the survey. We identified an approach of mixed survey modes, including experience-sampling procedures, as the most desirable modus operandi for community response assessment. Further, we propose a method for calculating desired sample sizes when applying linear mixed-effects modeling to data collected from a continental field study. [This project has received funding from the European Union's Horizon 2020 research and innovation program under Grant Agreement No. 769896.]

2:00

2pPA5. The effect of dose uncertainty on community noise dose-response outcomes. Richard D. Horonjeff (RDH Acoust., 48 Blueberry Ln., Peterborough, NH 03458, rhoronjeff@comcast.net)

Recent simulations have been performed to determine the effects of dose uncertainty (estimated participant sound levels) on community noise dose-response outcomes. This paper presents a number simulations that illustrate how dose estimation uncertainty, dose range and the frequency distribution of doses across that range combine to modify an underlying true dose-response relationship. It further shows how each combination creates a unique distortion to the underlying curve in the observed results. The complexity of compensating for these uncertainties is discussed, and the paper recommends the formation of standardized data collection practices to enable compensation for them in the analysis.

2:15–2:30 Break

2:30

2pPA6. X-59 sonic boom demonstration performance. John Morgenstern (Aeronautics, Lockheed Martin, 1011 Lockheed Way, B601, Mail 0138, Palmdale, CA 93599, john.morgenstern@lmco.com)

Lockheed Martin Aeronautics is building the X-59 Low Boom Flight Demonstrator (LBFD) for NASA's quiet boom testing program. To determine the acceptability of quiet booms on (predominantly indoor) observers, the X-59 vehicle to designed to produce shaped booms representative of transports employing this technology. During a flight, the vehicle is designed for two steady, level passes between Mach 1.4 to 1.5, covering 50 nm in length and 30 + nm (std. day) in boom carpet width. Boom loudness from 75 to 90 PLdB can be selected for each pass by variations in Altitude, Mach or trimmed control deflections. Quieter boom from 70 to 75 PLdB can be produced in a gentle turn up to 8° degrees in bank angle. Phase 1 of the LBFD program covers design, fabrication, ground test and flight safety demonstration. The first wind tunnel boom test of a 19 in. X-59 model is planned for later this year. Beginning 2023, Phase 2 plans to validate the X-59 boom loudness with in-flight and ground measurements. Phase 3 plans to demonstrate varied quiet boom exposures at several sites in the USA.

2:45

2pPA7. Simulated X-59 on- and off-design sonic boom levels in realistic atmospheres for noise dose range estimation. William Doebler (NASA Langley Res. Ctr., NASA Langley Res. Ctr., M.S. 463, Hampton, VA 23681, william.j.doebler@nasa.gov), Alexandra Loubeau (NASA Langley Res. Ctr., Hampton, VA), and Joel B. Lonzaga (Structural Acoust. Branch, National Aeronautics and Space Administration, Hampton, VA)

NASA is planning several community noise surveys across the USA using the X-59 low-boom aircraft. These surveys require a range of noise levels to resolve a dose-response relationship. The X-59 was designed to produce a shaped sonic boom with a Stevens' Perceived Level (PL) of 75 dB or less across the boom carpet in a standard atmosphere. However, the X-59's flight condition can be adjusted to produce levels other than 75 PLdB to obtain a range of doses during community testing. Simulated nearfield pressure waveforms of the X-59 C612A in its on-design condition (Mach 1.4 at 53 200 ft) and an off-design condition at a lower altitude (Mach 1.4 at 46 000 ft) were propagated using PCBoom through realistic atmospheres over the span of one year at several locations across the country. The predicted on-design and off-design boom levels and carpet widths are presented, resulting in a preliminary estimate of the dose range that the X-59 may produce. Future work is planned with additional off-design conditions to assess the true capable dose range of the X-59.

3:00

2pPA8. Developing certification procedures for quiet supersonic aircraft using shaped sonic boom predictions through atmospheric turbulence. Alexandra Loubeau (NASA Langley Res. Ctr., M.S. 463, Hampton, VA 23681, a.loubeau@nasa.gov), William Doebler, Sara R. Wilson, Kathryn Ballard, Peter G. Coen (NASA Langley Res. Ctr., Hampton, VA), Yusuke Naka (Japan Aerosp. Exploration Agency, Tokyo, Japan), Victor W. Sparrow (Penn State, University Park, PA), Joshua Kapcsos (Penn State, University Park, PA), Juliet A. Page, Robert S. Downs (Volpe National Transportation Systems Ctr., Cambridge, MA), Stéphane Lemaire (Dassault Aviation, Saint-Cloud, France), and Sandy R. Liu (Federal Aviation Administration, Washington, DC)

New sonic boom noise certification procedures for quiet supersonic aircraft are in development under the International Civil Aviation Organization for a proposed standard that could enable supersonic overland flight. Although these low-boom aircraft do not exist yet, the procedures can be developed and evaluated using existing empirical and simulation datasets. While prior analyses used N-wave datasets to exercise various proposed procedures, these evaluations were limited because the effects of atmospheric turbulence on N-waves do not necessarily generalize to shaped sonic booms. The analysis is therefore extended to include shaped sonic boom predictions through several atmospheric turbulence conditions, such as different atmospheric boundary layer heights, using three different numerical methods. Six noise metrics (PL, ASEL, BSEL, DSEL, ESEL, and ISBAP) are calculated for the ground waveform predictions and compared to metrics for predictions performed under quiescent standard day conditions. Methods for validating prediction tools or correcting for the atmospheric effects are discussed, and ideas for robust methods for implementation in certification procedures are proposed.

3:15

2pPA9. An overview of participation in NASA's CarpetDIEM campaign. Kent L. Gee (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT), J T. Durrant (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT, taggart.durrant@gmail.com), Mark C. Anderson, Logan T. Mathews, Reese D. Rasband, Daniel J. Novakovich (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT), Alexandra Loubeau (NASA Langley Res. Ctr., Hampton, VA), and William Doebler (NASA Langley Res. Ctr., Hampton, VA)

This talk summarizes Brigham Young University's (BYU) participation in NASA's 2019 sonic boom data collection campaign in California, USA. Dubbed "Carpet Determination In Entirety Measurement" (CarpetDIEM) Phase I, the program was designed to measure conventional cruise booms across a widespread time-synchronous array, at the site where initial acoustical testing of the X-59 low-boom supersonic aircraft is planned. BYU deployed a total of 11 portable data acquisition systems across 10 nautical miles and tested a variety of microphone and data acquisition configurations. This talk describes both technical and logistical lessons learned at Carpet-DIEM Phase I that can help with future X-59 test design including acquisition hardware comparison and evidence of turbulence. [Work supported by NASA Langley Research Center through the National Institute of Aerospace.]

3:30

2pPA10. Investigation of sonic boom waveforms and metrics at elevated receiver locations. Robert S. Downs (US DOT/Volpe Ctr., Cambridge, MA, Robert.Downs@dot.gov), Sophie Kaye, and Juliet A. Page (US DOT/Volpe Ctr., Cambridge, MA)

Microphones used for aircraft noise measurements are sometimes positioned above local ground level, for example to accommodate environmental protection or to comply with certification regulations. Acoustic waves reflected from the ground can interfere with waves propagating directly to elevated receivers. A modeling study was conducted of sonic boom waveforms received at ground level versus at elevated positions, using source characteristics for an early X-59 low-boom aircraft configuration (C609) and a variety of atmospheric conditions. Ground impedance effects from different ground cover types were also considered. Among several acoustic metrics, it was found that perceived level of loudness (PL) and A-weighted sound exposure level were in general the most sensitive to differences due to receiver position. Location within the boom carpet also affected receiver levels based on the angle between the incoming ray and the ground: the difference between metrics at ground and elevated receivers was generally higher at undertrack locations where that angle was largest. Depending on atmospheric conditions and receiver location within the carpet, predicted PL at an elevated receiver was lower than the level at the ground by up to 5.0 dB for a receiver height of 4 ft and 2.2 dB lower for a 1.6-ft receiver.

3:45

2pPA11. Effects of bandwidth limitations on low-boom perceived level. Mark C. Anderson (Dept. of Phys. and Astronomy, Brigham Young Univ., D-70 ASB, Provo, UT 84602, anderson.mark.az@gmail.com), Kent L. Gee, J T. Durrant, Daniel J. Novakovich (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT), and Alexandra Loubeau (NASA Langley Res. Ctr., Hampton, VA)

Estimating sonic boom noise levels during community noise testing of low-boom supersonic aircraft such as the NASA X-59 can be challenging because of bandwidth limitations caused by ambient noise contamination of boom recordings. This paper describes the effect of spectral bandwidth limitations on a candidate sonic boom metric for community response: the perceived level (PLdB). This metric was calculated using spectral data of measured sonic booms from NASA's Quiet Supersonic Flights 2018 (QSF18) test campaign. Spectral data were obtained using a 650 ms time window for both the boom and the ambient recordings, with the ambient recording immediately preceding the detected boom, and the measurement bandwidth estimated using the signal-to-noise ratio (SNR) at each frequency. Analysis of several booms at four different measurement stations, each with several measurement configurations, shows that not accounting for limited bandwidth can add several decibels to the sonic boom metrics. The effects of measurement location and instrumentation are discussed. Future work may include developing methods for how to account for limited bandwidth, including potential filtering and spectral extrapolation methods. [Work supported by NASA Langley Research Center through the National Institute of Aerospace.]

4:00

2pPA12. Prediction of loudness metrics at very high sampling frequencies using digital filters. Sriram K. Rallabhandi (NASA Langley Res. Ctr., NASA Langley Res. Ctr., MS 442, Hampton, VA 23681, Sriram.Rallabhandi@nasa.gov)

Numerical solution of the augmented Burgers equation is generally the widely used process to predict sonic boom signatures on the ground starting from disturbances generated by an aircraft flying at supersonic speeds. Once the ground waveforms are predicted, loudness metrics are calculated as a means to quantify the impact associated with the underlying sonic booms. This work uses sBOOM, an augmented Burgers equation solver. Within sBOOM, loudness metrics are determined using time-domain digital filters rather than relying on Fast-Fourier Transforms (FFT) and their inverse counterparts to transform back and forth from the frequency-domain. For propagating signals from aircraft concepts that produce extremely low loudness levels, large sampling frequencies may be needed to achieve loudness metric convergence. This work discusses digital filters used within sBOOM, how their accuracy deteriorates at large sampling frequencies, and the enhancements to the digital filter implementation. Additionally, this work will also discuss loudness metric gradients (helpful in aircraft design exercises) obtained using the digital filtering enhancements. Finally, results with and without these modifications, both in terms of loudness metrics and their gradients, will be discussed and presented for cases which may include shaped low-boom as well as strong shock signatures.

4:15–4:30 Discussion

Session 2pPP

Psychological and Physiological Acoustics: Linking Psychological and Physiological Acoustics II

Frederick J. Gallun, Cochair
Oregon Hearing Research Center, Oregon Health and Science University, 3181 Sam Jackson Park Road, Portland, OR 97239

Virginia Best, Cochair
Speech, Language and Hearing Sciences, Boston University, 635 Commonwealth Ave., Boston, MA 02215

Chair's Introduction—12:55

Contributed Papers

1:00

2pPP1. Comparing the differences in robustness between interaural time delay calculation methods. Matthew Neal (Otolaryngol. and Comm. Disord., Univ. of Louisville and Heuser Hearing Inst., 117 E Kentucky St., Louisville, KY 40203, matthew.neal.2@louisville.edu) and Pavel Zahorik (Otolaryngol. and Comm. Disord., Univ. of Louisville and Heuser Hearing Inst., Louisville, KY)

The interaural time delay (ITD) is a primary cue to lateral sound source direction and can be calculated from a head-related impulse response (HRIR). Although many ITD calculation techniques utilize cross-correlation, recent work suggests that for horizontal plane HRIRs, ITD calculation based on HRIR onset threshold may better match human perception of source location. The goal of the current study is to more comprehensively compare ITD calculation methods across a large sample of HRIRs. 2448 ITD calculation methods were compared using 42 240 HRIRs from the HUTUBS database (440 directions from 96 individuals). Within each method and individual, the calculated ITD function was compared to a spatially smoothed ITD function using a 10th-order spherical harmonic truncation. When large deviations from the smoothed version occurred (>250 μs), the method was tagged as being non-robust to calculation artifacts. Although the robustness of the onset threshold technique was found to be highly dependent upon threshold level and low-pass filter parameters, proper selection of these parameters resulted in little to no calculation artifacts and superior performance to other calculation methods. Improvements in the robustness of ITD calculation may help to optimize virtual auditory displays or HRIR personalization procedures using the minimum-phase plus ITD model.

1:15

2pPP2. Modeling sound-source localization of two sinusoidally amplitude-modulated noises in a sound field. M. Torben Pastore (College of Health Solutions, Arizona State Univ., P.O. Box 870102, ASU, Tempe, AZ 852870102, m.torben.pastore@gmail.com), Yi Zhou (College of Health Solutions, Arizona State Univ., Tempe, AZ), and William A. Yost (College of Health Solutions, ASU, Tempe, AZ)

Yost and Brown [*JASA* **133** (2013)] investigated the ability of listeners to localize two simultaneously presented, independent noises presented over loudspeakers from different locations. These experiments demonstrated that SAM noises that were out of phase at two spatially separated loudspeakers led to better localization performance than when the SAM noises were in phase at each loudspeaker. Performance was improved at SAM rates as high as almost 500 Hz as compared to non-SAM noise. Yost and Brown hypothesized that listeners' behavior might be explained as a temporal-spectral (T-S) analysis, and showed that such an approach could, qualitatively, account for some of their behavioral data. This presentation will explore the degree to which a quantitative, biologically inspired peripheral/brainstem auditory model can predict some of the listener performance presented in Yost and Brown 2013. Specifically, the model structure includes simulated auditory nerve response using the Zilany *et al.* model (*JASA*, 2014) with rate-count-based estimation of interaural differences of time and intensity as they occur in the presented stimuli recorded with a KEMAR manikin.

1:30

2pPP3. A framework for the analysis and optimization of adaptive psychophysical procedures. Eric C. Hoover (Dept. of Hearing and Speech Sci., Univ. of Maryland, 0100 LeFrak Hall, 7251 Preinkert Dr., College Park, MD 20742, ehoover@umd.edu)

Remote testing platforms have proven to be a viable tool for hearing research, but the ability to obtain efficient and reliable data remains a significant barrier. Adaptive up-down procedures are widely used to estimate hearing abilities because they can be performed easily with minimal assumptions about underlying mechanisms. However, they are inefficient compared to parametric alternatives, and the optimization of starting level, step size, stopping rule, and other factors continues to rely on trial and error. This reflects the limitations of our theoretical understanding, which cannot explain the complex, multi-component error patterns observed in thresholds obtained in controlled simulations. The present study reports on the development of a mathematical framework for nonparametric psychophysical procedures. A method will be described for creating models of the combined listener-procedure system as an equivalence class of directed graphs. The model can be used to calculate the trial-by-trial and asymptotic stimulus distributions for ascending and descending trials, the rate of convergence, and other fundamental properties. Using this approach, stimulus selection, stopping, and threshold calculation can be optimized with typical minimization procedures. Insights about the mathematical structure of psychophysical procedures promise to drive the development of novel tools to address the needs of remote test administration.

1:45

2pPP4. Dynamically varying timbre cues interfere with listeners' pitch perception. Ryan Anderson (Speech and Hearing Sci., Indiana Univ., 2631 East Discovery Parkway, Bloomington, IN 47408, anderyan@iu.edu), Yi Shen (Speech and Hearing Sci., Univ. of Washington, Seattle, WA), and William P. Shofner (Speech and Hearing Sci., Indiana Univ., Bloomington, IN)

One timbre cue that has been studied psychophysically is the spectral centroid of a steady-state harmonic complex, which corresponds to the "brightness" of the complex. Complexes having higher spectral centroids tend to be perceived as having higher pitches even with a constant fundamental frequency (F0). To further understand pitch-timbre interactions, the current study investigates whether dynamically varying spectral centroids of harmonic complexes affect the pitches. Normal-hearing listeners ranked the pitch of two harmonic complexes on each trial. In some trials the spectral centroid of one complex swept from low to high frequencies across its duration while the centroid of the other complex varied from high to low. Other trials had centroids moving from high to low then low to high across the interval. F0s of the two complexes differed by one just noticeable difference. Results show that a more recent rising spectral centroid tends to bias listeners to generate "higher pitch" responses, while a more recent declining spectral centroid tends to bias listeners to generate "lower pitch" responses, even when the rising and declining stimuli had identical long-term spectra. The results suggest that the spectral centroids at various temporal position of a harmonic complex do not influence pitch perception equally.

2:00

2pPP5. Forward masking of spectrotemporal modulation suggests modulation-frequency-selective channels. Christopher Conroy (Speech, Lang., & Hearing Sci. and Hearing Res. Ctr., Boston Univ., 635 Commonwealth Ave., Boston, MA 02215, cwconroy@bu.edu), Andrew J. Byrne, and Gerald Kidd (Speech, Lang., & Hearing Sci. and Hearing Res. Ctr., Boston Univ., Boston, MA)

Physiological data from several species suggest that the auditory system detects complex patterns of spectrotemporal modulation via spectrotemporal modulation-frequency-selective channels, a subset of which may be directionally selective (*i.e.*, prefer upward sweeping versus downward sweeping modulation). Psychophysical data suggesting the same, however, are scarce. In this study, we sought evidence of such channels using a psychophysical forward masking paradigm. The detectability of target spectrotemporal modulation (i–25-Hz/0.5-cyc/oct) applied to the final 55-ms of a 590-ms broadband-noise-like carrier was measured following exposure to masker spectrotemporal modulation applied to the initial 505-ms of the same carrier. Four maskers were tested: one with the same spectral modulation frequency as the target but a flat temporal envelope (0-Hz/0.5-cyc/oct), another with the same temporal modulation frequency as the target but a flat spectral envelope (–25-Hz/0-cyc/oct), and two with the same spectral and temporal modulation frequencies as the target and either the same (–25-Hz/0.5-cyc/oct) or opposite (+25-Hz/0.5-cyc/oct) sweep direction. Forward masking was greatest for the masker fully matched to the target, intermediate for the masker with the opposite sweep direction, and negligible for the other two. Taken together, these findings suggest that detection of the target may have involved a spectrotemporal modulation-frequency-selective channel with directional selectivity.

2:15

2pPP6. Effect of listeners versus experimental factors in multi-talker speech segregation. Robert A. Lutfi (Univ. of South Florida, Tampa, 4202 E. Fowler Ave., Tampa, FL 33620, rlutfi@usf.edu), Briana Rodriguez, and Jungmee Lee (Univ. of South Florida, Tampa, Tampa, FL)

Over six decades ago, Cherry (1953) drew attention to what he called the "cocktail-party problem"; the challenge of segregating the speech of one talker from others speaking at the same time. The problem has been actively researched ever since but, for all this time, one observation has alluded explanation. It is the wide variation in performance of individual listeners. That variation was replicated here for four major experimental factors known to impact performance: differences in task (talker segregation versus identification), differences in the voice features of talkers (pitch versus location), differences in the voice similarity and uncertainty of talkers and the presence or absence of linguistic cues. The effect of these factors on the segregation of naturally spoken sentences and synthesized vowels was largely eliminated in psychometric functions relating the performance of individual listeners to that of an ideal observer, d'_{ideal}. The effect of listeners remained as differences in the slopes of the functions (fixed effect) with little within-listener variability in the estimates of slope (random effect). The results make a case for considering the listener a factor in multi-talker segregation equal in status to any major experimental variable. [Work supported by NIDCD R01 DC001262-27.]

2:30–2:45 Discussion

2:45–3:00 Break

Contributed Papers

3:00

2pPP7. Testing the relationship between musical training and context effects in music perception. Anya E. Shorey (Psychol. and Brain Sci., Univ. of Louisville, 317 Life Sci. Bldg., Louisville, KY 40292, anya.shorey@louisville.edu), Kelly L. Whiteford (Psych., Univ. of Minnesota, Minneapolis, MN), and Christian E. Stilp (Psychol. and Brain Sci., Univ. of Louisville, Louisville, KY)

Contrast effects occur in all sensory modalities and are critical for auditory perception. When successive sounds differ in their spectra, the auditory system exaggerates this difference, and we perceive a larger change than is physically present. This is known as a spectral contrast effect (SCE). For example, when a context sound is filtered to emphasize the frequencies of the French horn (a predominantly low-frequency spectrum), listeners categorize a later target sound as tenor saxophone (comparatively higher-frequency spectrum) more often [Stilp *et al.*, *Atten. Percept. Psychophys.* **72**(2), 470–480 (2010)]. Musicians outperform non-musicians on many auditory tasks, including pitch discrimination, but whether this 'musician advantage' extends to SCEs in music perception is unknown. Here, on each trial, non-musicians and musicians heard a context sound (string quintet filtered to emphasize the frequencies of the horn or saxophone) before categorizing the target sound (six-step series that varied from horn to saxophone). Musicians are predicted to have larger SCE magnitudes than non-musicians due to their enhanced auditory skills. However, if musicians do not show larger SCEs, this suggests musical training might improve only some aspects of music perception. Results from this task, a pitch discrimination task, and musical experience questionnaires will be discussed.

3:15

2pPP8. Relationship between psychological and physiological measurements of auditory sensitivity in adolescents with attention-deficit/hyperactivity disorder. Alexandra Moore (Ctr. for Pediatric Auditory and Speech Sci., Nemours/Alfred I. duPont Hospital for Children, 1701 Rockland Rd., Wilmington, DE 19803, alexandra.moore@nemours.org), Shelby Sydenstricker, and Kyoko Nagao (Ctr. for Pediatric Auditory and Speech Sci., Nemours/Alfred I. duPont Hospital for Children, Wilmington, DE)

Abnormal auditory sensitivity is common in patients with ADHD, however, auditory sensitivity issues have not been well-studied in ADHD. This study investigated auditory sensitivity in ADHD using psychological and

physiological measures. A group of 13 adolescents aged 13 to 19 with a current ADHD diagnosis (ADHD group) and a group of 24 adolescents with normal development (control group) participated in this study. Acoustic reflex thresholds (ART) were obtained using pure-tone stimuli (500 Hz and 1 kHz) and wideband noise. Each stimuli was presented to each ear from 56 dB to 104 dB in a 2-dB step. Loudness discomfort levels (LDL) were also obtained using two stimuli (500 Hz and wideband noise) in each ear. ART and LDL were collected without daily stimulant medication in the ADHD group. Questions related to auditory sensitivity were obtained using the *Adolescent/Adult Sensory Profile*. Preliminary results indicated no significant correlation between ARTs and LDLs and between ARTs and sensory profile scores in both groups. We found a weak correlation between ARTs and some sensory profile scores in the ADHD group. The results suggested a mismatch between ARTs and behavioral measures on auditory sensitivity. [Work supported by the ACCEL grant (NIH U54GM104941), the State of Delaware, and Nemours Foundation.]

3:30

2pPP9. A summary of behavioral measures of cochlear gain and gain reduction in listeners with normal hearing or minimal cochlear hearing loss. Elizabeth A. Strickland (SLHS, Purdue Univ., 715 Clinic Dr., West Lafayette, IN 47907, estrick@purdue.edu), Miranda Skaggs, Anna Hopkins, Nicole Mielnicki, William B. Salloom, Hayley Morris, and Alexis Holt (SLHS, Purdue Univ., West Lafayette, IN)

This study examined the relationship between cochlear hearing loss and psychoacoustic measures related to cochlear function. Listeners' audiometric thresholds for long tones ranged from well within the clinically normal range to just above this range. Where thresholds were elevated, other clinical tests were consistent with a cochlear origin. Because the medial olivocochlear reflex decreases cochlear gain in response to sound, measures were made with short stimuli. Signal frequencies were from 1 to 8 kHz. One point on the lower leg of the input/output function was measured by finding threshold masker level for a masker almost one octave below the signal frequency needed to mask a signal at 5 dB SL. Gain reduction was estimated by presenting a pink broadband noise precursor before the signal and masker and measuring the change in signal threshold as a function of precursor level. Previous studies with listeners with normal hearing have shown that gain reduction begins at a low precursor level and grows compressively as the precursor level is increased. In the present study, the estimate of gain reduction decreased as quiet threshold increased, but was not solely determined by the amount of gain. [Work supported by NIH(NIDCD)R01 DC008327 (EAS) and NIH(NIDCD) T32 DC016853 (WBS).]

3:45

2pPP10. Effect of rhythm-based prediction on medial olivocochlear reflex and delta oscillations. Yuki Ishizaka (Ctr. for Frontier Medical Eng., Chiba Univ., #721, Sci. & Technol. Bldg., 1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan, ishizaka.y@chiba-u.jp), Sho Otsuka, and Seiji Nakagawa (Ctr. for Frontier Medical Eng., Chiba Univ., Chiba, Japan)

The medial olivocochlear reflex (MOCR) is an efferent feedback activated by acoustic stimulation. Our previous studies showed that a preceding sound expedites MOCR, which suggests that temporal expectation about the timing of stimulus occurrence can modulate MOCR. In contrast, the temporal structure, *e.g.*, regularity and rhythm, of preceding sequences also contains cues for temporal expectation about the timing of upcoming sounds. Here we investigate whether the regularities of preceding sound sequences can modulate MOCR. Simultaneously, we measured electroencephalography (EEG) delta-band oscillations whose phase-locking was reported to play a role in mediating the effects of anticipation on target detection. The predictability of target occurrence was modulated by adding jitter to the inter-stimulus interval (ISI) of the preceding sound sequence. Both the strength of MOCR and the phase synchronization of EEG delta oscillations decreased with increasing the jitter up to 20% of the ISI and are saturated above that percentage. The similar dependence on the amount of the jitter suggest the involvement of delta oscillations in the predictive control of MOCR based on the regularity of preceding sound sequences.

4:00

2pPP11. Enhancing the temporal fine structure with the temporal limits encoder for cochlear implants: Effects on pitch ranking. Huali Zhou (Acoust. Lab., School of Phys. and Optoelectronics, South China Univ. of Technol., Rm. 301, Bldg. 18, No.381, Wushan Rd., Tianhe District, Guangzhou 510641, China, mshualizhou@mail.scut.edu.cn), Guangzheng Yu, and Qinglin Meng (Acoust. Lab., School of Phys. and Optoelectronics, South China Univ. of Technol., Guangzhou, China)

Pitch perception remains a challenge for cochlear-implant (CI) users. Temporal periodicity, as the main cue for pitch, could not be finely encoded by current CI strategies that transmit envelopes only and discard the temporal fine structure (TFS). Moreover, temporal electric pitch percept saturates at a few hundred hertz, which is controversial and has been studied using various psychophysical and physiological methods. The temporal-limits-encoder (TLE) was proposed to enhance TFS representation by frequency-downshifting the high-frequency band-limited signals to a low-frequency temporal-pitch-limits range of CIs. In this work, eleven Nucleus CI subjects were recruited in a pitch ranking task using a CCiMobile processor. The original stimuli were five-harmonics complex tones. Fundamental-frequency difference limens (F0DLs) at two reference F0s 250 and 313 Hz (*i.e.*, center and upper cross-over frequencies of the most apical electrode) were tested using three TLE versions with different modulator lower limits 100, 200, and 300 Hz respectively and a standard advanced-combinational-encoder (ACE) strategy. Results showed that TLE had a comparable performance with ACE at 250-Hz reference F0, but could outperform ACE at 313-Hz reference F0. These indicate that the TLE strategy has the potential to improve pitch ranking in CIs, which implies an enhancement of TFS representation with TLE.

4:15–4:30 Discussion

Session 2pSA

Structural Acoustics and Vibration, Engineering Acoustics and Physical Acoustics: Acoustic Metamaterials II

Christina J. Naify, Cochair
Naval Research Lab, 4555 Overlook Ave. SW, Washington, D.C. 20375

Alexey Titovich, Cochair
Carderock Div., Naval Undersea Warfare Center, 9500 MacArthur Blvd, West Bethesda, MD 20817-5700

Bogdan-Ioan Popa, Cochair
Univ. of Michigan, 2350 Hayward St., Ann Arbor, MI 48109

Chair's Introduction—12:55

Invited Papers

1:00

2pSA1. Moth wings are acoustic metamaterials. Thomas R. Neil (Life Sci., Univ. of Bristol, Life Sci. Bldg., 24 Tyndall Ave., Bristol BS8 1TQ, United Kingdom, t.r.neil@bristol.ac.uk), Zhiyuan Shen, Daniel Robert (Life Sci., Univ. of Bristol, Bristol, United Kingdom), Bruce W. Drinkwater (Mech. Eng., Univ. of Bristol, Bristol, United Kingdom), and Marc W. Holderied (Life Sci., Univ. of Bristol, Bristol, United Kingdom)

Intense predation pressure from echolocating bats has led to the evolution of a host of anti-bat defences in nocturnal moths. The wings of moths are covered in scales that exhibit intricate shapes and sculpted nano structures. Here, we reveal that this scale layer forms a metamaterial ultrasound absorber that is 111 times thinner than the longest absorbed wavelength. Both experimental and numerical analyses of individual scale vibrodynamics reveal that the first three resonances of moth scales lie within the typical echolocation frequency range of bats, whilst scale shape diversity on the wing results in a broad resonance distribution. Individual scales form the resonant unit-cells on the wing and collectively they generate hard to attain broadband deep-subwavelength absorption. Numerical modelling confirms that the acoustic properties of moth wings originate from the interaction of differently tuned single scale resonators, creating emergent acoustic performance beyond that of its elements, confirming broadband metamaterial absorber functionality. This sound absorber provides moth wings with acoustic camouflage against echolocating bats, it combines broadband absorption of all frequencies used by bats with light and ultrathin structures that meet aerodynamic constraints on wing weight and thickness.

1:15

2pSA2. Broadband, frequency-independent acoustic metasurfaces through inverse design. Chen Shen (Dept. of Mech. Eng., Rowan Univ., 201 Mullica Hill Rd., 311 Rowan Hall, Glassboro, NJ 08028, shenc@rowan.edu), Hao-Wen Dong (Dept. of Mech. Eng., Hong Kong Polytechnic Univ., Hong Kong), Sheng-Dong Zhao (School of Mathematics and Statistics, Qingdao Univ., Qingdao, China), Yue-Sheng Wang (Department of Mech., School of Mech. Eng., Tianjin Univ., Tianjin, China), and Li Cheng (Dept. of Mech. Eng., Hong Kong Polytechnic Univ., Hong Kong, Hong Kong)

The recent development of acoustic metasurfaces has broadened the capabilities of wave engineering devices with a compact profile. However, the application of acoustic metasurfaces in many scenarios has been limited by their bandwidths. In this work, we report the realization of broadband acoustic metasurfaces that deliver frequency-independent functionalities. Three examples are demonstrated, namely beam steering, focusing and acoustic levitation with fixed refraction angle, constant focal depth and stable levitation. This is achieved by analyzing the requirement of each functionality and engineering the dispersion of the unit cells. The architecture of the unit cells is obtained through inverse design and each unit cell displays a unique dispersive response outlined by the theoretical requirements. The designed metasurface is experimentally verified and we demonstrate a fractional bandwidth of around 100% for all three functionalities. We also attempt to reveal the mechanism for such broadband by characterizing the behavior of representative unit cells.

Contributed Papers

1:30

2pSA3. On the acoustic black-hole effect in waveguides. Abbas Mousavi (Dept. of Computing Sci., Umeå Univ., UMIT lab, Västerbotten, 901 87 Umeå, Sweden, abbas.mousavi@umu.se), Martin Berggren (Dept. of Computing Sci., Umeå Univ., Umeå, Sweden), and Eddie Wadbro (Dept. of Mathematics and Comput. Sci., Karlstad Univ., Karlstad, Värmland, Sweden)

The acoustic black-hole (ABH) effect is a well-known way of controlling structural vibrations in solid beams and plates. The theory behind this effect is to reduce the velocity of waves by altering the physical properties of the domain according to a power-law profile. For an ideal ABH, this leads to vanishing reflections from the end of the termination. In practice, there will be a truncation in the profile, which leads to some reflections. A well-known way of minimizing this truncation error is to add damping material to the end of the ABH termination. For a waveguide embedding a set of rings with retarding inner radius according to a power-law profile, the velocity of sound waves tends to zero. However, unlike the structural counterpart, experimental results in the literature show that adding damping material to reduce the truncation error is not effective for waveguides. Here, we present a finite element simulation of the considered cylindrical setup. Our results confirm that the addition of damping material to the end of the waveguide is ineffective while suggesting that the local absorption effects at the lateral surface of the cylinder are a primary source of damping to achieve the ABH effect.

1:45

2pSA4. Acoustic black hole optimization. Kayla Petrover (NSWCCD, 1133 13th St. N.W., Apt. 8B, Washington, DC 20005-4207, kayla.petrover@gmail.com)

Acoustic black holes have a tapering profile to create the idealized phenomenon of zero reflection. This phenomenon relies on geometry instead of dampers, so it is an ideal way to remove vibrations without increasing mass or surface area. They can attenuate acoustic and structural vibrations for applications in air, space, ground, and marine vehicles and can be produced in ducts, beams, plates, and wedges. The phenomenon entails wave propagation in an ideal medium where the profile tapers according to the power law shortening the wavelength and decreasing the wave speed. Consequently, the wave's travel time goes to infinity so that it never reaches the termination and cannot be reflected—creating complete absorption. For the application of a circular duct, thin annular rings of inner radii decrease with the power law to control pressure levels. An infinite number of rings and a final cross sectional area of zero are needed to create an ideal acoustic black hole and is impossible to achieve. However, imperfections create scattering and other losses that increase damping performance. Therefore, various configurations need to be tested to tune parameters such as the amount, thickness, and spacing of tapering rings to produce minimal reflection across a frequency spectrum.

2:00–2:15 Break

2:15

2pSA5. Investigation of an additively manufactured pentamode material using non-contact vibration transmissibility measurements. Colby W. Cushing (Appl. Res. Labs. and the Walker Dept. of Mech. Eng., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, colby.cushing@utexas.edu), Matthew Kelsten, Andrew N. Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ), Preston S. Wilson, and Michael R. Haberman (Appl. Res. Labs. and the Walker Dept. of Mech. Eng., The Univ. of Texas at Austin, Austin, TX)

Pentamodal (PM) metamaterials are one potential means to enable concepts from transformation acoustics in underwater applications because they can be designed to support anisotropic longitudinal wave motion over wide frequency bands while simultaneously being impedance matched to water [Su *et al.*, *J. Acoust. Soc. Am.* **141**(6), (2017)]. In three dimensions, PM materials can be fabricated using additive manufacturing (AM) to create elastic lattice structures whose microstructure can be tailored to produce the desired anisotropic sound speed and impedance in a target frequency band. This work presents measurements of the vibrational response of a PM block designed to display anisotropic stiffness. The sample measures approximately 100x100x85 mm and is constructed from titanium using direct metal laser sintering. Measurements were made on a sample mounted on an electro-dynamic shaker providing base excitation between 0.05 and 20 kHz. A scanning laser Doppler vibrometer measured out-of-plane surface velocity with normals both parallel and orthogonal to the excitation axis. The finite extent of the sample introduces geometric asymmetry associated with domain truncation, which is observable in the vibrational modes. Measurements were made for various sample orientations and compared to full-featured finite element models. Simulation-experiment comparisons and other findings will be presented and discussed. [Work supported by ONR.]

2:30

2pSA6. Numerical simulation of the effect of absorption on the transmission of acoustic waves through 3D-printed ABS-plastic metamaterial. Alexander Korobov, Alexey Kokshaiskiy (Acoust., Phys., Lomonosov Moscow State Univ., Moscow, Russian Federation), Ruslan A. Zhostkov (Lab. 703, IPE RAS, Moscow, Russian Federation), Natalia Odina (Acoust., Phys., Lomonosov Moscow State Univ., Moscow, Russian Federation), Maria Izosimova (Dept. of Acoust., Faculty of Phys., M. V. Lomonosov Moscow State Univ., Leninskie Gory, Moscow 119991, Russian Federation, maria.izossimova@mail.ru), and Alexander Volodarsky (Acoust., Phys., Lomonosov Moscow State Univ., Moscow, Russian Federation)

When designing acoustic metamaterials, there is often a discrepancy between the calculated sound field and the experimental results. This does not allow you to accomplish the planned purposes, for example, using a metamaterial as a filter in a given frequency range. One of the reasons for this is associated with the effect of losses, which is often not considered. This paper presents the results of numerical simulation of effect of absorption on the acoustic waves propagation in metamaterial elements. Samples in the form of cubes with holes made of 3D-printed ABS-plastic were used as simulation. The attenuation coefficients were taken from the literature and measured in the samples of plastic the metamaterial was made of. Full-wave numerical simulation by the finite element method in the COMSOL Multiphysics software package is performed. Simulation allowed to analyze many different geometries and physical parameters of metamaterial samples and to choose ones with the most designatory properties. The effect of absorption on a number of features, in particular, on the pattern of the bandwidth and reject bands is noted. Numerical and physical experiments are compared. [The research was supported by a grant from the Russian Science Foundation (Project No. 19-12-00098).]

2:45

2pSA7. Achieving optimal attenuation in acoustic waveguides with 3D printed Helmholtz resonators. Matthew Kelsten (Mech. and Aerosp. Eng., Rutgers Univ., 98 Brett Rd., Piscataway, NJ 08854, mjk308@scarletmail.rutgers.edu) and Andrew N. Norris (Mech. and Aerosp. Eng., Rutgers Univ., Piscataway, NJ)

A double root, commonly referred to as an exceptional point (EP), for modal frequencies in a 2D or 3D waveguide can exhibit optimal attenuation rates over a relatively broad frequency range. The key to the phenomenon is that the wall impedance is such that modes coalesce at a complex-valued frequency. In this talk we consider a novel approach to feasibly achieve the aforementioned wall impedance with the use of simple resonators, which can be shown to exhibit mode coalescence at distinct frequencies when treated as a unit cell component of a larger metasurface. Numerical results of several unit cell designs are given to test the boundaries on the following constraints: realizable resonator dimensions, scale separation, and target attenuation goals. To validate the analytical work, experimental setups consisting of additively manufactured Helmholtz resonators incorporated onto a custom-made impedance tube are tested. The dependence of printed resonator quality on theoretical inertial, loss, and stiffness values are discussed in

tandem with printing repeatability. Simulated finite element model results will be used as comparative backdrops with the numerical and experimental results. Work supported by NSF.

3:00

2pSA8. Influence of structural resonances on the causal-based optimisation of micro-perforated absorbers. Teresa Bravo (Instituto de Tecnologias Fisicas y de la Informacion, Consejo Superior de Investigaciones Cientificas, Serrano 144, Madrid 28006, Spain, teresa.bravo@csic.es) and Cedric Maury (Lab. of Mech. and Acoust., Ecole Centrale Marseille, Marseille, France)

Fire-proofness, cleanability and lightweight constraints make micro-perforated panels an alternative to classical porous materials in demanding environments. However, the selection of their physical parameters constitutes a combinatorial optimization problem that involves the maximization of the absorption coefficient within a frequency band, imposing restrictions on the total thickness of the partition. In this work, we propose an alternative formulation based on the principle of causality. The optimization of micro-perforated absorbers (MPAs) by this criterion enables to identify the MPA constitutive parameters that achieve both critically coupled (CC) resonant states and the smallest thickness-to-bandwidth ratio. It includes the specific resonant state that maximizes the total absorption for a given overall thickness of the absorber. However, the optimization of lightweight absorbers requires that the parameter space involves sub-millimetric panel thicknesses. In this case, the effect of elasticity and finite-sized structural resonances are hardly negligible on the absorption performance. In this study, the causality criterion developed for rigid MPAs has been extended to account for the effect of the panel vibrations on the perforations impedance. Of interest is to examine how this influences the thickness-to-bandwidth performance of the MPA and the related CC resonances, especially when they strongly couple with the cavities Helmholtz-type resonances.

3:15–3:40 Discussion

WEDNESDAY AFTERNOON, 9 JUNE 2021 — 12:55 P.M. TO 2:30 P.M.

Session 2pSCa

Speech Communication: Speech Studies Conducted Remotely: Methods and Examples II

Sandie Keerstock, Cochair
Psychological Sciences, University of Missouri, 124 Psychology Bld, Columbia, MO 65201

Pasquale Bottalico, Cochair
Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901 South Sixth Street, Champaign, IL 61820

Eric Hunter, Cochair
Com Sciences & Disorders, Michigan State University, 1026 Red Cedar Road, East Lansing, MI 48824

Chair's Introduction—12:55

Invited Papers

1:00

2pSCa1. Conducting speech perception experiments remotely: Some tools, successes, and challenges. Rachel M. Theodore (Univ. of Connecticut, 2 Alethia Dr., Unit 1085, Storrs, CT 06269-1085, rachel.theodore@uconn.edu)

The use of remote (*i.e.*, web-based) data collection for psycholinguistics research has proliferated in recent years, reflecting the emergence of new tools for promoting high-quality data collection beyond the traditional laboratory environment. This is particularly true this past year, demonstrating one way that the pandemic has transformed research in the short-term. In the long-term, remote approaches will remain a powerful tool in the domain of psycholinguistics, in part because they help (1) promote diversity among participant samples and (2) increase feasibility of the new best practices for promoting reproducibility of research (*e.g.*, larger sample sizes, in-house replications, assessing generalization to novel stimulus sets). However, embracing remote data collection is not without its challenges, especially for speech perception researchers who require some degree of control over the listening environment and participants' linguistic background. In this talk, I will describe tools, successes, and challenges related to our experiences in conducting remote speech perception experiments for a variety of phenomena (*e.g.*, categorical perception, perceptual learning, talker adaptation, Ganong effect), tasks (*e.g.*, phonetic identification, lexical decision, talker discrimination, transcription), and dependent measures (*e.g.*, reaction time, accuracy, sensitivity, psychometric response functions).

1:20

2pSCa2. Reaching from afar: Pitfalls and promises of online auditory testing. Valeriy Shafiro (Commun. Disord. and Sci., Rush Univ. Medical Ctr., 600 South Paulina St., 1015 AAC, Chiago, IL 60612, Valeriy_Shafiro@rush.edu) and Yan Li (Rush Univ. Medical Ctr., Chicago, IL)

Online testing of speech perception and auditory abilities over the Internet can be a cost-effective and efficient way to collect data. It eliminates travel requirements, provides flexibility in scheduling tests, and enables broader and safer outreach to potential participants. However, online testing also involves considerable risks to data quality and integrity stemming from multiple factors, which are often difficult to control. These include access to an appropriate testing environment, availability of broadband Internet connection, and adequate computing and audio equipment. Participants also need to have a sufficient level of computer literacy and engagement. In recent years, several approaches and software applications have been used for online data collection. Selection of a specific approach involves a careful balancing of its strengths and weaknesses, based on the goals of a specific study. This presentation will describe one such approach that led to the development of Basic Auditory Skills Evaluation (BASE) battery. The battery was designed for comprehensive online assessment in adults with cochlear implants and has been recently extended to examine speech perception in other populations. The presentation will describe some applications of BASE battery, discuss the advantages and disadvantages of using this approach to online auditory testing, and review initial findings.

1:40

2pSCa3. Evaluating speech enhancement for cochlear implants using a web application. Raymond L. Goldsworthy (Otolaryngol., Univ. of Southern California, 1640 Marengo St., HRA 326, Los Angeles, CA 90033, rgoldswo@usc.edu), Susan Bissmeyer (Otolaryngol., Univ. of Southern California, Los Angeles, CA), and Jayaganesh Swaminathan (Audiol., Univ. of the Pacific, Berkeley, CA)

People who suffer from hearing loss struggle to maintain social relationships, which diminishes their quality of life. As technology progresses, video calls are an increasingly common way of communicating with family and friends. This trend has been accelerated by the rapid rise of software for video conferencing to support communication during the past year of pandemic restrictions. Consequently, using the same media devices that are used for video calls is an ecologically valid way of assessing hearing. This presentation describes a web application for conducting remote hearing assessments on any media device. The features of the web application will be introduced, and research results will be presented from a study of speech enhancement for cochlear implants. Consonant perception is innately challenging for listeners with hearing loss and transmission of speech over communication channels further deteriorates the acoustics of consonants. We hypothesized that consonant enhancement at the source would improve identification. The results indicate that transient emphasis does improve consonant identification for cochlear implant users while preserving their vowel identification accuracy. Discussion will consider general use of hearing assessments using media devices that people use in their daily lives.

2:00–2:30 Discussion

Session 2pSCb

Speech Communication: Speech Studies Conducted Remotely: Methods and Examples III

Sandie Keerstock, Cochair
Psychological Sciences, University of Missouri, 124 Psychology Bld, Columbia, MO 65201

Pasquale Bottalico, Cochair
Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901 South Sixth Street, Champaign, IL 61820

Eric Hunter, Cochair
Com Sciences & Disorders, Michigan State University, 1026 Red Cedar Road, East Lansing, MI 48824

Chair's Introduction—2:45

2:50

2pSCb1. Variability of disyllabic tone 4 sandhi in colloquial Beijing. Ruoqian Cheng (Dept. of Linguist., Univer. of Kansas, Lawrence, KS, rqcheng@ku.edu) and Jie Zhang (Dept. of Linguist., Univer. of Kansas, Lawrence, KS)

This study collects production data remotely from speakers of colloquial Beijing in China. Acoustic analysis is conducted to test the surface variation of an underlying falling tone between falling and rising when preceding another underlying fall tone.

2:55

2pSCb2. Estimating the performance gap between lab and remote speech perception experiment. Martin Cooke (Ikerbasque and Univ. of the Basque Country, Vitoria-Gasteiz, Spain, m.cooke@ikerbasque.org) and M. L. Garcia Lecumberri (Univer. of the Basque Country, Spain)

The presentation will report on an online replication of several lab-based studies in the perception of masked, distorted and enhanced speech in which listener-related differences were controlled.

3:00

2pSCb3. Voices of lockdown: Using self-recorded lockdown diaries to investigate phonetic change in Edinburgh and the Lothians. Nina Markl (Univ. of Edinburgh, Scotland, Edinburgh, UK, nina.markl@ed.ac.uk), Lauren Hall-Lew, Claire Cowie, Catherine Lai, and Stephen Joseph McNulty (Univ. of Edinburgh, Scotland, Edinburgh, UK)

The Lothian Diary Project is an interdisciplinary research project inviting residents of the Lothians region of Scotland to contribute self-recorded audio and video diaries about their experiences of the COVID-19 pandemic. We present a brief case study, highlighting sociophonetic features of Scottish English which have been undergoing change in the recent years.

3:05

2pSCb4. Tips for interviewing people with hearing loss over Zoom. Madison Pearson (Oklahoma State Univ.–Sociophonetics Lab, Stillwater, OK, madison.pearson@okstate.edu) and Valerie L. Freeman (Oklahoma State Univ., Stillwater, OK)

This presentation will cover considerations for effectively conducting interviews or other interactive experiments over Zoom with individuals who have hearing loss, with or without assistive listening devices, closed captioning, interpreters, or other accommodations.

3:10–3:25 Discussion

3:25

2pSCb5. Recall of vowel sequences in altered rhythm contexts: In-person versus online testing. Dylan Pearson (Speech and Hearing Sci., Indiana Univ.–Bloomington, Bloomington, IN, dylpears@iu.edu), Yi Shen (Univ. of Washington, Seattle, WA), Gary R. Kidd (Indiana Univ., Bloomington, IN), and J. Devin McAuley (Michigan State Univ., MI)

This presentation will outline the online replication of an in-lab vowel recall experiment to demonstrate the feasibility of conducting behavioral experiments that address high-level auditory processes through online-experiment platforms.

3:30

2pSCb6. Testing phonetic and phonological learning skills remotely: Common challenges and solutions. Laura Spinu (Communications & Performing Arts, CUNY Kingsborough, Brooklyn, NY, lspinu@kcbb.cuny.edu), Laura Muscalu (Ithaca College, Ithaca, NY), and Julia Wallace (Kingsborough Community College, Brooklyn, NY)

We compared monolinguals' and bilinguals' ability to learn an artificial accent of English upon brief initial exposure in an online experiment ($n = 40$) using the pavlovia.org platform. Our findings replicated those of an earlier experiment conducted in the lab ($n = 60$), leading us to conclude that remote testing can offer a promising alternative to traditional lab testing in this particular line of research.

3:35

2pSCb7. Voicing contrasts and prosody in Majhi. Panjabi Noah Usman (Univ. of California, Berkeley, CA, nusman@berkeley.edu)

This project examines the understudied phonetic inventory of Majhi Panjabi, particularly the factors that contribute to the perception of a three-way voicing contrast in stops and affricates: falling pitch contour and de-aspiration of following consonants. I further explore the possible impact of contact with the non-tonal qualities of Urdu in this change.

3:40

2pSCb8. Socially distanced psychoacoustics. Vayda Wilson (Speech Communication, SUNY New Paltz, New Paltz, NY, wilsonv2@hawkmail.newpaltz.edu), Anne C. Balant, and Heather L. Lai (SUNY New Paltz, New Paltz, NY)

This presentation will describe the successful adaptation of a psychoacoustic study on acoustic analogs of flutter echoes for remote participation. The data collection software was installed on a campus server and the investigators guided the participants through three different listening tasks via screen-sharing and videoconferencing.

3:45–4:00 Discussion

4:00

2pSCb9. To touch or not to touch: Variations in mouse tracking across equipment profiles during online incidental learning of novel tone categories. Jonathan Wright (Univ. of Oregon, Eugene, OR, jwright8@uoregon.edu) and Melissa Baese-Berk (Univ. of Oregon, Eugene, OR)

We measure mouse tracking during the incidental acquisition of novel tone categories, permitting a confusion matrix analysis of four novel tone categories. We present variations in mouse tracking response data that arise from inevitable differences in individual equipment profiles (e.g., touchpad, external mouse, etc.) as participants take the study online, rather than in a controlled environment.

4:05

2pSCb10. Rhotics and affricates in Sursilvan Romansh: Evidence from remote preliminary research on an under-documented language. Ashlyn Wright (Univ. of California, Berkeley, CA, ashgw@berkeley.edu)

Based on my remote phonetic documentation of the Sursilvan variety of Romansh (roh-sul, Gallo-Iberian, Switzerland), I propose a phonetic inventory and present acoustic analyses of variation in rhotics [ʁ] & [χ] as well as contrasts and coarticulation within the affricate system. This contribution to the scarce documentation on Sursilvan Romansh highlights the opportunities presented by remote methods for preliminary research on under-documented language varieties.

4:10–4:30 Discussion

Additional Lightning Round presentations and discussions may be added

WEDNESDAY AFTERNOON, 9 JUNE 2021 — 12:55 P.M. TO 4:30 P.M.

Session 2pSP

Signal Processing in Acoustics and Computational Acoustics: Bayesian Signal Processing and Machine Learning II

Ning Xiang, Cochair
School of Architecture, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY 12180

Stan Dosso, Cochair
School of Earth and Ocean Sciences, University of Victoria, Victoria V8W 2Y2, Canada

Peter Gerstoft, Cochair
Scripps Inst. of Oceanography, 9500 Gilman Drive, La Jolla, CA 92093

Chair's Introduction—12:55

Invited Papers

1:00

2pSP1. A Bayesian active-learning test for remote hearing-aid fitting. Josef Schlittenlacher (Univ. of Manchester, Oxford Rd., Manchester M139PL, United Kingdom, josef.schlittenlacher@manchester.ac.uk), Karolina Kluk, Michael Stone, and Emanuele Perugia (Univ. of Manchester, Manchester, United Kingdom)

A major problem of remote or online hearing tests is the calibration of the equipment and control of the acoustic environment: For example, an audiogram requires calibrated headphones with a wide dynamic range and a silent room. Instead, a notched-noise test alleviates these problems and gives valuable information about auditory filters that can be used to fit a hearing aid. Although absolute levels still play a role, relative levels between signal and noise are more robust as the environment does not need to be quieter than the noise. Using traditional methods, determination of auditory-filter shapes across the whole frequency range would take hours. We developed a notched-noise test that uses Gaussian Processes to maintain a probabilistic estimate of the outcome, and to select stimulus parameters

based on mutual information. This active-learning method gives an estimate of auditory-filter shapes in about 30 minutes across a wide range of frequency. We demonstrate that these estimates, even when obtained with headphones for which the frequency response and exact calibration is unknown, are sufficient to give a good initial fit of a hearing aid.

1:15

2pSP2. Relative entropy of machine-learning for long-range sound propagation. Carl R. Hart (U.S. Army Engineer Res. and Development Ctr., Cold Regions Res. and Eng. Lab., 72 Lyme Rd., Hanover, NH 03755, carl.r.hart@erdc.dren.mil), D. Keith Wilson (U.S. Army Engineer Res. and Development Ctr., Cold Regions Res. and Eng. Lab., Hanover, NH), Chris L. Pettit (Aerosp. Eng., U.S. Naval Acad., Annapolis, MD), and Edward T. Nykaza (U.S. Army Engineer Res. Development Ctr., Construction Eng. Res. Lab., Champaign, IL)

Machine-learning algorithms can provide fast surrogate models when trained on sampled predictions from physics-based numerical models. However, it is unknown whether surrogate data generated from propagation through single realizations of atmospheric turbulence, or from an ensemble of multiple realizations of turbulence, is most suitable for machine-learning models. This study examines the use of a Crank-Nicholson parabolic equation (CNPE) for generating surrogate data, and Latin hypercube sampling for the CNPE input. Two separate datasets are generated for 5000 samples of governing parameters. In the first dataset, each transmission loss field is computed for a single realization of turbulence, whereas the second uses transmission loss from an ensemble of 64 realizations. Errors for various machine learning approaches are evaluated against experimental observations of long-range (out to 8 km) sound propagation. Between experimental and surrogate differences in transmission loss at four ranges, the average deviation from zero relative entropy was quantified. As a measure of dissimilarity between two distributions it is 0.17 for single realizations of turbulence, and 0.29 for 64 realizations of turbulence. Surrogate data generated from single realizations of turbulence agree better with experimental data.

1:30

2pSP3. Deep embedded clustering of coral reef bioacoustics. Emma Reeves Ozanich (AOPE, Woods Hole Oceanographic Inst., 9525 Genesee Ave., Apt. 204, San Diego, CA 92121, ecreeves@ucsd.edu), Aaron M. Thode, Peter Gerstoft (Scripps Inst. of Oceanogr., Univ. of California, San Diego, La Jolla, CA), Lauren A. Freeman, and Simon E. Freeman (Naval Undersea Warfare Ctr., Middletown, RI)

Deep clustering was applied to unlabeled, automatically detected signals in a coral reef soundscape to distinguish fish pulse calls from segments of whale song. Deep embedded clustering (DEC) learned latent features of the signals and formed clusters using fixed-length power spectrograms of the signals. Handpicked spectral and temporal features were also extracted and clustered with Gaussian mixture models (GMM) and conventional clustering. DEC, GMM, and conventional clustering were tested on simulated datasets of fish pulse calls and whale song units with randomized bandwidth, duration, and SNR. Both GMM and DEC achieved high accuracy and identified clusters with fish calls, whale song units, and simultaneous fish calls and whale song units. Conventional clustering methods K-means and hierarchical agglomerative clustering had low accuracy in scenarios with unequally sized clusters or multiple signals. Experimentally detected fish pulse calls and whale song units recorded near Hawaii in February–March 2020 were clustered with DEC, GMM, and conventional clustering. DEC demonstrated the highest accuracy on a small, manually labeled dataset and successfully separated clusters of fish calls and whale song units. GMM achieved high recall for detecting whale song units but accuracy. Both GMM and DEC overpredicted the number of whale song unit signals.

Contributed Papers

1:45

2pSP4. Semi-supervised deep learning of source location and seabed class from unlabeled merchant ships in the shallow ocean. Mason C. Acree (Phys. and Astronomy, Brigham Young Univ., N283 ESC, Provo, UT 84602, mason7acree@gmail.com), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX), and William Hodgkiss (Marine Physical Lab., Scripps Inst. of Oceanogr., San Diego, CA)

Understanding sound propagation in a shallow ocean environment is complicated but important for naval technologies. Some researchers are currently applying a variety of supervised deep learning methods, such as convolution neural networks, for either source localization or seabed classification. One of the costs of supervised learning is the requirement for large amounts of labeled data. In the present study, unlabeled data are used to train a Transformer model. Transformer-based models have demonstrated ability for predicting sequential data; examples are Google's BERT and OpenAI's GPT-3. In our technique, we train a transformer-based model in a twopart process. First, self-supervised learning is implemented using synthetic ship spectrograms for various shallow ocean environments. The model is trained as an encoder/decoder to perform sequence-to-sequence prediction. Second, the transformer model is fine-tuned to predict the source location and seabed class from a small set of labeled synthetic samples. Data samples measured during the Seabed Characterization Experiment 2017 are utilized as a testing dataset. The advantages of this approach are the ability to train a model with a larger variety of data, including the use of unlabeled data and data of variable input length.

2:00

2pSP5. Seabed classification from ship-radiated noise using an ensemble deep learning. Christian D. Escobar-Amado (Elec. and Comput. Eng., Univ. of Delaware, 139 The Green, Newark, DE 19716, escobarc@udel.edu), Mohsen Badiey (Elec. and Comput. Eng., Univ. of Delaware, Newark, DE), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), Jhon A. Castro-Correa (Elec. and Comput. Eng., Univ. of Delaware, Newark, DE), and David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX)

An ensemble of deep learning algorithms is employed for seabed classification using merchant ship-radiated noise recorded on a single receiver. Five different convolutional neural network (CNN) architectures and one residual neural network (ResNet) are trained on synthetic data generated using 34 seabed types found in the literature from different areas of the world that span from soft-muddy to hard-sandy sediments. Validation results show an accuracy above 97.15% for all the networks using the five-fold cross-validation method. To assess the generalizability performance of the ensemble deep learning, the networks were tested on 69 data samples measured on three VLAs in the Seabed Characterization Experiment in 2017 (SBCEX 2017) from merchant ships passing by close to the receivers. Results show that the most likely sediments were the mud over sand environments inferred in previous geoacoustic inversions for the SBCEX 2017 area with 94% of the predictions from all the trained networks. This work presents evidence that the ensemble of deep learning algorithms has learned how the signature of the sediments is encoded in the ship-radiated noise providing a unified classification result when tested on real-world data. Work supported by ONR, Contract No. N00014-19-C-2001.]

2:15 - 2:30 Discussion

2:30 - 2:45 Break

Contributed Papers

2:45

2pSP6. Designing a covariance matrix tapered beamformer that is universal over notch width. Savas Erdim (ECE, Univ. of Massachusetts Dartmouth, 285 Old Westport Rd., North Dartmouth, MA 02747, serdim@umassd.edu) and John R. Buck (ECE, Univ. of Massachusetts Dartmouth, Dartmouth, MA)

Universal adaptive beamformers (UABFs) combine classic adaptive beamformers with ensemble methods from machine learning to design new beamformers whose asymptotic performance rivals the performance of the best beamformer in a set. The UABF array weights blend a weighted average of the competing beamformer array weights based on past performance using the *softmax* function. This model averaging approach avoids a difficult model selection problem by hedging performance across a family of models rather than committing to a single model. This talk presents a UABF which blends covariance matrix tapers (CMT). The CMT technique creates broader notches in beampatterns for environments with moving interferers. Interferers moving with high bearing rates cross resolution cells faster and violate the stationarity solution of the minimum variance distortionless response (MVDR) beamformer. The performance of the CMT depends on the chosen notch width. The UABF adapts to find the blend of CMT notch widths that best balances the interferer output power with white noise gain. We present simulation results illustrating the benefits of the UABF approach for CMT in the presence of moving interferers. [Work supported by ONR 321US.]

3:00

2pSP7. A substitution of convolutional layers by FFT layers—A low computational cost version. Umar Farooq Mohammmad (Comput. Sci. and Eng., Penn State Univ., State College, PA), Mohammad Wasih (Comput. Sci. and Eng., Penn State Univ., State College, PA 16803, mvw5820@psu.edu), and Mohamed Almekkawy (Comput. Sci. and Eng., Penn State Univ., State College, PA)

Convolutional Neural Networks (CNNs) have become recently a very common application of accurate diagnosis and early detection of liver abnormalities. CNN's have very promising outputs and showed accurate results comparable to classical detection methods. However, one of their drawbacks is the exponential increase of the computational cost with the increase of the image size. We propose an upgraded neural network (NN) -based approach in which the convolution layers are replaced with Fast Fourier transform (FFT) Layers. Instead of the convolution of each pixel in a large ultrasound image with the kernel where the computational cost is of $O(N^2)$, we calculate the FFT of the image and the kernel separately and multiply them in the frequency domain where the computational cost is of $O(N \log N)$ and then calculate the inverse Fourier transform of the result. Accordingly, we have replaced the convolution with FFT for the forward and the backward propagation in the NN for the liver steatosis classification from ultrasound images of benign and malignant fatty liver. CNN layers resulted in 89.82% accuracy to classify 550 Ultrasound fatty liver images while our approach resulted in just a 4% reduction in the classification accuracy but with an 83.3% reduction in the computational time.

3:15

2pSP8. Incidence of data augmentation in machine learning using broadband spectrograms. Jhon A. Castro-Correa (Elec. and Comput. Eng., Univ. of Delaware, 139 The Green, 3rd Fl., Newark, DE 19716, jcastro@udel.edu), Mohsen Badiey (Elec. and Comput. Eng., Univ. of Delaware, Newark, DE), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), and David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX)

One of the main problems in ocean acoustics is the lack of training data that assist networks to generalize better understand undersea environments. In deep learning, data augmentation is commonly used to add variability to the data by applying small transformations to the samples with the purpose of improving the performance and generalization capabilities of the networks. Here, this definition is extended to broadband spectrograms from merchant ships collected during the Seabed Characterization Experiment in 2017. In this study, residual neural networks were used as the machine learning algorithm for performing source localization and environment classification. Additionally, nine different data augmentation techniques were considered for studying their performance predictions. Each of the transformations was applied to the data set during the training stage, and the results were compared to establish the effects in the performance for both regression and classification tasks. The metrics used were the root mean squared error for regression and accuracy in the case of seabed classification. The results show a favorable potential of residual-based deep learning models to differentiate the seabed types and the source position based on these types of data, in addition to the improvements in performance after applying complex transformations during the training. [Work supported by the Office of Naval Research, Contract No. N00014-19-C-2001.]

3:30

2pSP9. Improved Siamese Network for motion tracking in ultrasound images. Skanda Bharadwaj (Comput. Sci. and Eng., Penn State Univ., W103, Westgate Bldg., University Park, State College, PA 16802, ssb248@psu.edu) and Mohamed Almekkawy (Comput. Sci. and Eng., Penn State Univ., State College, PA)

In recent years, the use of Convolutional Neural Networks in medical imaging applications has been increasing drastically. Siamese Networks are among the top architectures that are being borrowed for motion tracking. In this work, we propose an improved Siamese network for robust and accurate landmark tracking in ultrasound image sequences. Despite the staggering efficacy of Siamese networks, the inherent assumptions in the original architecture lead to certain limitations. The assumption of the constant position model and not incorporating any motion model remain unaddressed. In our proposed model, we employ a reference template update module to resolve the assumption of the constant position model and incorporate a Linear Kalman Filter to address the issue of the missing motion model. The proposed model was evaluated for robustness on the training set of the Liver Ultrasound Tracking (CLUST) 2D data set. The robustness of the architecture was evaluated by inducing synthetic occlusions around the landmark. The performance was then compared to the original architecture. Experiments proved that the proposed model outperformed the original model by a significant margin.

3:45

2pSP10. Automated detection of liver steatosis in ultrasound images using convolutional neural networks. Umar Farooq Mohammmad (Comput. Sci. and Eng., Penn State Univ., 201 Vairo Blvd L348B, State College, PA 16803, umarfarooqngm@gmail.com) and Mohamed Almekkawy (Comput. Sci. and Eng., Penn State Univ., State College, PA)

Ultrasound imaging is the most commonly applied imaging modality for the diagnosis of fatty liver disease. It is considered malignant if there is more than 5% of fatty hepatorenal steatosis. The classical methods to classify liver steatosis usually involve experienced physicians or radiologists to identity them. In this work, we introduce a Convolutional Neural Network (CNN) based approach to classify the malignant and benign fatty livers from ultrasound images. The pre-trained network of Inception Resnet which is initially trained on the ImageNet dataset is used for transfer learning on B-mode ultrasound liver images for classification. We used the open-source ultrasound liver dataset of 55 patients with 10 image sequences for each making a total of 550 images with 170 benign and 340 malignant samples. Since the dataset size is small for training, we have applied various data-augmentation techniques and have employed the transfer-learning approach using Inception ResNet architecture. We were able to achieve, using our approach, a very high classification accuracy of 98.48%, whereas the area under the curve of the classical hepatorenal index method is 0.959 and the Gray-level co-occurrence algorithm is 0.893.

4:00

2pSP11. Ultrasound liver tumor segmentation with nested U-Net and dynamic feature extraction. Qinhan Gao (Comput. Sci. and Eng., Penn State Univ., 1013 South Allen St., #604, State College, PA 16803, qxg7@psu.edu) and Mohamed Almekkawy (Comput. Sci. and Eng., Penn State Univ., State College, PA)

Locating tumor from ultrasound images is of high importance in medical analysis and diagnosis. There are mainly two challenges for segmenting tumors from ultrasound images. The first challenge is the low resolution and high speckle noise of ultrasound images. The second challenge is the various shapes and sizes of tumors. We propose a multi-level feature extraction neural network to automatically segment the data. Our purposed model is trained and tested with liver tumor ultrasound images from an open source dataset. Specifically, after pre-processing the dataset with median filter and data augmentation, we employ a collaborative model that utilizes nested U-net, U-Net++ as a backbone. The model is integrated with dense short skip connections within sub-networks to further improve the gradient flow and feature preservation. In addition, we modify the original atrous spacial pyramid to an adaptive pooling for better compatibility with nested U-Net. Adaptive atrous spacial pyramid pooling is designed to extract features from different levels and cover the increasing range of feature extraction with regard to the depth of the nested network. Segmentation results showed that the proposed model outperformed multiple network structures, and achieved a 0.915 3 dice coefficient, 0.843 8 intersection-over-union and 0.0019 mean square error.

4:15–4:30 Discussion

WEDNESDAY AFTERNOON, 9 JUNE 2021 4:30 P.M. TO 6:00 P.M.

Session 2pID

KEYNOTE LECTURE

Tyrone M. Porter, Univ. of Texas at Austin, Austin, TX 78712

Chair's Introduction—4:30

2pID1. A personal perspective and journey through DEI and STEM. Sylvester James Gates, Jr. (Brown Theoretical Physics Center, Brown University, Providence, RI 02912)

Abdus Salam, a 1979 Nobel Prize recipient in Physics, once told the speaker there was a possibility of "Jazz in Physics" coming into existence when the field became more diverse. This presentation will present a personal interpretation and story on the meaning of this "puzzling" comment and how it led to a citation by the Supreme Court of the United States.

Q&A will follow presentation

Session 3aAA

Architectural Acoustics, Structural Acoustics and Vibration, Computational Acoustics, Musical Acoustics, and Noise: Acoustics in Coupled Volume Systems

Ning Xiang, Cochair
School of Architecture, Rensselaer Polytechnic Institute, 110 Eighth Street, Troy, NY 12180

Michael Vorlaender, Cochair
ITA, RWTH Aachen University, Kopernikusstr. 5, Aachen 52056, Germany

Chair's Introduction—9:30

Invited Papers

9:35

3aAA1. Experience with coupled spaces: From theory to practice. Zühre Sü Gül (Architecture, Bilkent Univ., METU Technopolis KOSGEB-TEKMER No. 112, ODTU Cankaya, Ankara 06800, Turkey, zuhre@mezzostudyo.com)

It has been more than a couple of decades since the interest in coupled volume systems started to grow rapidly among researchers. Basically, due to their increasingly popular applications in music halls for providing a rich acoustical environment either to fulfill the competing criteria of clarity and reverberance or simply to tune the auditoriums for multi-functional use. A lifelong experience with coupled spaces is the main motivation behind this paper. The journey starts with further developing the theoretical knowledge through scale model experiments. The results of which are utilized to observe the effects of the aperture size and shape on non-exponential sound energy decay by applying Bayesian analysis. The investigations have continued by field tests of real-size architectural monuments, specifically, worship spaces with multi-volume and domed typology. The relation of non-exponential energy decay and architectural parameters, for different scenarios or original uses of historical buildings, are searched through energy flow decays by applying the diffusion equation model. Simultaneously, all of these findings from academic research have been a source to produce acoustical design solutions for either small sized recording studios or large-scale multi-purpose auditoria in landmark buildings, all of which are briefly exemplified within this study.

9:50

3aAA2. Directional sound field decay analysis in coupled spaces. Marco Berzborn (RWTH Aachen Univ., Kopernikusstr. 5, Aachen 52064, Germany, marco.berzborn@akustik.rwth-aachen.de), Jamilla Balint, and Michael Vorlaender (RWTH Aachen Univ., Aachen, Germany)

Multi-exponential energy decays—showing a distinct curvature in the measured decay curve—are a well known phenomenon in coupled spaces if both spaces exhibit different reverberation times due to their specific absorption characteristics or volumes. Recently, Berzborn *et al.* (2019) investigated directional energy decay curves—calculated from a plane wave decomposition of the sound field—as an analysis framework for the angular distribution of energy during the decay process in reverberation rooms. In this contribution, we investigate the directional characteristics of the energy decay in two rooms connected by a door. Spherical microphone array measurements at two different receiver positions and coupling areas were performed. Results indicate a distinct anisotropic energy decay in the room with the shorter reverberation time, showing a decreased isotropy in the late decay process compared to the early part.

10:05

3aAA3. Synthesis of acoustics of coupled volumes—Perceptual approach. Wieslaw Woszczyk (Music Res., Schulich School of Music, McGill Univ., 527 Sherbrooke St., Rm. A-636, Montreal, QC H3K 3G9, Canada, Wieslaw.Woszczyk@mcgill.ca)

Connected, acoustically coupled spaces are typically characterized by non-exponential decay with double or multiple slopes. In some cases, two volumes of different absorption characteristics are connected through an aperture that may be opened to vary the engagement between the two acoustics, *e.g.*, the auditorium and the reverb chamber. In a large complex room, acoustic energy emanating from the source will simultaneously and sequentially engage a number of different volumes (regions), depending on how the space is physically laid out, and where the source and receiver are. The regions shape and exchange energy collectively. The listener's overall room impression will be due to an overlayed mix of spatially and temporally distributed ambient responses reaching the listener or receiver position. In synthesis of complex acoustic spaces, we take a perceptual approach where we combine elements of measured spatial room impulse responses, divide them into meaningful temporal segments, shape their envelopes, and recombine these varied characteristics for multichannel convolution with a source. Different variants of processing the impulse responses create different perceptual

outcomes, and a variety of aurally diverse spaces can be created for applications in virtual acoustics and immersive audio production. These perceptual approaches, balancing clarity and reverberation, will be discussed in this presentation.

10:20

3aAA4. Practitioner experience of coupled volume auditorium design. Philip Wright (Acoust., Arup, Ove Arup and Partners Ltd., 13 Fitzroy St., London W1T 4BQ, United Kingdom, philip.wright@arup.com), Paul Adams, Tateo Nakajima (Acoust., Arup, London, United Kingdom), Todd Brooks (Acoust., Arup, New York, NY), and Alban Bassuet (Acoust., Arup, Boston, MA)

This paper is written from the perspective of practitioners who approach the use of coupled volumes—in auditorium design in particular—as one element taken from a diverse acoustic design toolkit to be employed when appropriate to achieve an intended sound aesthetic conceived in response to the specific cultural setting of each space. In this approach, coupled volumes are considered part of a continuum of design options encompassing volumetric coupling effects and their inter-relationship with separation of early reflecting elements and room boundaries. The practice has experience with coupled volume design spanning a number of decades and from extensive listening and engagement with artists who have evolved through their experiences in these spaces. We describe particular insights gained as acoustics designers of the National Forum of Music concert hall in Wroclaw through our engagement from early strategic planning through initial operations relating to subjective and artistic preferences for set-up in performance across a varied repertoire. From a perspective spanning historical examples of coupled volume acoustics, through a consideration of auditorium design in recent history, we consider the place of coupled volume design in future.

10:35–10:50 Break

Contributed Papers

10:50

3aAA5. Simulation of coupled volume acoustics with coupled volume scattering delay network models. Timuçin B. Atalay (Modelling and Simulation, Middle East Tech. Univ., Orta Doğu Teknik Üniversitesi, Üniversiteler Mahallesi, Dumlupınar Bulvarı No. 1 06800 Çankaya Ankara/Türkïye, Ankara 06800, Turkey, timucinberk@gmail.com), Zühre Sü Gül (Bilkent Univ., Ankara, Turkey), Enzo De Sena (Univ. of Surrey, Guildford, United Kingdom), Zoran Cvetkovic (King's College London, London, United Kingdom), and Hüseyin Hacıhabiboğlu (Modelling and Simulation, Middle East Tech. Univ., Ankara, Turkey)

Simulation of the acoustics of coupled rooms is an important problem not only in architectural acoustics but also in immersive audio applications that require acoustic simulation at interactive rates. Requirements for such applications are less demanding for accuracy but more demanding for computational cost. Scattering delay network (SDN) is a real-time, interactive room acoustics simulator for cuboid rooms. SDN affords an exact simulation of first-order early reflections, a gracefully degrading simulation of second and higher-order specular reflections and an accurate simulation of the statistical properties of the late reverberation. We propose coupled-volume SDN (CV-SDN) as an extension of the SDN model to simulate acoustics of coupled volumes. The proposed model retains the desirable characteristics of the original SDN model while allowing the simulation of double-slope decays with direct control over the simulated aperture size. The double-slope characteristics of room impulse responses simulated with CV-SDN agree well with those of measured impulse responses from a scale model and state-of-the-art room acoustics simulation software.

11:05

3aAA6. Electronic Architecture solves acoustical problems with coupled volumes that cannot be easily remedied using architectural treatments. Steve Barbar (E-coustic Systems, 30 Dunbarton Rd., Belmont, MA 02478, steve@lares-lexicon.com)

There are a multitude of venues throughout the world supporting music and performing arts with architecture that incorporates coupled volumes. It may be a large balcony—or seating under a large balcony—loge or under loge seating, box seats, or opera boxes. One of the most common coupled volumes in such venues is the performance stage. When that stage is outdoors, another set of challenges arises. In worship spaces, this can be a "platform" for musicians with a choir loft, or a chancel with choir and organ, or a bimah. For many years, we have been successfully employing Electronic Architecture to solve acoustical problems that are all but impossible to resolve with architectural treatments alone. In this presentation, we will describe solutions implemented in several venues that substantially improve the listening experience.

11:20

3aAA7. On the acoustics of coupled volumes in the safavid architecture—Comparison of computer-modeled objective parameters of two historic buildings. Nima Farzaneh (Architecture, Rensselaer Polytechnic Inst., 1520 6th Ave., Apt. 407, Troy, NY 12180, farzan@rpi.edu) and Jonas Braasch (School of Architecture, Rensselaer Polytechnic Inst., Troy, NY)

One of the typical architectural prototypes in the Safavid era is the utilization of nested rooms for creating assembly spaces with spatial connectivity. Varied in geometry and size, each volume contributes differently to the acoustical environment. Shah Mosque prayer hall and Ali Qapu Palace music room are the two rooms that employ this organization system in their planning. Various simulations have been performed on 3D models of these architectural entities to study the mechanism of sound energy exchange and the impact of each volume on the perceived acoustic characteristics. The objective parameters were collected for both rooms and compared in various configurations to understand each cluster of space's impact on the overall acoustic experience. Furthermore, materials' properties, proportions, and architectural features are discussed as contributing factors to the sonic landscape. The result shows that the sound energy decay behaves differently mainly due to the two rooms' differences in scale and sound absorptive properties. The comparative analysis verifies some of the previous research on coupled volumes in which these two precedents exhibit a similar non-exponential sound energy decay.

11:35–12:00 Discussion

Session 3aBA

Biomedical Acoustics: Therapeutic Ultrasound

Himanshu Shekhar, Chair
Indian Inst. of Technology, Gandhinagar Campus, Gandhinagar 382355

Chair's Introduction—9:30

Contributed Papers

9:35

3aBA1. Array-based focusing of therapeutic ultrasound to the spinal canal. Meaghan A. O'Reilly, Rui Xu, and David Martin (Sunnybrook Research Inst., Toronto, ON, Canada)

The development of clinical-scale technology for non-invasively focusing to the spinal cord has the potential to enable the translation of novel treatments, such as enhanced drug delivery via ultrasound modification of the blood-spinal cord barrier. This talk will present recent simulation and experimental results evaluating array-based focusing to the human spinal canal with non-invasive aberration correction.

9:40

3aBA2. Acoustic holograms for thalamic focusing through the temporal-bone window. Diana Andrés (Universitat Politècnica de València, Spain, Valencia, diaanbau@upv.es), Noé Jiménez, and Francisco Camarena (Universitat Politècnica de València, Spain, Valencia)

In this work, we numerically investigate the performance of acoustic holograms created using k-space simulations and a phase-conjugation method at 650 kHz to simultaneously target both thalami through the temporal bone window compared to a curved transducer. Furthermore, we calculate how a misalignment of the acoustic hologram and the skull could affect the resulting acoustic image in terms of focus pressure and treated volume. Our results show that transtemporal acoustic holograms are a robust method to improve focus quality and to enhance sonicated volumes on target deep-brain even under small misallocations of the therapeutic ultrasound device that can be used for highly selective and low-cost blood-brain barrier opening and neuromodulation applications.

9:45

3aBA3. Engulfed targeted microbubbles: Sonoporation from within the endothelial cell. Klazina Kooiman (Dept. of Biomedical Eng., Thoraxcenter, Erasmus MC Univ. Medical Center Rotterdam, Rotterdam, the Netherlands, k.kooiman@erasmusmc.nl), Inés Beekers, Simone A.G. Langeveld, Bram Meijlink 1, Antonius F. W. van der Steen, Nico de Jong (Dept. of Biomedical Eng., Thoraxcenter, Erasmus MC Univ. Medical Center Rotterdam, Rotterdam, the Netherlands), and Martin D. Verweij (Dept. of Imaging Physics, Delft Univ. of Technol., Delft, the Netherlands)

Targeted microbubbles are currently regarded as objects attached to the outside of the endothelial cell membrane; nonetheless our study shows that microbubbles targeted to the angiogenic biomarker $\alpha v\beta 3$ were fully engulfed by the human umbilical vein endothelial cells, while those targeted to the endothelial biomarker CD31 varied from partially to fully engulfed and non-targeted and IgG1? control-targeted microbubbles were not engulfed at all. The engulfed microbubbles had lower excursion amplitudes than non-engulfed microbubbles and the sonoporation threshold was lower for the engulfed $\alpha v\beta 3$-targeted microbubbles than for all other microbubble types investigated, suggesting they can augment the receptiveness to sonoporation from within the cell.

9:50

3aBA4. Multi-cavity PLGA particles as a theranostic agent. James Kwan (Univ. of Oxford, Oxford, UK, james.kwan@eng.ox.ac.uk), Xiaoqian Su, Moumita Rakshit, Prativa Das, Ipshita Gupta, Dhiman Das, Manojit Pramanik, and Kee Woei Ng (NTU, Singapore)

We have developed drug-loaded multi-cavity PLGA microparticles that act as both a cavitation nuclei and drug vehicle. Our work shows that these particle can be embedded into a tissue model, release a drug to reduce inflammation in a 3D cell culture model, and be imaged with B-mode ultrasound.

9:55–10:10 Discussion

10:10

3aBA5. Oxygen scavenging using acoustic droplet vaporization while altering droplet diameter and droplet concentration. Rachel P. Benton (Dept. of Internal Medicine/Univ. of Cincinnati, Cincinnati, OH, bentonrp@mail.uc.edu), Abby Clark, and Manaswini Nedunuri (University of Cincinnati, Cincinnati, OH)

Transiently reducing the bioavailability of oxygen within an ischemic heart at the time of reperfusion may reduce the formation of reactive oxygen species and therefore reduce the amount of cell death. In vitro studies describe how the magnitude of oxygen scavenging changes as perfluorocarbon droplet diameter and droplet concentration are varied under ultrasonic exposure from an EkoSonic intravascular catheter.

10:15

3aBA6. Self-demodulation revisited: Effect of nonlinear propagation on stable cavitation from ultrasound contrast agents. Vagisha (Electrical Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, Gujarat, India, vagisha.18110179@iitgn.ac.in), Kenneth Bader (Dept. of Radiology, Univ. of Chicago, Chicago, IL), and Himanshu Shekhar (Discipline of Electrical Eng., Indian Inst. of Technology Gandhinagar, Gandhinagar, Gujarat, India)

Stable cavitation from microbubbles is important for both ultrasound-mediated therapy and contrast-enhanced imaging. Here, we extend the findings of prior studies, which indicate that the self-demodulation of the excitation pulse caused by nonlinear propagation can enhance stable cavitation.

10:20

3aBA7. Acoustic characterization and stability assessment of size-isolated protein-shelled microbubbles. Boyapati Suresh (Electrical Eng., Indian Inst. of Technology Gandhinagar, Gandhinagar, Gujarat, India, suresh_boyapati@iitgn.ac.in), Aaqib Khan (Chemical Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, India), Dipesh Shah (Biological Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, India), Sameer V. Dalvi (Chemical Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, India), and Himanshu Shekhar Shah (Electrical Eng., Indian Inst. of Technol. Gandhinagar, Gandhinagar, India)

The side size distribution of ultrasound contrast agents has a strong effect on their performance in therapy and imaging. In this work, attenuation spectroscopy was performed to characterize the acoustic response and stability of three size-isolated populations of protein-shelled microbubbles with mean diameters ranging from 1.66 to 3.77 μm.

10:25

3aBA8. Focused ultrasound mediated intranasal delivery. Dezhuang Ye (St. Louis, dezhuang.ye@wustl.edu)

This presentation will introduce that focused ultrasound combined with intranasal delivery can achieve locally enhanced delivery of anti-programmed cell death-ligand 1 antibody to an intracranial murine glioma model.

10:30–10:45 Discussion

10:45 Break

11:00

3aBA9. The role of U.S. thermal stress in modulating the vascular transport dynamics in the brain tumors. Costas Arvanitis (Georgia Inst. of Technol., Atlanta, GA, costas.arvanitis@gatech.edu), Chulyong Kim, Yutong Guo, and Anastasia Velalopoulou (Georgia Inst. of Technol., Atlanta, GA)

We hypothesized that localized thermal stress could change the cerebrovascular transport dynamics in the brain tumor micro-environment. Our findings, using a closed-loop trans-cranial MR guided FUS system, support our hypothesis and provide evidence that spatially controlled thermal stress can enable the development of therapeutic strategies to reduce systemic toxicity while attaining high drug accumulation to the tumor core.

11:05

3aBA10. Metabolic shock wave after acoustically-mediated blood-brain barrier opening: Investigations of CSF and serum metabolomes. Antoine Presset (Tours Cedex, antoine.presset@univ-tours.fr), Sylvie Bodart, Antoine Lefevre, Anaïs Millet, Edward Oujagir, Ayache Bouakaz, Patrick Emond, Jean-Michel Escoffre, and Lydie Nadal-Desbarats

In this study, rats' right striata were exposed to microbubble-assisted ultrasound in order to open the BBB. This work aimed to investigate the metabolic consequences of this process on rat's serum and cerebrospinal fluid using the 1H-NMR spectroscopy study. The biochemical analysis of CSF and serum metabolomes indicated significant changes in several metabolic pathways related to alternative sources of cellular energetic metabolism, immediately and up to 48 h after the BBB opening. These findings could highlight the implication of hypoxia-associated processes into the BBB opening or the modulation of neurotransmission.

11:10

3aBA11. Real-time cavitation control and monitoring for focused ultrasound blood-brain barrier opening via dB-based subject calibrated feedback controller. Chih-Yen Chien (Washington Univ., St. Louis, MO, c.chien@wustl.edu)

With proposed the dB-based subject calibrated feedback controller, we can achieve different levels of blood-brain barrier opening by adjusting the desired dB level.

11:15

3aBA12. Histotripsy combined with catheter-directed thrombolytics for clot disintegration *in vitro*. Samuel A. Hendley (Univ. of Chicago, Chicago, IL, hendley@uchicago.edu), Aarushi Bhargava, Jonathan D. Paul, and Kenneth B. Bader (Univ. of Chicago, Chicago, IL)

Histotripsy is a focused ultrasound therapy under development as an adjuvant to lytic therapy for the treatment of deep vein thrombosis. In this study, we investigate the mechanisms of clot disintegration (e.g., hemolysis and thrombolysis) under the action of histotripsy and catheter-directed thrombolytics, and demonstrate that this combination significantly reduces the threshold lytic dose required for effective thrombolysis.

11:20–11:35 Discussion

11:35

3aBA13. The influence of echogenic liposome bubble nuclei on histotripsy cavitation dynamics. Aarushi Bhargava (Univ. of Chicago, Chicago, IL, aarushib@uchicago.edu), Shaoling Huang, David D. McPherson (Univ. of Texas Health Science Center-Houston, Houston, TX), and Kenneth B. Bader (Univ. of Chicago, Chicago, IL)

Histotripsy is a focused ultrasound therapy under development for thrombus ablation through bubble cloud nucleation, and combining it with a thrombolytic-loaded theragnostic agent will expand its treatment capacity. In this study, echogenic liposomes encapsulating a lytic were exposed to histotripsy pulses, and the resulting bubble dynamics were examined with passive and active imaging.

11:40

3aBA14. Sonothermogenetics for noninvasive and cell-type specific deep brain neuromodulation. Yaoheng Yang (Washington Univ., St. Louis, MO, mack.yang@wustl.edu), Christopher Pham Pacia, Dezhuang Ye, Lifei Zhu, Hongchae Baek, Yimei Yue, Jinyun Yuan, Mark J. Miller (School of Medicine,Washington Univ., St. Louis, MO), Jianmin Cui, Joseph P. Culver (Washington Univ., St. Louis, MO), Michael R. Bruchas (Univ.of Washington, Seattle, WA), and Hong Chen (Washington Univ., St. Louis, MO)

This study aimed to develop sonothermogenetics for noninvasive, deep-penetrating, and cell-type-specific neuromodulation by combining a thermosensitive ion channel TRPV1 with focused ultrasound (FUS)-induced brief, non-noxious thermal effect. Sonothermogenetics is a noninvasive and cell-typespecific neuromodulation approach with the capability to target the deep brain.

11:45

3aBA15. Static magnetic fields dampen focused ultrasound-mediated blood-brain barrier opening. Yaoheng Yang (Washington Univ., St. Louis, MO, mack.yang@wustl.edu), Christopher Pham Pacia (Washington Univ., St. Louis, MO), Dezhuang Ye (Dept. of Mechanical Eng. and Material Science, Washington Univ., St. Louis, MO), Yimei Yue, Chih-Yen Chien, and Hong Chen (Washington Univ., St. Louis, MO)

The static magnetic field of an MRI scanner was found to dampen the microbubble cavitation activity and decrease the focused ultrasound-combined with microbubble-mediated blood-brain barrier opening.

11:50

3aBA16. Bovine tendon atomization. Molly Smallcomb (The Pennsylvania State Univ., University Park, PA, molly.smallcomb@gmail.com) and Julianna C. Simon (The Pennsylvania State Univ., University Park, PA, USA)

Thus far, histotripsy has not successfully fractionated tendon tissues, possibly due to bubbles being of insufficient size to create a pressure-release interface. In this study, a planar tissue-air interface was treated with histotripsy to create a micro-fountain and atomization; particulates ejected from the tendon sample were collected and analyzed histologically to determine whether tissue fractionation was achieved. [Work supported by NSF GRFP DGE1255832 and NIH NIBIB EB027886.]

11:55–12:10 Discussion

12:10

3aBA17. Histotripsy bubble dynamics in an anisotropic tissue-mimicking phantom. Jacob C. Elliott (The Pennsylvania State Univ., State College, PA, jce29@psu.edu), Julianna Simon, and Andrea Arguelles (The Pennsylvania State Univ., State College, PA)

Collagenous, anisotropic tissue such as tendon has proven resistant to fractionation by histotripsy, prompting the need to better understand and quantify bubble dynamics in anisotropic tissue. The elastic moduli in each axial direction were measured for collagen, fibrin, and polyacrylamide hydrogels prior to applying histotripsy; high-speed photography and cavitation emission data were used to evaluate bubble size and collapse strength. [Work supported by NIH R21EB027886.]

12:15

3aBA18. Bubble-enhanced HIFU. Michalakis A. Averkiou (Univ. of Washington, Seattle, WA, maverk@uw.edu), Eric Juang, and Alicia Clark (Univ. of Washington, Seattle, WA)

The addition of contrast agent microbubbles during HIFU can increase the temperature dramatically compared to conventional HIFU. Higher microbubble concentrations enhance this phenomenon but they also cause acoustic shadowing along the path of the HIFU beam and thus local injections are preferred over systemic delivery.

12:20–12:30 Discussion

THURSDAY MORNING, 10 JUNE 2021 — 9:30 A.M. TO 11:15 A.M.

Session 3aEA

Engineering Acoustics: Back to the Future: Historical Perspectives and Current Engineering Topics

Michael R. Haberman, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758

Roger Richards, Cochair
169 Payer Lane, Mystic, CT 06355

Chair's Introduction—9:30

Invited Paper

9:35

3aEA1. Predator and prey: The origin of antisubmarine warfare. Roy Manstan (NUWC (Retired), 30 Hedlund Rd., East Haddam, CT 06423, roymanstan@toast.net)

The month America entered The War [That Did Not] End All Wars, in April 1917, Germany's relentless U-boat predators hunted their prey throughout the Mediterranean and Atlantic, sending 400 ships to the bottom. During those 30 days, hundreds more were damaged and put out of commission. Soon after his arrival in England, Admiral Sims, Commander of U.S. Naval Forces in Europe, sent a warning to the Secretary of the Navy that with the "appalling destruction" by U-boats, the "unconditional surrender of the British Empire would inevitably take places…." After a three year stalemate along the Western Front, Germany was becoming dependent on the *Unterseeboot*, declaring: "[T]here is no possibility of bringing the war to a satisfactory end without ruthless U-boat warfare." Briefly reaching back to 1776 when David Bushnell's submersible vessel *Turtle* attempted to sink a British man-of-war, this presentation will focus on the emergence of submarine and antisubmarine technologies at the beginning of the 20th century. The U-boat solution would come from a cadre of scientists and engineers at the Naval Experimental Station in New London, CT, adapting the hydrophone to exploit a submarine's vulnerability: they were extremely noisy. The predator now became the prey.

Contributed Papers

9:50

3aEA2. Evolution of some newer flextensional transducer designs. John Butler (Image Acoust., Inc., Quincy, MA) and Victoria Curtis (Image Acoust., Inc., 40 Willard St., Ste. 201, Quincy, MA 02169, vcurtis@imageacoustics.com)

Flextensional transducers, such as the classic oval Class IV, have provided a means for magnified high output at low frequencies from a small size, when compared with Tonpilz piston transducers. We present here a transition to other newer flextensional types and shapes, such as the cylindrical Trioid and LCAT transducers and the piston cantilever mode transducer, CMX. We will show that these transitions came about after a flextensional X-spring design was realized. Although the X-spring was originally conceived to increase the output and also lower the resonance frequency of Tonpilz piston transducers, it also turned out to provide a significant means for the development of newer flextensional transducer designs. Examples of these newer designs and their operation, as well as an initially unexpected improved lower frequency performance from an array of CMX transducers, will be presented. [Work supported in part by Office of Naval Research.]

10:05

3aEA3. Nonlinear thermoacoustic instability investigation on ammonia-hydrogen combustion in a longitudinal combustor with double-ring inlets. Dan Zhao (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand), Siliang Ni (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand, siliang.ni@pg.canterbury.ac.nz), and Di Guan (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand)

The greenhouse effect induced by the combustion of hydrocarbon fuel is an urgent environmental problem. Ammonia gas, as a renewable energy with a high proportion of hydrogen content, can achieve zero CO_2 emission. In order to ignite ammonia and obtain continual flame, a partial premix entry condition of $NH_3/H_2/O_2$ with double-ring inlets is adopted. The *RNG* k-ε model and EDC model are used to analyse the self-excited oscillation and the total heat release. After the numerical results and experimental data are validated, the following aspects are investigated: (1) total mass flow rate; (2) mass fraction of hydrogen; (3) mass flow ratio of inlets; and (4) the temperature of the heat exchanger. The results are compared with the traditional single-ring structure under the same condition. It is found that the exothermic heat of double-ring structure increases by 98.7% on average. The frequency of intermittent oscillation increases with the decrease in HN_3 proportion. When pure hydrogen is passed through the outer ring, the combustion limit can be greatly expanded even if the inlet mass fraction of hydrogen is very small. This study contributes to provide an alternative method to enhance ammonia combustion and improve its flammability limit.

10:20

3aEA4. On a high-speed hearing measurement considering the age of both ears. Seong-Geon Bae (IT, KangNam Univ., YongIn, Kyunggido 16979, South Korea, sgbae@ssu.ac.kr) and Myungjin Bae (Commun. Eng., Soongsil Univ., Seoul, South Korea)

In order to enrich the human senses, care must be taken not to damage your hearing. Hearing damage suffered in a living environment is difficult to find out because there are few initial symptoms. Existing pure tone hearing test detects whether pure tones are heard well for each frequency for 250–8000 Hz sound, which is mainly used in everyday conversation, but it is inaccurate and takes a long time. Therefore, in this paper, we proposed a high-speed measurement method that can easily and quickly self-measure both ears' hearing damage through an APP of a smart-phone. In this method, nine pure tones that are age-compensated for each voice sub-band are alternately heard in both ears, thereby self-identifying their own hearing damage at high speed. When 18 tone pulses were heard for 27 s per person, 1 out of 12 subjects was identified as suspected of partial hearing damage. When the test subjects were informed of the hearing determination method for the number of hearings, the participants themselves immediately determined whether their hearing was damaged. Eventually, both ears' hearing damage was easily and accurately measured by the method proposed, which took more than 10 min with the existing manual method. As a result, it is possible to maintain a healthy life by simply determining whether or not there is a hearing loss.

10:35

3aEA5. A study on the conversion of rhythmic Klaxon sound with an instant touch. Myung-Sook Kim (Commun. Eng., Soongsil Univ., 369 Sangdo-ro, Dongjak-gu, Seoul, South Korea, kimm@ssu.ac.kr) and Myungjin Bae (Commun. Eng., Soongsil Univ., Seoul, South Korea)

With more and more cars and more complex road conditions, Klaxon sound is more often used in driving cars. Retaliation psychological driving caused by this sound is causing serious social problems. Therefore, a new rhythmic Klaxon sound is needed to prevent psychological stress and retaliation from being triggered. If rhythm or tempo is given to the existing Klaxon sound, it can relieve the other driver's retaliatory psychology or the pedestrian's surprise. However, since the existing Klaxon sound has been used for more than a hundred years, a new method to switch to the rhythmic Klaxon is proposed depending on whether the handle is touched instantly. This paper proposes a line controller that converts the Klaxon switch of the handle to a rhythmic Klaxon sound when an instant ON-OFF touch occurs within 0.2 s. Existing Klaxon's retaliatory psychology appeared as a delta wave and beta wave, respectively, in EEG, and the degree of surprise was obtained differently according to the listening distance and sound level. The noise level felt when performing the object test was −15 dB lower in the rhythmic Klaxon sound than before. The MOS-test result of the listener group (100 people)'s preference for rhythm Klaxon sound was 4.3 or higher. In conclusion, if you are using the existing Klaxon sound and then touch the handle momentarily and keep turning ON, the rhythm sound that awakens a great awareness even with a low-level horn sound can be used immediately.

10:50–11:15 Discussion

Session 3aMU

Musical Acoustics: Focus on Student and Early Career Researchers

Andrew A. Piacsek, Cochair
Dept. of Physics, Central Washington University, 400 E. University Way, Ellensburg, WA 98926-7422

Kurt R. Hoffman, Cochair
Physics, Whitman College, 345 Boyer Ave., Hall of Science, Walla Walla, WA 99362

Chair's Introduction—11:00

Contributed Papers

11:05

3aMU1. Analysis and perception of a viscoelastic, frequency-dependent Finite-Difference Time Domain damping model of a drum. Theresa Pauli (Inst. of Systematic Musicology, Univ. of Hamburg, Espenreihe 11b, Hamburg 22589, Germany, theresakjeks.pauli@gmail.com) and Rolf Bader (Inst. of Systematic Musicology, Univ. of Hamburg, Hamburg, Germany)

This study investigates the influence of viscoelastic damping parameters in a Viscoelastic Finite Difference Time Domain (FDTD) model on the sound of a drum head. Due to the strong nonlinearity between the complex, frequency-dependent Young's modulus as a model input parameter and resulting damping frequencies and damping strength, this relation can no longer be analyzed analytically. One reference and eight altered membranes are constructed. Integrating the sound into minor third bands, nonlinear mode couplings due to viscoelasticity are found, relating to the real part of the Young's modulus as well as to the Laplace-Transform parameter of the FDTD model. Furthermore, the perception of the sounds was investigated. The results are compared to the physical observation, showing variations in brightness and pitch. Hereby, the perception can be described as proportional to the physical analysis, as long as the variation of the Laplace parameter in one or more damped frequencies does not lead to a huge difference in the sounds decay time, which seems to distract the attention from other acoustical characteristics.

11:20

3aMU2. The impact of temperature and humidity variations on the resulting frequencies of metal flue pipes in pipe-organs: An analytical model. Piergiovanni Domenighini (Engineer/Ciriaf, Univ. of Perugia, Via Goffredo Duranti, 67, Perugia 06125, Italy, domenighinip@yahoo.com)

Pipe organs are probably the biggest existing instruments. Apart from *positive organs* that wheels can move, pipe organs remain in the same place where they have been installed and become parts of the buildings architecture that host them. Churches are the main venues for these instruments due to their important role in the liturgy. Unfortunately, these buildings, usually characterized by huge volumes, are hardly air-conditioned except during events, and temperature and humidity variations affect the pipes' sound. An analytical model has been developed for metal flue pipes to analyse the entity of the emitted-frequency variations. Temperature and humidity affect the dimensions of the pipe as well as air density and sound's velocity. The model involved plane wave mode and air-jet analysis dynamics depending on the temperature and humidity of the flowed air. Thermo-viscous effect of air flowing into the pipe is also considered. Results have been compared to the spectral analysis of a metal flue pipe of an existing pipe organ located inside a church. Conclusions gather the differences between the results and explain the open opportunities for this research.

11:35

3aMU3. Improved steelpan pitch detection through audio feature extraction and machine learning. Colin Malloy (Music, Univ. of Victoria, 3330 Richmond Rd., Victoria, BC V8P 4P1, Canada, malloyc@uvic.ca)

The steelpan, a significant musical instrument invented in the mid-20th century, is a harmonically complex system making fundamental pitch detection a difficult task. Initial experiments using state-of-the-art pitch detection algorithms have shown significant difficulties in detecting the pitch of individual steelpan notes. This paper presents a method of improved pitch detection accuracy by combining music information retrieval techniques with machine learning algorithms. An audio sample set consisting of thousands of steelpan notes from ten different tenor steelpans is used to quantitatively evaluate the proposed methodology. Low-level audio features are extracted from the audio samples and used to train a machine learning algorithm which identifies the salient features for pitch estimation. This method's performance is measured against the current state-of-the-art pitch detection methods, pYIN (a probabilistic autocorrelation method) and CRéPE (a convolutional neural network-based method), showing improved performance at steelpan pitch detection. The machine learning model developed for this paper using this methodology is focused on the tenor steelpan but is intended to lead to a more generalized model for pitch detection of all types of steelpans.

11:50–12:30 Discussion

Session 3aNS

Noise and Psychological and Physiological Acoustics: Non-Occupational Noise and Hearing Loss I

William J. Murphy, Cochair
Division of Field Studies and Engineering, Noise and Bioacoustics Team, National Institute for Occupational Safety and Health, 1090 Tusculum Ave., M.S. C-27, Cincinnati, OH 45226-1998

Bonnie Schnitta, Cochair
SoundSense, Wainscott, NY

Chair's Introduction—9:30

Invited Papers

9:35

3aNS1. Reducing hearing loss through safe listening: An initiative of the World Health Organization. Shelly Chadha (WHO Programme for Ear and Hearing Care Sensory Functions, Disability and Rehabilitation, World Health Organization, Ave. Appia 20, Schweiz, Geneva 1202, Switzerland, chadhas@who.int)

Globally, over one billion people are estimated to be at risk of hearing loss due to the common practice of listening to loud sounds in recreational settings. Given the current situation and projected rise in need for hearing care over the coming decades, prevention of hearing loss has become an urgent public health need. To address this, WHO, in 2015, launched the Make Listening Safe initiative. Focused on adolescents and young adults, this aims at raising awareness among this group about the need for and the means of safe listening. At the same time, it works to influence societal and political change so as to facilitate the practice of safe listening. Toward this end, WHO is working to ensure that personal devices such as smartphones and MP3 players include safe listening features and that entertainment venues can create a safe listening environment. Through this talk, WHO will share information of its evidence-based recommendations for safe listening, as well as efforts to promote their implementation.

9:50

3aNS2. Preventing noise induced hearing loss: Issues and challenges facing musicians. Kris Chesky (College of Music, Univ. of North Texas, 210 Wellington Oaks Ct, Denton, TX 76210, kris.chesky@unt.edu)

National and state education standards now require collegiate and public school music programs to address concerns for noise induced hearing loss related to consuming, learning, and performing music. The expected outcomes include ensuring awareness, knowledge, and self-efficacy for managing music-related exposures and activities. Based on extensive efforts to implement these standards in a large College of Music and across an independent school district that includes numerous middle and high school choir, orchestra, and band programs, this session will provide insight into the various challanges and opportunities related to positively influencing cultural norms and traditions within the music discipline.

10:05

3aNS3. Effect of the reduction in passengers on excessive subway noise in NYCT stations. Patrick Murray (SoundSense, 535 Fifth Ave., Fl 16, New York, NY 10017, patrick@soundsense.com) and Bonnie Schnitta (SoundSense, Wainscott, NY)

An examination is made on the reduced number of passengers riding the NYCT subway and its effect on the average reverberation time within the subway stations. Excessive reverberation times can have the effect of compounding the noise from train operation, including breaking and other noises. Approximations are made of the reverberation time at selected subway platforms and how those have changed during the COVID-19 pandemic. Approximations are made of the potential hearing impacts on the remaining subway commuters and staff.

10:20

3aNS4. Protecting sleep from noise in the built environment. Jo M. Solet (Div. of Sleep Medicine, Harvard Med. School, 15 Berkeley St., Cambridge, MA 02138, joanne_solet@hms.harvard.edu)

Recognition is growing over the need to protect patrons from hearing damage caused by high sound levels in stadiums and concert halls. In parallel, attention must be drawn to the health and safety impacts of lower level sound exposures, which may produce resident sleep loss in built environments: homes, dormitories, hotels, and care facilities. Many localities have ordinances that define day and night sound level maximums as measured at property lines. These ordinances apply to noise nuisance produced on one property and experienced on another. Some are complaint-driven; these do not apply in advance during the review process for acquiring building permits. Those living in poorly built, multiple occupancy buildings may have substantial exposure to noise intrusions, including those produced within their own building envelope. Sleep disruptive noise intrusions are especially common in crowded, under-resourced

neighborhoods and contribute to health disparities. To protect sleep, noise ordinances and building codes need to be informed by scientific evidence derived from sleep disruption research. Insufficient sleep is known to have multiple negative consequences, including impaired antibody production. Supporting the immune system through sufficient sleep is especially critical during the COVID crisis, for directly fighting infection, as well as for supporting adequate vaccine response.

10:35–10:50 Break

10:50

3aNS5. Creating problems by problem solving: A conversation on how "single problem focus" can ignore or even cascade into undesired, and potentially harmful acoustical issues. Kenneth W. Good (Armstrong World Industries, Inc., 2500 Columbia Ave., Lancaster, PA 17601, kwgoodjr@armstrong.com) and Bonnie Schnitta (SoundSense, LLC, Wainscott, NY)

A significant part of our profession is translation. It is far too easy to provide the exact right answer to the wrong question and the right solutions are often beyond the problem presented. This conversation will discuss cases where misunderstanding or misleading information was followed by folks asking the wrong question. These examples did or could have resulted in unsatisfactory outcomes at best and deadly outcomes at worst.

11:05

3aNS6. Expanding communication of acoustical knowledge around the globe: Examples of outreach and the use of social media. Thais C. Morata (Div. of Field Studies and Eng., NIOSH, 1090 Columbia Tusculum Ave., Cincinnati, OH 45229, tmorata@cdc.gov)

For five decades, the National Institute for Occupational Safety and Health (NIOSH) has studied the effects of noise and disseminated public health information on hearing health. Today, the public expects greater transparency, responsiveness, and accountability, and organizations must respond with authenticity and engagement to maintain the public's confidence. Social media channels have emerged as an effective platform for public health communication. While health communication specialists are integral to framing and delivering appropriate messages, scientists cannot remain disconnected from this process. Subject matter experts are uniquely positioned to leverage these tools to communicate their science directly to the public in a timely manner. This lecture will focus on NIOSH's recent outreach and science communication efforts to reach the general public and include results of the Wiki4 Year Of Sound 2020 effort. This and several other examples are part of collaborative outreach activities with the CDC's National Center for Environmental Health and other governmental agencies, several professional organizations (including the Acoustical Society of America), and the World Health Organization. [The findings and conclusions in this report are those of the author and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention.]

11:20

3aNS7. Non-occupational noise exposure in the United States: A review. Daniel Fink (The Quiet Coalition, P.O. Box 533, Lincoln, MA 01773, djfink01@aol.com)

That occupational noise exposure causes hearing loss has long been known, but non-occupational noise exposure was generally not recognized as causing hearing loss until the 1960s. Audiometric evaluation of populations not exposed to occupational noise was used to establish normal hearing baselines for workers compensation purposes. Audiometery in these groups, and in isolated populations not exposed to loud noise, suggested that hearing was preserved without noise exposure. The word sociocusis was used to describe non-occupational hearing loss. There are no federal recommendations, guidelines, or standards for non-occupational noise exposure. Perhaps because of a misconception that the 85 A-weighted decibel recommended occupational noise exposure limit is safe for the public without time limit, everyday noise exposure appears to have increased. Noise-induced hearing loss (NIHL) has become a major public health problem in the U.S., with approximately 20% of adolescents age 12–19 and 25% of adults age 20–69 having NIHL Common sources of non-occupational noise exposure include transportation noise, music and entertainment including personal listening devices, restaurant noise, kitchen appliances and power tools, hobbies, and sports. Efforts to reduce non-occupational noise exposure must include public education and the promulgation and enforcement of standards for non-occupational noise exposure.

Contributed Papers

11:35

3aNS8. Personal audio system use can harm auditory health. Jan L. Mayes (none, 323 67A St., Delta, BC V4L 2B8, Canada, author@janlmayes.com) and Daniel Fink (The Quiet Coalition, Lincoln, MA)

Personal audio systems (PAS) are a major source of harmful noise doses, especially for children, teenagers, and young adults, who typically listen many hours daily at volumes exceeding the globally recommended public health limit of 70 dBA L_{EQ24h}. PAS users increase listening volume to overcome high ambient noise. Research shows that (1) PAS use among people aged 9 + is associated with permanent, progressive hearing health disabilities including tinnitus, hyperacusis, speech communication impairments, and noise-induced hearing loss (NIHL); i(2) auditory health risk is highest for personal listening 1 + hours daily at over 50% volume with 5 + years of exposure; (3) clinical measures demonstrate noise-induced neural or retrocochlear auditory processing disorders precede sensory or cochlear impairments; and (4) children are highest risk because auditory system maturation is incomplete and normal hearing health is vital for learning, socialization, and vocational potential. Acquired hearing loss is associated with increased risk of accidents, communication difficulties, social isolation, and health impairments, including dementia in later life. Public health hearing conservation policies are needed to prevent an imminent NIHL epidemic in younger generations, including PAS noise emission standards and public education on the dangers of PAS use and about safer listening behaviors.

11:50–12:20 Discussion

Session 3aPA

Physical Acoustics and Engineering Acoustics: Acoustical Methods and Sensors for Challenging Environments I

Cristian Pantea, Cochair
Materials Physics and Applications, Los Alamos National Lab., MPA-11, Los Alamos, NM 87547

Dipen N. Sinha, Cochair
Los Alamos National Lab., 112 Shirlane Place, Los Alamos, NM 87544

Chair's Introduction—9:30

Invited Papers

9:35

3aPA1. Determining the full elastic tensor using resonant ultrasound spectroscopy in extreme environments. Boris Maiorov (National High Magnetic Field Lab., Los Alamos National Lab., M.S. E536, Los Alamos, NM 87545, maiorov@lanl.gov)

Elastic moduli are fundamental thermodynamic susceptibilities that connect directly to thermodynamics, electronic structure and mechanic properties. Thus, determining the changes of elastic moduli as a function of time and temperature is a powerful tool to study a variety of phenomena. The Resonant Ultrasound Spectroscopy (RUS) technique is based on the measurement of mechanical resonance frequencies that can be made with extreme precision and used to compute the elastic moduli without corrections. In this talk, I will give show several examples of the use of RUS in different systems, ranging from magnetic phase transition, determining very small degrees of elastic anisotropy in metals as well as changes in time product of radioactive decay. I will discuss the latest advances made at Los Alamos on measuring and determination of elastic constants. This allow to track the resonance position with high precision, obtaining moduli with an absolute precision of 0.5% and relative changes smaller than part per 10 million.

9:50

3aPA2. Integrating ultrasound directed self-assembly and additive manufacturing to fabricate engineered materials. Bart Raeymaekers (Univ. of Utah, 1495 E 100 S RM 1550, Salt Lake City, UT 84112, bart.raeymaekers@utah.edu)

Engineered materials comprising specifically designed patterns of particles embedded in a matrix material can display exotic physical properties when interacting with an external field, such as metamaterials (electromagnetic wave field) and structural materials (force field), to only name a few. Altering the pattern of particles that constitutes the microstructure of the engineered material enables tuning its properties. We describe a fabrication process to implement macroscale engineered materials layer-by-layer using additive manufacturing, where in each layer we organize a user-specified pattern of particles using ultrasound directed self-assembly to tailor the microstructure of the material. In contrast with previous demonstrations of fabricating engineered materials that are limited to laboratory-scale and/or 2D implementations, this process enables fabricating macroscale specimens with complex 3D geometry required for engineering applications. Hence, this platform technology has significant implications for fabricating engineered materials relevant to a wide range of applications including manufacturing of composite materials, engineered materials for acoustic and electromagnetic cloaking and sub-wavelength imaging, and 3D printing structures with embedded electrical wiring, among others.

10:05

3aPA3. Material properties at extreme pressures and temperatures using ultrasound. Blake Sturtevant (Shock & Detonation Phys., Los Alamos National Lab., M.S. P952, Los Alamos, NM 87545, bsturtev@lanl.gov), Eric Moss, Nenad Velisavljevic (Shock & Detonation Phys., Los Alamos National Lab., Los Alamos, NM), Rostislav Hrubiak, Curtis Kenney-Benson, and Yoshio Kono (High Pressure Collaborative Access Team, Argonne National Lab., Lemont, IL)

Accurate knowledge of material properties at extreme pressures and temperatures is very valuable in the fields of planetary science and condensed matter physics, as well as in mechanical and structural engineering applications. Sound speeds and elastic moduli are particularly important properties since they can be used to refine equation of state and strength models. One way to determine the temperature and pressure dependence of sound speeds and elastic moduli is to use the ultrasonic pulse-echo technique on a sample compressed in a hydraulic press, often *in situ* at a synchrotron X-ray source. X-ray radiography is used to determine the physical dimensions of the sample during compression which is needed for sound speed determination. Additionally, X-ray diffraction is used to determine the sample's density, which is used to determine the elastic moduli. This talk will present the technique and some results of such measurements using the Paris-Edinburgh hydraulic press at the High Pressure Collaborative Access Team (HPCAT) sector of the Advanced Photon Source.

10:20

3aPA4. Engineering the electromechanical response of piezoelectric transducers: Some challenging applications. Vamshi K. Chillara (Los Alamos National Lab., 3000 Trinity Dr. Apt. 83, Los Alamos, NM 87544, vchillara@lanl.gov)

Piezoelectric transducers are widely used for ultrasonic applications both as actuators to excite and as sensors to receive vibration/wave response. The electromechanical characteristics of the piezoelectric transducers dictate their choice for specific applications. These can be tuned in several ways ranging from modifying the geometry and material properties of the element to changing the excitation electrode pattern and the boundary conditions of the vibrating piezoelectric element. This talk discusses two different ways to achieve such tuning for single-element piezoelectric transducers and their corresponding applications. The first application is to achieve a low-frequency collimated beam using lateral stiffening of a piezoelectric disc vibrating in its radial resonance. The resonance and vibration characteristics of such a disc are presented and the ultrasonic wave propagation from such a laterally stiffened disc in fluids is discussed. The second application uses tailored polarization profiles for piezoelectric elements to enhance/suppress specific resonant modes in an otherwise homogeneous element. The fundamental theory for such behavior is presented and some applications of such polarization-tuned piezoelectric elements are discussed.

Contributed Papers

10:35

3aPA5. Noninvasive acoustic measurements in high explosives using neural networks. John Greenhall (Los Alamos National Lab., P.O. Box 1663, Los Alamos, NM 87545, jgreenhall@lanl.gov) and Cristian Pantea (Mater. Phys. and Applications, Los Alamos National Lab., Los Alamos, NM)

Acoustic measurements serve as a noninvasive means of measuring the temperature or mechanical state of high explosive material without disturbing the material. These measurements work by measuring the time-of-flight of an acoustic burst generated by a transmitter on one side of the material and measured by multiple receivers distributed around the material. In many applications, it is a straightforward process to identify the acoustic burst arrival and use that information to derive information about the material state. For HE materials in metallic containers, however, this process is complicated by interference between the bulk waves propagating through the HE material and guided waves propagating around the circumference of the container walls. We demonstrate the use of neural networks to overcome this limitation. In addition to measurements in HE materials, the neural network technique can provide a means of performing acoustic evaluation in a wide range of materials and in conditions with multi-path acoustic propagation and interference. As a result, the work provides a technique to interpret complex acoustic data and extract useful information about the material state.

10:50–11:05 Break

11:05

3aPA6. *In situ* resonant ultrasound spectroscopy for neutron scattering. James Torres (Mater. Sci. and Technol. Div., Oak Ridge National Lab., P.O. Box 2008, M.S. 6062, Oak Ridge, TN 37831, torresj@ornl.gov), Victor Fanelli (Neutron Scattering Div., Oak Ridge National Lab., Oak Ridge, TN), Yuya Shinohara, Andrew May (Mater. Sci. and Technol. Div., Oak Ridge National Lab., Oak Ridge, TN), Mariano Ruiz-Rodriguez (Neutron Technologies Div., Oak Ridge National Lab., Oak Ridge, TN), and Raphael Hermann (Mater. Sci. and Technol. Div., Oak Ridge National Lab., Oak Ridge, TN)

Resonant ultrasound spectroscopy (RUS) is an efficient nondestructive technique to study the elastic properties of solid materials. In principle, the full elastic tensor can be determined for regularly shaped solids (*e.g.*, sphere, cuboid, cylinder). Here, we report our progress in developing RUS probes for *in situ* neutron scattering at beamlines of the Spallation Neutron Source at Oak Ridge National Laboratory. A low-temperature (2–300 K) probe has been assembled and tested at the NOMAD and SEQUOIA beamlines to assess the probe's neutronics, data acquisition system, and compatibility with the existing sample environment. Our discussion will include how the probe and data acquisition system operate as well as results for two measurements: bulk metallic glass ($La_{65}Cu_{20}Al_{10}Co_5$) and bismuth-antimony ($Bi_{0.89}Sb_{0.11}$ [1]). Assembly of a high-temperature (300–875 K) probe is currently underway and both probes are scheduled to be available to users by late-2021. Our aim is to provide users with live monitoring of an intrinsic variable at the neutron scattering beamlines, in addition to existing controls, to monitor the state of their samples and make informed decisions in real time. The probe developments are accompanied by developments of data acquisition and analysis software. 1. D. Vu *et al.*, arXiv: 1906.02248 [cond-mat.mtrl-sci] (2019).

11:20

3aPA7. A wavelength-dependent radiator for improved non-contact measurements of elastodynamic guided waves. Christopher Hakoda (Mater. Phys. and Applications, Los Alamos National Lab., P.O. Box 1663 M.S. D429, Los Alamos, NM 87545, chakoda@lanl.gov), Cristian Pantea, and Vamshi K. Chillara (Mater. Phys. and Applications, Los Alamos National Lab., Los Alamos, NM)

Air-coupled transducers are great for making non-contact measurements of the acoustic leakage emitted from ultrasonic guided waves that travel within an elastic solid. Often times, however, this measured acoustic leakage has a low signal amplitude which only gets worse the further away you position the air-coupled transducer. To improve the measured signal amplitude, we have designed a simple radiator that more efficiently converts elastodynamic wave energy into acoustic wave energy. The radiator is wavelength-dependent which allows for mode-dependent sensitivity and it can be made out of well-understood, durable materials. The end result of this is that the air-coupled transducer can be positioned further away in a safer environment or the increased signal strength can be used to improve the signal-to-noise ratio in a noisy environment. In this presentation, we will discuss our preliminary radiator design, discuss the various parameters that affect its performance and simulation results that demonstrate its effectiveness when compared to your typical acoustic leakage.

11:35

3aPA8. Correcting microphone response mismatch for improved intensity measurements at infrasonic frequencies. Francisco J. Irarrazabal (Phys. and Astronomy, Brigham Young Univ., 876 E 900 N Apt. 11, Provo, UT 84604, firarrazabal@gmail.com), Kent L. Gee (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT), Scott D. Sommerfeldt, and Mylan R. Cook (Phys. and Astronomy, Brigham Young Univ., Provo, UT)

Sound intensity measurements using multimicrophone probes at infrasonic frequencies are challenging mainly because the mismatch between microphone responses can be larger than the acoustic differences. Correcting microphone response mismatch via relative calibration requires an infrasound source that can provide good signal-to-noise ratios and sufficiently long averaging times. This paper describes the use of a moving vehicle as an infrasound source to obtain the necessary transfer functions between 12.7 mm diameter, type-1 microphones. The calibration approach is validated and an improved infrasound and low-audio range intensity measurement capability is demonstrated using hot-air balloon burners.

11:50

3aPA9. The effect of moisture content on the acoustic characteristic of bioenergy feedstocks—Corn Stover. Hung T. Doan (MPA-11, Los Alamos National Lab., P.O. 1663, Los Alamos, NM 87545, hung@lanl.gov), Christopher Hakoda, John Greenhall, Cristian Pantea, and Troy Semelsberger (MPA-11, Los Alamos National Lab., Los Alamos, NM)

Corn stover is increasingly being used as a bioenergy feedstock. From harvest to handling and storage, its inconsistent moisture content imposes limits on the industry's growth and profitability. We propose an acoustic approach that can detect changes in corn stover moisture content and shows the capability to propagate through corn stover and improve the moisture sensing range and accuracy as compared to currently available technologies. Using air-coupled transducers that operate at 20 kHz and a simple experimental setup, we determine the sound speed in corn stover. Signal analysis using cross-correlation and fast Fourier transform allows the calculation of sound speed and signal amplitude from the A-scan. An inverse relationship between the sound speed and the packing density of corn stover is found. Sound speed and transmission amplitude data enable the determination of corn stover's moisture content between 10i% and 55%. The benefit of this technology also lies in its ability to sense through the center of a packed sample of corn stover at a density above 300 kg/m^3. The improvement promises a decrease in the cost of handling and processing, which will help establish corn stover as an economically-viable bioenergy feedstock.

12:05–12:30 Discussion

THURSDAY MORNING, 10 JUNE 2021 — 9:30 A.M. TO 12:15 P.M.

Session 3aSA

Structural Acoustics and Vibration, Physical Acoustics, Computational Acoustics, and Engineering Acoustics: Capabilities and Limitations of the Computational Analysis of Metamaterials

Anthony L. Bonomo, Cochair
Naval Surface Warfare Ctr., Carderock Div., 9500 MacArthur Blvd, West Bethesda, MD 20817

Benjamin M. Goldsberry, Cochair
Applied Research Lab, The University of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758

Amanda Hanford, Cochair
Penn State Univ., P.O. Box 30, State College, PA 16802

Chair's Introduction—9:30

Invited Paper

9:35

3aSA1. Finite element analysis as a tool to design acoustic metamaterials by a non-expert user. Christina J. Naify (Appl. Res. Labs: UT Austin, 4555 Overlook Ave. SW, Washington, DC 20375, christina.naify@gmail.com)

Computational tools such as finite element methods are an extremely powerful tool for design of acoustic metamaterials. The ability of these tools to couple multi-physics such as structural mechanics and acoustics within an off the shelf graphical user interface opens the tools to a wide range of users. It is very easy, however, to use these tools without full understanding of the physics involved, which may lead to non-physical results. Additionally, FEM problems can be limited in their ability to handle large problems, such as 3D geometries, or small features on large parts, requiring simplifications on the part of the user. This presentation will review several acoustic metamaterial case studies where finite element methods are used to predict response of multi-physics problems, and compare those computational studies to experimentally measured results. These case studies will be presented from the perspective of a casual user of computational tools, someone who understands the physics of the problem, but may be limited in fully exploiting the capabilities of specific tools. Discussion will focus on areas where user tools and interfaces could be improved, as well as where shortcuts have been taken and the effect of those shortcuts.

Contributed Paper

9:50

3aSA2. Computational analysis of acoustic metamaterials: An outsider's perspective. Anthony L. Bonomo (Naval Surface Warfare Ctr., Carderock Div., 9500 MacArthur Blvd, West Bethesda, MD 20817, anthony.l.bonomo@navy.mil)

Numerical simulation has become an increasingly important tool in the study and design of acoustic metamaterials. However, most of the work to date seems limited to the classical Galerkin finite element method as implemented in commercial off-the-shelf software. In this talk, the limitations of this conventional approach are outlined and alternative computational techniques that can and should be brought to bear for the advanced analysis of acoustic metamaterials are discussed.

Invited Paper

10:05

3aSA3. Some perspectives on the modeling of acoustic metasurfaces. Yun Jing (Acoust., Penn State Univ., 201 Appl. Sci. Bldg., State College, PA 16802, jing.yun@psu.edu)

Numerical modeling is an important tool for the study of acoustic metasurfaces as it can shed light on the physical principles of these engineered acoustic structures and be used for optimization purposes. In this talk, I will discuss challenges that we have encountered in modeling acoustic metasurfaces using commerical software and semi-analytical models. I will focus on sound-absorbing acoustic metasurfaces and diffractive acoustic metasurfaces. I will also discuss the possibility of using open-source wave solvers (such as *k*-Wave and mSOUND) to model acoustic metasurfaces, which has been largely unexplored.

Contributed Paper

10:20

3aSA4. Simulating wave propagation in acoustic metamaterials with isogeometric analysis. Benjamin M. Goldsberry (Appl. Res. Labs., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, bgoldsberry@utexas.edu), Samuel P. Wallen, and Michael R. Haberman (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

Finite element analysis (FEA) is commonly used to simulate and design acoustic metamaterials (AMM). Numerical studies employing FEA often rely on Bloch-Floquet analysis of a single unit cell or direct numerical simulations that include many unit cells. Unfortunately, AMM unit cells with fine features necessitate dense computational meshes to resolve the geometry and accurately model wave motion, sometimes prohibiting the use of FEA. Isogeometric Analysis (IGA) is a potential alternative approach to FEA for wave propagation problems. IGA utilizes basis functions that are typically employed in Computer Aided Design (CAD) software, such as B-splines and Non-Uniform Rational B-Splines (NURBS), to represent both the geometry and the wave solution. The direct utilization of the CAD geometry eliminates the need for a separate computational mesh of the geometry and the smoothness of the NURBS basis functions provides increased accuracy per degree of freedom. The latter point is particularly useful for high frequency problems. This talk presents IGA as a means to model AMM behavior and compares results with FEA simulations in terms of total simulation time and accuracy. Finally, we comment on the current limitations of IGA and discuss avenues of future research. [Work supported by the ARL:UT postdoctoral fellowship program.]

10:35–10:50 Break

Invited Paper

10:50

3aSA5. Sound manipulation through multi-scattering, gradient-based optimization, deep learning and reinforcement learning. Feruza Amirkulova (Mech. Eng., San Jose State Univ., 1 Washington Sq., San Jose, CA 95192, feruza.amirkulova@sjsu.edu)

This talk discusses recent advances and current challenges encountered during the application of gradient-based optimization, deep learning, reinforcement learning, and generative modeling in an inverse design of acoustic metamaterials. We first summarize and group existing approaches in the inverse design of metamaterials then discuss current algorithmic limitations and open challenges to preview possible future developments in metamaterial design. Specifically, broadband sound focusing, cloaking, steering, localization, and diffusion are the focus of this talk. The objective (loss) functions are evaluated by means of multiple scattering theory, and analytical gradients are evaluated with respect to a design vector, *i.e.*, the positions of each scatterer. Our observations show that the development of hybrid models improves the performance of these algorithms. Specifically, the performance of deep reinforcement learning and gradient-based optimization as well as generative network models are enhanced when gradients of target functions are supplied to the model. In reinforcement learning models, the agent receives a reward proportional to the negative of the target function. The performance of the double-deep Q-learning network (DDQN) and the deep deterministic policy gradient (DDPG) algorithms were improved when gradients were supplied to the reward function. Numerical examples are presented for planar configurations of cylindrical scatterers.

Contributed Paper

11:05

3aSA6. Total multiple scattering cross section evaluation using convolutional neural networks for forward and inverse designs of acoustic metamaterials. Thang Tran (Phys. and Astron., San Jose State Univ., 7313 Eagle Pass Dr., Sachse, TX 75048, thang.tran01@sjsu.edu), Ehsan Khatami (Phys. and astronomy, San Jose State Univ., San Jose, CA), and Feruza Amirkulova (Mech. Eng., San Jose State Univ., San Jose, CA)

We design convolutional neural network models to simulate acoustic multiple scattering from cylindrical structures. The models are trained on data generated by multiple scattering theory to approximate total scattering cross section (TSCS) at different wavenumbers. In our first case study, the input of convolutional neural networks are binary images of positions of the cylinders, and the output is the TSCS, evaluated at eleven discrete values of wavenumber. We consider different planar configurations with five different numbers of cylinders ranging from 2 to 10. Our results show a good correspondence between predicted values and actual TSCS. However, we find that the training accuracy decreases as the number of scatterers increases. In a second case study, we develop convolutional autoencoder models, which take scatterer configuration images as input and, in the process of reproducing the same configurations at the output, reduces the dimensionality of the data to a small number of latent variables. We then use the latent variables in various inverse designs, producing scatterer configurations given values of TSCS. Despite its limitations the autoencoder proves to be a promising tool in searching for desired scatterer configuration without expensive computational cost.

Invited Papers

11:20

3aSA7. Spectral variational multiscale enrichment method—A new computational approach to transient dynamics of phononic crystals and acoustic metamaterials. Caglar Oskay (Vanderbilt Univ., VU Station B#351831, 2301 Vanderbilt Pl., Nashville, TN 37235, caglar.oskay@vanderbilt.edu) and Ruize Hu (Vanderbilt Univ., Nashville, TN)

Phononic crystals and acoustic metamaterials hold tremendous potential in controlling mechanical and acoustic waves, thereby enabling remarkable and novel engineering applications such as seismic wave mitigation, impact wave mitigation, elastic cloaking, and acoustic superlens. Given the potential complexity associated with the microstructure of these materials, direct numerical simulation of irregularly shaped and/or large engineering components could be computationally very costly and in many cases prohibitive. Multiscale computational modeling, coupled with model order reduction methodologies present a feasible strategy to simulate the dynamic response of phononic crystals and acoustic metamaterials. In this study, we present the spectral variational multiscale enrichment approach that allows the analysis of a broad range of material microstructures for phononic crystals and acoustic metamaterials. The spectral coarse-scale representation is proposed to capture the salient transient wave phenomena, such as wave dispersion and band gaps that occur in the short wavelength regime. A material phase based model order reduction strategy is devised at the fine-scale. By using the reduced basis for the fine-scale problem, significant numerical efficiency is achieved. Transient elastic wave propagation in two-dimensional phononic crystals and acoustic metamaterials are investigated and the proposed multiscale approach is verified against direct numerical simulations.

11:35

3aSA8. Spectral extended finite element method for band structure calculations in phononic crystals. Eric B. Chin (Lawrence Livermore National Lab., 7000 East Ave., Livermore, CA 94550, chin23@llnl.gov), Amir A. Mokhtari, Ankit Srivastava (Illinois Inst. of Technol., Chicago, IL), and N. Sukumar (Univ. of California, Davis, Davis, CA)

This talk introduces the extended finite element method (X-FEM) on structured higher-order (spectral) finite element meshes for computing the band structure of one- and two-dimensional phononic composites. The X-FEM enables the modeling of holes and inclusions in geometry through the framework of partition-of-unity enrichment. This reduces the burden on mesh generation, since meshes do not need to conform to geometric features in the periodic domain. Further, with iterative design processes such as phononic shape optimization, the need for remeshing is eliminated. To obtain theoretical rates of convergence with higher-order extended finite elements, careful consideration of curved geometry representation and numerical integration is required. In two dimensions, we adopt rational Bezier representation of conic sections or optimized cubic Hermite functions to model implicit boundaries described by level sets. Efficient computation of weak form integrals is realized through the homogeneous numerical integration scheme—a method that uses Euler's homogeneous function theorem and Stokes's theorem to reduce integration to the boundary of the domain. Ghost penalty stabilization is used to improve matrix conditioning on finite elements that are cut by a hole. Band structure calculations on perforated materials as well as on two-phase phononic crystals are presented that affirm the sound accuracy and optimal convergence of the method on structured, higher-order spectral finite element meshes.

11:50–12:15 Discussion

Session 3aSC

Speech Communication, Education in Acoustics and Psychological and Physiological Acoustics: Teaching Speech and Hearing Science to Undergraduates I

Tessa Bent, Cochair
Speech and Hearing Sciences, Indiana University, 200 S. Jordan Ave., Bloomington, IN 47405

Jennifer Lentz, Cochair
Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405

Paul E. Reed, Cochair
Dept. of Communicative Disorders, University of Alabama, Box 870242, Tuscaloosa, AL 35487

Chair's Introduction—9:30

Invited Papers

9:35

3aSC1. Framing undergraduate education approaches in speech and hearing sciences—Liberal arts, vocational, or skill-set oriented? Adrian KC Lee (Speech & Hearing Sci., Univ. of Washington, 1417 NE 42nd St., Seattle, WA 98105, akclee@uw.edu)

Human communication is complex and the academic disciplines associated with speech and hearing sciences are necessarily interdisciplinary. In the past few years, the role of and models for undergraduate education in this discipline have been debated within the American Speech-Language-Hearing Association (ASHA) and the Council of Academic Programs in Communication Sciences and Disorders (CAPCSD). Traditionally, these undergraduate programs are collectively referred to as Communication Sciences and Disorders (CSD) education, and historically they employed a broad educational perspective based in the liberal arts and sciences. However, many programs today have evolved to focus more primarily on pre-professional education in the clinical fields of speech-language pathology and audiology. From the standpoint of education in acoustics, how should we frame our undergraduate courses to provide the necessary broad general knowledge and skills while satisfying an expectation of vocational preparation from students and other clinically oriented professional organizations? In this talk, I argue that a skill-set oriented approach may be more suitable to prepare CSD undergraduates for a variety of career paths.

9:50

3aSC2. A linguist's perspective on teaching communication disorders. Robert Hagiwara (Dept. of Linguist, Univ. of MB, Winnipeg, MB R3T 5V5, Canada, robh@umanitoba.ca)

I am a linguist in a linguistics department rather than a clinician in an accredited program, and thus some aspects of a typical intro speech and hearing science course are well beyond my capabilities and experience, *e.g.*, clinical decision making, intervention, etc. My approach to teaching communication disorders to linguistics students has always been to focus on discussing the communication breakdown in relation to standard linguistic insights of a typical speaker/hearer, things like natural classes and markedness, content versus grammatical function, and so on. I ask my students to understand, for instance, what is going on when a child learns phonology or an adult brain processes language; what seems to be 'breaking' when a child presents a speech sound disorder or an adult presents aphasia; and how a "standard" linguistic view handle (or not) the relationship of these cases. While there are many outstanding textbooks intended to introduce the field of communication disorders to students entering the field, there are few suitable for a course from "my perspective" aimed to linguistics students. Some years ago, I realized that I was probably going to have to write (or edit) one myself. In this presentation, I present my plans for the content and organization for this textbook.

10:05

3aSC3. Teaching phonetics in a flipped classroom. Melissa M. Baese-Berk (Univ. of Oregon, 1290 University of Oregon, Eugene, OR 97403, mbaesebe@uoregon.edu)

Within the typical undergraduate linguistics curriculum, phonetics can maintain a special status. Instead of a lecture with discussion sections, students are often faced with labs and assignments that look suspiciously like those in their science classes instead of their humanities and humanistic social science courses. As such, some students struggle in these classes when they are taught in traditional lecture-lab formats. Here, I present the format I have recently used for teaching phonetics—"flipping" the classroom. Rather than completing assignments outside of class as in a traditional lecture-style class, participants watch lecture modules outside of class and class time is devoted to demonstrations, tutorials, and working through labs and related content. This format has resulted in increased student satisfaction and increased performance on an array of assessments. I will specifically discuss how I design the lecture modules, how we incorporate the in-class activities, and how this can be modified for a remote classroom if COVID-19 restrictions persist.

10:20

3aSC4. Course structure and projects for undergraduate CSD Acoustic Phonetics courses. Susannah V. Levi (Communicative Sci. and Disord., New York Univ., 665 Broadway, 9th Fl., New York, NY 10012, svlevi@nyu.edu)

Virtually all undergraduate communication sciences and disorders programs require a course in acoustic phonetics (sometimes titled speech science). In our undergraduate program, students have a separate phonetics (transcription) course prior to taking the acoustic phonetics course. My acoustic phonetics course splits the content into two halves: In the first half of the course we focus on the source, including basic acoustics (SHM, harmonics), vocal fold vibration, modes of phonation, and intonation. In the second half of the course, we focus on the filter, including resonance and tube models, vowel formants, and consonant acoustics. In this way, more abstract and basic acoustic properties are interwoven with specific examples of speech-related acoustics. Students complete one project using Praat that focuses on intrinsic F0. The project is divided into four components across the semester. The talk will focus on changes in course structure and the project.

10:35

3aSC5. Teaching about acoustic measurement and analysis using smartphones. Jennifer Lentz (Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405, jjlentz@indiana.edu) and Donghyeon Yun (Indiana Univ., Bloomington, IN)

Because smartphones are ubiquitous in modern society, they can serve as excellent mobile tools for students to explore aspects of acoustic measurements in and outside of the classroom. In this talk, I will present a set of lab activities based on smartphones which have allowed students studying speech, language and hearing sciences to use their smartphones as a sound level meter and waveform/spectrum analyzer to measure sounds in their daily lives. In group work, students can compare results from apps installed on different cell phone platforms with measures from a calibrated sound level meter, thereby giving them an opportunity to explore the strengths and limitations of cell phones as measurement devices. This presentation will also discuss how lab reports and classroom discussion can foster the development of analytical skills pertaining to sound analysis.

10:50–11:05 Break

11:05

3aSC6. Articulatory descriptions: It is all fun and games. Tessa Bent (Speech, Lang. and Hearing Sci., Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405, tbent@indiana.edu)

In the 100-level Phonetics for Speech and Hearing Sciences course at Indiana University, students learn articulatory descriptions for the vowels and consonants of American English. I have incorporated activities to help students practice the descriptions and apply them to real-world problems. The activities include (1) articulatory description puzzles: Students are given a series of consonant and vowel articulatory descriptions. They must then determine the corresponding vowels and consonants, which ultimately make up a quote. (2) Sounds of Fortune: In this "Wheel of Fortune"-style game rather than guessing letters in standard orthography, the answer is in IPA and students make their guesses by using the articulatory description (*e.g.*, "I'd like to buy a high front tense vowel"). (3) Misheard song lyrics: Students are presented with song clips, which are likely to result in errors. The students write down what they hear in orthography. After that, they are presented with the actual lyric. They then phonemically transcribe both the real and misheard lyrics. They identify consonant errors across the two transcriptions and then compare in terms of their place, manner and voicing characteristics. These activities can be used directly after the introduction of the material as well as for review exercises.

11:20

3aSC7. Incorporating dialectal variation into the introductory phonetics course: The class is the data. Paul E. Reed (Dept. of Communicative Disord., Univ. of Alabama, Box 870242, Tuscaloosa, AL 35487, pereed1@ua.edu)

Recognizing and understanding social and regional variation is crucial for beginning speech science students as well as future speech-language clinicians. However, social variation of language is often confined to a single module or chapter that presents dialectal differences as divergent from some mainstream norm, rather than an essential element present in the speech of all persons. In this talk, I will discuss a series of in-class and homework activities that demonstrate and incorporate vocalic variation across several activities during an introductory phonetics semester. Discussion will focus on how to guide students toward recording and transcribing their own speech, building informative individual vowel plots, discussing and analyzing vowel plots in small groups, and also creating a class-wide vowel plot.

11:35

3aSC8. Perception experiments to try on your friends. Valerie Freeman (Dept. of Commun. Sci. & Disord., Oklahoma State Univ., 042 Murray Hall, Stillwater, OK 74078, valerie.freeman@okstate.edu)

This talk presents hands-on activities to give intermediate students experience conducting phonological perception experiments and deepen their grasp of categorical consonant perception. It focuses on two assignments in which students gather categorical perception responses from friends, graph them to reveal crossover points, form hypotheses about contributing cues, and apply Praat measurement skills to test them. In the first, students and naïve friends respond to online phoneme identification and discrimination tasks involving a synthesized /ba-da-ga/ continuum varying only in formant transitions. They tally and graph the pooled responses, identify crossover points, and answer interpretation questions. In the second task, students and friends identify words on a *bad-bat* continuum varying only in vowel length. They hypothesize which phonetic features might distinguish the words, then measure them in Praat to discover that vowel length cues final consonant voicing, not voice onset time as learned in previous lessons. These activities have been used successfully in an advanced introduction to speech science for speech-language pathology undergraduates with an introductory English phonetics prerequisite. They form many students' first experience conducting experiments, and the hypothesis, deduction, and interpretation portions stretch their critical thinking skills.

11:50–12:20 Discussion

Session 3aSP

Signal Processing in Acoustics: Recent Research in Acoustic Signal Processing

Brian E. Anderson, Cochair
Department of Physics & Astron., Brigham Young University, N245 ESC, Provo, UT 84602

Trevor Jerome, Cochair
Naval Surface Warfare Center, Carderock Division, 9500 MacArthur Blvd, BLDG 3 #329, West Bethesda, MD 20817

Chair's Introduction—11:00

Contributed Papers

11:05

3aSP1. Robust speech separation in underdetermined conditions by estimating Green's functions. J. Keith McElveen (Wave Sciences, Charleston, SC, keith.mcelveen@wavesciencescorp.com)

Research results from near and far field speech separation in cocktail party environments using compact arrays of four or more microphones to robustly estimate Green's Functions of real rooms with reverberation, co-speech, and ambient noise.

11:10

3aSP2. Fast and accurate demodulation of wideband signals. Mantas Gabrielaitis (Inst. of Science and Technology, Klosterneuburg, Austria, mgabriel@ist.ac.at)

We introduce a new convex-programming-based approach to amplitude demodulation of arbitrary-bandwidth signals. While featuring recovery guarantees for a wide class of relevant signals, the new method surpasses competing techniques in terms of computational efficiency by many orders of magnitude; this opens the door for previously inaccessible applications of amplitude demodulation of arbitrary-bandwidth signals in online and large-scale offline settings. See https://arxiv.org/abs/2102.04832 for more information.

11:15

3aSP3. Extrapolation of Green's functions using the waveguide invariant. Hee-Chun Song (Univ. of California, LaJolla, hcsong@ucsd.edu) and Gihoon Byun

A Green's function observed at one location can be extrapolated into adjacent ranges in shallow water by exploiting the waveguide invariant theory.

11:20–11:35 Discussion

11:35

3aSP4. Acoustic tracking of surface waves. Edward L. Richards (Univ. of California Santa Cruz, Santa Cruz, CA, EdwardLRichards@gmail.com)

Doppler sensitive probe signals, transmitted in a bi-static geometry, can be used to localize and track moving surface waves that are acting as reflectors.

11:40

3aSP5. Undersea detection of aerial targets. Matthew T. Adams (The MITRE Corp., Bedford, MA, mtadams@mitre.org), Brian Bishop, Jesse Moore, Justin Tufariello, and Jerry Kim (MITRE, Bedford, MA)

The undersea detection of aerial targets is a difficult acoustic problem that was first examined almost 50 years ago and has received renewed interest lately for several important applications. In this work, the authors are interested in the trade space of feasibility for airborne sources at different altitudes and atmospheric conditions and for undersea receivers subject to different sound speed and bathymetry profiles.

11:45

3aSP6. Effects of acoustic nonlinearity on through-tissue communication performance. Gizem Tabak (Univ. of Illinois at Urbana-Champaign, IL, tabak2@illinois.edu), Michael L. Oelze (Univ. of Illinois at Urbana-Champaign, IL), and Andrew C. Singer (Univ. of Illinois at Urbana-Champaign, IL)

Wide signal bandwidth and high signal amplitude, which are desirable properties to achieve high data rates with linear communication systems, may cause performance degradation in through-tissue communication applications because of acoustic nonlinearity. In this talk, I will quantify the effects of acoustic nonlinearity on data rates and achievable bit error rates in a simulated through-tissue communication system.

11:50–12:00 Discussion

Session 3aUW

Underwater Acoustics: Seabed Characterization Experiment 2017 Studies I

Tracianne B. Neilsen, Cochair
Physics and Astronomy, Brigham Young University, N251 ESC, Provo, UT 84602

Zoi-Heleni Michalopoulou, Cochair
Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ 07102

Charles W. Holland, Cochair
Electrical and Computer Engineering, Portland State University, Portland, OR 97207

Chair's Introduction—9:30

Invited Papers

9:35

3aUW1. An overview of seabed characterization experiment. Preston S. Wilson (Mech. Eng. and Appl. Res. Labs., The Univ. of Texas at Austin, 204 East Dean Keeton St., M.S. C2200, Austin, TX 78712-0292, pswilson@mail.utexas.edu) and David P. Knobles (Knobles Sci. and Anal., Austin, TX)

An overview of the Spring 2021 component of the Seabed Characterization Experiment will be presented. The project is focused on the acoustics of fine-grained ocean bottom sediments. The study site is the New England Shelf, south of Martha's Vineyard, MA, USA. The goals of the project are (1) understand the physical mechanisms that control acoustic propagation in fine-grained sediments, (2) quantify uncertainties in the estimation of seabed parameters, (3) correlate the observed horizontal variations in the acoustical field with the measured horizontal variability of the seabed and (4) assess the performance of the resulting geoacoustic models, and inversion and statistical inference methods. These goals have been pursued by obtaining direct measurements and/or inferring the values of the following parameters over a wide frequency band: compressional wave speed and attenuation, shear wave speed and attenuation, and seabed layering and gradients. Oceanographic data were collected to support both forward and inverse modeling efforts. A major part of this effort was completed in 2017 and a follow-on effort is planned for 2021 and 2022. This presentation provides an overview of the project, a summary of past results, and a discussion of the most recent work. [Work supported by ONR.]

9:50

3aUW2. Vector acoustic observations of underwater ship noise from the 2017 seabed characterization experiment. Peter H. Dahl (Appl. Phys. Lab., Univ. of Washington, 1013 NE 40th St., Seattle, WA 98115-7834, dahl@apl.washington.edu) and David R. Dall'Osto (Appl. Phys. Lab., Univ. of Washington, Seattle, WA)

The Intensity Vector Autonomous Recorder (IVAR) measures acoustic particle velocity and pressure simultaneously. IVAR was deployed on the seabed at depth of 75 m during the 2017 Seabed Characterization Experiment (SBCEX) with objective to study sound propagation within underwater waveguides for which the seabed consists of fine-grained, muddy sediments. In this presentation, vector acoustic observations of ship generated noise recorded by IVAR from a cargo ship traversing the central region of the SBCEX are discussed. Pressure and particle velocity data as a function of frequency are converted into a bounded, non-dimensional form known as circularity, a quantity that is independent of the ship noise source spectrum and which can be interpreted as the normalized curl of active intensity. The frequency dependent pattern in circularity is sensitive to the sediment layering structure, and bathymetry. This pattern, as the vessel closes and opens in range, is inverted for sediment properties using a Bayesian framework, with inversion model space consisting of a low-compressional speed elastic layer, above an elastic half-space. Change in water depth between the location of the ship source and IVAR over the 20-min observation period is addressed using adiabatic mode theory. [Study supported by Office of Naval Research.]

10:05

3aUW3. Estimation of bottom parameters in the New England Mud Patch using geophone and hydrophone measurements. James H. Miller (Ocean Eng., Univ. of Rhode Island, 215 South Ferry Rd., Narragansett, RI 02882, miller@uri.edu), Gopu R. Potty (Ocean Eng., Univ. of Rhode Island, Narragansett, RI), Ying T. Lin (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, RI), and Julien Bonnel (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, MA)

Measurements of acoustic pressure and particle velocity were made during the Seabed Characterization Experiment (SCEx) in the New England Mud Patch south of Cape Cod in about 70 m of water. The University of Rhode Island and Woods Hole Oceanographic Institution deployed the "geosled" with a four-element geophone array, a tetrahedral array of four hydrophones, and Several Hydrophone

3a THU. AM

Receive Units (SHRUs) as data acquisition packages. In addition, a recently developed low frequency source, the interface Wave Sediment Profiler (iWaSP), was deployed to excite interface waves (Scholte waves) on the seabed. The geophone array was localized using the known locations of the small explosive sources and noise from the research vessel. Modal arrivals from broadband sources on geophones and hydrophones were used to invert for compressional and shear wave speeds and attenuation in the mud layer and the underlying sand layer. The Scholte wave arrivals from the iWaSP source measured by the geophone array also provided estimates for these parameters. The inversion results are compared to modeling using the viscous grain shearing (VGS) theory. [Work supported by the Office of Naval Research, Code 322 OA.]

Contributed Paper

10:20

3aUW4. Sound classification during Seabed Classification Experiment 2017. Allison N. Earnhardt (Phys., Purdue Univ., 610 Purdue Mall, West Lafayette, IN 47907, aearnhar@purdue.edu), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), Mason C. Acree (Phys., Brigham Young Univ., Provo, UT), William Hodgkiss (Marine Physical Lab. - Scripps Inst. of Oceanogr., San Diego, CA), and David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX)

In ocean acoustics, finding acoustic signals within long recordings is usually time consuming. The need to optimize this process we propose an experiment to discover the optimal acoustic signal classification model using the PyTorch deep learning package. This machine learning algorithm was designed to recognize and classify various sources from an input of spectrograms compiled from raw sound data. In the case of continuous audio files, this model's purpose is to identify areas of interest for human operators so they don't need to listen to each hour of the audio files marking down noises as they are heard. Four Convolutional Neural Networks (CNN) with differing numbers of layers took in one minute spectrograms. The most successful of the CNNs acted on time-averaged spectrograms, and resulted in a model which achieved a high degree of accuracy. This machine learning algorithm can help identify underwater sound signal sources, and can more efficiently identify when different signals are present in long audio files. The results of these tests imply that time averaging spectrograms may improve the identification of long term signal sources by a CNN. [Research supported by the NSF REU program.]

Invited Papers

10:35

3aUW5. Correlation of deep seabed structure with waveguide invariant β in $\pm\infty$ regime. David P. Knobles (Phys., Knobles Sci. and Anal., 5416 Tortuga Trail, Austin, TX 78731, dpknobles@kphysics.org), Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT), and Preston S. Wilson (Mech. Eng. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

An examination of the received spectrogram levels of merchant ship recordings has identified an important acoustic feature at the very-low frequencies (VLF). The data were recorded on vertical line arrays deployed in the New England *Mudpatch* during the Seabed Characterization Experiment 2017 in about 75 m of water. The VLF feature occurs when the group velocities of modes 1 and 2 are equal at a frequency $f = \mathbf{F}$. The average value of **F** from about twenty ship signatures observed in the Mudpatch is about 24.5 Hz. Generally, the observation of this VLF feature is a result of $\beta_{mn}(\mathbf{F}) =$ infinity where β_{mn} is the waveguide *invariant* for modes n and m. The sign of the waveguide invariant is determined by the sign of the difference between the phase speeds at **F**. Also, we predict what **F** would be in two areas south of the Mudpatch, including a second smaller Mudpatch in about 125 m of water and an area near the slope in about 250 m of water where the sediment is reported to be sand over multiple layers of softer sediments. Finally, **F** is predicted on the Atlantis II seamount with a limestone seabed in about 1650 m of water.

10:50–11:00 Discussion

11:00–11:15 Break

Invited Papers

11:15

3aUW6. Geoacoustic inversion of modal dispersion on the New England Mud Patch. I: Experimental quantification of information content in higher-order modes. Julien Bonnel (Woods Hole Oceanographic Inst., 266 Woods Hole Rd., M.S. 11, Woods Hole, MA 02543-1050, jbonnel@whoi.edu), Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada), Preston S. Wilson (Mech. Eng. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX), and David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX)

This paper presents the results from a geoacoustic inversion study performed using a combustive sound source signal recorded on a vertical line array during the 2017 Seabed Characterization Experiment (SBCEX17). A single receiver modal estimation method (source deconvolution and warping) is recursively applied along the array channels to estimate modal time-frequency dispersion, resulting in modal dispersion data for 18 modes between modes 1 and 21. These data are then used as an input for trans-dimensional Bayesian geoacoustic inversion. The paper compares inversion results obtained with subsets of modes (1 to 7 and 1 to 15) to those obtained with the whole set (modes 1 to 21) to explore the data information content associated with high-order modes. The study shows that high-order modes enable the resolution of fine details in the seabed sound-speed profile, such as a small sound speed increase over the first 8 m of

the seabed (*i.e.*, within the upper portion of the so-called "mud layer," an important feature of the experiment area). [Work supported by the Office of Naval Research.]

11:30

3aUW7. Geoacoustic inversion of modal dispersion on the New England Mud Patch. II: Hybrid parameterization for gradient estimation. Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC V8W 2Y2, Canada, sdosso@uvic.ca), Julien Bonnel (Woods Hole Oceanographic Inst., Woods Hole, MA), David P. Knobles (Phys., Knobles Sci. and Anal., Austin, TX), and Preston S. Wilson (Mech. Eng. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

This paper applies Bayesian geoacoustic inversion with a hybrid seabed model parameterization to modal-dispersion data from the New England Mud Patch to attempt to estimate gradient structure in the upper mud layer. The hybrid seabed parameterization is based on an upper layer with a general representation of gradients based on Bernstein-polynomial basis functions, above an unknown number of discrete (uniform) layers formulated trans-dimensionally. The dataset, collected during the 2017 Seabed Characterization Experiment (SBCEX17), involves high-order modes (up to mode 21) extracted via warping time-frequency analysis from recordings of a combustive sound source on a vertical hydrophone array. The inversion results are compared to those from a trans-dimensional inversion of the same data with no gradient layer, and to results from other acoustic data sets collected in the region as well as to nearby core measurements.

Contributed Papers

11:45

3aUW8. Information content of reflection-coefficient data versus angle and frequency for geoacoustic inversion. Yong-Min Jiang (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC V8W2Y2, Canada, minj@uvic.ca), Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada), Charles W. Holland (Appl. Res. Lab., Penn State Univ., Philadelphia, PA), and Jan Dettmer (Dept. of Geoscience, Univ. of Calgary, Calgary, AB, Canada)

This paper considers the information content of seabed reflection-coefficient data (as a function of angle and frequency) to resolve fine seabed structure through geoacoustic inversion. During the 2017 Seabed Characterization Experiment conducted on the New England Mud Patch, two types of measurement systems were employed to collect reflection data. One is a bistatic system with bottom-moored hydrophones and an omni-directional towed source, and the other is a towed system that uses the same source and a 15.4 m acoustic array on the same cable (source separation to the closest sensor is $\sim$ 27 m). Limited by the source–receiver geometry and data quality, the angular coverages of the reflection data for the bistatic and towed systems are $\sim$25–58° and $\sim$43–55°, respectively. This study aims to assess the capabilities of these systems to infer sediment structure using simulations over a frequency band of 1–6 kHz. Inversions show that the data simulated for the bistatic system better resolve fine structure of the seabed even with fewer frequency components, while the data for the towed system must include reflections at higher frequencies to get acceptable results. [Work supported by the Office of Naval Research.]

12:00–12:15 Discussion

Session 3pAO

Acoustical Oceanography: Long Term Acoustic Time Series in the Ocean III

Jennifer Miksis-Olds, Cochair
University of New Hampshire, 24 Colovos Rd., Durham, NH 03824

Joseph Warren, Cochair
School of Marine and Atmospheric Sciences, Stony Brook University, 239 Montauk Hwy, Southampton, NY 11968

Chair's Introduction—12:55

Invited Papers

1:00

3pAO1. The impact of the "Anthropause" on the communication and acoustic habitat of Southeast Alaskan humpback whales. Michelle E. Fournet (Ctr. for Conservation Bioacoustics, Cornell Univ., 159 Sapsucker Woods Rd., Ithaca, NY 14850, michelle.fournet@cornell.edu), Leanna P. Matthews (Sound Sci. Res. Collective, Denver, CO), and Christine Gabriele (Humpback Whale Monitoring Program, Glacier Bay National Park and Preserve, Gustavus, AK)

The COVID-19 pandemic caused profound changes in global human behavior, including substantial decreases in marine transportation, a pervasive ocean noise source. The human tragedy of the pandemic provides an unprecedented opportunity to investigate how humpback whales communicate in the absence of chronic noise common to their acoustic habitats. The Alaskan tourism industry was impacted particularly strongly; Southeast Alaska experienced a near complete absence cruise ships during the 2020 tourism season (May—September). In summer 2019 and 2020, we deployed a SoundTrap hydrophone in Glacier Bay National Park to document vessel-generated ambient noise and vocal characteristics of humpback whales (*Megaptera novaeangliae*) which have been studied in this region since the 1980's. In the absence of cruise ships, underwater noise from vessels was significantly lower in Glacier Bay compared to 2019. Median daily noise levels (dB_{RMS} 100–1500 Hz) were three times quieter during 2020 than in 2019. Preliminary analyses of humpback whale calling behavior show an increased number of call types in 2020 compared to the same period in 2019. Documenting humpback whale communication in quiet conditions can help illuminate impacts of chronic vessel noise and aid the development of measures to reduce human impacts in this and other marine protected areas.

1:15

3pAO2. Local oceanographic conditions link predator-prey dynamics from surface waters to the deep ocean. Simone Baumann-Pickering (Scripps Inst. of Oceanogr., Univ. of California San Diego, San Diego, CA, sbaumann@ucsd.edu), Ana Širović (Texas A&M Univ. at Galveston, Galveston, TX), Jenny S. Trickey, Ally Rice, Matthias Lankhorst, Uwe Send (Scripps Inst. of Oceanogr., Univ. of California San Diego, La Jolla, CA), Josiah S. Renfree, and David A. Demer (Southwest Fisheries Sci. Ctr., National Oceanic and Atmospheric Administration, La Jolla, CA)

Offshore pelagic environments are dynamic and rich in biodiversity, yet our understanding of these habitats is lacking as they are surveyed less frequently than coastal areas. We present results from one-year (October 2016i–October 2017) of comprehensive oceanographic mooring measures from a site located 150 nmi offshore Southern California in abyssopelagic waters, spanning water mass, nutrient, primary productivity, fish, and cetacean variables. We identified abrupt changes in water properties, bringing distinct biological communities to our site. Some examples were active acoustically observed backscatter from diel vertical migrators, present during parts of summer and throughout fall, coincided with passive acoustically measured night-time echolocation of common dolphins (*Delphinus delphis*). Risso's (*Grampus griseus*) and Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) echolocation was also coincident with near-surface backscatter but during winter and early spring. Backscatter during that time was predominantly from small pelagic fishes, as diel vertical migration was virtually absent. Echolocation from Cuvier's beaked whales was prominent during winter and spring, associated with colder water from the California Current, but were absent in early summer when the water in the deep sea abruptly warmed. This study demonstrates how local oceanographic conditions link predator-prey dynamics from surface waters to the deep sea.

1:30

3pAO3. Baleen whale presence in northern Mariana islands in 2015–2017. Camille Ollier (Dept. of Marine Biology, TAMUG A&M Univ., P.O. Box 1675, Galveston, TX 77553, ollier.cam@gmail.com), Megan A. Wood (Dept. of Marine Biology, TAMUG A&M Univ., Galveston, TX), Erin M. Oleson (Pacific Islands Fisheries Sci. Ctr., National Oceanic and Atmospheric Administration, Honolulu, HI), and Ana Širović (Dept. of Marine Biology, TAMUG A&M Univ., Galveston, TX)

Many baleen whale vocalizations are species, and in some cases, population−specific. Although baleen whale occurrence has been studied in different parts of the ocean, little is known about the seasonal distribution of baleen whales in the Western Pacific. Since 2010, more concerted visual and acoustic survey effort has been occurred around a very remote region of the western Pacific Ocean, the Northern Mariana Islands. Passive acoustic data were collected at two locations in the Northern Mariana Islands, Tinian and Saipan, from 2015–2017 and they were analyzed for call characteristics and occurrence of different baleen whale call types from blue whales, fin whales, and Bryde's whales. There was a clear seasonal pattern in fin whale calls, with peak call detections during winter and spring. Low levels of blue whale calls were detected year-round with peaks in winter (December) and summer (June). Bryde's whales were detected sporadically at both locations. Moreover, two low-frequency sounds with currently unknown origin were detected, one tonal and one pulsed sound. The former was more common at Tinian and the latter at Saipan. This work enhances our understanding of the species' vocal repertoire and population structure.

1:45

3pAO4. Long-term analysis of ocean ambient noise recorded at the northeast Pacific continental margin. Matthew Munson (School of STEM, Univ. of Washington, 185 Stevens Way, Paul Allen Ctr., Rm. AE100R, Seattle, WA 98195, mmunson2@uw.edu), Felix Schwock, and Shima Abadi (Elec. and Comput. Eng., Univ. of Washington, Seattle, WA)

Long-term underwater ambient noise analysis provides valuable insight into the changing soundscape of the ocean. This study evaluates four years of hydrophone data recorded at four locations off the Oregon coast between 2015 and 2019. The hydrophones record the soundscape continuously with a sample rate of 64 kHz and are deployed at depths ranging from 80 to 2900 m. The size of the dataset required processing to be distributed between 32 separate cloud machines. To facilitate long-term analysis, the data are averaged into sequential fifteen minute power spectral density (PSD) estimates. The PSD estimates are used to create long-term spectrograms and time series for various frequencies, which are analyzed for long-term trends and seasonal patterns. Spectrograms and ambient noise time series are used to identify different sound sources such as storms and periods of intense shipping and marine mammal activity. Furthermore, cross-element comparisons of the noise level are made to evaluate the site and depth dependence of the ambient noise. [Work supported by ONR.]

2:00–2:30 Discussion

THURSDAY AFTERNOON, 10 JUNE 2021 — 12:55 P.M. TO 2:25 P.M.

Session 3pBAa

Biomedical Acoustics: Instrumentation and Simulation in Biomedical Acoustics: Rapid Prototyping for Focused Ultrasound Sources

Adam Maxwell, Cochair
Dept. of Urology, Univ. of Washington, Seattle, WA 98195

Timothy J. Hall, Cochair
1153 WIMR, UW-Medical Physics, Madison, WI 53705

Chair's Introduction—12:55

This panel discussion will review current methods in prototyping therapeutic ultrasonic sources. State of the art techniques will be outlined and current limitations addressed. While principally targeting therapeutic transducers, these design and fabrication techniques apply to other ultrasound sources as well.

Panelists: Gilles, Thomas, Univ. of Washington; Jeremy Brown, Dalhousie University; Kyle Morrison, Sonic Concepts, Inc.; Noé Jiménez, Univ. Politècnica de València; Sandy Cochran, Univ. of Glasgow; Timothy Hall, Univ. of Michigan

THURSDAY AFTERNOON, 10 JUNE 2021 2:40 P.M. TO 3:40 P.M.

Session 3pBAb

Biomedical Acoustics and Physical Acoustics: Future Directions in Therapeutic Ultrasound

Kenneth B. Bader, Chair
Department of Radiology, University of Chicago, 5835 South Cottage Grove Ave., MC 2026, Q301B, Chicago, IL 60637

Chair's Introduction—2:40

Panelists from academia and industry will discuss current and future perspectives in the field of therapeutic ultrasound.

Panelists: Gail ter Haar, Inst. of Cancer Research; Hong Chen, Washington Univ.; Jeff Powers, Philips Medical Systems; Jon Cannata HistoSonics, Inc.; Klazina Kooiman, Erasmus Medical Center; Lawrence A. Crum, Univ. of Washington; Mathieu Burtnyk, Profound Medical Inc.

THURSDAY AFTERNOON, 10 JUNE 2021 12:55 P.M. TO 2:55 P.M.

Session 3pCA

Computational Acoustics: Innovative Ideas for Computational Acoustics

Mallory Morgan, Cochair
Rensselaer Polytechnic Institute, 110 8th St., Troy, NY 12180

Mahdi Farahikia, Cochair
Mechanical Engineering Dept., SUNY Binghamton, Rm. 1330, 85 Murray Hill Rd., Binghamton, NY 13902

Andrea Calilhanna, Cochair
MARCS Institute for Brain, Behaviour and Development, 2 Kayla Way, Cherrybrook, Sydney 2126, Australia

Chair's Introduction—12:55

Contributed Papers

1:00

3pCA1. Nonlinear bulk wave in a functionally graded symmetric hysteretic material model—A numerical study. Pravinkumar Ramchandra Ghodake (Dept. of Mechanical Eng., Indian Inst. of Technology Bombay, Mumbai, India, mech7pkumar@gmail.com)

A simple spring-mass chain implemented to model nonlinear wave propagation through a functionally graded hysteretic material. Harmonics generation due to single-frequency forward and reflected waves along with the corresponding hysteretic curves discussed.

1:05

3pCA2. Intrinsic coordinates algorithm for efficient simulation of weak-shock propagation in relaxing media. William A. Willis III (Applied Research Laboratories, The Univ. of Texas at Austin, Austin, TX, william.willis@utexas.edu), Mark F. Hamilton (Applied Research Laboratories, The Univ. of Texas at Austin, Austin, TX), and John M. Cormack (Center for Ultrasound Molecular Imaging and Therapeutics, Univ. of Pittsburgh Medical Center, Pittsburgh, PA)

An algorithm based on intrinsic coordinates is presented for calculating the propagation of a weak shock starting with an arbitrary initial waveform in a fluid with multiple relaxation mechanisms. Use of intrinsic coordinates avoids discretization of thin shocks, allowing for more efficient simulation.

1:10

3pCA3. Recent advances in multi-frequency analysis with the boundary element method. Suhaib Koji Baydoun (Technical Univ. of Munich, Garching 85748, Germany, suhaib.baydoun@tum.de) and Steffen Marburg (Technical Univ. of Munich, Garching, Germany)

The boundary element discretization of the acoustic Helmholtz equation yields frequency-dependent linear systems, which require efficient solution strategies for multi-frequency analysis. We briefly review recent advances in this field covering frequency approximation and extraction of coefficient matrices, frequency sampling strategies, iterative solvers for frequency-dependent linear systems and model order reduction techniques.

1:15

3pCA4. Wide-angle PE for a moving medium. D. Keith Wilson (Cold Regions Research and Engineering Laboratory, U.S. Army Engineer Research and Development Center, Hanover, NH, D.Keith.Wilson@usace.army.mi)

How to easily convert a NAPE (narrow-angle parabolic equation) code to an accurate WAPE (wide-angle parabolic equation) code for a moving medium.

1:20–1:35 Discussion

1:35

3pCA5. Gauss-Markov model for scattering of acoustic signals from rough surfaces. Geoffrey H Goldman (U.S. Army Research Laboratory, Adelphi, MD, geoffrey.h.goldman.civ@mail.mil)

Simple models are used to characterize the acoustic signal reflected by the ground and received by an array of microphones for elevated sources in the farfield.

1:40

3pCA6. Numerical evaluations of the lossy spatial impulse response for a circular piston in the far field. Drew A. (Michigan State Univ., East Lansing, Michigan, murraydr@msu.edu) and Robert J. McGough (Michigan State Univ., East Lansing, MI)

Numerical evaluations of the lossy spatial impulse response are achieved by substituting Green's functions from the Power Law Wave Equation into the Rayleigh integral. The addition of loss introduces noticeable attenuation, dispersion, and delay into the impulse response, which become more pronounced in the far field.

1:45

3pCA7. Parallelizing viscoelastic shear wave simulations with MPI and CUDA. Luke M. Wiseman (Michigan State Univ., East Lansing, MI, wisemanl@msu.edu) and Robert J. McGough (Michigan State Univ., East Lansing, MI)

Three dimensional (3D) simulations of shear wave elasticity imaging (SWEI) are performed by computing a 3D push beam in FOCUS, the "Fast Object-oriented C++ Ultrasound Simulator" (https://www.egr.msu.edu/~fultras-web) followed by the superposition of Green's function solutions to Navier's equation in viscoelastic media. Results show that these Green's function calculations are particularly amenable to parallel implementations that combine MPI and CUDA.

1:50

3pCA8. Numerical solutions of the inviscid Burgers equation with the discontinuous Galerkin method. Vaughn E. Holmes (Michigan State Univ., East Lansing, MI, holmesv3@msu.edu) and Robert J. McGough (Michigan State Univ., East Lansing, MI)

Solutions to the inviscid Burgers equation are numerically computed with the discontinuous Galerkin method with basis functions up to 16th order. Simulation results show that shock waves are effectively modeled and that in the absence of filtering, significant oscillations are observed.

1:55–2:10 Discussion

Additional presentations and discussions may be added

Session 3pEA

Engineering Acoustics: Engineering Acoustics in Industry

Michael R. Haberman, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758

Gary W. Elko, Cochair
mh acoustics, 25A Summit Ave., Summit, NJ 07901

Chair's Introduction—12:55

Contributed Papers

1:00

3pEA1. The control of quadcopter propeller radiated noise. Timothy A. Brungart (Appl. Res. Lab., The Penn State Univ., P.O. Box 30, State College, PA 16804-0030, tab7@arl.psu.edu), Stephen T. Olson, Brian L. Kline, and Zachary W. Yoas (Appl. Res. Lab., The Penn State Univ., State College, PA)

Simple scaling analysis is used to show that significant reductions in quadcopter propeller radiated noise can be achieved, at the hover condition, by reducing the quadcopter and/or payload weight to, in turn, reduce the propeller tip speed. The scaling analysis shows that the propeller radiated noise, at the hover condition, scales as the cube of the combined quadcopter and payload weight. The reductions in radiated noise predicted from the scaling analysis are verified experimentally with quadcopter propellers in an anechoic chamber. Experiments also show that reducing the propeller tip speed by increasing the propeller blade pitch or blade number, while maintaining a given static thrust, is ineffective at reducing the radiated noise. In fact, it is shown that too high a blade pitch and/or blade number can significantly increase propeller radiated noise even though the blade tip speed is significantly reduced. This is attributed to increased propeller blade and blade wake interactions for the increased blade pitch and number.

1:15

3pEA2. Numerical prediction of hydro-acoustics signature of NACA foils for tidal turbines. Dan Zhao (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand) and Xiran Liu (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand, xiran.liu@pg.canterbury.ac.nz)

Tidal power is one of the renewable energy sources. The tides produced in the water is used to drive the blade rotation of a tidal turbine for energy conversion. However, the blade rotation produces noises over 10–150 kHz that affect underwater mammals. In this wok, numerical simulations are conducted to predict the hydro-acoustics signature of different NACA foils, which could be used for tidal turbine blades. Finite volume and Ffowcs-Williams Hawking's method are used to predict the fluid dynamics and acoustics signatures. We first study the effect of thickness to chord ratio ($T_b/c_b = 0.1$, 0.13 and 0.19) on the noise generation from three different NACA foils (*i.e.*, NACA0012, 0018, and 2410). Hydrodynamic data of these three foils are used for validation of its hydro-acoustics signature. Hydro-acoustics data are acquitted over the propagation distance from 50 m to 2.6 km at different angular positions and at various angles of attack (AOA) ($AOA = 0°$, 9°, and 15°). To shed lights on the sound generation mechanism, the NACA 2410 foil with vortex generator-produced perturbations is chosen as a case study. Comparison is then made between the prediction and the acoustic data of an actual foil.

1:30

3pEA3. Aeroacoustics damping performances of double-layer perforated pipes at low grazing-bias flow Mach number. Dan Zhao (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand) and YX Gay (College of Eng., Nanyang Technol. Univ., Singapore, Singapore, GayYX@e.ntu.edu.sg)

The present work studies the aeroacoustics damping characteristics of double-layer perforated pipes (DPP) at low grazing-bias flow Mach number. The noise damping mechanism involved with thermos-viscous and vortex shedding, through which acoustical energy is somehow absorbed by a few tiny circle-shaped orifices perforated on the cylindrical pipes. Here, Δ_b (sound absorption coefficient) is used as a noise damping measure. It characterizes the fraction of incident sound energy being attenuated. DPP are associated with a bias flow passing through each orifice and a grazing flow. It is another flow stream grazing the inner surface of the inner perforated pipe. The grazing flow velocity is denoted by Mach number M_g. Since the DPP have different porosities δ_i and δ_o, we use M_b to denote the bias flow Mach number at the outlet of the cooling flow pump. Experimental evaluations on Δ_a are performed on five double-layer perforated pipes over the Strouhal number range of $0.25 \leq S_t \leq 1.2$. It is shown that increasing the grazing flow M_g gives rise to deteriorated overall acoustic damping performances over the measured S_t range. However, it is found that acoustic damping is improved, *i.e.*, Δ_a is increase with the implementation configuration of $\delta_i > \delta_o$.

1:45

3pEA4. Numerical investigation on the porosity effect of a bias-flow perforated liner on attenuating self-excited thermoacoustic oscillations. Di Guan (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand, di.guan@pg.canterbury.ac.nz), Dan Zhao (Dept. of Mech. Eng., Univ. of Canterbury, Christchurch, New Zealand)

Self-excited thermoacoustic oscillations are unwanted in propulsion and stationary gas turbines due to the undesirable structural and heating damage to the engine systems. To prevent overheating and damping noise, perforated liners are widely applied in engines. It is a cylindrical metal sheet perforated with a number of millimetre-size circle orifices. In this work, numerical studies are conducted on an acoustically open-open thermoacoustic combustor with premixed propane and air fuelled and burnt. A perforated liner with a porosity σ is implemented downstream of the combustor in the presence of a cooling flow (also known as bias flow). The effects of (1) the cooling mass flow rate $\dot{m}_b$ and (2) the porosity σ_p are examined one at a time. It is found that in the absence of the cooling flow, *i.e.*, $\dot{m}_b = 0$, the perforated liner's acoustic damping effect is quite small. Increasing is found to increase the liners damping performance in terms of attenuating the thermoacoustic oscillations, due to the enhanced vortex shedding generated over the rims of the perforated holes. In addition, there is an optimum cooling flow rate corresponding to the maximum acoustic damping effect of the liner. Furthermore, for a given mass flow rate, there is an optimum porosity.

2:00–2:15 Break

2:15

3pEA5. Numerical investigation of a Y-shaped thermoacoustic combustor with a Helmholtz resonator implemented and operated at off-design conditions. and Dan Zhao (Dept. of Mech. Eng., Univ. of Canterbury, Private Bag 4800, Christchurch 8140, New Zealand, dan.zhao@canterbury.ac.nz)

Self-excited thermoacousitc instability is undesirable in propulsion and gas turbine engines. To attenuate these instabilities, Helmholtz resonators shaped like a beer bottle are typically applied to dampen combustion-driven acoustic oscillations. The damping effect is maximized at resonance, since large volume of fluid in the cavity volume compresses and expands periodically, while a mass of the fluid in the resonator neck oscillates. Such periodic motions lead to thermos-viscous and vortex shedding losses. In this work, two-dimensional numerical studies on a Y-shaped thermoacoustic combustor with a Helmholtz resonator attached are conducted to shed lights on the damping performances of the resonators at off-resonance conditions. The Y-shaped system has a mother stem at the bottom. It splits into 2 bifurcating upper branches with different lengths corresponding to 2 non-harmonic longitudinal modes. Premixed propane and air are burnt in the bottom stem. The effects of the off-design conditions achieved by varying the resonator cavity volume on the limit cycle oscillations and the combustion products are examined in details. It is found that when the mass flow rate oscillation amplitude at the neck is increased by 1500%, the acoustic pressure amplitude is reduced by 20%. However, the dominant and secondary mode frequencies are almost unchanged.

2:30

3pEA6. Selective monitoring of noise emitted by vehicles involved in road traffic. Andrzej Czyzewski (Multimedia Systems, Gdansk Univ. of Technol., Narutowicza 11/12, Gdansk 80-233, Poland, andczyz@gmail.com)

An acoustic intensity probe was developed measures the sound intensity in three orthogonal directions, making possible to calculate the azimuth and elevation angles, describing the sound source position. The acoustic sensor is made in the form of a cube with a side of 10 mm, on the inner surfaces of which the digital MEMS microphones are mounted. The algorithm works in two stages. The first stage is based on the analysis of sound intensity signals, and it detects acoustic events. The second stage analyses a detection function based on the normalized source position; its task is to determine whether the acoustic event represents a vehicle passing the sensor and detecting its movement direction. The acoustic probes were mounted inside intelligent lamps that illuminate the roadways depending on the volume of traffic. The paper explains how accurately traffic can be monitored through directional noise analysis and shows the resulting application to smart cities. [The project has been subsidized by the Polish National Centre for Research and Development (NCBR) from the European Regional Development Fund No. POIR.04.01.04/2019 entitled: INFOLIGHT—"Cloud-based lighting system for smart cities."]

2:45

3pEA7. Circular synthetic aperture acoustic imaging of spherical targets in cylindrical rod clutter. Juliana J. LaFrance (Phys., U.S. Naval Acad., U.S. Naval Acad., 572 C Holloway Rd., Annapolis, MD 21402, m213696@usna.edu) and Murray S. Korman (Phys., U.S. Naval Acad., Annapolis, MD)

A model apparatus has been built to demonstrate acoustic imaging of several spherical targets in cylindrical clutter. Reflective ultrasonic tomography imaging was chosen because the medical community, using photo-acoustic tomography imaging, utilizes a similar back-projection imaging algorithm. The experiment involves suspending an ultrasonic transducer unit (resonant frequency 1.0 MHz) in an aquarium filled with water. The transducer (sender-receiver) generates a 5-cycle tone burst. The circular plane array transducer diameter is $D = 1.27$ cm. Its wavelength is 1.48 mm (using $c = 1482$ m/s). The target, located 15 cm from the source, consists of two 0.64 cm diameter metal spheres separated by 5 cm. A mechanical structure of thin perforated disks (10 cm diam) comprise a step-motor controlled rotational platform that supports the targets and slender stainless steel cylindrical vertical rods (2 mm diameter, 10 cm long) that serve as the clutter. Received echoes versus time (data sets) were measured at 10° rotation increments of the structure (from 0° to 360°) for back-projecting the 2-D image reflectance of the targets among the clutter (using Mathematica®). The original apparatus and supporting electronics were built by Madeline Bell for her USNA Capstone research (Fall 2020) involving scattering from cylindrical targets.

3:00

3pEA8. Experimental demonstration of a two-dimensional sound diffusing acoustic metasurface with subwavelength thickness. Janghoon Kang (Walker Dept. of Mech. Eng., The Univ. of Texas at Austin, 204 E. Dean Keeton St., Stop C2200, Austin, TX 78712-1591, jh3010.kang@utexas.edu) and Michael R. Haberman (Walker Dept. of Mech. Eng. and Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

Acoustic diffusers are surfaces that minimize the strength of room modes in small- and medium-sized rooms and reduce specular reflections in large spaces. Since diffusers are surface treatments that are mounted to walls of interior spaces, it is desirable to reduce their thickness in order to maximize usable space. Traditional diffuser designs, such as the quadratic residue diffuser (QRD) make use of variable depth wells to control the local phase of the reflected field. In these designs, well depth is directly proportional to the reflected phase, rendering the overall thickness dependent on the design frequency. Coiled-space (CS) structures are good candidates to minimize diffuser thickness while maintaining performance. However, CS structures have tortuous channels which are susceptible to viscous losses which can degrade diffuser performance. This work presents a CS design for a 2D QRD ($N = 7$) diffuser with minimal viscous losses and $\lambda/8$ thickness, a 4x reduction compared to traditional QRD. Six unit-cell designs were optimized, fabricated, and measured in an impedance tube. Measured reflection coefficients are in a good agreement with predictions. The 3D diffusion performance of the CS and traditional diffusers were measured on multiple planes orthogonal to the diffuser surface with CS and traditional designs performing comparably.

Invited Papers

3:15

3pEA9. Development of multimode and spiral wave acoustic transducers: Yesterday, today, and tomorrow. David A. Brown (ECE, Univ. Massachusetts Dartmouth, 151 Martine St., Ste. 123, Fall River, MA 027230000, dbrown@umassd.edu)

This presentation reviews the early development of multimode transducers in both U.S. and Russia and their use in DIFAR sonobuoys and other directional receivers. This lead the way for today's development of the spiral wave transducer that creates outward diverging acoustic waves from a single transducer, whose wavefront (surface of constant phase) is a continuous outgoing spiral surface created by the superposition of orthogonal dipoles driven in phase-quadrature. Spiral waves hold promise for tomorrow's underwater acoustic navigation beacons in GPS-denied access areas and for broader bandwidth underwater communications.

3:30–3:55 Discussion

Session 3pNS

Noise and Psychological and Physiological Acoustics: Non-Occupational Noise and Hearing Loss II

William J. Murphy, Cochair
Division of Field Studies and Engineering, Noise and Bioacoustics Team, National Institute for Occupational Safety and Health, 1090 Tusculum Ave., Mailstop C-27, Cincinnati, OH 45226-1998

Bonnie Schnitta, Cochair
SoundSense, Wainscott, NY

Chair's Introduction—12:55

Invited Papers

1:00

3pNS1. Improving our understanding on non-occupational noise-induced hearing loss. Richard L. Neitzel (Environ. Health Sci., Univ. of Michigan, 1415 Washington Heights, 6611 SPH I, Ann Arbor, MI 48109, rneitzel@umich.edu)

Noise is among the most common occupational and non-occupational exposures globally. As a result, the public health burden of noise-induced hearing loss is high. Some estimates suggest that roughly 20% of all hearing loss cases result from occupational noise exposure. Occupational noise exposures have been extensively studied and regulated in many countries for decades, and as a result the risk of occupational noise-induced hearing loss associated with different exposure levels and durations has been modeled and quantified. However, non-occupational exposures have not been nearly as well-characterized, and the risk of non-occupational noise-induced hearing loss is not well understood. This presentation will describe a systematic review conducted to evaluate the risk of noise-induced hearing loss associated with non-occupational noise. The presentation will also discuss knowledge gaps in our understanding of non-occupational noise exposures, and the need for tools to allow individuals to evaluate their own exposures against recommended non-occupational noise exposure limits, and ideally to share these "citizen-science" data for aggregated analysis. This approach is now being utilized in the Apple Hearing Study, a partnership between Apple, Inc., and the University of Michigan. Details will be provided on the research approaches and some preliminary results from the Apple Hearing Study.

1:15

3pNS2. Hearing disorders secondary to infection with SARS-CoV-2. Colleen Le Prell (Speech, Lang., and Hearing, Univ. of Texas at Dallas, 1966 Inwood Rd., Callier Ctr., Rm. J216, Dallas, TX 75235, colleen.leprell@utdallas.edu)

A recent emerging concern is the relationships between SARS-CoV-2 (COVID-19) and otolaryngological symptoms such as dizziness, tinnitus, hearing loss. Emerging data suggest auditory and vestibular symptoms are more likely with COVID-19 than previous coronaviruses and Middle East Respiratory Syndrome (MERS). Data from recent reports suggest auditory and vestibular dysfunction secondary to COVID-19 may be greater in females than in males, and in patients older than 60 years. This presentation will discuss these emerging data and the possibility that stress and anxiety during COVID-19 recovery may further contribute to perceptions of exacerbated tinnitus. One factor that may increase anxiety is perceived lockdown-related stress, which has been associated with worsening of tinnitus distress in the absence of COVID-19 infection. A second factor linking increases in anxiety with COVID-19 is increased concern about communication needs as expressed by patients with hearing loss, based on concerns about the negative impact of mask use and social distancing on audibility and communication ability. Finally, it must be noted that proposed treatments for COVID-19 including chloroquinine and hydroxychloroquinine can have auditory side effects including tinnitus, and the doses used in COVID-19 patients significantly exceed doses recommended for treatment of malaria which increases the likelihood of side effects.

1:30

3pNS3. Centers for Disease Control and Prevention non-occupational noise campaign. John Eichwald (National Ctr. for Environ. Health, Centers for Disease Control and Prevention, 2562 Meadowglen Trail, Snellville, GA 30078, jeichwald@cdc.gov)

In February 2017, an intra-agency workgroup within the Centers for Disease Control and Prevention (CDC) National Center for Environmental Health (NCEH) launched a hearing loss campaign to increase awareness that excessive exposure to loud sounds outside of the working environment can lead to permanent noise-induced hearing loss (NIHL). The NCEH workgroup initiated research efforts and participated in activities to promote the prevention of NIHL from non-occupational noise exposures. This included the development of an online toolkit with infographics, videos, and other sharable media, several available in English and Spanish. Publication of CDC NIHL research has included peer-reviewed journals, partner articles and Morbidity and Mortality Weekly Report (MMWR) manuscripts. The CDC NIHL workgroup engages with various organizations and continues to analyze national data to prioritize public health needs

in this area. CDC continues to develop communication materials, social media content, videos, and factsheets to support partners and other stakeholders. By providing evidence and education/health communication; through its partners CDC collaborates with other national efforts to increase awareness and behavioral change to prevent NIHL at home and in the community.

1:45

3pNS4. National data on noise exposure, hearing trouble, and protective behaviors in the United States. Christa L. Themann (Noise and Bioacoustics Team, National Inst. for Occupational Safety and Health, 1090 Tusculum Ave., M.S. C-27, Cincinnati, OH 45226, clt6@cdc.gov)

Although exposure to hazardous noise is generally considered to be the major cause of preventable hearing loss among adults, the U.S. does not have a measurement-based surveillance system to track noise exposure. However, several national health survey systems collect self-reported noise exposure information as well as related data including self-rated and/or audiometrically-measured hearing trouble and self-reported hearing protection use. This presentation will provide estimates of exposure to loud noise from various sources among a nationally representative sample of U.S. adults based on data from the National Health Interview Survey and the National Health and Nutrition Examination Survey. Prevalence of self-reported and measured hearing impairment as well as tinnitus will also be reported and examined in relation to the various types and combinations of exposure. In addition, the frequency of hearing protector use and audiometric monitoring among individuals exposed to various types of noise will be examined to evaluate their possible influence on the prevalence of auditory symptoms and identify groups in particular need of targeted interventions. This presentation will provide a snapshot of the noise exposure problem in the U.S., illustrate its effects on hearing ability among U.S. adults, and highlight the most significant hearing-related public health needs.

2:00

3pNS5. Progress on the National Occupational Research Agenda for hearing loss prevention. William J. Murphy (Div. of Field Studies and Eng., Noise and Bioacoustics Team, National Inst. for Occupational Safety and Health, 1090 Tusculum Ave., Mailstop C-27, Cincinnati, OH 45226-1998, wjm4@cdc.gov), Lauraine L. Wells (Personal Safety Div., 3M, St. Paul, MN), Rudy J. Matetic (Office of the Director, National Inst. for Occupational Safety and Health, Bruceton, PA), Elizabeth Masterson (Div. of Field Studies and Eng., Health Informatics Branch, National Inst. for Occupational Safety and Health, Cincinnati, OH), and Amanda S. Azman (Pittsburgh Mining Res. Div., Health Hazard Prevention Branch, National Inst. for Occupational Safety and Health, Bruceton, PA)

In 2019, the National Institute for Occupational Safety and Health, Hearing Loss Prevention (HLP) Cross-sector Council published the National Occupational Research Agenda (NORA) for Hearing Loss Prevention. The agenda consisted of five objectives: (1) provide input for policies and guidelines that will inform best practices for hearing loss prevention efforts; (2) develop effective, evidence-based education designed to improve hearing conservation program outcomes for exposed workers and management; (3) develop, commercialize, and widely implement noise control solutions on jobsites in key industries; (4) develop audiological tests for hearing loss prevention; and (5) improve occupational hearing loss surveillance. In this paper, these objectives will be reviewed with regards to progress that has been accomplished. The NORA HLP Cross-sector Council has focused on expanding awareness for noise awareness and developing guidance for hearing protector fit testing. While these efforts are more directed to preventing occupational noise-induced hearing loss, the principles carry over to preventing hearing loss outside of the occupational setting.

2:15–2:45 Discussion

Session 3pPA

Physical Acoustics and Engineering Acoustics: Acoustical Methods and Sensors for Challenging Environments II

Cristian Pantea, Cochair
Materials Physics and Applications, Los Alamos National Lab., MPA-11, Los Alamos, NM 87547

Dipen N. Sinha, Cochair
Los Alamos National Lab., 112 Shirlane Place, Los Alamos, NM 87544

Chair's Introduction—12:55

Contributed Papers

1:00

3pPA1. Radiation force fields formed by a standing surface acoustic wave in a viscous liquid layer lying on an elastic half-space. Denis A. Zharkov (Dept. of Acoust., Physical Faculty, Lomonosov Moscow State Univ., GSP-1, Leninskie Gory, Moscow 119991, Russian Federation, denis.Zharkov2014@yandex.ru) and Vladimir A. Gusev (Dept. of Acoust., Physical Faculty, Lomonosov Moscow State Univ., Moscow, Russian Federation)

The field of a surface acoustic wave in the system "viscous fluid layer—elastic substrate" is calculated taking into account the shear components in the fluid. On the basis of the dispersion equation, the velocity and attenuation of the surface wave are calculated. It is shown that for low-viscosity liquids the change in velocity is insignificant, but the shear components make the main contribution to the attenuation of the wave. The radiation pressure corresponding to a standing surface wave in a viscous fluid and acting on an element of its volume due to the nonlinearity of the equation of motion is calculated. It is shown that taking viscosity into account changes the spatial distribution of radiation pressure. In the presence of suspended particles in the liquid form, the attenuation of the wave causes an additional tendency to collect these particles in the center of the system. The shear components have significant radiation pressure gradients near the interface. They play a decisive role in the formation of ordered ensembles of particles at the last stage of the self-organization process. [The study was supported by the Russian Foundation for Basic Research under Project No. 20-02-00493-a.]

1:15

3pPA2. Elastic properties of iron and tantalum at high pressure and temperature. Richard L. Rowland (Los Alamos National Lab., Bikini Atoll Rd., Los Alamos, NM 87545, RLRowland@LANL.Gov) and Blake Sturtevant (Los Alamos National Lab., Los Alamos, NM)

Iron and tantalum have many important applications in tools, infrastructure, and electronics. In service, metallic parts can experience extreme stresses and temperatures (*e.g.*, jet engine components, chemical processing equipment, supports for large structures), thus it is important to understand their elastic properties as a function of both pressure and temperature in order to allow engineers to appropriately design components using these materials. To determine these properties, we measured sound speeds and densities of Fe and Ta samples as a function of pressure and temperature. These measurements were performed in a large volume hydraulic pressure cell *in situ* at the Advanced Photon Source. Ultrasound time-of-flight was measured using the pulse-echo method and the sample dimensions were measured using x-ray radiography. x-ray diffraction was used to determine the sample densities. The longitudinal and shear sound speeds and the density measurements were combined to determine the bulk, Young's, and shear moduli and Poisson's ratio as pressure and temperature was changed. This talk will present these elastic properties as a function of pressure (up to 7 GPa) and temperature (up to 1000 °C). Finally, electron microscopy techniques will be discussed as a method of quantifying texture evolution during sample compression.

1:30

3pPA3. Broadband operation of acoustic collimated beam source. Sincheng Huang (Los Alamos National Lab., MPA-11, D429, Los Alamos, NM 87545, shuang@lanl.gov), Cristian Pantea (Mater. Phys. and Applications, Los Alamos National Lab., Los Alamos, NM), Vamshi K. Chillara, and John Greenhall (Los Alamos National Lab., Los Alamos, NM)

A low-frequency acoustic collimated beam (ACCObeam) source was recently developed by our team using the radial mode excitation of a piezoelectric disc. It relies on lateral clamping of the piezoelectric disc to produce a collimated sound beam while minimizing unwanted side lobes that occur for a free disc. ACCObeam has previously been explored and characterized for operation at the radial resonance frequencies; however, high-resolution ultrasound imaging requires broadband signals. We explore the characteristics of the broadband beam profile of ACCObeam. This requires beam profile characterization at multiple frequencies, typically incurring long measurement times. We investigate the possibility of characterizing beam profiles at multiple frequencies by exciting the ACCObeam with a broadband waveform such as a linear chirp or a Gaussian pulse. Subsequent post-processing can extract the beam profile for any specific frequency. In this talk, we present ACCObeam broadband measurements and compare them with both fixed-frequency measurements as well as numerical simulation. We also discuss the important parameters that affect the quality of beam profile characterization.

1:45

3pPA4. Acoustic manipulation of metallic particles for improved in-field material analysis. Eric S. Davis (MPA-11, Los Alamos National Lab., P.O. Box 1663, M.S. D429, Los Alamos, NM 87545, esdavis@lanl.gov), Ann Junghans, Craig A. Chavez (Los Alamos National Lab., Los Alamos, NM), Christopher Hakoda, and Cristian Pantea (MPA-11, Los Alamos National Lab., Los Alamos, NM)

In-field material analysis is an important area of analysis, having the great advantage that the analytical measurement is performed at the site where the material is located, leading to faster and more informed decision making. This turns out to be very important for some very specific materials,

such as high explosives or chemical/bio warfare agents, especially if the area to be inspected was thoroughly cleaned. The latter makes sample collection extremely difficult. However, regardless of how clean a surface is, trace amounts of the material of interest are still left behind. A combination of optical and acoustical methods that leads to improved detection efficiencies is presented. Surface-enhanced Raman spectroscopy (SERS) is a surface-sensitive technique that greatly enhances the Raman scattering by factors up to 1015, leading to detection down to the single molecule level. This technique requires very careful substrate preparation as well as very large spectroscopy equipment, which are not viable for infield analysis. In order to adapt SERS for in-field analysis, acoustic manipulation of metallic particles is used. Aggregation of particles on the surface of interest leads to a strong Raman enhancement factor, which will allow for much less sensitive handheld Raman instruments to be used in the field. Currently, preliminary results have achieved 103 enhancement, with much higher enhancement possible.

2:00

3pPA5. A noninvasive approach for temperature determination in confined Cyclotol. Cristian Pantea (Los Alamos National Lab., MPA-11, Los Alamos, NM 87547, pantea@lanl.gov), John Greenhall, David K. Zerkle, Eric S. Davis, Craig A. Chavez, Robert M. Broilo, Jonathan M. Zucker, William S. Shofner, Sarah L. Blog, and Larry D. Vaughan (Los Alamos National Lab., Los Alamos, NM)

Cyclotol is a melt-castable high explosive consisting of a mixture of RDX and TNT (75:25 wt. %). While used in conventional military applications, it can also be encountered in some types of IEDs (Improvised Explosive Devices). It is related to the more common Comp B (60:40 wt. %), and in the present work it was chosen as a case-study for noninvasive temperature determination in confined high explosives. An acoustics-based approach was used, based on (i) a collimated low-frequency acoustic beam, (ii) travel-time measurements of sound propagating along multiple paths, and (iii) sound speed-temperature inversion. Experiments were performed in a hermetically sealed cylindrical container with a volume of about 2 l, filled with casted Cyclotol. The container boundary temperature was varied between room temperature and ignition temperature. The experimentally determined acoustic temperature was in good agreement with other means of temperature measurements and finite-element modeling of temperature evolution in casted Cyclotol.

2:15–2:40 Discussion

Session 3pSCa

Speech Communication, Education in Acoustics and Psychological and Physiological Acoustics: Teaching Speech and Hearing Science to Undergraduates II

Tessa Bent, Cochair
Speech and Hearing Sciences, Indiana University, 200 S. Jordan Ave., Bloomington, IN 47405

Jennifer Lentz, Cochair
Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405

Paul E. Reed, Cochair
Dept. of Communicative Disorders, University of Alabama, Box 870242, Tuscaloosa, AL 35487

Chair's Introduction—12:55

Invited Papers

1:00

3pSCa1. A listening laboratory-based approach to teaching clinical phonetic transcription. Tyler K. Perrachione (Dept. of Speech, Lang., and Hearing Sci., Boston Univ., 635 Commonwealth Ave., Boston, MA 02215, tkp@bu.edu) and Barbara B. Oppenheimer (Dept. of Speech, Lang., and Hearing Sci., Boston Univ., Boston, MA)

Knowledge of acoustic and articulatory phonetics is fundamental to learning applied phonetic transcription skills during (pre-) clinical training in speech-language pathology. Furthermore, knowledge of acoustic and articulatory phonetics is foundational to success in advanced speech science coursework and research. We recently implemented extensive revisions to our undergraduate phonetics course aimed at improving students' ability to deploy conceptual knowledge about acoustics and articulation in developing their phonetic transcription skills, and especially in applying these skills to phonetic transcription of developmental and disordered speech. The paramount revision incorporates a weekly, collaborative listening and transcription lab led by the instructor and modelled on listening exercises in foreign language classes. Lab worksheets train transcription skills by integrating aural and acoustic analysis of speech in diverse contexts, from idealized citation speech through connected speech from children and adults with developmental or acquired phonological and speech motor disorders. Transcription skills are refined and enhanced by progressing from simple to complex applications both within and across labs. Exercises integrate visualization of speech acoustics with transcription to improve students' familiarity with waveforms and spectrograms. Course evaluations reveal students' positive valuation of lab experiences, and follow-up assessments demonstrate retention of concepts and skills.

1:15

3pSCa2. Applied hearing aids and signal processing for aural (re-)habilitation. Rachael F. Holt (Speech and Hearing Sci., Ohio State Univ., 110 Pressey Hall, 1070 Carmack Rd., Columbus, OH 43210, holt.339@osu.edu)

Students who complete undergraduate aural (re-)habilitation courses in the speech and hearing science are generally interested in going into speech-language pathology, and in lower numbers, audiology, healthcare or education. A fundamental concept that students learn in this course is the applied relation among speech acoustics, signal processing, and hearing loss. I have incorporated an in-class hearing aid laboratory to provide students with the opportunity to (1) handle hearing aids, understand their components and accessories; (2) troubleshoot basic problems with hearing aids (*e.g.*, dead battery, acoustic feedback) that they might encounter in clinical or educational settings (*e.g.*, therapy session, classroom, nursing home, etc.); and (3) listen to hearing aids to determine what speech frequency ranges are influenced when settings are changed and how this relates to a listener's hearing loss and their access to the speech spectrum. The lab is carried out in small groups with both current hearing aids and older models that allow students to change the frequency spectrum without a computer (*e.g.*, screw sets that adjust the gain in specific frequency ranges), so that the lab can easily be completed in class following lectures introducing the material.

1:30–2:00 Discussion

Session 3pSCb

Speech Communication, Education in Acoustics and Psychological and Physiological Acoustics: Teaching Speech and Hearing Science to Undergraduates III

Tessa Bent, Cochair
Speech and Hearing Sciences, Indiana University, 200 S. Jordan Ave., Bloomington, IN 47405

Jennifer Lentz, Cochair
Indiana Univ., 200 S. Jordan Ave., Bloomington, IN 47405

Paul E. Reed, Cochair
Dept. of Communicative Disorders, University of Alabama, Box 870242, Tuscaloosa, AL 35487

Chair's Introduction—2:15

Contributed Papers

2:20

3pSCb1. Lab kits for remote and socially distanced instruction in a GE Acoustics Course. Anne C. Balant (Dept. of Communication Disorders, SUNY New Paltz, New Paltz, NY, balanta@newpaltz.edu)

A lab kit that has been developed for teaching a general education acoustics course online has proven useful for socially distanced instruction in seated courses as well. This presentation will give an overview of the kit and experiences with adapting and using it to provide flexibility for students in all modalities of instruction during COVID-19.

2:25

3pSCb2. Teaching speech acoustics with adaptable Praat labs. Kathleen A. Siren (Loyola Univ. Maryland, Baltimore, MD, ksiren@loyola.edu)

Students identify and measure acoustic characteristics of vowel and consonant production in a series of labs utilizing Praat. The labs are particularly well-suited for synchronous Zoom classes with break out groups, but can be modified to be different lengths, to be completed asynchronously, and/or to be completed individually.

2:30

3pSCb3. Experiential learning of categorical perception. Allison I. Hilger (Univ. of Colorado Boulder, CO, allison.hilger@colorado.edu)

Categorical perception can be a complicated topic for undergraduate students to grasp. In this presentation, I will share how I use experiential learning to help students understand categorical perception by allowing them to 'participate' in the original Liberman et al. (1957) study.

2:35

3pSCb4. Using browser-based software to teach acoustic theory of speech production. Amy T. Neel (Univ. of New Mexico, Albuquerque, NM, atneel@unm.edu)

I will demonstrate how I use browser-based software authored by Mark Huckvale to promote active learning of the acoustic theory of speech production. Students create the complex glottal tone using ESynth, filter the glottal tone with various vocal tract filters with ESystem, explore the impact of vocal tract shapes on formants using VTDemo, and examine their own vowel formants with ESection.

2:40

3pSCb5. A place to share teaching resources: Speech and language resource bank. Benjamin V. Tucker (Univ. of Alberta, Edmonton, Alberta, Canada, benjamin.tucker@ualberta.ca), Matthew C. Kelley (Univ. of Alberta, Edmonton, Alberta, Canada), and Charles Redmon (Univ. of Oxford, Oxford, UK)

One of the major difficulties of teaching is accessing the vast amounts of material/resources already available to instructors. The Speech and Language Resource Bank (SLRB) is a platform and central repository for sharing, managing, and growing community resources for teaching and research in the speech and language sciences.

2:45

3pSCb6. Velocity estimation via Doppler signal processing: An educational experiment. Jonah Singer (Mahomet-Seymour High School, Mahomet, IL, jonahryansinger@gmail.com) and Eden Oelze (Mahomet Seymour High School, Mahomet, IL)

In a previous talk, we presented the use of Doppler processing of an acoustic signal recorded from a moving RC car to estimate the speed of the RC car traveling to and away from an observer. In this work, a multi-harmonic dynamic model for the RC car motor is incorporated into the acoustic model and this multi-harmonic tracking algorithm is used to estimate the velocity of the RC car based on this improved model, implemented in Python.

2:50–3:15 Discussion

Session 3pSCc

Speech Communication: Speech Studies Conducted Remotely: Methods and Examples IV

Sandie Keerstock, Cochair
Psychological Sciences, University of Missouri, 124 Psychology Bld, Columbia, MO 65201

Pasquale Bottalico, Cochair
Department of Speech and Hearing Science, University of Illinois at Urbana-Champaign, 901 South Sixth Street, Champaign, IL 61820

Eric Hunter, Cochair
Com Sciences & Disorders, Michigan State University, 1026 Red Cedar Road, East Lansing, MI 48824

Chair's Introduction—3:30

Session will be cancelled if no additional Lightning Round presentations are submitted.

Session 3pUW

Underwater Acoustics: Seabed Characterization Experiment 2017 Studies II

Tracianne B. Neilsen, Cochair
Physics and Astronomy, Brigham Young University, N251 ESC, Provo, UT 84602

Zoi-Heleni Michalopoulou, Cochair
Department of Mathematical Sciences, New Jersey Institute of Technology, Newark, NJ 07102

Charles W. Holland, Cochair
Electrical and Computer Engineering, Portland State University, Portland, OR 97207

Chair's Introduction—12:55

Contributed Papers

1:00

3pUW1. Compressional wave attenuation in muddy sediments at the New England Mud Patch. Charles W. Holland (Elec. and Comput. Eng., Portland State Univ., Portland, OR 97207, charles.holland@pdx.edu) and Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada)

A new method for measuring *in situ* compressional wave attenuation exploiting the spectral decay of Bragg resonances is applied to sediments at the New England Mud Patch. Measurements of layer-averaged attenuation in a 10.3 m mud layer yield 0.04 {0.03 0.055} dB/mi kHz (braces indicate outer bounds); the attenuation is twice as large at a site with 3.2 m mud thickness. Both results are strongly influenced by a $\sim$1 m sand-mud transition interval, created by geological and biological processes which mix sand (at the base of the mud) into the mud. Above the transition interval, homogeneous mud exhibits an attenuation 0.01–0.02 dB/m kHz, lower than that in the sand-mud transition interval by a factor of 10. Informed by these and additional observations, mud attenuation in and above the transition interval appears to be roughly spatially invariant across the area, explaining the factor of two in attenuation between the two sites by simple depth scaling. Further, the ubiquity of the processes that form the transition interval suggests that the scaling may be broadly applied to other muddy continental shelves. In principle, attenuation predictions in shallow water could be substantively improved with a modest amount of geologic and biologic information. [Research supported by ONR Ocean Acoustics.]

1:15

3pUW2. A discussion of the physical mechanisms of acoustic attenuation in the New England mud patch based on results of the Seabed Characterization Experiment. Allan D. Pierce (Cape Cod Inst. for Sci. and Eng., P.O. Box 339, 399 Quaker Meeting House Rd., East Sandwich, MA 02537, allanpierce@verizon.net) and T. Douglas Mast (Biomedical Eng., Univ. of Cincinnati, Cincinnati, OH)

Experimental results for attenuation reported in connection with the Seabed Characterization Experiment 2017 are discussed and analyzed. Much of the results suggest attenuation depends on depth within a mud layer and that, over a wide frequency range, attenuation is nearly proportional to frequency. The present paper suggests that attenuation in mud is due almost entirely to localized processes, including (1) viscous flow (Stokes flow) around suspended sand particles, (2) sliding friction between particles, and (3) relaxation effects associated with breaking and re-association of bonds between clay particles. Present theories due to Buckingham and Chotiros and others are reviewed, and a fresh case is made for relaxation processes as a dominant contributor. Theoretical results show that a continuous smear of relaxation processes can account for a linear or power-law dependence of attenuation on frequency over a wide range, but excluding frequencies close to zero. Similar considerations apply to propagation of ultrasound in blood. All physically viable mechanisms will result in a frequency-squared dependence at low frequencies, but the dependence can change to linear dependence at frequencies slightly above zero. Theories based on Stokes flow around suspended sand particles can explain the dependence on porosity and on the number density of particle grains. Relaxation processes appear to be ubiquitous, and can be associated with diverse types of solid particles nominally touching each other, sliding, and separating.

Invited Papers

1:30

3pUW3. Spatial variation of sediment geoacoustic properties at the Seabed Characterization Experiment site. Jie Yang (Appl. Phys. Lab, Univ. of Washington, 1015 NE 40th St., Seattle, WA 98105, jieyang@uw.edu), Darrell R. Jackson (Appl. Phys. Lab, Univ. of Washington, Seattle, WA), and John Goff (Inst. for Geophys., Univ. of Texas, Austin, Austin, TX)

The Seabed Characterization Experiment, sponsored by the Office of Naval Research, was carried out 5 March–10 April, 2017 (SBCEX17) on the New England Mud Patch, approximately 100 km south of Martha's Vineyard. The main SBCEX17 experimental site covers an area of 15 km × 30 km with water depth in the range of 75–80 m. The Sediment Acoustic-speed Measurement System (SAMS) is designed to measure sediment sound speed and attenuation simultaneously over the surficial 3 m of sediments. Sediment sound speed results in the frequency band of 2–10 kHz can be found in an earlier publication (*IEEE JOE*, doi:10.1109/JOE.2019.2946004). During SBCEX17, SAMS was successfully deployed at 18 sites, which were chosen to be co-located with gravity or piston cores that were collected during the two recent survey cruises in 2015 and 2016. In this talk, our previous results are extended to include both sound-speed and attenuation. The frequency range is widened, and preliminary results for the dependence of sediment sound-speed and attenuation on both range and depth are presented. Sediment geoacoustic properties obtained by SAMS at the 18 sites are compared with historical and recent sediment property surveys giving information on bottom layering, porosity, and grain size. [Work supported by ONR.]

1:45

3pUW4. Mud as a porous medium. Nicholas P. Chotiros (Appl. Res. Labs., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, chotiros@utexas.edu)

Since marine mud supports shear waves, it must have an elastic, though fragile, frame. It is also saturated with seawater, therefore it could be modeled as a porous medium. It is an unusual porous medium for a number of reasons. The boundary between the skeletal frame and the pore fluid is difficult to define. The effective porosity of the skeletal frame is not the same as the bulk fluid fraction. The chemistry of mud suggests that a fraction of the water is an integral part of the skeletal frame. Similarly, a fraction of the solid particles may be suspended in the pore fluid. The structure of the skeletal frame is a function of several factors, including salinity of the water and mineralogy of the clay particles. Porous media have two main loss mechanisms: losses in the skeletal frame and viscous losses due to relative motion between the frame and the pore fluid. In the case of marine mud, the frame losses may be modeled as a relaxation process. The measurements from the Seabed Characterization Experiment show it has a spectrum of relaxation frequencies, consistent with a stationary creep process. [Work supported by ONR, Ocean Acoustics Program.]

2:00–2:15 Discussion

OPEN MEETINGS OF TECHNICAL COMMITTEES

The Technical Committees of the Acoustical Society of America will hold open meetings on Tuesday and Thursday evenings. Meetings will begin at 6:00 p.m. on Tuesday and 5:00 p.m. on Thursday, except for Noise and Speech Communication as noted in the list below.

These are working, collegial meetings. Much of the work of the Society is accomplished by actions that originate and are taken in these meetings including proposals for special sessions, workshops, and technical initiatives. All meeting participants are cordially invited to attend these meetings and to participate actively in the discussion.

Committees meeting on Tuesday are as follows:

Acoustical Oceanography
Animal Bioacoustics
Architectural Acoustics
Engineering Acoustics
Physical Acoustics
Psychological and Physiological Acoustics
Signal Processing in Acoustics
Structural Acoustics and Vibration

Committees meeting on Thursday are as follows:

Biomedical Acoustics
Computational Acoustics
Musical Acoustics
Noise—4:30 p.m.
Speech Communication—5:30 p.m.
Underwater Acoustics

Please see the Acoustics in Focus webpage for open meeting registration links acousticalsociety.org/asa-meetings/

AUTHOR INDEX

to papers presented at

180th Meeting of the Acoustical Society of America