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Role of Acoustics in Energy Focusing Phenomena

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Fluids and solids that are driven off equilibrium do not relax smoothly to equilibrium. Although the march to equilibrium is characterized by an ever increasing entropy, continuous media can nevertheless pass through configurations which display a wide range of phenomena which concentrate the energy density.

Sonoluminescence (SL) is the paradigm of energy focusing phenomena.[1] Here, a standing sound wave causes a trapped bubble to pulsate so violently [acceleration of the bubble wall can reach 10^{12}g] that acoustic energy is transduced into flashes of ultraviolet light whose duration can be much shorter than a nanosecond. When water is used as the fluid, SL can be observed at sound fields with an amplitude of about 1 atmosphere. At this amplitude each water molecule is vibrating with an energy of about 1.5×10^{-23}erg, whereas a photon, which we assume originates from the region of a single atom, has been observed to have an energy as high as 6 eV. A comparison of these numbers indicates that SL involves a concentration of the energy density by at least a factor of 4×10^{11}. The SL spectrum might extend to even higher energies but observations have been limited by the extinction coefficient for light traveling through water.

When a 30-kHz sound wave acts on a bubble containing helium atoms the observed spectrum is accurately fit by Planck's blackbody law[2] with a temperature of 20,000 K, four times hotter than the surface of the sun. A condition for blackbody radiation is that the size of the hot spot must be greater than the photon matter interaction distance. But this SL hot spot has a radius that is smaller than 1/2 micron and it is difficult to understand how it can be opaque. If the hot spot is smaller than the interaction length it would be transparent and the spectrum would look like Bremsstrahlung radiation from a plasma. A plasma forms because the contents of the imploding bubble get so hot that the atoms ionize. The free electrons will then zip around with a velocity determined by the temperature of the plasma. When the electrons collide with much heavier ions they accelerate and radiate light [Bremsstrahlung]. If the light escapes without absorption the plasma is transparent, if it is absorbed the plasma is a blackbody. For the alternative model of the hot spot, the transparent plasma scenario, the best fit [helium] spectrum would have a temperature of 50,000 K [as compared to 20,000 K for the blackbody model which displays a better overall fit to the data]. At acoustic frequencies of 1MHz, the bubble is smaller and the observed spectrum is now best fit by the transparent plasma model, and a temperature of about one million degrees.[3]

Evidence that SL originates in a plasma has been provided by application of plasma diagnostics to argon bubbles in sulfuric acid.[4] At drive levels so low that these bubbles are dimmer than bubbles in water, lines from excited states of argon ion [Ar+] that are 37eV above the ground state can be observed. The width of emission from neutral argon lines yields an average pressure of 1,500 atm, which also matches the average pressure determined by light scattering measurements of the radius of these bubbles. At higher sound fields the lines are broadened and unresolvable but light scattering yields pressures over 3,500 atm suggesting that the high drive bubbles are substantially hotter than the weakly driven case where the Ar+ lines were first discovered.

The densities and temperatures which can be accessed with modest sound fields are extraordinary. One is tempted to wonder if bubble acoustics can be used to reach conditions for nuclear fusion. Although this is an exciting and worthwhile direction of research claims of such a success[5] have met with strong skepticism.[6] Some optimism that

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We hear that...

• **Neville Fletcher** received the first award for Outstanding Contribution to Acoustics from the Australian Acoustical Society (AAS). The award was made at the AAS conference in Busselton. Neville was especially recognized for his contributions to musical acoustics and biological acoustics. He has also served as editor of the journal *Acoustics Australia*. Neville is a Fellow of ASA, and received the Silver Medal in Musical Acoustics in 1998.

• The President's Prize, for the best technical paper at a conference of the Australian Acoustical Society was presented to **Laura Brooks, Rick Morgans,** and **Colin Hansen** for their paper "Learning Acoustics Through the Boundary Element Method: An Inexpensive Graphical Interface and Associated Tutorials." This paper is reprinted in the December issue of *Acoustics Australia*.

From the Editor: Selling acoustics

One of the standing committees of ASA is the Public Relations Committee, chaired by Geoffrey Edelmann, whose purpose is to make the public more aware of acoustics and the ASA. In 1991 this committee started *ECHOES* for this very purpose, and it also sponsors awards to journalists and scientists for good science writing about acoustics for the public. It sponsors a World Wide Pressroom, and at many meetings it sponsors a press luncheon at which reporters can meet and interview authors of timely papers. In recent years, Ben Stein and Martha Heil from the American Institute of Physics (AIP) have ably handled much of the media relations, both before and during our meetings.

Two important areas in which we have not been very successful in promoting acoustics, however, are films and television. A few years ago, the movie "Chain Reaction" misrepresented sonoluminescence (see the Spring 1988 issue of *ECHOES*), and I'm sure that we all know of cases in which acoustics has been rather misrepresented on local TV. That has been the case with science in general, although the health sciences and space science have fared better than most other sciences. In an effort to promote physics on local TV, AIP has created a series of short videos called "Discoveries and Breakthroughs Inside Science" (see the Summer 2004 issue of *ECHOES*) and a few of them have dealt with acoustics.

The New York based Alfred P. Sloan Foundation has a program in public understanding of science, which supports books, radio, film, television and theater intended to reach a lay audience. They funded such plays as *Proof* (which became a movie), *QED*, and *Copenhagen*. They also sponsor Sloan Feature Film Prizes at the Hamptons International Film Festival and the Sundance Film Festival. Since 2004 they have funded a screenplay development program in partnership with the Tribeca Film Institute, which was co-founded by Robert De Niro. "De Niro Seeks Science Scripts" was the header of a press release sent out by the Sloan Foundation when the screenplay competition was launched. Among the winners have been "Hubble" (the story of astronomer Edwin Hubble) and "The Broken Code" (the story of Rosalind Franklin's contribution to the discovery of DNA's double helix structure).

When will someone write a successful screenplay or stage play about acoustics? Sound and music are naturals for capturing the attention of young people. Breakthroughs in medical acoustics (bloodless surgery, ultrasonic imaging, lithotripsy, etc.) have a lot of public appeal. Thermoacoustics and sonoluminescence have great media potential, even without exaggeration or misrepresentation. What about the drama of speech and hearing?

I sincerely hope that someone will write a successful script for film or television that will convey to the public some of the excitement we acousticians experience almost every day. We are told that the TV series "LA Law" dramatically increased numbers of applications to law schools. Hospital sitcoms have undoubtedly done the same for medicine and nursing. Can you imagine what a successful series in which the hero or heroine is an acoustician would do for our profession?

From the Student Council

Andrew Ganse

The Providence meeting was perhaps slightly subdued in terms of student attendance compared to recent meetings—come on, we can admit it, everyone's saving up for the next ASA meeting in Hawaii! Still, the student social events were well attended—the Student Icebreaker on the first night, the informal Student Outing midweek which landed a crowd at Snooker's Bar & Grill playing pool and listening to reggae. Preceding the outing was the more structured Student Reception, hosting a buffet dinner and recognition ceremony at which Dr. Lawrence Crum was presented with the Student Council Mentoring Award. Students are greatly encouraged to nominate ASA members for the Mentoring Award; the process is ongoing and nomination forms are found on the ASA student website under Activities.

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cavitation will provide a route to fusion is provided by the observation that SL enjoys a big parameter space. For instance in the water hammer arrangement[7] the integrated light emission has been scaled up by a factor of 1 million as shown by the photo of a single such flash in Fig. 1.

Fig. 1. Single flash of light emitted by a collapsing bubble of xenon gas in a vertically excited vibration.

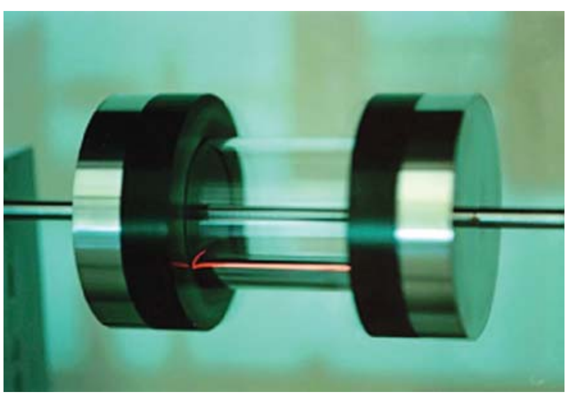

Fig. 2. Barometer light emitted where the Hg meniscus scrubs against the ascending glass wall of a cylinder rotating about the horizontal axis.

In the 1930's the well known phenomenon of frictional electricity formed the basis for the prediction of SL. A realization of frictional electricity that goes back to Picard's "barometer light" of 1676 is shown in Fig. 2. Here the scrubbing of the Hg meniscus against the ascending wall of a glass tube with a rotational velocity of 1 mm/sec around its horizontal axis generates picosecond electrical discharges where the electrons are accelerated to over 1% the speed of light.[8] The red line is light emission from the excited states of neon gas in the cell.

Can ripping mercury off a dielectric surface create even more energetic emissions where electrons are accelerated to x-ray energies? Evidence that this may be possible comes from reports of just such observations when mica is fractured.[9] This work has not been independently reproduced, possibly because of its timing and context relative to "cold fusion." After all, if a process delivers enough energy to accelerate electrons to 10's of keV then the delivery of that energy to individual ions will meet conditions for nuclear fusion if, of course, the appropriate ion such as deuterium is employed. That thermal gradients in a cubic centimeter size crystal can lead to x-ray emission has actually been known and patented and reproduced since the 1970's.[10] This effect is most prominent in ferroelectric crystals. These materials have an enormous spontaneous polarization. In fact freshly made lithium niobate has a spontaneous polarization of 70 $\mu C/cm^2$ which is equivalent to an internal electric field of about 10^7 V/cm! In an uncontrolled environment stray charges attach to the surface and cancel the intrinsic field of the crystal. But by heating [or cooling] the crystal in a vacuum the dependence of spontaneous polarization on temperature creates an unbalanced charge on the surface. Typically tens of degrees creates a field of 100 keV. If fractured mica really makes x-rays then it is likely due to the appearance of similar surface charges at the cleaved surfaces.

Now if a modestly heated cubic centimeter crystal makes 100-keV x-rays then configuring the crystal so as to deliver this energy to a deuterium ion should generate nuclear fusion. This has been achieved[11] via mounting a 100 nm wide tungsten tip on the crystal [Fig. 3]. Neutral deuterium molecules that drift into the region of the tip are dissociated and ionized by the huge electric field. If the crystal is oriented so that the field is positive then the

Fig. 3. Lithium iobate crystal mounted on a heater/cooler. A tungsten tip is attached to a copper electrode that is fixed to the surface of the crystal.

Role of acoustics in energy focusing phenomena

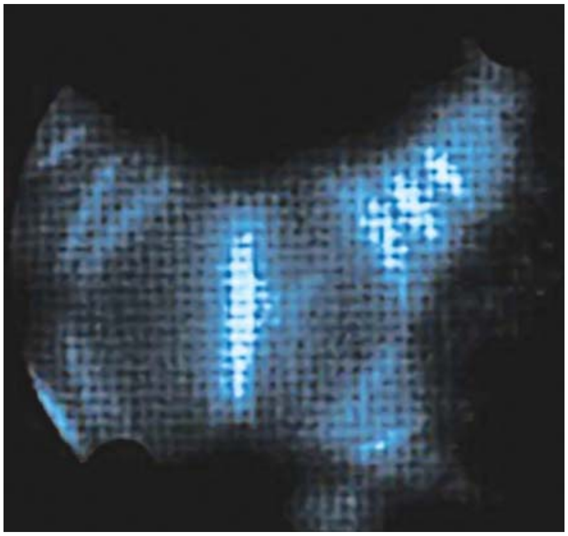

Fig. 4. Image of ions striking a scintillator after being accelerated by the crystal's electric field. When the target is deuterated the bright areas locate the region where nuclear fusion occurs.

freshly produced ions receive 100keV of potential and are energetic enough to fuse with a deuterium target. An example of the pattern of energetic ions striking a target is shown in Fig. 4.

Strong ferroelectricity such as observed in lithium niobate has its origin in the instability of high-frequency modes of oscillation of an ionic crystal.[12] If, for simplicity, one imagines a crystal lattice where the short range repulsive forces are provided by springs and the attractive forces are due to long range coulomb interaction between the ions, then there exists a range of values for the interatomic spacing and spring constant for which the small amplitude normal mode of oscillation becomes unstable for the long wavelength transverse optical mode. This results in a relative displacement of the ions to a state which has a spontaneous polarization. Calculation of the new equilibrium state is a matter of compelling current interest.[13]

Sonoluminescence, frictional electricity, fracture and ferroelectric emission are phenomena characterized by energy density concentration. It will be interesting to see what additional natural processes can be added to this list.

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Seth Putterman, a faculty member at UCLA since 1970, is a researcher in nonlinear fluid mechanics and acoustics who (with coworkers) has developed the theory of universal power spectra in wave turbulence, and participated in the discovery of fifth sound, superfluid two-phase sound and resonant mode converstion in 4He. He also participated in the discovery of kink solitons and envelope solitons in various elastic media. Most recently he is responsible for the renewed interest in energy focusing phenomena and their relationship to sonoluminescence, friction, triboelectrification, and crystal-generated nuclear fusion. He is a Fellow of the Acoustical Society of America and the American Physical Society and a past recipient of an Alfred P. Sloan Fellowship.

Optimization of Miniature Thermoacoustic Coolers

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The ever increasing need for high-power density thermal management in various electronic devices and systems has motivated the development of miniature thermoacoustic coolers and heat pumps. A thermoacoustic approach is presented here because it is relatively simple, it has very few moving parts, it is quite efficient, and it can be applied to a wide range of systems needing thermal management; this work deals with the development of such a device.

Heat is pumped up a temperature gradient using an intense sound field inside a resonator. Cooling is produced because a sound field has inherent temperature oscillations which are caused by acoustic pressure variations; the temperature variations are thermally rectified using a stack of high surface area material, like cotton wool, placed in a resonator. A loud sound is produced by an acoustic driver which is coupled to the resonator. The stack is located inside the resonator at a position where the generated standing wave has a maximum intensity. In order to have an operational cooler, a heat exchanger is thermally attached to each end of the stack. Thus heat will be absorbed from the cold heat exchanger and it will be pumped acoustically to the hot heat exchanger, where it is dissipated in air. In miniaturizing such a device the resonator length scales inversely with pumping frequency. It is typically ~ 4 cm for 4 kHz, and 7 mm for 24 kHz. Figure 1 shows a schematic of a thermoacoustic refrigerator operating at approximately 4 kHz. Its cooling power density scales with the acoustic intensity produced by the driver in the resonator. Hence in the optimization of this device, it is essential to achieve high acoustic intensity. That is one of the goals of this project.

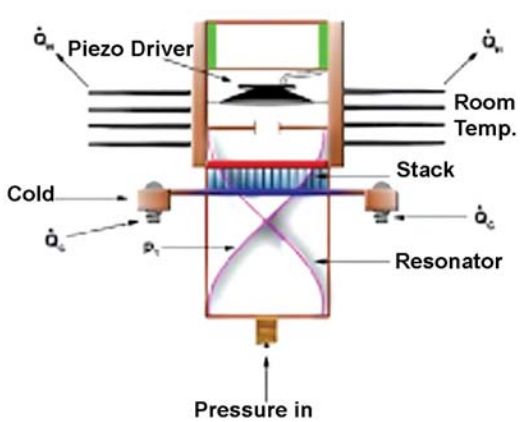

Figure 1 shows the acoustic driver coupled to a half-wave cylindrical resonator. The rate of heat extraction at the cold heat exchanger is Q_C and the rate of heat rejection at the hot heat exchanger is Q_H. The driver consists of a piezoelectric element, in the bimorph configuration, which is impedance matched to the resonator by means of a light cone, firmly glued to a low impedance point of the piezo driver. Impedance matching can also be achieved by means of a Helmholtz resonator, tuned to the piezo driver. The stack, with a heat exchanger at each end, is located in the resonator at an axial position where sound intensity is maximum; it is approximately 3 mm long.

The cold heat exchanger, consisting of copper wire mesh, extends radially outside the resonator; thermal contact to the sample or device needing cooling is made there. The pumped heat and acoustic work are dissipated in the hot heat exchanger, also made out of copper mesh. This heat exchanger is thermally anchored to copper or aluminum fins cooled convectively by air at ambient temperature. Since the hot heat exchanger can be a significant thermal bottleneck it is made out of two to four layers of copper mesh, soldered to the fin structure. The working gas in the cooler has usually been air, for convenience. Better performance can be achieved with helium gas or a gas mixture such as helium-argon.

Since the cooling power density of this device depends directly on the acoustic intensity inside the resonator, a special effort was taken to optimize this part of the cooler. An acoustic intensity of 160 dB can lead to a cooling power density of 0.5 watt/cm^2, using air at one atmosphere. In order to raise this level of cooling, as needed in many applications, the cooler was pressurized up to 15 atmospheres. This raises the cooling power accordingly. Increasing the working gas static pressure provides a better impedance match between the driver and working gas, thus raising the sound level for fixed electrical power input. In fact making the driver more efficient means that its power output can be reduced, thus extending its lifetime. Since the devices are small, the pressure of the working gas can be raised to much higher levels than 15 atmospheres without exceeding the strength of materials.

Even though the piezoelectric driver is essentially a capacitor (but it is a lossy one), it does get heated up by two main mechanisms, electric hysteresis losses and mechanical straining on resonance, as well as Joule heating in input leads. This has two negative effects on the cooler in that there is a stray heat influx and that the sound level output saturates with electrical power input. The issue of impedance matching has been addressed again by coupling the piezo driver to a Helmholtz resonator which drives the cooler resonator. The advantages of such an arrangement are that the sound level is raised, the driver heating is contained within the hot part of the refrigerator, and there is a better defined standing wave inside the resonator. It is important to note that tuning to resonance of all the elements in this unit is important for optimal performance.

Using a laser particle image velocimeter, streaming inside the cooler was studied in order to determine its effects on the cooling power and to minimize its effects by modifying the cooler geometry. The streaming effect deals with acoustically stimulated gas flow within the cooler which transfers heat to its cold parts; this is due to acoustically stimulated viscous losses with the cooler walls and with the stack which causes forced connection .

As a result of this study dealing with higher acoustic intensity levels we show that an optimized high frequency thermoacoustic cooler can reach cooling power density levels of a few hundred watts per square centimeter, with applications to laser cooling, electronic cooling, and other applications needing thermal management.

This work is funded by The Office of Naval Research.

This article is based on paper 4pPA11 presented at the 151st ASA meeting in Providence.

Husam El-Gendy, Laurence Lyard, and Orest Symko.

CLASSIFYING KILLER WHALE VOCALIZATION USING TIME WARPING

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Fig. 1 Recording killer whale sounds.

Introduction and background

Marine mammals produce a wide range of vocalizations; therefore an improved ability to classify recorded sounds could aid in species identification as well as in tracking movements of animal groups. Killer whales produce three forms of vocalizations: clicks, whistles, and pulsed calls. Clicks consist of an impulse train (series of broadband pulses); whistles consist, for the most part, of a single sinusoid with varying frequency; and pulsed calls are more complex sounds with many harmonics. The repetition rate is a measure of the periodicity of the signal, and its measurement is called "pitch tracking" or "fundamental frequency tracking" in the speech literature. This measure gives rise to a pitch contour which is equivalent to the melodic line of a song (see Fig. 2).

Killer whales produce a number of highly stereo-

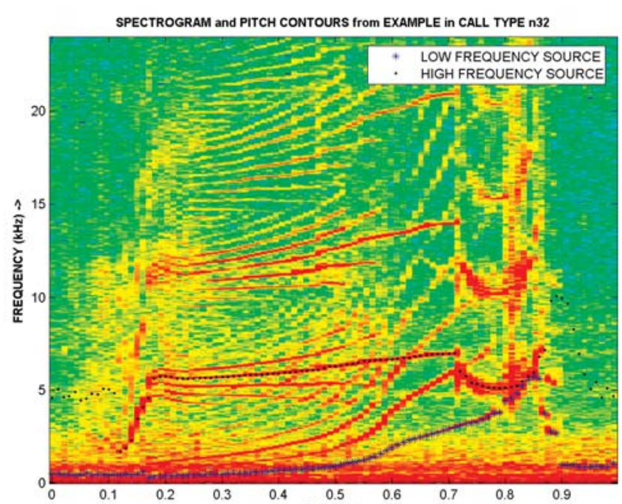

Fig. 2. Spectrogram showing pitch contours of the low frequency and high frequency sources in one killer whale pulsed call. Note there is noise before and after the onset of the calls.

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typed (repeated and recognizable) pulsed calls, which are thought to be learned within the pod (living group). Repertoires of these stereotyped calls are pod specific, and the pitch contours of shared stereotyped calls are also group-specific from matrilineal lines (group with same mother) to larger pods (consisting of several matrilineal lines) to clans (even larger groups sharing calls). One of the remarkable features of killer whale pulsed calls is that they contain two overlapping but independently modulated contours or "voices." These are shown superposed on the spectrum as in Fig. 2. Bi-phonation, as this is called, is common in birds but has been described for few other marine mammal sounds. One of the challenges of analyzing these complex sounds is to "pitch-track" these two components from the same sound as shown in the example.

For the most part, the sounds produced by killer whales have been classified into groups called "call types" by humans from listening to the calls and observing their spectra.[1] This human classification by eye and ear is quite consistent, and has been useful to reveal group-specific acoustic repertoires and matching vocal exchanges. It would, nonetheless, be useful to replace human classification with an automatic technique because of the large amounts of data to be classified, and the fact that automatic methods can be fully replicated in subsequent studies.

In our studies we examined two sets of sounds previously classified into call types by human listeners. The first set was recorded from captive killer whales in Marineland in the French Antilles, and the second set from northern resident whales recorded on the open sea.

Dynamic time warping (DTW) and dissimilarity of pitch contours

The sounds that were classified into each call type have a similar shape or contour within that group

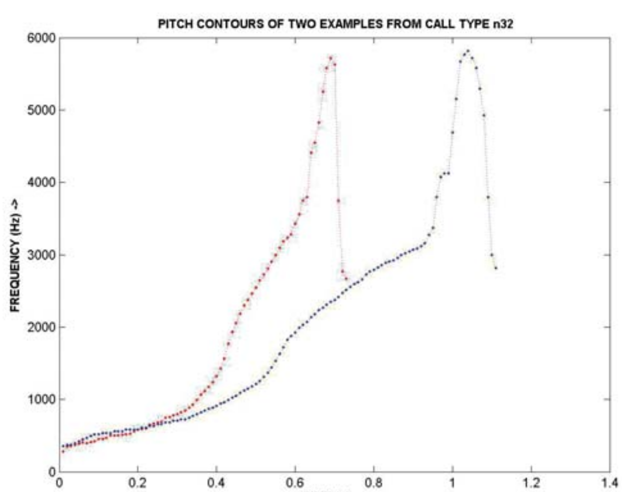

Fig. 3. Pitch contours of two examples from call type n32. The shorter contour is from the sound with spectrum in Fig. 2.

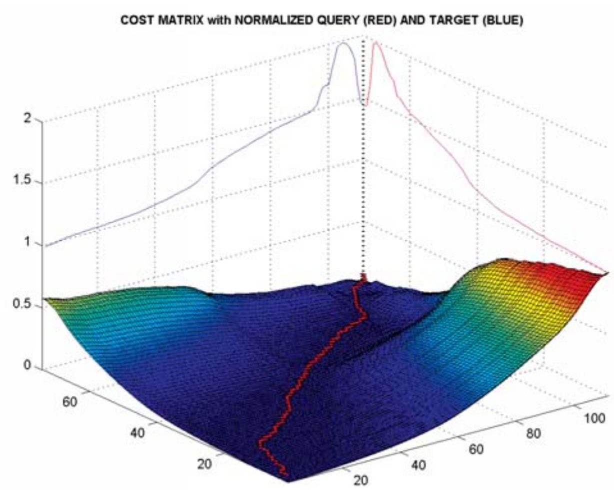

Fig. 4. Cost matrix with minimum cost path in bold red through the center. The shorter sound is called the query and the longer sound the target.

although the lengths of the calls will differ. For the automatic classification, a technique for quantitatively comparing curves of similar shape but different length is required. Dynamic time warping was widely used in the early days of speech recognition and more recently in musical information retrieval, and it is ideal for this task. The basic idea of DTW can be explained with an example using two sounds from the same group "n32."

A difference matrix is constructed from each number of sound 1 subtracted from each number of sound 2. This will give low values where the curves have similar values. From these numbers a cost matrix is constructed, which can be loosely thought of as a running sum of the differences between the two curves for all possible paths. The minimum path will follow the low numbers measuring overall differences in the best match of the two curves; this path can be traced and the final distance or dissimilarity is the last number attained in the minimum path. This can be visualized in Fig. 4 as the path of minimum effort through a mountainous terrain.

The "dissimilarity" or distance thus obtained is an excellent measure of contour differences. Identical signals will have a diagonal best path and a cost of zero (zero dissimilarity), while larger contour differences will have a correspondingly larger cost/dissimilarity. For classification these costs are a means of clustering the calls having the smallest dissimilarities.

Classification

The computer classification based on minimum dissimilarity within groups was compared to the human classification into call types for each of the two sets of whale sounds. For the Marineland calls using these distances and then running through the calculation a second time using the derivative of each of the contours (measuring the shape rather than the absolute value), an outstanding 99 % agreement with the human grouping was obtained. For the northern resident whales, dissimilarity matrices for the low frequency and high frequency calls were added to give an overall distance. Agreement with the perceptual classification was 90 % which is amazingly good given the similarity of contours in several of the sub-groups.

Conclusion

Dynamic time warping shows promise for automatic classification of killer whale call types. One of the most exciting applications of this technique would be the ability to monitor the movements and habitat-preferences of killer whales just by tracking sounds heard at remote monitoring stations. This will only be possible with systems developed to automatically process and identify calls heard at those locations so that the group producing them can be identified remotely.

Acknowledgment

JCB is very grateful to Dr. Eamonn Keogh for his MATLAB code which was adapted to give Fig. 3. Funding was provided to PJOM by Woods Hole Oceanographic Institution's Ocean Life Institute and a Royal Society fellowship.

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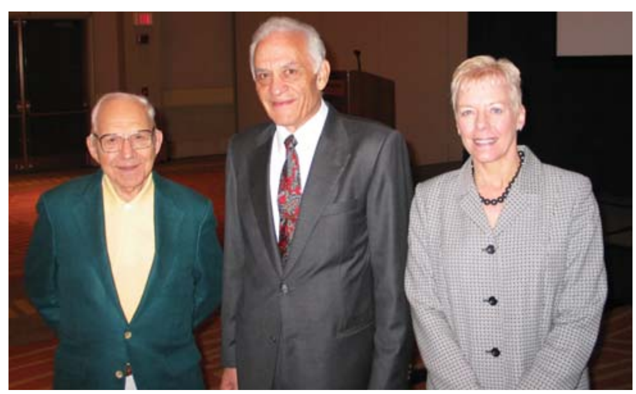
Patrick Miller is a Senior Research Fellow at the Sea Mammal Research Unit in the University of Saint Andrews in Scotland, and recent holder of a Royal Society USA/Canada Fellowship. Miller completed the Ph.D. on vocal signals of killer whales in 2000 jointly from the Woods Hole Oceanographic Institution and the Massachusetts Institute of Technology. His research focuses on acoustic communication and social behavior of marine mammals, foraging and diving.

This article is based on paper 5aABb2 at the 151st ASA meeting in Providence.

At the College of Fellows luncheon at the Providence meeting Dr. Amar Bose gave an interesting lecture on a novel suspension system his company has developed for automobiles. Each of the four wheels is independently controlled by a computer which is modeled to react to potholes, bumps, and turns. A fascinating video showed cars leaning into turns (more like a motorcycle) rather than out. Also cars were shown smoothly going over speed bumps, which raised one obvious question from the audience (and maybe the police). The four wheel controllers can also be directly controlled, so that by appropriately raising and lowering the front and rear wheels the car was made to jump over a small hurdle—impressing everyone in attendance.



Dr. Amar Bose (center) is joined by Leo Beranek and Jan Weisenberger, Chair of College of Fellows. (Photo by Charles Schmid)

Scanning the Journals

Thomas D. Rossing

•**"Virtual Acoustic Prototypes:** Listening to Machines that Don't Exist" is the title of a paper in the December issue of *Acoustics Australia*. A virtual acoustic prototype (VAP) is a computer representation of a machine such that it can be heard without having to exist as a physical assembly. Whereas visualization tools are well developed in the field of visual design, the analogous tools for auralization are still in their infancy. In order to construct a VAP, a method is needed to represent the excitation and transmission mechanisms. Airborne sound, fluid-borne sound, and structure-borne sound must be considered. This paper was adapted from the keynote lecture at Acoustics 2005.

•Physicists have developed a mathematical model to explain the breathing patterns of **canaries when they sing**, according to a paper in the 10 February issue of *Physical Review Letters*. By treating both a bird's vocal organ and neurons as nonlinear systems, researchers have found that complex songs, involving notes of many frequencies and lengths, might be produced by surprisingly simple neurological structures and processes. The new model shows that birdsong is produced from the interplay between the air sac and the neural system in contrast to the long-held view in which a nervous system sends instructions to a passive body. This suggests that subharmonic behavior can play an important role in providing a complex variety of responses with minimal neural substrate.

•"Sound ideas" is the title of a feature article on **phononic crystals** in the December issue of *Physics World*. When a wave passes through a periodic structure, interference leads to the formation of "band gaps" that prevent waves with certain frequencies from traveling through the structure. Band gaps are observed for electron waves in semiconductors, electromagnetic waves in photonic crystals, and sound waves in phononic crystals. The periodic variation in the density and speed of sound that is needed to make a phononic crystal can be achieved by making air holes in an otherwise solid structure. Negative refraction in phononic crystals is possible due to multiple scattering of sound waves at the solid-air interfaces. Phononic crystals could provide researchers in acoustics and ultrasonics with new components that offer the same level of control over sound that mirrors and lenses provide over light. [Phononic crystals were reported in *Phys. Rev. Letts.* **93**, 024301 (July 9, 2004); see Fall 2004 issue of *ECHOES*].

• The **spiral shape of the cochlea** increases sensitivity to low frequency sound, according to a paper in the March 3 issue of *Physical Review Letters*. Although calculations show that curvature has little effect on the average vibrational energy traveling along the tube, energy increasingly accumulates near the outside edge of the spiral rather than remaining evenly spread across it. Low frequencies travel the furthest into the spiral, so the effect is strongest for them. Concentration of sound intensity translates into higher sensitivity. The researchers liken the sound propagation to the "whispering gallery modes" found in domes such as London's St. Paul's Cathedral.

• The complex **songs of humpback whales** have their own syntax or grammar, according to an article in the 23 March issue of *New Scientist*. Male humpback whales produce songs that last anywhere from six to thirty minutes, and these vocalizations vary across the seasons. During breeding periods they are thought to help attract female partners. Now computer programs have been used to analyze complete songs and to demonstrate their hierarchical syntax. Shorter whale songs appear more complex than longer ones. The investigators admit that we are still a long way from understanding the meaning of whale songs, however. Some of the whale songs can be heard at www.newscientist.com/channel/life/dn8886.html.

• The **acoustics of the singing voice** is the topic of a review article in the April issue of *Physics World*. Scientists are now able to record spectra of the human voice using relatively simple equipment, and this is having a major impact on the way singing is learned, performed, and recorded. Displaying the spectral signature of the voice in real time on a computer screen, for example, provides an effective teaching aid. It is possible to detect piracy in commercial recordings and even to synthesize the human voice to recreate lost sounds. Almost all songs recorded nowadays have undergone some degree of pitch shifting, the article claims, to disguise the fact that many pop stars cannot sing very well.

• The use of **ultrasonic communication** by the concave-eared torrent frog is reported in the 16 March issue of *Nature*, Males of this species emit birdlike melodic calls with pronounced frequency modulations that often contain spectral energy in the ultrasonic range. This extraordinary upward extension into the ultrasonic range is likely to have evolved in response to the low-frequency ambient noise near streams.

• Regular **didgeridoo** playing has been found to be an effective treatment for patients with obstructive sleep apnea, according to a report in the 23 December issue of the *British Medicine Journal*. Participants practiced an average of 5.9 days a week for 25.3 minutes.

• New digital video technology can reveal **shock waves** as never before according to an article in the January-February issue of *American Scientist*. Shock waves, like sound waves, are usually as invisible as the air through which they travel. However, schlieren and shadowgraph techniques have been used for flow visualization for at least 100 years. Now high-speed digital cameras with retroreflective screens can record shock position over time and use this information to determine post-shock fluid properties.

• "Drowning in Sound" is the title of an article in the April issue of *IEEE Spectrum* that discusses the **sonar vs. whales**

Scanning the Journals

story. In January 2005 dozens of pilot whales began to run themselves onto the sand beach along North Carolina's Outer Banks. The U. S. Navy had been conducting a training exercise in the area around the time of the event, and an initial report by the National Marine Fisheries Service listed sonar as a possible cause for the incident. The Navy stated that the exercise took place about 100 kilometers from where the whales beached, too far to have had any effect. More than a year after the stranding, doubts still linger. The sonar controversy has also focused attention on a broader issue: oceans everywhere are getting noisier because of commercial shipping, underwater oil and gas exploration, and other human activity, and scientists have no clear idea what harm these noises have on whales and other sea creatures.

• **Solitons** have been observed in solid crystals for the first time according to a paper in the 29 March issue of *Physical Review Letters*. Solitons are stable localized waves that propagate through a medium with spreading. They were first observed by the Scottish scientist John Russell in 1834 when he was watching horses drag a barge along a canal. When the boat suddenly stopped, a wave of water continued along the canal without changing shape or slowing down. Now solitons have been observed in crystals of uranium when firing beams of neutrons and X-rays into the material. Vibrations, which have wavelengths as small as the spacing between atoms in the crystal, form randomly throughout the material.

• "Nanomechanics of the subtectorial space caused by electromechanics of **cochlear outer hair cells**" is the title of a paper in the February 14 issue of *Proceedings of the National Academy of Sciences*. The electromechanical properties of the soma of the outer hair cells in a guinea-pig cochlea was used to generate mechanical force over the entire functionally relevant range of 50 kHz. Vibration responses were measured with a laser Doppler vibrometer. For frequencies up to about 3 kHz, the apical surface of the inner hair cells and the opposing surface of the tectorial membrane were found to vibrate with similar amplitudes but opposite phases. At high frequencies there was little relative motion between these surfaces. For frequencies up to at least 3 kHz there appears to be direct fluid coupling between outer and inner hair cells.

• **Songbirds** may be able to learn grammar, according to a letter in the 27 April issue of *Nature*. European starlings learned to recognize acoustic patterns defined by a recursive, self-embedding, context-free grammar. The simplest grammar, long thought to be one of the skills that separate man from beast, can be taught to a common songbird, the study suggests.

• French physicists say they have cracked the riddle of "**singing sand dunes**" and they are compiling a CD of sand music, according to a note in the 17 September issue of *New Scientist*. Using sand from Moroccan singing dunes shipped to their laboratory, they found that they could play notes by pushing the sand by hand or with a metal handle. After a month of singing, however, the sands seemed to lose their voice. The singing grains were round with a smooth coating of silicon, iron and manganese, which probably formed on the sand when the dunes once lay beneath an ancient ocean, the researchers said. But in muted grains this coat had been worn away, which explains why only some dunes can sing. What determines frequency is the grain size. However, the role of the coating on the grains is still not well understood. (Ed's. note: some of the sounds can be heard at www.lps.ens.fr/~douady/SongofDunes/ArticleJduC/CD_CNRS/CD_piste3.html).

Acoustics in the news

• "Risks Fall, Hopes Rise for Hearing Implants" is the comforting headline of a story in the March 7 issue of *The New York Times*. Earlier a high incidence of meningitis was found in deaf children with cochlear implants, but this was mainly in children with an implant type that is no longer on the market. Deaf children already stand a higher than normal chance of contracting meningitis, an infection of the fluid surrounding the brain and spinal cord, because they often have abnormalities in their inner ears. On the other hand, early implantation is important. Kids who are implanted by age 3 or 4 have language that is pretty normal and can be educated in mainstream classes rather than in special schools for the deaf. In the past 20 years, it is estimated that 11,000 American children have received implants. Early implantation is encouraged so that children can hear in the crucial years to learn language.

• In an attempt to give the public audible evidence of what is normally invisible, artist Carrie Bodle created a multi-speaker sound installation on the Green Building at MIT, according to a story in the September 12 issue of *The Boston Globe*. The speakers broadcast audio representations of sound waves embedded in the Earth's upper atmosphere each day from noon to 1:00 pm for a week in September. In another story about the "Sonification/Listening Up" installation, the September 16 issue of the MIT newspaper *The Tech* reported that some listeners likened the experience to an airplane circling overhead while others described it as a "big didgeridoo."

• The debate over whether the Navy's use of sonar to detect submarines is harming whales and other sound-sensitive species is back again, according to an editorial in the March 7 issue of *The New York Times*. This time the

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battleground is the waters off the southeastern United States where the Navy hopes to establish a training area for sailors to practice their sonar skills in a shallow ocean environment. The National Oceanic and Atmospheric Administration (NOAA) has expressed significant concerns about the proposed sonar activity, including its potential to injure or kill beaked whales, which are especially sensitive. The agency also contends that the sound thresholds the Navy deems acceptable are well above the levels known to disrupt marine mammal behavior in the wild. While no one can deny that the Navy needs to conduct sonar training in shallow waters, the editorialist writes, it behooves the Navy to move with extreme caution.

• More whale strandings have been linked to sonar, according to a news report in the 30 March issue of *Nature*. Examinations of four whales found stranded along the Spanish coast seem to confirm earlier reports linking sonar to the deaths of several beaked whales. The whales are thought to take evasive action to avoid the noise, sometimes diving and surfacing until they suffer decompression sickness and die. Air bubbles have been found in the tissues of dead whales discovered in Spain. Earlier 45 pilot whales died after stranding on the western side of the island of Sulawesi following joint US and Indonesian naval exercises in the nearby Macassar Strait. The cause of this stranding is under investigation.

• A novel application of acoustics could make loitering youths a thing of the past, according to a story in the November 29 issue of *The New York Times*. An inventor in Wales claims that his device, which emits burst of high-frequency noise up to 16 kHz, can be used to disperse a troublesome gang of youngsters but will not affect older people who have lost the ability to hear sounds at these frequencies. The device is called the Mosquito.

• Vibrations can cause flowing beads to "freeze" into an orderly pattern like atoms in a crystal, according to a paper at the March meeting of the American Physical Society reported in the 31 March issue of *Science*. The surprising observation could lead to deeper insights into disorderly solids such as glasses. Pumping energy into a solid usually raises its temperature and scrambles the regular pattern of items, perhaps even causing it to melt. However granular materials may behave differently. For example, shaking beads of varying size in a can may drive the larger ones to the top (the so-called Brazil-nut effect) or the bottom, depending on the sizes and masses of the beads. When the shaking is sufficiently vigorous, however, the flow may stop, according to the report.

• Less than 4 seconds after the ground ruptured off San Francisco's coast on April 18, 1906, much of San Francisco was destroyed, according to a story in the March 29 issue of the *San Francisco Chronicle*. The great quake ripped the Earth's surface for 300 miles along the San Andreas Fault at speeds up to 13,000 mph. A new computer simulation of the ground-shaking violence has been created by the U. S. Geological Survey, was shown for the first time at an earthquake conference in San Francisco on the 100th anniversary of the great quake, and it can be seen online at earthquake.usgs.gov/regional/nca/1906/simulations (Editor's note: highly recommended!)

From the Student Council *Continued from 41*

Over fifty people attended the second grant-writing workshop for students. Student Council member Jennell Vick facilitated this one, reviewing examples of proposals by ASA members and recommended do's and don'ts in grant writing. The previous workshop hosted presentations by representatives from organizations offering funding in areas related to acoustics. Please share your ideas and requests for future workshops with your student council representative, and meanwhile note the additional grants/funding information on the student website.

The Student Council would like to encourage more students to take advantage of the "Students Meet Members for Lunch" program. The ASA Education Committee provides this avenue for a student to meet one-on-one with a member of the Acoustical Society over lunch, making it easier for students to meet and interact with members at ASA Meetings. Sign-up information is available on, you guessed it, the student website.

Your student council representative is your one-stop-shop for all your ASA student needs—information, requests for new events, feedback on ASA programs. You will find their contact information on, where else? The ASA student website! Thats www.acosoc.org/student. And be sure to track down your rep at the next ASA meeting in Honolulu—they'll be wearing the telltale Student Council label on their name badge and a pair of sunglasses.

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