Session 3aAAa

Architectural Acoustics: Memoriam for Jerry Christoff

Samantha Rawlings, Chair
Veneklasen Associates, 1711 16th Street, Santa Monica, CA 90404

Invited Papers

8:00

3aAAa1. Celebrating the life and achievements of Jerry Christoff. Samantha Rawlings (Veneklasen Assoc., 1711 16th St., Santa Monica, CA 90404, srawlings@veneklasen.com), John Lo Verde, and Wayland Dong (Paul S. Veneklasen Res. Foundation, Santa Monica, California, CA)

Jerry spent 61 years of his life in the service of acoustics. He was one of the first people hired by one of the first established acoustical firms in the United States, moving from staff engineer to firm Principal. Jerry started with designing and developing microphones early in his career, followed by his work in auditorium acoustics, remnants of which we still see in today's auditorium design practices. Later in his career, Jerry worked on improving the measurement methods for exterior façade noise reduction evaluation, and ultimately on HVAC noise study and improvements. Jerry has done it all and left the acoustical community better than he found it. Come join us in celebrating his life and his achievements during this special session.

8:20

3aAAa2. Jerry Christoff: A career driven by curiosity. George C. Kourtis (Threshold Acoust., 141 W Jackson Blvd., Ste. 2080, Chicago, IL 60604, gckourtis@gmail.com)

This session aims to present accounts and examples of the curiosity that drove Jerry Christoff in his work as a consultant and mentor as seen through the eyes of George Kourtis. George joined the staff of Veneklasen Associates in 2013 and directly assisted Jerry as a consultant from approximately 2015–2017 before Jerry's retirement. George subsequently moved on from VA in 2018 and is now a Senior Consultant at Threshold Acoustics. A throughline George observed both before joining VA and while working directly with Jerry was the almost childlike fascination and curiosity Jerry expressed for all areas of acoustics, even as an 82-year-old consultant with over 60 years of experience. In the spirit of Paul Veneklasen's research-based approach and legacy, Jerry's lines of inquiry and investigations on everything from concert hall design to plumbing noise inspired others, including George, to, in good faith, think critically, ask questions, and perform their own research, with the goal of always providing the best possible acoustical outcomes.

8:40

3aAAa3. Revisiting the Seattle Opera House. Jennifer Levins (Acentech, 33 Moulton St., Cambridge, MA 02138, jlevins@acentech.com)

Jerry Christoff played an integral part of the Seattle Opera House design in the early 1960s. An overview of the acoustic design elements for this space was published in 1964 in a paper co-authored with Paul Veneklasen. Many of the concepts presented in this paper, like reverberance, clarity, and envelopment, still influence acoustical design today. We will highlight the key points from this paper and share anecdotes from Jerry's career.

9:00

3aAAa4. Jerry Christoff's contribution to the development of performing arts acoustical design practices. John Lo Verde (Paul S. Veneklasen Res. Foundation, 1711 Sixteenth St., Santa Monica, CA 90404, jloverde@veneklasen.com), Samantha Rawlings (Veneklasen Assoc., Santa Monica, CA), and Wayland Dong (Paul S. Veneklasen Res. Foundation, Santa Monica, California, CA)

In the 1960s, Jerry Christoff, alongside Paul S. Veneklasen, performed research and development into acoustics for performing arts spaces. Some of the practices developed by these researchers are precursors to modern-day design metrics, as they looked at lateral reflections and source strength, to name a few. Small-scale models of performance spaces were being constructed with an ultrasonic source to better understand and visualize how sound waves behave within a performance space. This presentation will be focused on Jerry's contribution to science with regard to the design of performing arts spaces.

9:20

3aAAa5. Advancement of the exterior façade measurement method by Jerry Christoff. Wayland Dong (Paul S. Veneklasen Res. Foundation, 1711 Sixteenth St., Santa Monica, CA 90404, wdong@veneklasen.com), Samantha Rawlings (Veneklasen Assoc., Santa Monica, CA), and John Lo Verde (Paul S. Veneklasen Res. Foundation, Santa Monica, CA)

Acoustical design of façade elements is a key element in architectural acoustics. The assessment is required for multi-family housing projects and environmental projects. In the 1980s, when labs around the US were measuring the transmission loss (TL) of exterior façade elements, it was assumed that measurement of TL with a diffuse sound field method is valid for TL of real facades where a diffuse sound field does not exist. Jerry evaluated how the TL of exterior façade elements change based on the incident angle. In this talk, we will shed some light on the history of the work done by Jerry in the advancement of the exterior façade assessment methods.

WEDNESDAY MORNING, 15 MAY 2024 ROOM 207, 8:00 A.M. TO 12:00 NOON

Session 3aAAb

Architectural Acoustics: Soundscape Simulation: Opportunities and Challenges I

Catherine Guastavino, Cochair
CIRMMT & School of Information Studies, McGill University, 3661 Peel, Montreal, H3A 1X1, Canada

Josep Llorca-Bofi, Cochair
Institute for Hearing Technology and Acoustics, RWTH Aachen University, Kopernikustrasse 5, Aachen 52074, Germany

Andre Fiebig, Cochair
Engineering Acoustics, TU Berlin, Einsteinufer 25, Berlin 10587, Germany

Chair's Introduction—8:00

Contributed Papers

8:05

3aAAb1. Simulation of acoustical parameters of churches in a virtual acoustics laboratory. Gianluca Grazioli (McGill Univ., 555 Sherbrooke St. W, Montreal, QC H3A 1E3, Canada, gianluca.grazioli@mail.mcgill.ca) and Andrea Gozzi (Université de Montreal, Montreal, QC, Canada)

Current ISO standards for acoustical assessment limit the use of traditional mono-dimensional microphones for measuring equipment. However, microphone arrays offer more accurate spatial information compared to traditional microphones. This presents an opportunity to enhance research on architectural acoustics and preserve the acoustics of cultural heritage more effectively. Furthermore, modern recording studios equipped with virtual acoustics systems allow for the integration of spatial room impulse responses. This enables real-time auralization in controlled environments and enhances the overall immersive audio experience for users and musicians. This paper analyzes the main acoustical parameters obtained from spatial impulse responses captured in churches using various ambisonic microphones and inserted into a controlled, interactive, and immersive virtual acoustics system. The captured spatial acoustic measurements are then reproduced and evaluated in a virtual acoustics laboratory to identify any discrepancies between real and virtual spaces.

8:20

3aAAb2. Sandiaoling eco-friendly tunnel soundscape and virtual reality analysis. Khaing Thinzar (Dept. of Architecture, National Taiwan Univ. of Sci. and Tech., 43 Keelung Rd. Sec. 4, Taipei 106, Taiwan, M11213801@mail.ntust.edu.tw), Phoa Angela Grace Wibowo, Ni Made Putri Indriyani, Nikita Grace Manullang, Roxana Ghadiri, Stijn Zeger van Brug, Juliana Manuela Muet, Tuan Sanh Diep, Clarissa Averina, Chau N. Truong, Gabriela Niederberge, Shiang-I Juan, and Lucky S. Tsaih (Dept. of Architecture, National Taiwan Univ. of Sci. and Tech., Taipei, Taiwan)

Soundscape of Sandiaoling Ecological Tunnel, a 1.852 km bike path tunnel, has been studied for the taxonomy of sound sources, equivalent sound pressure levels, and the perceived sonic quality. This paper focuses on examining simulated sound source propagations in the tunnel using both omni and directional sound sources with Odeon Room Acoustic software. Additionally, it compares the specific receivers' auralizations with *in situ* recorded sounds in a virtual reality model along with a questionnaire to evaluate the distinctions between the two. The preliminary results showed that the simulated sonic quality in tunnel is less reverberant than expected. Proximity of receivers to sound source, the boundary of air to source and receivers inside tunnel as well as the absorption, scattering and transparency coefficients of materials used in simulated model are adjusted. Future work will explore into audio post-production and visual effects.

8:35

3aAAb3. Ambisonic recordings of sound fields from commonly occupied built environments. Hezekiah George (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, 1110 S. 67th St., PKI 210-F, Omaha, NE 68182-0816, hgeorge@mail.bradley.edu) and Lily M. Wang (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, Omaha, NE)

There is growing use of simulated soundscapes to study human perception, such as for testing hearing aids or cochlear implants. Ambisonics is one method to record and then simulate three-dimensional sound fields with more accurate directional information. In this project, our aim has been to expand the currently available database of ambisonic recordings of soundscapes in built environments. To this end, we have made recordings of sound fields in frequently occupied spaces in the built environment such as classrooms and food courts, using a commercially available ambisonic microphone capturing up to first-order spherical harmonics. While databases of such recordings are available online, many recorded samples are short in duration, typically less than 5 min. long. Furthermore, there are fewer samples taken from occupied spaces in the built environment which are of interest in architectural acoustics. We will review recordings that are already available online and describe our acquired recordings which sample additional spaces and are longer in length. We will share a link to where these can be accessed and downloaded. An ultimate goal is for researchers to utilize these recordings to generate more ecologically valid sound fields when testing human responses in more controllable, simulated test environments.

Invited Papers

8:50

3aAAb4. A virtual reality method for assessing human responses to soundscapes. Andre Fiebig (Eng. Acoust., TU Berlin, Berlin, Germany), Niklas Meier (Technische Universität Berlin, Berlin, Germany, niklas.meier@tu-berlin.de), and Christian Dreier (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Aachen, Germany)

Virtual realities and simulations are becoming increasingly popular due to constant technological advancement offering more and more realistic scenarios. However, cases of VR being used to assess soundscape-related aspects of perception still appear to be rare. Here, a method for conducting auditory perception experiments in a virtual urban environment is presented and discussed. Participants are exposed to virtual scenarios simulating an urban green area with nearby traffic noise sources, whose visualization draws on physically-based visual renderings. The acoustic scenario is auralized in real-time using geometrical acoustic approaches including simulated and recorded sounds. The virtual environment is presented via head-mounted display and headphones. In this setting, evaluation and behavioural experiments are conducted, with the environment's acoustic and visual characteristics being experimentally manipulable or controllable. The presented method allows for perception experiments with a high degree of ecological validity while maintaining a controlled laboratory setting. As a practical application, the method is used to determine the impact of road traffic configurations on the restoration quality in an urban green area. Proceeding from the applied method, general opportunities and limitations of experiments performed in virtual urban environments to study noise effects in urban soundscapes are discussed.

9:10

3aAAb5. Enhancement of virtual acoustics rendering using boundary mounted dipole loudspeakers. Richard King (Graduate Program in Sound Recording, McGill Univ., Music Res., Montreal, QC H3A 1E3, Canada, Richard.King@mcgill.ca), Wieslaw Woszczyk, and Michail Oikonomidis (Graduate Program in Sound Recording, McGill Univ., Montreal, QC, Canada)

The Immersive Media Lab at McGill University hosts a Virtual Acoustics Technology (VAT) system incorporating a suspended array of omnidirectional loudspeakers. Using a convolution reverb engine, acoustic simulations of real spaces can be realized via a catalog of Room Impulse Response measurements. Reflected sound in the room helps to disguise the location of the sound emitters rendering virtual acoustics. One limitation of the system, however, is the interference between the lab's natural acoustics and the virtual environment generated by the VAT system. The improvement under consideration is to enhance diffusion along the walls of the lab, in order to mask the acoustical characteristics related to the physical dimensions of the room. Dipole loudspeakers are installed on the room boundaries and used to scatter reflections and reverberation along the wall surfaces enlarging the effective radiation surface of the walls. The scattered energy may mask specular reflections and reduce localization of the virtual acoustic sources. Investigations compare the result of scattering reflected sound vertically as opposed to horizontally across the boundaries. Measurements illustrate the effect of the dipole loudspeaker system when used on its own as well as working in conjunction with the existing omnidirectional loudspeaker array.

Contributed Paper

9:30

3aAAb6. One size does not fit all: Three tools and approaches for soundscape simulations. Valérian Fraisse (Schulich School of Music, McGill Univ. / STMS Ircam-CNRS-SU / Ctr. for Interdisciplinary Res. in Music Media and Technol., Montréal, QC, Canada, valerian.fraisse@mail.mcgill.ca), Cynthia Tarlao, Richard Yanaky, and Catherine Guastavino (Information Studies, McGill Univ. / Ctr. for Interdisciplinary Res. in Music Media and Technol., Montreal, QC, Canada)

We present a reflection on three prototypes of real-time interactive soundscape simulators aimed at supporting participatory urban sound planning and interventions. These prototypes were developed as part of the Sounds in the City cross-sectoral partnership through an iterative process involving various stakeholders. Each prototype enables different ways to manipulate soundscapes through tailored interfaces and audio/visual outputs, targeting different types of users. The first version is audio-only and uses live music tools for Ambisonics spatialization, with limited environmental modeling for co-design exercises with urban and sound professionals. The second version builds on the idea of the first and adds acoustic modeling. It was used to assess the impact of sound installations in public spaces through research-creation involving sound artists and residents. The last version utilizes (desktop or head-mounted) virtual reality with binaural rendering, immersing the user in an audio-visual city to raise sound awareness and support urban soundscape design. We emphasize that there is no one-size-fits-all tool. Rather, we highlight how different tools are needed for different auralization tasks and target user groups. These tools are presented through examples of early-stage conceptualization, educational components, creative processes, laboratory-based soundscape assessments, and both individual and participatory design sessions.

9:45

3aAAb7. Urban background sound recordings for virtual acoustics under various weather conditions. Josep Llorca-Bofi (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Kopernikustrasse 5, Aachen 52074, Germany, josep.llorca@akustik.rwth-aachen.de), Jonas Heck, Christian Dreier, and Michael Vorlaender (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Aachen, Germany)

One of the major challenges in the auralization of complex urban simulations is the presence of ambience, for example background sounds. Omitting them can result in a sterile and implausible impression. In this work we present a dataset of spatially recorded ambient sounds with metadata on meteorological and acoustical parameters. The recordings are ready to be admixed with simulated soundscapes corresponding to various weather conditions. In particular, 28 soundscapes have been recorded at the IHTApark (green space next to the Institute for Hearing Technology and Acoustics) in Aachen (Germany) in winter and spring. They have been segmented into 30-s auralizable snippets. Moreover, the database contains a statistical and psychoacoustical evaluation of the recordings.

10:05–10:20 Break

10:20

3aAAb8. Validation of auralized impulse responses considering masking, loudness and background noise. Jonas Heck (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Kopernikusstrasse 5, Aachen 52074, Germany, jonas.heck@akustik.rwth-aachen.de), Josep Llorca-Bofí, Christian Dreier, and Michael Vorlaender (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Aachen, Germany)

The use of outdoor virtual scenarios promises to have a lot of potential to facilitate reproducible sensory evaluation experiments in laboratory. Auralizations allow for the integration of simulated or measured sound sources and transfer paths between the sources and receivers. Nonetheless, pure simulations can lack perfect plausibility. This contribution investigates the augmentation of auralized outdoor scenes based on simulated impulse responses (IRs) by ambient or background sounds. For this purpose, foreground events such as car pass-bys are created by simplified simulation of impulse responses. Due to their large number of events, however, ambient sounds are typically not simulated. Instead, spherical microphone array recordings can be used to capture the background sound. Using synthesized car sounds, we examine how much the augmentation by background sound improves the auditory plausibility of simulated impulse responses in comparison with the equivalent measured ones.

10:40

3aAAb9. Perceptual study on combined real-time traffic sound auralization and visualization. Christian Dreier (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Kopernikusstrasse 5, Aachen 52074, Germany, christian.dreier@akustik.rwth-aachen.de), Rouben Rehman (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Aachen, Germany), Niklas Meier, Andre Fiebig (Eng. Acoust., TU Berlin, Berlin, Germany), and Michael Vorlaender (Inst. for Hearing Technol. and Acoust., RWTH Aachen Univ., Aachen, Germany)

Auralization is a promising approach for future application in urban planning including noise aspects. From a technical point of view, auralization of the urban environment is challenging due to the high number of sound sources, time-variant and inhomogeneous atmospheric conditions and the large scale of scenarios. This work presents the modeling and computationally efficient implementation of traffic sound sources and its integration to a complex urban scenario with real-time auralization. Furthermore, it presents results from a perceptual study whose immersion is enhanced by presenting a coupled visualization of the scene to the participants by using a head-mounted display. Whereas the experiment on the one hand comprises virtual reality-related aspects considering the assessment of immersion and plausibility of the scenario, on the other hand it covers the assessment of individual noise events in the urban soundscape. The experiment focuses on acoustically prominent noise events, such as particularly loud and harsh sources, or resulting from specific driving behavior. The results are discussed in the foreground for further improvements for audio-visual simulations of the urban environment.

11:00

3aAAb10. Towards a better understanding of multimodal integration and sensorimotor adaptation to audiovisual environmental incongruence using Virtual Reality. Xinyi Zhang (Dept. of Elec. Eng., École de Technologie Supérieure, 1100 Notre-Dame St W, Montreal, QC H3C 1K3, Canada, xinyi.zhang.1@ens.etsmtl.ca), Arian Shamei (Dept. of Elec. Eng., École de Technologie Supérieure, Vancouver, BC, Canada), Florian Grond (Dept. of Design and Computation Arts, Concordia Univ., Montreal, QC, Canada), Ingrid Verduyckt (École d'orthophonie et d'audiologie, Université de Montréal, Montreal, QC, Canada), and Rachel Bouserhal (Dept. of Elec. Eng., École de technologie supérieure, Montréal, QC, Canada)

People use previous knowledge and *in situ* judgment to produce speech with a vocal effort appropriate to a given environment's acoustics. To test how people integrate auditory and visual cues in speech production, we employed a three-by-three cross-conditional audiovisual match-mismatch paradigm. Three visually distinct environments with three different room acoustics were selected: a gymnasium, a classroom, and a hemi-anechoic room. The visual environment was presented with a Virtual Reality (VR) headset and the auditory environment was a diffuse room impression, playing back the participants' speech through loudspeakers in the room with different reverberation times. Participants were prompted to speak in all nine combinations of the audiovisual conditions, with three being congruent and six incongruent. Linear mixed-effects regression modeling was used to evaluate the effect of the audiovisual manipulations and time course on mean intensity. Preliminary results indicate that participants initially spoke at a level that matched the visual expectation and then adapted to the audio condition; detailed analysis of the time course of adaptation is ongoing and will be presented.

This study furthers our understanding of multimodal integration and the sensorimotor adaptation of speech production, which finds applications in fields including communication in noise and VR soundscape design.

11:20

3aAAb11. Museum Acoustics: Classification and auralization of design approaches. Milena J. Bem (School of Architecture, Rensselaer Polytechnic Inst., 1605 Hutton St., Apt. 10, Troy, NY 12180, jonasm@rpi.edu), Mincong Huang (School of Architecture, Rensselaer Polytechnic Inst., Troy, NY), Vic Brooks, Samuel Chabot (Experimental Media and Performing Arts Ctr., Rensselaer Polytechnic Inst., Troy, NY), and Jonas Braasch (School of Architecture, Rensselaer Polytechnic Inst., Troy, NY)

Architecture defines various aspects of museum spaces. Despite often being considered secondary importance by some deciders and designers, the acoustic environment significantly shapes the interpretation of exhibitions and human-building interactions. Focusing on enhancing museum acoustics, this study builds upon previous research that developed a methodology for simulating and evaluating museum soundscapes through psychophysical experiments in immersive environments, showing that participants preferred congruent soundscapes over generic noise maskers [J. Acoust. Soc. Am. **154**, A257]. Expanding on these previous investigations, our current research involves cataloging and classifying design approaches currently used within museum contexts—architectural elements, acoustic characteristics, spatial distribution, exhibition strategies, multimodal approaches, etc. Subsequently, we present an auralization method for these museum spaces using the ray tracing method developed for collaborative virtual reality systems [J. Acoust. Soc. Am. **143**, 1824]. This method is used within the CRAIVE-Lab at Rensselaer Polytechnic Institute to facilitate tangible analysis, enriching our understanding of these solutions to support future design efforts by guiding architects and acousticians to optimize the museum experience. It offers significant insights into current practices, emerging trends, or notable innovations, thereby promoting more experiential design approaches to shaping the acoustic impacts of the museum environment.

11:40

3aAAb12. Reducing noise with augmented reality in indoor soundscapes. Nicolas Misdariis (Sound Percept. and Design group, Ircam STMS Lab, 1, Pl. Igor Stravinksy, Paris F-75004, France, nicolas.misdariis@ircam.fr), Mathieu Lagrange (LS2N Ecole Centrale Nantes, Nantes, France), and Romain Serizel (LORIA, Vandœuvre lès Nancy, France)

Noise pollution has a significant impact on quality of life. In indoor soundscapes like open offices, noise exposure creates stress that leads to reduced performance, provokes annoyance and changes in social behaviour. The ReNAR project aims at studying two augmented reality approaches, targeted towards additional sound sources which levels are below or equal to the noise sources ones The first approach tend to conceal the presence of unpleasant sources by adding some spectro-temporal cues which will seemingly convert it into a more pleasant one. Adversarial machine learning techniques will be considered to learn correspondences between noise and pleasing sounds and to train a deep audio synthesiser able to generate an effective concealing sound of moderate loudness. The second approach tend to tackle a common issue encountered in open offices, where the ability to concentrate on the task at hand is made harder when people are speaking nearby. We propose to reduce the intelligibility of nearby speech by the addition of sound sources whose spectro-temporal properties are specifically designed or synthesised with a generative model to conceal important aspects of the nearby speech. The formal position, general frame and expected outcomes of the project will be developed and discussed.

Session 3aAAc

Architectural Acoustics: AIA CEU Presenters Course Training Session

K. Anthony Hoover, Cochair
McKay Conant Hoover, 5655 Lindero Canyon Road, Suite 325, Westlake Village, CA 91362

Kenneth W. Good, Cochair
Armstrong World Industries Inc., 2500 Columbia Avenue, Lancaster, PA 17601

Bennett M. Brooks, Cochair
Brooks Acoustics Corporation, 49 N. Federal Highway, #121, Pompano Beach, FL 33062

Chair's Introduction—9:55

Invited Papers

10:00

3aAAc1. Architectural acoustics short course presentation material. K. Anthony Hoover (McKay Conant Hoover, 5655 Lindero Canyon Rd., Ste. 325, Westlake Village, CA 91362, thoover@mchinc.com) and Kenneth W. Good (Armstrong World Industries Inc., Lancaster, PA)

The Technical Committee on Architectural Acoustics (TCAA) is a Registered Provider in the American Institute of Architects (AIA) Continuing Education System (CES). The TCAA has developed a standardized introductory short course for architects called "Architectural Acoustics," An architect can earn one continuing education unit (CEU) by attending this short course, if presented by a qualified member of TCAA. The course covers topics in sound isolation, mechanical system noise control, finish treatments, and implementation of quality acoustical spaces. This paper will cover the course material in order to prepare and qualify potential presenters. In order to qualify as an authorized presenter for this AIA/CES short course, attendance at this special session and membership in TCAA are required.

11:00

3aAAc2. Architectural acoustics continuing education course—Presenter registration and reporting. Kenneth W. Good (Armstrong World Industries Inc., 2500 Columbia Ave., Lancaster, PA 17601, kwgoodjr@armstrong.com) and Bennett M. Brooks (Brooks Acoust. Corp., Pompano Beach, FL)

The Technical Committee on Architectural Acoustics (TCAA) is a Registered Provider in the American Institute of Architects (AIA) Continuing Education System (CES). The TCAA has developed a standardized introductory short course for architects called "Architectural Acoustics," for which attendees can earn one continuing education unit (CEU). This paper will cover the administrative requirements of the ASA/CES, to prepare potential presenters. These requirements include the proper handling of paperwork so that AIA members may receive credit for the course. The manner in which the course is given is also dictated by AIA requirements. TCAA membership and attendance at this workshop are required to qualify as an authorized presenter for this AIA/CES short course. Of course, anyone is free to register with the AIA to provide their own CEU program. However, the advantages of participating in this program are that the TCAA short course is already prepared, it is pre-approved by the AIA, and the registration fees are paid by the Acoustical Society of America.

Session 3aAB

Animal Bioacoustics: Acoustic Ecology, Biological Soundscapes, and Animal Vocal Communication and Physiology I

Laura Kloepper, Chair
Department of Biological Sciences, University of New Hampshire, 230 Spaulding Hall, Durham, NH 03824

Contributed Papers

8:00

3aAB1. Harmonizing nature's symphony: Computational filtering unveiling the secrets of animal acoustics. Lisa M. DiSalvo (Comput. Sci., Columbia Univ., 1612 Mount Laurel Rd., Temple, PA 19560, lisdis19@gmail.com) and Laura Kloepper (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH)

By harmonizing and unveiling the symphony of nature, we seek to reveal the mysteries embedded in the soundscape of various species with acoustic filters. Utilizing computational filtering, we can draw specific conclusions about the evolution of animal populations and understand the significant role the environment plays in interacting with animal populations. By employing these computational acoustic filtering techniques, we can analyze and decode intricate patterns, frequencies, and nuances embedded in animal vocalizations. This interdisciplinary approach not only enhances our understanding of animal communication systems but also sheds light on the ecological dynamics at play both within animal vocalization and environmental vocalization. These conclusions contribute to the broader field of bioacoustics, providing insights that may have implications for wildlife conservation, behavioral ecology, and the delicate balance of ecosystems. Beyond advancing bioacoustics, our research highlights the educational impact of teaching computational acoustic filtering in Python and R. This research seeks to emphasize the importance of equipping young ecological researchers with these skills to foster a holistic understanding of ecological dynamics. The ultimate goal of our educational research pursuit is to prepare the next generation of researchers to contribute meaningfully to wildlife conservation, and ecology as a whole with interdisciplinarity in mind.

8:15

3aAB2. A PAMGuard catalog for comparing detection and classification performance of two mode decomposition algorithms. Kerri D. Seger (Appl. Ocean Sci., 2127 1/2 Stewart St., Santa Monica, CA 90404, kerri.seger.d@gmail.com), Sujay Balebail (Dept. of Biology, Univ. of Washington, Seattle, WA), Imogen Lucciano (Oregon State Univ., Ithaca, NY), Yue Liang (Dept. of Elec. and Comput. Eng., Univ. of New Hampshire, Durham, NH), Mahdi Al-Badrawi (Elec. and Comput. Eng., Univ. of Maine, Orono, ME), and Nicholas J. Kirsch (Dept. of Elec. and Comput. Eng., Univ. of New Hampshire, Durham, NH)

The ONR project "Application of an Empirical Mode Decomposition (EMD) detection and classification process to environments for Naval monitoring and detection" created empirical and variational mode decomposition analysis workflows to detect and cluster diverse underwater signals across four distinct datasets. Twenty-five call types from the Bering and Chukchi Seas, Aeon's North Atlantic sites, CTBTO hydroacoustic stations, and the Chambal River were detected and clustered with varying levels of success. The final precision, recall, and accuracy results of these call types will be presented. Evaluating the performance of our developed detection and classification algorithms involved a comparison with the widely used open-source software, PAMGuard. However, obtaining information about the parameters used to construct detectors for different call types in PAMGuard proved challenging due to limited literature availability. To the best of our knowledge, some call types had never been processed in PAMGuard, and for those that had, not all parameters required for adapting the detectors to our datasets were consistently published. To facilitate the use of our PAMGuard detectors by other researchers for their own datasets, we will present a user-friendly guide that will outline the features that yielded optimal PAMGuard performance for each call type.

8:30

3aAB3. Spatiotemporal patterns of fish chorusing in California National Marine Sanctuaries. Ella B. Kim (Scripps Inst. of Oceanogr., Univ. of California San Diego, 8635 Kennel Way, Ritter Hall, La Jolla, CA 92037, ebkim@ucsd.edu), Annebelle Kok (Scripps Inst. of Oceanogr., Univ. of California San Diego, Groningen, Netherlands), Emily Donahue (California State Univ. Monterey Bay, Monterey Bay, CA), Emma Beretta (California Polytechnic State Univ., San Luis Obispo, San Luis Obispo, CA), Leila Hatch (Office of National Marine Sanctuaries, Scituate, MA), John E. Joseph, Tetyana Margolina (Oceanogr., Naval Postgrad. School, Monterey, CA), Lindsey Peavey Reeves (National Marine Sanctuary Foundation, Silver Spring, MD), and Simone Baumann-Pickering (Scripps Inst. of Oceanogr., Univ. of California San Diego, La Jolla, CA)

In aggregations, some male fish will sing together in "chorus" for hours, to attract female mates. Through analyzing passive acoustic data, one can determine which, when, and where fish are chorusing, to identify breeding grounds, species distributions, and mating seasons. National marine sanctuaries aim to protect marine ecosystems, particularly breeding and feeding grounds for at risk species. Through the Sanctuary Soundscape Monitoring project, a cumulative 17.9 years of passive acoustic data were manually analyzed for fish chorusing in Monterey Bay, Channel Islands, and proposed Chumash Heritage National Marine Sanctuaries. We aimed to determine which fish were chorusing within the sanctuaries, where and when they occurred, and if fish were engaging in acoustic niche partitioning (minimizing overlap in time/frequency to reduce competition). We found five unique fish choruses including plainfin midshipman, bocaccio rockfish, white seabass, and two unidentified fish choruses, which showed distinct diel, seasonal, and spatial preferences. Fish were found to partition acoustic space in frequency but not in time. Understanding fish reproductive habitat and behavior within sanctuaries is crucial for safeguarding threatened fish species. Moreover, studying fish chorusing is a powerful tool to noninvasively monitor fish to understand their reproductive habits, with goals of better protecting them.

8:45

3aAB4. Particle motion polarization of offshore fish vocalizations, boat noise, and ambient soundscapes. Ian T. Jones (Ctr. for Acoust. Res. and Education, Univ. of New Hampshire, Durham, University of New Hampshire, 8 College Rd., Morse Hall, Durham, NH 03824, ian.t.jones@unh.edu) and Julien Bonnel (Woods Hole Oceanographic Inst., Woods Hole, MA)

Acoustic particle motion is an important acoustic cue for fish and aquatic invertebrate hearing. When reported for bioacoustics applications, it is often described as a magnitude only. However, particle motion is a vector quantity with polarization information (including directionality) relevant to

detection and localization of sound cues by fishes and invertebrates. This study applied established metrics of particle motion polarization including ellipse amplitude, angle, orientation, and degree of polarization, to compare sounds of fish vocalizations with that of boat and ambient sounds at a 900 m-deep site (in the Atlantic Deepwater Ecosystem Observatory Network) offshore of Florida. Polarization metrics were computed for bivariate signals in the plane formed by the horizontal source-receiver and vertical axes. Boat sound polarization was quantified at multiple distances from the closest point of approach. Fish and boat sounds had narrower particle motion ellipses and larger amplitudes in the horizontal compared to ambient sounds that were more circular with larger relative vertical amplitudes. Fish and boat sounds were often strongly polarized, which may allow spatial release from masking given sufficient angular separation of sounds. This analysis framework has promising applications for monitoring *in situ* directionality of fish and other animal vocalizations and for modelling directional masking.

9:00

3aAB5. Effects from particle motion and substrate-borne vibration on fishes and invertebrates: Recommendations on research questions and methodologies. Shane Guan (Div. of Environ. Sci., Bureau of Ocean Energy Management, 45600 Woodland Rd., Ste. #455-C33, Sterling, VA 20166, guan@cua.edu) and Arthur N. Popper (Univ. of Maryland, College Park, MD)

There have been substantially increased interest in effects of particle motion and substrate-borne vibration on fishes and aquatic invertebrates over the past decade. This is because these signals, unlike sound pressure, are the basis of hearing in most fishes and in all aquatic invertebrates. However, studies to address these issues continue to face challenges due to the diversity of species, the broad range of hearing mechanism, and the complexity of the physical acoustic environment in conducting studies. Additionally, we do not yet have a good understanding of, and mechanisms for, source generation, calibration, and measurements to be able to examine effects properly. Related to this is the critical issue is how research questions are applicable to regulatory agencies. In October 2023, the US Bureau of Ocean Energy Management held a workshop to address different research methodologies and their pros and cons as the basis for study of the behavioral and physiological responses to particle motion and substrate-borne vibration. Subsequently, a review was conducted linking research priorities previously identified concerning anthropogenic noise effects on animals with appropriate research methodologies. The review also provides recommendations on experimental settings that are most appropriate to address specific research questions for regulatory concerns.

9:15

3aAB6. Using acoustic energy of vocalizations to monitor population size and phenology of anurans. Callyan L. Lacio (Dept. of Biological Sci., Univ. of New Hampshire, 105 Main St., Durham, NH 03824, callyan.lacio@unh.edu), David S. Steinberg (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH), Andrea M. Simmons (Cognit., Linguist., & Psychol. Sci., Brown Univ., Providence, RI), and Laura Kloepper (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH)

As a species that lives at the land/water interface, the American bullfrog (*Rana catesbeianus*) serve as a bioindicator in many habitats, yet also invasive in many locations. Due to challenges with traditional monitoring approaches, there is a lack of fine-scale population and phenological data for bullfrogs. Passive acoustic monitoring (PAM) can provide a low-cost alternative with high-resolution data for monitoring vocal animals. Sexually mature male bullfrogs attract mates by calling from exclusive territories. These vocalizations can be used to explore bullfrog behavior, population size, and phenology. We describe the analysis framework and initial results from an project monitoring the vocal behavior of frogs in 25 ponds in southeastern New Hampshire during the reproductive season using acoustic arrays. By using an acoustic energy index (RMS amplitude), we can estimate numbers of frogs in ponds, determine timing of reproduction, and even document anthropogenic disturbance. Our results can lead to future uses of PAM to monitor population size and phenology and develop reliable long-term management and conservation strategies.

9:30–9:45 Break

9:45

3aAB7. Using bioacoustics to determine bird community patterns in a post-industrial city. Christopher Dennison (Dept. of Biology, Carleton Univ., 1125 Colonel By Dr., Ottawa, ON K1S5B6, Canada, christopherontheriver@gmail.com), Rachel T. Buxton (Inst. of Environ. and Interdisciplinary Sci., Carleton Univ., Ottawa, ON, Canada), Katherine Brown, and Amber L. Pearson (Michigan State Univ., Flint, MI)

Urban landscapes experiencing population loss often maintain high quantities of vacant land which cause social stress but also create opportunities for conservation of wildlife, including birds. Understanding how features of the urban environment affect bird communities is needed to support planning and policy that creates more effective biodiversity outcomes. Using acoustic recorders, we explored the factors that affect bird communities in Detroit, MI, based on features in surrounding neighborhoods. We compared Shannon diversity, richness, and acoustic detection of birds at 110 recording sites from 2021 to 2023. We used a generalized linear model approach to determine the moderating effect of variables including Normalized Difference Vegetation Index (NDVI) and density of vacant lots around recording sites on bird community space use. We found increased bird diversity at recording sites surrounded by higher densities of vacant land and evidence that some habitat specialists use these areas more than others. Our results indicate habitat preference for areas with more vacant lots, and general preferential habitat selection for certain features of the urban environment. Understanding how urban bird communities use space in a post-industrial, urban landscape will help inform more effective nature-based solutions and urban plans that balance conservation, health, and social justice goals.

10:00

3aAB8. Using soundscape to monitor population size, demographics, and antipredator behavior in a dense aggregation of colonial seabirds. Valerie M. Eddington (Dept. of Biological Sci., Univ. of New Hampshire, 6 Stonecroft, Apt. 6, Portsmouth, NH 03801, valerie.eddington@unh.edu), Joseph Brosseau (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH), Liz Craig (Shoals Marine Lab., Univ. of New Hampshire, Durham, NH), Easton White, and Laura Kloepper (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH)

Migratory seabirds are vulnerable to decline due to climate change and anthropogenic disturbances. Common terns (*Sterna hirundo*) are highly vocal colonial seabirds that serve as bioindicators of their foraging grounds throughout their migratory range. Historically, monitoring colonial seabirds is invasive and time-consuming, and traditional acoustic approaches are complicated by high amounts of call overlap. Monitoring the behavioral ramifications of disturbance, as well as overall colony size and health, is crucial to implementing effective management decisions. However, methods are needed to do so efficiently and with minimal disturbance. In this study, we demonstrate that population size, demographics, and behavior can be assessed acoustically through changes in acoustic energy across varying temporal scales. To do this, we compared acoustic energy to in-person observations of nest density, chick-hatching, and investigator disturbance. We found that trends in acoustic energy align with observations of nest density, and the distribution of acoustic energy across frequency bands is indicative of colony demographics. Furthermore, we found a significant relationship between acoustic energy and investigator disturbance within 20 meters of an acoustic recorder. Overall, our findings suggest that colony-wide trends in population size, demographics, and behavior can be monitored via acoustic energy without the time-consuming analysis of individual calls.

10:15

3aAB9. Characteristics of courtship calls that could provide clues to physiological state or genetics of the emperor penguin, *Aptenodytes forsteri:* A case study of analysis using the Teager-Kaiser energy operator.
Kody C. Seger (Marine Technol. Society, Columbus, OH), Kerri D. Seger (Appl. Ocean Sci., 2127 1/2 Stewart St., Santa Monica, CA 90404, kerri.seger.d@gmail.com), Justin Brackett (SeaWorld San Diego, San Diego, CA), and Ann E. Bowles (Hubbs SeaWorld Res. Inst., San Diego, CA)

Vocal behavior can be an indicator of physiological state or genetic make-up, but has not been developed as a diagnostic tool in seabirds. Aptenodytes penguins lack external sexual dimorphism, but the sexes have dimorphic courtship calls. We present a case study in which unique call structure of an emperor penguin (*Aptenodytes forsteri*) was associated with a same-sex bonded pair. Typical males produce lower frequency calls with proportionally more long bursts, while typical females produce slightly higher frequency calls with proportionally more short bursts. We recorded two male emperor penguins (E-79 and E-81) at SeaWorld San Diego that behaved as a bonded pair. E-79 produced a call that was qualitatively different from the male type to human listeners. Using the Teager-Kaiser Energy Operator to visualize bursts, we calculated and compared burst rates of E-79 and E-81 to other emperor penguins in the SeaWorld colony and a colony at Cape Crozier, Antarctica. Analysis showed E-79's calls had a unique burst rate structure that was intermediate between typical male and female patterns. Our results suggest that while emperor courtship calls are usually strongly sexually dimorphic, it is not always the case. The exceptions could provide interesting insights into call development, physiology, and/or genetics.

10:30

3aAB10. Acoustic ecology of Adélie penguins in the West Antarctic Peninsula.
Danielle T. Fradet (Dept. of Biological Sci., Univ. of New Hampshire, Spaulding Hall, Durham, NH 03823, dtf1008@usnh.edu), Megan A. Cimino (Inst. of Marine Sci., Univ. of California Santa Cruz, Santa Cruz, CA), Easton White, and Laura Kloepper (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH)

Adélie penguins (*Pygoscelis adeliae*) are bioindicators for the rapidly changing Antarctic environment, making understanding their population dynamics and behavior of high research priority. However, collecting detailed population data throughout the breeding season on many colonies is difficult due to Antarctica's harsh conditions and remote location. The colonial breeding ecology of Adélie penguins has led to the evolution of a highly vocal species with individualized calls, making them well-suited for passive acoustic monitoring (PAM) with autonomous recording. PAM units can potentially provide an easily deployable and scalable way to collect fine-scale data on population estimates and breeding phenology. Here I present a framework for using acoustic indices to monitor phenology of dense penguin colonies even under high wind conditions. I evaluate the relationship between acoustic indices such as RMS amplitude and penguin colony size between distinct breeding stages (incubation, guard, crèche, and fledge) on Torgersen and Humble Islands in the West Antarctic Peninsula with an automated pipeline implemented in R. Using PAM to interpret penguin vocalizations for population size and breeding phenology estimates could lead to the development of a real-time remote monitoring system over a large spatial footprint, revealing Adélie penguin responses to climate change.

10:45

3aAB11. Ontogeny of vocalizations in Adélie penguin (*Pygoscelis adeliae*) chicks from West Antarctica.
Michele L. Adams (Dept. of Biological Sci., Univ. of New Hampshire, 83 Main St., 10953 Granite Square Station, Durham, NH 03824, Michele.Adams@unh.edu), Danielle T. Fradet (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH), Megan A. Cimino (Inst. of Marine Sci., Univ. of California, Santa Cruz, CA), Easton White, and Laura Kloepper (Dept. of Biological Sci., Univ. of New Hampshire, Durham, NH)

Acoustic indices are an efficient method for monitoring dense aggregations of vocal animals but require understanding the acoustic ecology of the species under examination. The present understanding of avian behavior and vocal development is primarily derived from the research of songbirds (Passeriformes). However, given that behavior and environment can differ greatly among bird orders, passerine birdsong may be insufficient to define the vocal ontogeny of non-passerine birds. Like many colonial nesting seabirds, the Adélie penguin (*Pygoscelis adeliae*) is adapted to loud and congested environments with limited cues to identify kinship within aggregations of conspecifics. In addition to physical or geographical cues to identify offspring, adult *P. adeliae* rely on vocal modulation. Numerous studies have been conducted on mutual vocal modulations in mature *P. adeliae*, but limited research has explored the vocal repertoire of the chicks and how their vocalizations evolve over time. Using the deep learning-based system, DeepSqueak, this study characterized the vocal ontogeny of *P. adeliae* chicks in the West Antarctic Peninsula to aid in autonomously tracking their age. Understanding the phenological communication patterns of vocal-dependent seabirds can help measure the impact of climate change on this indicator species through non-invasive methods.

Session 3aAOa

Acoustical Oceanography: Topics in Acoustical Oceanography II

Ernst Uzhansky, Cochair
Marine Geosciences, University of Haifa, Izhaq Greenboim St., apt. 12, (Korean Family), Haifa 3498793, Israel

Andone C. Lavery, Cochair
AOPE, Woods Hole Oceanographic Institution, 98 Water Street, Woods Hole, MA 02543

Contributed Papers

7:55

3aAOa1. A comparison of tidal components across multiple sites using ultra-low frequency ocean acoustic measurements. Anthony Eller (Appl. Ocean Sci., Springfield, VA) and Kevin D. Heaney (Appl. Ocean Sci., 11006 Clara Barton Dr., Fairfax Station, VA 22039, oceansound04@yahoo.com)

Recent long-term analysis of the hydrophone measurements taken in the deep sea reveals indications of multiple tidal components. Tidal harmonics corresponding to solar and lunar diurnal and semi-diurnal tide components were determined by analyzing the Cepstrum (variance of a spectral power) of the year or more long time series (0.5 Hz) of mid-water column measurements taken by the United Nations Comprehensive Test Ban Treaty Organization (CTBTO) in the Pacific, Atlantic and Indian Ocean. Postulations for the origin of this signal include rolling rocks, ocean turbulence, a change in the surface height, currents, mechanical/electrical (non-acoustic) noise and wind/wave induced noise propagating in the ocean. In this paper, this work is extended to more sites and encompasses a larger portion of the ultra-low frequency range (i $<$ 5 Hz). it is found that different sites have quite different tidal components (as expected) but also have different frequency components (some with 0.5–1 Hz and others with 3–5 Hz). This opens the possibility of acoustic soundscape differences between sites due to regional source generation and local acoustic propagation.

8:10

3aAOa2. Marine soundscape monitoring from underwater autonomous vehicles—Passive acoustic monitoring gliders. Pierre Cauchy (Inst. des Sci. de la mer (ISMER), Université du Québec à Rimouski (UQAR), 310 allée des Ursulines, Rimouski, QC G5L 3A1, Canada, pierre_cauchy@uqar.ca)

Ocean gliders are buoyancy-driven autonomous underwater platforms, able to collect oceanographic measurements along vertical profiles during multi-months missions, covering thousands of kilometers. They glide quietly through the water column without propulsion noise and are therefore extremely suitable for Passive Acoustic Monitoring (PAM) of the marine environment. From PAM glider data in the Mediterranean Sea and the Southern Ocean, we illustrate the current and potential uses of PAM gliders for the study of physical oceanography, biology, ecology and for regulatory purposes. We evaluate limiting factors for PAM glider survey, such as platform-generated and flow noise, instrument size and power constraints, profiling ability and movement of the platform. We provide recommendations and good practices for typical PAM glider surveys and present future developments identified by the PAM glider community to further develop the readiness level and societal impact of PAM glider observation: (1) Calibration of the PAM glider to collect absolute sound levels; (2) adapted sampling methods and statistical analysis techniques to perform population density estimation; and (3) Integration of PAM glider observation to existing monitoring programs.

8:25

3aAOa3. Cooperative-hydrophone-based underwater soundscape monitoring in a bustling harbor enhanced by coral ecosystem. Ben Liu (Inst. of Deep-Sea Sci. and Eng., Chinese Acad. of Sci., Hainan, Sanya 572000, China, liub@idsse.ac.cn) and Wen Xu (Zhejiang Univ., Sanya, China)

Anthropogenic underwater noise is an emerging pollutant, urging a focus on studying the spatial and temporal dynamics of underwater soundscapes for effective environmental protection. This study centers on a bustling harbor enriched by coral ecosystems, employing 5–8 spatially distributed bottom-mounted passive acoustic monitoring (PAM) nodes strategically placed at locations of interest with diverse natural conditions and ship traffic intensities. Focused on the intricate interplay between anthropogenic and natural contributors, including shipping traffic and coral ecosystems, one-third octave band sound pressure levels SPLs were calculated and analyzed at different frequencies, revealing significant variations in levels across different times and locations. Diurnal variations in ambient noise levels highlight the complex relationship between human activities and marine ecosystems. Higher and more variable SPLs, primarily related to shipping traffic, were recorded during the daytime, while lower SPLs, accompanied by increased fish sounds, were observed at night. The collaborative deployment of multiple hydrophones enables an estimation of noise source direction, and multi-hydrophone based principal component analysis (PCA) for dimensionality reduction and subsequent clustering methods were used for noise source classification. This study significantly contributes to the field of underwater noise monitoring, offering a holistic perspective on busy harbor environments.

8:40

3aAOa4. Quantitative comparison of ocean soundscape model and measurements in the Atlantic outer continental shelf. Kevin D. Heaney (Appl. Ocean Sci., 11006 Clara Barton Dr., Fairfax Station, VA 22039, oceansound04@yahoo.com)

For 4 years, the Atlantic Deep Water Ecosystem Observing Network (ADEON), measured the acoustic soundscape using 7 bottom mounted landers off the coast of the South East United States (from Florida to Virginia). A shipping and noise model was built to generate regional sound maps, as well as to perform site-specific modeling for frequencies ranging from 20 Hz to 3150 Hz. The regional sound maps reveal that water depth is the key driver to local sound levels followed by the local geo-acoustic properties. It is predicted that the sound can be as much as 10 dB higher on the seafloor than at depths of 10 m. The site specific (where landers were deployed) model was run with a wide range of sediment uncertainty in the model, given our lack of knowledge of the sediment structure in water depths of 200 to 800 m deep, far from shore. A simple qualitative comparison of the soundscape measurements with the model provides immediate insight into the type of sediment at each lander position. Using this estimated sediment type, quantitative comparisons between the model and the data are made.

8:55–9:15 Break

9:15

3aAOa5. Comparing coastal marine habitats by combining passive acoustics with metagenomics. Grant A. Milne (Univ. of New Hampshire, 14 Chesley Ave., Somersworth, NH 03878, grant.milne@unh.edu), Jennifer Miksis-Olds, Alyssa Stasse, Bo-Young Lee, Dylan Wilford (Univ. of New Hampshire, Durham, NH), Shaurya Baruah (The Peddie School, Hightstown, NJ), and Bonnie Brown (Univ. of New Hampshire, Durham, NH)

Past studies have combined passive acoustic monitoring with environmental genetic methods to detect target organisms, however, no studies to date have employed metagenomics concurrent with passive acoustic monitoring of soundscapes for comparison of marine habitats. The present study used both approaches simultaneously for holistic observation of marine habitats to reveal information beyond using either technique independently. Water samples for metabarcoding (four primer sets) were collected during periods of passive acoustic monitoring from three different marine habitats, each at four different geographic locations along the New Hampshire/Maine coastlines. Multivariate analyses compared discrimination among habitat types and geographic locations by analyzing acoustic metrics generated using the Soundscape Code and metagenomic taxonomic assignments. Passive acoustic monitoring provided insight into environmental features that were unobservable with metagenomics, especially anthropogenic activity and geophysical processes, whereas metagenomics provided a more complete picture of the biological composition of habitats through detection of organisms that were not actively producing sound. This enables simultaneous evaluation of biological and functional connectivity of marine habitats by detecting what organisms are present and their contributions to the soundscape. In future, genetic and acoustic indicators will be used for prediction of substrate characteristics and sound sources to model acoustic propagation environments.

9:30

3aAOa6. Doppler sonar records of fish movement through a strong tidal stream: 3-months of observations from Grand Passage Nova Scotia. Len Zedel (Phys. and Physical Oceanogr., Memorial Univ. of NF, 287 Prince Phillip Dr., St. John's, NF A1B 3X7, Canada, zedel@mun.ca), Alex E. Hay (Oceaography, Dalhousie Univ., Halifax, NS, Canada), and Shane Anderson (Phys. and Physical Oceanogr., Memorial Univ. of NF, St. John's, NF, Canada)

Coastal passages with strong tidal streams present potential for renewable energy generation with in-stream hydrokinetic turbines. However, there are concerns that these systems will lead to environmental impacts when marine life interact with moving turbine blades. We explore measurements of fish movement using Doppler current profilers as a way of quantifying the frequency of such interactions. Fish are detected in Doppler sonar data using calibrated backscatter levels in each of the four acoustic beams; by reprocessing un-averaged data it is possible to extract both fish and water velocities independently. We analyzed three months of Doppler sonar data collected in Grand Passage Nova Scotia from September until December 2014. The data show fish detections in large numbers for only a few days on three occasions at the deployment site. Most of the observations show fish moving at the same speed as the water but there are times when there is significant difference in fish and water speeds.

9:45

3aAOa7. Humpback whale song vocalization behavior and temporo-spatial distributions in the Norwegian and Barents Sea observed with a coherent hydrophone array. Saunak Samantray (Elec. and Comput. Eng., Northeastern Univ., 360 Huntington Ave., Boston, MA 02115, samantray.s@northeastern.edu), Arpita Ghosh, Sai Geetha Seri (Elec. and Comput. Eng., Northeastern Univ., Boston, MA), Hamed Mohebbi-Kalkhoran (Mech. Eng., Massachusetts Inst. of Technol., Cambridge, MA), Olav R. Godoe (Inst. of Marine Res. Norway, Bergen, Norway), Nicholas C. Makris (Mech. Eng., Massachusetts Inst. of Technol., Cambridge, MA), Heidi Ahonen (Norwegian Polar Inst., Tromsø, Norway), and Purnima R. Makris (Elec. and Comput. Eng., Northeastern Univ., Boston, MA)

The vocalization behavior of humpback whales in the Norwegian and Barents Seas is examined based on recordings of a large-aperture, densely-populated coherent hydrophone array system. The passive ocean acoustic waveguide remote sensing (POAWRS) technique is employed to provide detection, bearing-time estimation, time-frequency characterization and classification of the humpback whale vocalizations. The song vocalizations, composed of highly structured and repeatable set of phrases, were detected throughout the diel cycle between February 18 to March 8, 2014. The beamformed spectrograms of the detected humpback vocalizations are classified as song sequences based on inter-pulse intervals and time-frequency characteristics, verified by visual inspection. The song structure is compared for humpback whale vocalizations recorded at three distinct regions off the Norwegian coast, Alesund, Lofoten and Northern Finmark. Multiple bearing-time trajectories for humpback songs were simultaneously observed indicating multiple singers present at each measurement site. Humpback whale received call rates and temporo-spatial distributions are compared across the three measurement sites. Geographic mapping of humpback whale calls from their bearing-time trajectories is accomplished via the moving array triangulation technique.

10:00

3aAOa8. Active learning algorithms for autonomous platforms to characterize underwater static acoustic sources. Prajna Jandial (Ocean and Resources Eng., Univ. of Hawai'i at Manoa, 2440 Kuhio Ave., Honolulu, HI 96815, prajna@hawaii.edu), Frances Zhu (Hawai'i Inst. of Geophys. and Planetology, Univ. of Hawai'i at Manoa, Honolulu, HI), and Eva-Marie Nosal (Ocean and Resources Eng., Univ. of Hawai'i at Manoa, Honolulu, HI)

Integrating passive acoustics with autonomous platforms presents an opportunity to complement the spatial constraints of traditional fixed sensor methods by leveraging the capacity of autonomous underwater vehicles (AUVs) to make real-time decisions. We present algorithms that adaptively sample a survey region based on the sound field characteristics. These algorithms use an active learning strategy based on Gaussian Process (GP) regression to characterize a static sound field in a survey region. With each location sampled, the algorithms employ a GP to estimate the distribution and quantify the uncertainty of static acoustic sources within the region. The uncertainty metric is used to then choose the next sampling location. This dynamic approach not only maximizes the information gained by the AUV at every location that it samples but also ensures an efficient convergence toward the true distribution of underwater static sources in that region. These algorithms were developed in simulation and will be tested in controlled experiments.

10:15

3aAOa9. Underwater sound source direction finding with sparsity optimization framework using distributed fiber optic acoustic sensing system. Siyuan Cang (Southern Marine Sci. and Eng. Guangdong Lab. (Guangzhou), No.1119, Haibin Rd., Nansha District, GuangZhou, Guangdong 511458, China, cangsiyuan@gmlab.ac.cn), Huayong Yang, Chao Li, Zhongyao Wang, Xiaoming Cui, Jiantong Chen, and Dehou Yang (Southern Marine Sci. and Eng. Guangdong Lab. (Guangzhou), Guangzhou, Guangdong, China)

Distributed fiber Acoustic Sensing (DAS) technology has become increasingly popular in recent years due to its resistance to electromagnetic interference, long-distance dynamic monitoring, dense spatial sensing, maintenance-free sensing ends, and low cost. Our team conducted an underwater acoustical experiment using the DAS system at the Xin-Feng-Jiang Reservoir in Guangdong, China. This report presents the relevant experimental findings. Underwater ambient noises exhibit heteroscedastic statistics in the time/space/frequency domains, thereby posing a challenge in robustly estimating the bearings of underwater sound sources. Using the DAS system, we collected ambient noise data monthly and analyzed their statistical characteristics. To suppress the heteroscedastic noise, a robust bearing estimation method was designed for the DAS system. The proposed method relies on the generalized sparse covariance fitting and optimization framework, allowing us to capture the trajectory of a towed transducer. Furthermore, by post-processing the DAS data with high-resolution, even a fast-moving boat can be dynamically traced. Both the simulation and the experiment prove the algorithm's effectiveness, highlighting the potential of the DAS system in tracking underwater targets.

WEDNESDAY MORNING, 15 MAY 2024 ROOM 215, 10:45 A.M. TO 12:00 NOON

Session 3aAOb

Acoustical Oceanography, Underwater Acoustics and Animal Bioacoustics: Sound at Temperate and Tropical Coral Reefs

Lauren Freeman, Chair
NUWC Newport, NUWC, Naval Undersea Warfare Ctr., 1176 Howell St., Newport, RI 02841

Chair's Introduction—10:45

Invited Paper

10:50

3aAOb1. SoundGarden: Applying healthy soundscapes to support coral reef restoration. T. Aran Mooney (Biology Dept., Woods Hole Oceanographic Inst., 266 Woods Hole Rd., Marine Res. Facilty 227 (MS# 50), Woods Hole, MA 02543-1050, amooney@whoi.edu), Nadége Aoki (Biology Dept., Woods Hole Oceanographic Inst., Woods Hole, MA), Benjamin Weiss (Woods Hole Oceanographic Inst., Woods Hole, MA), Sierra Jarriel (Biology, Woods Hole Oceanographic Inst., Woods Hole, MA), Youenn Jézéquel (Biology Dept., Woods Hole Oceanographic Inst., Trélévern, France), Alexandra Gutting, Jessica Ward (The Nature Conservancy, St. Croix, Virgin Islands (U.S.)), Weifeng G. Zhang (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., Woods Hole, MA), and Amy Apprill (Marine Chemistry and Geochemistry, Woods Hole Oceanographic Inst., Woods Hole, MA)

Coral reefs are a hub of ocean biodiversity supporting a range of socioeconomic and ecosystem services. Yet reefs and these important services are imperiled due to climate change and related stressors. Healthy coral reefs can be characterized by distinctive soundscapes, and there is increasing realization that acoustic cues are vital ecosystem components. Here we present a series of experiments examining if replaying healthy soundscapes can increase the settlement of coral larvae, a fundamental ecological process. Work was conducted in the U.S. Virgin Islands, leveraging a decade of soundscape studies on those reefs, and used a novel solar-powered acoustic playback system calibrated in sound pressure and particle motion. We studied larvae from three coral species, brooding *Porites astreoides* and *Favia fragum*, and broadcast-spawning *Diploria labyrinthiformis*. Larvae on degraded reefs enriched with healthy reef sounds settled at significantly higher rates compared to control sites that were not acoustically enriched. Acoustic enrichment settlement rates were influenced by received level, ecosystem properties and species biology reflecting the need for holistically evaluating the reef restoration process. Overall, this work outlines a new, potentially scalable means of supporting healthy reef habitat, and enhancing coral settlement on imperiled reefs undergoing restoration.

Contributed Paper

11:10

3aAOb2. Unidentified fish sounds as indicators of coral reef health and comparison to other acoustic methods. Sierra Jarriel (Biology, Woods Hole Oceanographic Inst., 266 Woods Hole Rd MS#50, Woods Hole, MA 02543, sierra.jarriel@whoi.edu), Nathan Formel (Biology, Woods Hole Oceanographic Inst., Woods Hole, MA), Sophie R. Ferguson (Marine Biological Lab., Woods Hole, MA), Frants H. Jensen (Dept. of Ecoscience, Aarhus Univ., Aarhus, Denmark), Amy Apprill (Marine Chemistry and Geochemistry, Woods Hole Oceanographic Inst., Woods Hole, MA), T. Aran Mooney (Biology Dept., Woods Hole Oceanographic Inst., Woods Hole, MA), Miles J. Parsons (Australian Inst. of Marine Sci., Perth, Western Australia, Australia), and Lucia Di Iorio (Univ. of Perpignan, Perpignan, France)

As biodiversity hotspots, coral reefs are rich with sound cues. Monitoring these soundscapes for changes is essential as coral reefs decline around the world rapidly. Despite this, acoustic metrics that reliably represent reef health are still debated, and ground-truthing of methods are limited. We sought to investigate the occurrence and prevalence of fish sounds in relation to reef health, providing a foundation to compare assessment methods. We first quantified fish call rates for three U.S. Virgin Islands reefs exhibiting different community assemblages, by manually annotating fish calls across 8 days per site. Call rates were then compared with traditional visual surveys, and several acoustic methods commonly used in underwater soundscape research. Manually detected fish call rates successfully differentiated between the three reefs, capturing variation in crepuscular activity levels and predicting hard coral cover, fish abundance, and fish species richness. Meanwhile, most acoustic indices failed to parse out fine distinctions among the three sites, although sound pressure level showed the greatest correlation to call rates. Development of methods to improve the utilization of unknown fish sounds, such as automatic detection and classification tools, supports global sound library efforts and is essential to implement large-scale passive acoustic monitoring of coral reefs.

Invited Paper

11:25

3aAOb3. Unraveling biological responses to oceanographic equipment: Insights from forward-facing active acoustics and low-light imagery using small boats. Rendhy M. Sapiie (Ocean Eng., Univ. of Rhode Island, 15 Receiving Rd., Narragansett, RI 02881, renmsapiie@uri.edu), Lauren Freeman (NUWC, Naval Underwater Warfare Ctr., Newport, RI), Chris Roman, David Casagrande (Graduate School of Oceanogr., Univ. of Rhode Island, Narragansett, RI), and Brennan Phillips (Ocean Eng., Univ. of Rhode Island, Narragansett, RI)

Over six decades, extensive research has delved into the intricate interactions between marine animals and oceanographic sampling equipment, recognizing the impactful influence of light and sound emissions on mobile fauna behavior during surveys. This study, conducted through three mid-water experiments in the Solomon Islands (2019) and Bermuda (2021 and 2023), utilizing small boats, aims to unravel the effects of light on the distribution of biological scattering layers. Employing broadband active acoustics, dimmable lights, and low-light imaging on an observation-class ROV and a custom-made instrument frame, the experiments dynamically adjusted light intensity to track changes in volume backscattering strength. Amidst challenges encountered along the way, the study notably succeeded in observing avoidance behaviors from mesopelagic animals in response to the presence of our equipment. This study provides valuable insight for fisheries acoustics and echosounder applications, particularly in coral reef environments where small boats play a crucial role. This paper reviews the system setup, data processing, and presents fused backscatter data over depth, concluding with lessons learned, recommendations, and future study goals, contributing to the broader understanding of marine animal interactions with sampling equipment.

Contributed Paper

11:45

3aAOb4. Passive acoustic monitoring of tropical and temperate reefs reveals ambient noise cycles on multiple time scales. Lauren Freeman (NUWC Newport, NUWC, Naval Undersea Warfare Ctr, Newport, RI, lauren.a.freeman3.civ@us.navy.mil), Daniel Duane (NUWC Newport, Newport, RI), and Ian Rooney (NUWC Newport, Newport, RI)

Passive acoustic monitoring programs of tropical and temperate reefs in Hawaii, Bermuda, and New England have been underway for several years using omni-directional recorders placed near shallow reef sites. These multi-year time scale datasets allow us to observe not only diurnal cycles that are becoming a familiar facet of biological soundscapes, but seasonal, lunar, and inter-annual variability driven by light and sea surface temperature. Coupling acoustic data collections with non-acoustic validation such as *in situ* video and oceanographic measurements offers additional insights as to what is driving variability and increasingly predictable patterns in biological ambient noise in littoral settings. This overview will highlight work in three distinct regions with a focus on repeatable cycles associated with non-anthropogenic environmental drivers, and finally will explore the effects of human activity on reefs that may be reflected in reef soundscapes.

Session 3aBAa

Biomedical Acoustics, Physical Acoustics and Structural Acoustics and Vibration: SonoDynamic Therapy. A New Hope

James Kwan, Chair

Engineering Science, University of Oxford, Department of Engineering Science, University of Oxford, Parks Road, Oxford OX1 3PJ, United Kingdom

Contributed Papers

7:55

3aBAa1. Extracellular adenosine-5′-triphosphate release kinetics following microbubble cavitation in cultured human endothelial cells. Marie Amate (Biomedical Inst., Univ. of Montréal, 900 Rue Saint-Denis, Montréal, QC H2X 0A9, Canada, marie.amate@umontreal.ca), Ju Jing Tan, Francis Boudreault, Ryszard Grygorczyk (Dept. of Medicine, Univ. of Montreal, Montreal, QC, Canada), Thomas Gervais (Dept. of Eng. Phys., Polytechnique Montréal, Montreal, QC, Canada), and François Yu (Radiology, Université de Montréal, Montréal, QC, Canada)

Ultrasound Targeted Microbubble Cavitation (UTMC) causes vasodilation, which can improve radiotherapy efficacy, but the mechanisms remain unknown. Herein, we characterize extracellular Adenosine Triphosphate (eATP) release kinetics *in vitro* following UTMC using live microscopy. eATP was measured in real-time with a bioluminescent Luciferin-Luciferase (LL) assay. Human endothelial cells were grown in microfluidic chips. A microbubble solution (Definity: 10^7 MB/ml) containing propidium iodide (25 μg/ml) and LL was added to the chips before sending a single ultrasound pulse (A303S-SU, 1MHz, 0.5 in., Olympus, pressure: 300 kPa; 10, 100, or 1000 cycles). The bioluminescence signal of eATP reaction with the LL was captured with an EMCCD camera and converted into eATP released quantity, as in the study by Tan *et al*. (2019). After the acquisition, a viability assay was done using calcein-AM (4 μg/ml). We found a significantly higher total eATP released by dead cells than live sonoporated cells. The eATP release rate was also significantly higher in dead cells than in sonoporated cells at 4s after the pulse. At that time, we could estimate the eATP released by individual cells within a cell cluster before the individual bioluminescent signals merged due to diffusion. This will able us to understand better the eATP release mechanism *in vitro* and *in vivo*.

8:10

3aBAa2. An investigation on the mechanism(s) behind sonodynamic therapy and the use of sonosentizers. Stephanie C. Walton (Eng. Sci., Univ. of Oxford, Flat 16, 1 Thames St., Oxford OX1 1SL, United Kingdom, worc6254@ox.ac.uk)

Over the last 30 years, sonodynamic therapy (SDT) has been under investigation as a treatment for malignant tumours. SDT utilizes ultrasound in combination with a sonosensitizer to cause cell death. While this treatment is in use, there remains critical questions that limit the translation of this promising therapy into the clinic. Chemical or physical changes occurring due to ultrasound may explain the efficacy observed and depending on the frequency and intensity of sound used, cavitation may be an important component of this. Some findings indicate that collapsing bubbles, or sonoluminescence, may cause the sonosensitizers to split, creating reactive oxygen species (ROS). Other research suggests damage to cell structure due to the ultrasound waves is the key. Understanding the required balance of chemical and physical effect for varied cancer cells is critical to optimization of the treatment. This paper presents a preliminary investigation of the cause of cell death observed in SDT, with focuses on ROS generation, the use of ultrasound to activate chemical compounds, and observable mechanical damage to cells following ultrasound exposure.

8:25

3aBAa3. Subharmonics are not the full story—Searching for acoustic signatures of cavitation and other fantastic beasts. Qiang Wu, Michael Gray, Cameron Smith, Robin O. Cleveland (Univ. of Oxford, Oxford, United Kingdom), Constantin Coussios (Univ. of Oxford, Headington, Oxford, Oxfordshire, United Kingdom), and Eleanor P. Stride (Univ. of Oxford, Inst. of Biomedical Eng., Oxford OX3 7DQ, United Kingdom, eleanor.stride@eng.ox.ac.uk)

Cavitation induced bio-effects are being exploiting in a wide range of applications from physiotherapy to brain surgery. The acoustic emissions generated by bubble activity are extremely useful in enabling real time treatment monitoring. The relationship between the spectral characteristics of these emissions and bubble dynamics is, however, complex. Here we report data from experiments with simultaneous ultra-high-speed optical imaging and passive acoustic mapping of individual microbubbles exposed to 50 cycles of ultrasound at 0.5 MHz with varying peak negative pressures. The spectral content of the acoustic emissions from individual microbubble was compared to the bubble dynamics observed by the imaging. As expected from prior work, both the number of discrete harmonics and broadband content in the emissions increased with increasing amplitude of bubble oscillation. There was no clear correlation, however, between the presence of ultra and sub-harmonic components and bubble behaviour. Indeed, these components were frequently absent. Moreover, phenomena such as microjetting, fragmentation and coalescence, that could produce very different effects in tissue, were indistinguishable acoustically. The results thus indicate that the definition of cavitation thresholds or doses should be very carefully considered depending on the therapeutic effect (or avoidance of unwanted bioeffects) required for a particular application.

8:40

3aBAa4. Ultrasonically induced electrical potentials in PLLA film and bone. Shouta Kitajima (Doshisha Univ., Kyotanabe, Japan, ctwj0326@mail4.doshisha.ac.jp), Keigo Maehara, and Mami Matsukawa (Doshisha Univ., Kyotanabe, Kyoto, Japan)

Osteosynthesis materials are used for the fixed treatment of serious bone fractures. Titanium and bioabsorbable poly-L-lactic acid (PLLA) are often used. PLLA is known to have piezoelectricity, and its contribution to bone fracture healing has been discussed. On the other hand, bone fracture healing using low-intensity-pulsed-ultra-sound (LIPUS) is also popular although the initial mechanism (how bones sense ultrasound) is still unclear. One key factor is the weak piezoelectricity of bone. If ultrasound was able to induce higher electrical potentials in PLLA than in bone, the combination treatment of PLLA and LIPUS would be effective for bone fracture healing. Then, we experimentally investigated the piezoelectricity of PLLA and bone in the MHz range. First, we fabricated an ultrasonic receiver using a cortical bone plate (thickness 1 mm) covered by a stretched PLLA film (thickness 50 mm)

as a piezoelectric material. Second, we irradiated ultrasound in the MHz range to the receiver and measured electrical potentials as the output of the receiver. As a result, the average electrical potentials were about 1.4 times higher than those of a receiver made of bone without the PLLA film. This result indicates that ultrasonically induced potentials around bone may increase by the PLLA film.

8:55

3aBAa5. Investigation of the ultrasound-mediated toxicity mechanisms of IR780 iodide. Kritika Singh (Univ. of Oxford, Old Rd., Headington, Oxford OX3 7LD, United Kingdom, kritika.singh@magd.ox.ac.uk), Alexandra Vasilyeva, LuNa Hu, Jia Ling Ruan, Michael Gray (Univ. of Oxford, Oxford, United Kingdom), John Schiller (National Institutes for Health, Bethesda, VA), and Eleanor P. Stride (Univ. of Oxford, Oxford, United Kingdom)

IR780 iodide is a lipophilic cation heptamethine dye that has emerged as a potential fluorescent probe for *in vivo* tumor imaging. Previous work has shown it to be a sono- and photo-sensitizer (sound- and light-activated molecule) suitable for use in sonodynamic therapy (SDT) due to its proposed ability to produce ROS when 'activated' by ultrasound. This study evaluated IR780 iodide as an SDT agent *in vitro* using A549s, HeLas, and HeLa S3 cell lines, a broad range of ultrasound and light parameters, multiple ultrasound and light systems, and with and without cavitation nuclei. Through temporal uncoupling of ultrasound application and compound administration *in vitro* and *in vivo*, evaluation of cavitation-only related cell death, assessment of the dark toxicity of IR780 iodide, and development of positive controls for cell permeabilization (sonoporation), this study shows that dark toxicity and cavitation play an important role in IR780 SDT-induced cell death. This potentially explains the high levels of cell death observed for comparatively low concentrations of ROS. Additionally, this study proposes a standard set of controls for SDT mechanistic studies, which were used to further help study the mechanisms of other SDT drugs including Rose Bengal, 5-aminolevulinic acid, and indocyanine green.

9:10

3aBAa6. Ultrasound Targeted Microbubble Cavitation (UTMC) for the treatment of Myocardial Microvascular Obstruction (MVO). Muhammad Wahab Amjad (Medicine, Univ. of Pittsburgh, 3550 Terrace St., 959 Scaife Hall, Pittsburgh, PA 15213, MUA56@pitt.edu), Soheb Anwar Mohammed, Xucai Chen (Medicine, Univ. of Pittsburgh, Pittsburgh, PA), Flordeliza S. Villanueva (Medicine/Cardiology, Univ. of Pittsburgh, Pittsburgh, PA), and John J. Pacella (Medicine, Univ. of Pittsburgh, Pittsburgh, PA)

Congestive heart failure following acute myocardial infarction is increasing due to microvascular obstruction (MVO), for which there is no effective therapy. We have been developing ultrasound-targeted microbubble cavitation (UTMC) as a potential treatment. Rapacz familial hypercholesterolemic (RFH) pigs were used in this study. MVO was created in the left anterior descending (LAD) microcirculation. UTMC therapy was applied during infusion of Definity®. Left ventricular (LV) segmental wall motion and microvascular perfusion were assessed with ultrasound. Cardiac MRI was obtained to measure infarct size and area of MVO; ultrasound imaging and coronary angiography were performed at 48h. LAD angiographic flow was improved at 48 h post-treatment in comparison to control. UTMC treatment significantly improved echo-based LV systolic performance. UTMC was also found to significantly enhance LAD blood volume at 48h versus control. MRI-derived LV segmental wall motion and ejection fraction also improved post-treatment. Infarct size was reduced as assessed by both Evans Blue/TTC staining and MRI. In conclusion, we demonstrated that UTMC significantly reduced infarct size, enhanced LAD microvascular perfusion and improved LV systolic performance.

Invited Paper

9:25

3aBAa7. Curiouser and curiouser—Sonoluminescence, sonoporation, and sonodynamic therapy. Luca Bau (Univ. of Oxford, Oxford, United Kingdom), Niclas Westerberg, Richard Lane (Glasgow Univ., Glasgow, United Kingdom), LuNa Hu, Kritika Singh (Univ. of Oxford, Oxford, United Kingdom), John Callan, Anthony McHale (Ulster Univ., Coleraine, United Kingdom), Daniele Faccio (Glasgow Univ., Glasgow, United Kingdom), and Eleanor P. Stride (Univ. of Oxford, Inst. of Biomedical Eng., Oxford OX3 7DQ, United Kingdom, eleanor.stride@eng.ox.ac.uk)

The potential of sonodynamic therapy (SDT) for delivering highly localised therapy with minimal side-effects is extremely attractive for a range of applications, including multiple forms of cancer and antibiotic resistant infections. There is also increasing evidence of beneficial immunostimulatory effects for treating metastatic disease. Yet, despite the growing evidence for both the pre-clinical and now clinical efficacy of SDT, the mechanisms underpinning ultrasound mediated drug activation remain unclear. This has inhibited optimisation of ultrasound exposure conditions and dosing protocols. This talk will review the range of mechanisms proposed in the literature and the corresponding supporting and contradictory evidence. These will include recent investigations by the authors into the role of sonoporation, and theoretical and experimental quantification of sonoluminescence. The importance of selecting appropriate treatment monitoring protocols to detect cavitation will also be discussed.

Session 3aBAb

Biomedical Acoustics: Biomedical Acoustics Best Student Paper Award Poster Session

Kenneth B. Bader, Cochair
Department of Radiology, University of Chicago, 5835 South Cottage Grove Ave., MC 2026, Q301B, Chicago, IL 60637

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

The ASA Technical Committee on Biomedical Acoustics offers a Best Student Paper Award to eligible students who are presenting at the meeting. Each student must defend a poster of her or his work during the student poster session. This defense will be evaluated by a group of judges from the Technical Committee on Biomedical Acoustics. Additionally, each student will give an oral presentation in a regular/special session. Up to three awards will be presented to the students with USD $500 for first prize, USD $300 for second prize, and USD $200 for third prize. The award winners will be announced at the meeting of the Biomedical Acoustics Technical Committee.

Below is a list of students competing, with abstract numbers titles. Full abstracts can be found in the oral sessions associated with the abstract numbers. All entries will be on display, and all authors will be at their posters from 10:00 a.m. to 12:00 noon.

1aBAa8. Evaluation of sonobiopsy feasibility and safety in a mouse model of diffuse intrinsic pontine glioma
Student author: Dingyue Zhang

1aBAb5. Towards reduced ultrasound localization microscopy acquisition time by means of monodisperse microbubbles uncoupling
Student author: Giulia Tuccio

1aBAb6. Acoustic emissions-based estimation of the temporal changes in microbubble radius during ultrasonic excitation
Student author: Hohyun Lee

1aBAb7. Investigating the resonance response of a system of two ultrasound-driven lipid encapsulated microbubbles confined within a viscoelastic vessel
Student author: Hossein Yusefi

1pBAa1. Native bubble nuclei for acoustic cavitation in 3D cell cultures
Student author: Ferdousi Sabera Rawnaque

1pBAa12. Analysis of gas evolution in the heart, liver and kidney of turtles presenting with gas embolic pathology based on ultrasonography
Student author: Katherine Mary Eltz

1pBAa2. Real-time assessment of focused ultrasound-induced bioeffects in elastic tissues
Student author: Jacob C Elliott

1pBAa3. The role of fluid flow patterns in microbubble-mediated endothelial cell membrane permeabilization
Student author: Elahe Memari

1pBAa4. Focused ultrasound and microbubble induced changes in the phenotype of breast cancer cell lines
Student author: Dure S. Khan

1pBAa9. Focused shear wave beam propagation through a 3D printed human rib cage
Student author: Yu-Hsuan Chao

1pBAb5. Improving photoacoustic imaging through the skull using deep learning: a numerical study
Student author: Matthew James Olmstead

1pBAb6. Plane wave approaches with dual-frequency arrays for superharmonic contrast imaging
Student author: Jing Yang

2pBAa1. In vitro comparison of subharmonic-aided pressure estimation sensitivity among microfluidic monodisperse microbubbles, Sonazoid, and Definity
Student author: Ga Won Kim

2pBAa3. Microstreaming profile of a phospholipid-coated wall-attached microbubble undergoing shape oscillation
Student author: Hongchen Li

2pBAa5. An in vitro investigation into Lumason's utility for subharmonic-aided pressure estimation with direct comparison to Sonazoid and Definity
Student author: Hailee Mayer

2pBAa8. Extracellular matrix stiffness affects microbubble-assisted endothelial permeabilization under flow
Student author: Zoe Daniela Katz

2pBAb10. Experimental and numerical comparison of multiple passive beamformers for separating intra- and extra-canal cavitation activity during transvertebral spinal cord therapy
Student author: Andrew Paul Frizado

2pBAb2. Volumetric beamforming in real-time using commodity hardware
Student author: Sebastian Kazmarek Praesius

2pBAb3. Tunable liquid-based lenses for ultrasonic beamforming
Student author: Sina Rostami

3aBAa1. Extracellular Adenosine-5. '-Triphosphate Release Kinetics following microbubble cavitation in cultured human endothelial cells
Student author: Marie Amate

3aBAa2. An investigation on the mechanism(s) behind sonodynamic therapy and the use of sonosentizers
Student author: Stephanie Carmen Walton

3aBAa4. Ultrasonically induced electrical potentials in PLLA film and bone
Student author: Shouta Kitajima

3aBAa5. Investigation of the ultrasound-mediated toxicity mechanisms of IR7. 8. 0 iodide
Student author: Kritika Singh

4aBAa11. Validation of mSOUND using a fully heterogeneous skull model
Student author: Jeff James Bell

4aBAa12. Simulation-corrected focusing to the vertebral canal
Student author: David Martin

4aBAa2. Poroelastic model of the lungs at low frequencies predicted by Biot's theory
Student author: Arife Uzundurukan

4aBAa5. Surfacic characterization of soft tissues biomechanical properties using impact-based methods: A comparative study
Student author: Arthur Bouffandeau

4pBAa3. Ultrasound responsive multi-layered emulsions for drug delivery
Student author: Aaqib Haroon Khan

4pBAa8. Optimization of ultrasound contrast agent and treatment duration for drug delivery to methicillin-resistant Staphylococcus aureus diabetic wound biofilms in mice
Student author: Kelly VanTreeck

4pBAb1. Heterogeneous ultrasonic wave properties in leg cortical bones of thoroughbreds
Student author: Shuta Kodama

4pBAb13. Shear wave propagation in a fiber-laden viscoelastic waveguide under prestress: inverse modeling challenges
Student author: Lara Nammari

4pBAb2. Assessment of cortical bone phantom properties using ultrasonic guided waves transduced with a multi-element transducer
Student author: Aubin Antoine Chaboty

5aBAa4. Simulation of high frame rate spread-spectrum color Doppler imaging of pulsatile flow
Student author: Kian Esmailian

5aBAb10. Correlation of Escherichia coli inactivation with histotripsy bubble cloud size
Student author: Pratik A Ambekar

5aBAb12. The roles of pulse length and duty cycle in the fractionation of tendinopathic tendons
Student author: Grace M Wood

5aBAb14. Active targeting of nanotherapeutics using power cavitation imaging with a linear array transducer
Student author: Kamso Onyemeh

5aBAb3. Targeted delivery of miR-1 to the heart using clinical contrast ultrasound
Student author: Davindra Singh

5aBAb4. Monodisperse microbubble-mediated drug delivery: influence of microbubbles size on drug delivery outcome
Student author: Yuchen Wang

5aBAb5. Focused ultrasound-guided delivery of gene editing protein in human induced pluripotent stem cells
Student author: Kyle Hazel

5aBAb8. Towards real-time decompression sickness mitigation using wearable capacitive micromachined ultrasonic transducer arrays
Student author: Joshua B Currens

5aBAb9. Designing a benign prostatic hyperplasia dual-mode cavitation cloud and boiling histotripsy therapy transducer
Student author: Yashwanth Nanda Kumar

WEDNESDAY MORNING, 15 MAY 2024 ROOM 102, 8:30 A.M. TO 11:55 A.M.

Session 3aCA

Computational Acoustics, Physical Acoustics and Structural Acoustics and Vibration: The Phononic Dispersion Relations: Calculation, Interpretation, and Applications in Phononics and Metamaterials

S. Hales Swift, Cochair
Sandia National Laboratories, P.O. Box 5800, MS 1082, Albuquerque, NM 87123-1082

Matthew D. Guild, Cochair
Naval Research Lab, 4555 Overlook Ave SW, Acoustics Division, Code 7160, Washington, D.C. 20375

Chair's Introduction—8:30

Invited Papers

8:35

3aCA1. Synthetically non-Hermitian nonlinear wave-like behavior in a topological mechanical metamaterial. Haning Xiu, Ian Frankel (Univ. of California San Diego, San Diego, CA), Harry Liu (Phys., Univ. of Michigan, Ann Arbor, MI), Kai Qian (Univ. of California San Diego, San Diego, CA), Siddhartha Sarkar (Phys., Univ. of Michigan, Ann Arbor, MI), Brianna MacNider (Univ. of California San Diego, San Diego, CA), Zi Chen (Harvard Univ., Boston, MA), Nicholas Boechler (Univ. of California San Diego, San Diego, CA), and Xiaoming Mao (Phys., Univ. of Michigan, 450 Church St., Ann Arbor, MI 48108, maox@umich.edu)

Topological mechanical metamaterials have enabled new ways to control stress and deformation propagation. Exemplified by Maxwell lattices, they have been studied extensively using a linearized formalism. Herein, we study a two-dimensional topological Maxwell lattice by exploring its large deformation quasi-static response using geometric numerical simulations and experiments. We observe spatial nonlinear wave-like phenomena such as harmonic generation, localized domain switching, amplification-enhanced frequency conversion, and solitary waves. We further map our linearized, homogenized system to a non-Hermitian, nonreciprocal, one-dimensional wave equation, revealing an equivalence between the deformation fields of two-dimensional topological Maxwell lattices and nonlinear dynamical phenomena in one-dimensional active systems. Our study opens a regime for topological mechanical metamaterials and expands their application potential in areas including adaptive and smart materials and mechanical logic, wherein concepts from nonlinear dynamics may be used to create intricate, tailored spatial deformation and stress fields greatly transcending conventional elasticity.

9:00

3aCA2. Pseudo-spin polarized one-way elastic wave eigenstates in one-dimensional phononic superlattices. Pierre A. Deymier (New Frontiers of Sound (NewFoS), Univ. of Arizona, 1235 E. James E. Rogers Way, Mater. Sci. and Eng., University of Arizona, Tucson, AZ 85721, deymier@arizona.edu), Keith Runge (New Frontiers of Sound (NewFoS), Univ. of Arizona, Tucson, AZ), Alexander Khanikaev, and Andrea Alu (Phys. Program/NewFoS, City Univ. of New York, New York, NY)

We use a one-dimensional discrete binary elastic superlattice bridging continuous models of superlattices that showcase one-way propagation character and the discrete elastic Su-Schrieffer-Heeger model that does not. By considering Bloch wave solutions of the superlattice wave equation, we demonstrate conditions supporting elastic eigenmodes that do not satisfy translational invariance of Bloch waves over the entire Brillouin zone, unless their amplitude vanishes for some wave number. These modes are characterized by a pseudo-spin, and occur only on one side of the Brillouin zone for given spin, leading to spin-selective one-way wave propagation. We demonstrate how these features result from the interplay of translational invariance of Bloch waves, pseudo-spin, and a Fabry-Pérot resonance condition in the superlattice unit cell.

9:25

3aCA3. Multiple scattering analysis of phononic crystals. Daniel Torrent (Universitat Jaume I, Av Vicente Sos Bayntat, Castellon de la Plana, Castellón 12071, Spain, dtorrent@uji.es), Marc Martí Sabaté, and Sebastien Guenneau (Imperial College London, London, United Kingdom)

Multiple scattering theory allows for the computation of states and scattering fields on a diverse variety of wave systems. Through rigorous analysis, this theory provides insights into wave phenomena such as diffraction, reflection, and transmission, contributing to a comprehensive understanding of the intricate dynamics of classical systems. Our study focuses on flexural waves in thin elastic plates, with point-like mass spring resonators serving as scatterers attached the plate's top surface. Finite clusters of scatterers will be analysed without imposing symmetries or periodicity in the system. Despite the apparent simplicity of this model, it proves capable of unveiling and predicting many behaviours related to the latest topics on metamaterials, including phononic crystals, quasicrystals, topological insulators, rainbow trapping effects or spatio-temporal modulation. In essence, this technique offers a foundation for advancements in materials science, structural engineering and all the domains where metamaterials and phononic crystals find application.

9:50–10:05 Break

10:05

3aCA4. Considering the role of the phononic dispersion relations in understanding the performance of phononic pseudocrystals and similar structures. S. Hales Swift (Sandia National Labs., P.O. Box 5800, MS 1082, Albuquerque, NM 87123-1082, shswift@sandia.gov)

Dispersion calculations have been an essential tool for investigating and predicting the performance of conventional phononic crystals because they offer the opportunity to accurately characterize the behavior of a structure based on the smallest characteristic piece of that structure. For phononic pseudocrystals—in which translational symmetry is replaced by cyclic symmetry and radial self similarity—the scaled dispersion relations of the unit pseudocell provide useful information; however, the behavior of a completed article comprised of multiple pseudocells is less completely articulated than for conventional phononic crystals. This paper will explore the uses of dispersion-type calculations applied to characteristic wedges of phononic pseudocrystals in an effort to evaluate what additional information they can potentially provide. [*SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525*.]

10:30

3aCA5. Inverse design of arbitrary non-reciprocal acoustic dispersion in non-local phononic crystals and metamaterials. Muhammad Bilal Khan (Mech. Eng., Stevens Inst. of Technol., Hoboken, NJ) and Christopher Sugino (Mech. Eng., Stevens Inst. of Technol., 1 Castle Point, Hoboken, NJ 07030, csugino@stevens.edu)

We present inverse methods to obtain arbitrary non-reciprocal dispersion relations in periodic, multi-degree-of-freedom lattices with non-local interactions. Just as phase-delayed interactions such as local resonance govern the frequency-dependence of a lattice's dispersion relation, spatially non-local interactions govern the wavenumber dependence of the coefficients of the lattice's characteristic equation. Thus, the use of fully general non-local interactions can, in principle, specify every branch of the dispersion diagram at every wavenumber. However, calculating a viable set of non-local interactions for a given set of desired dispersion curves is challenging, as there are multiple possible sets of coefficients that yield the same polynomial roots. To solve this problem, we first present a general method to calculate the dispersion relation of multi-degree-of-freedom non-local lattices, showing that non-local interactions create a Fourier series expansion that governs the wavenumber dependence of each matrix element. Next, we present numerical techniques to solve the inverse problem—i.e., given the desired dispersion relation, calculate the required non-local interactions—and discuss the associated computational challenges. Finally, we discuss practical methods to realize non-local interactions leveraging piezoelectric sensors and actuators, and we highlight how non-local interactions can be introduced in unit-cell based finite-element dispersion calculations.

10:55–11:55
Panel Discussion

Session 3aED

Education in Acoustics and Musical Acoustics: Artistic and Technical Approaches to Acoustics

Gordon P. Ramsey, Cochair
Physics Dept., Loyola Univ. Chicago, Chicago, IL 60660

Andrea Calilhanna, Cochair
Faculty of Arts, Elder Conservatorium of Music, The University of Adelaide, New South Wales, Sydney, 2126, Australia

Olivier Robin, Cochair
Université de Sherbrooke, 2500, bd de l'université, Faculté de Génie - Dpt Génie Mécanique, Sherbrooke, J1H1L2, Canada

Chair's Introduction—8:30

Invited Papers

8:35

3aED1. Beatboxing: Teaching technical acoustical concepts through pop culture. Alex C. Brown (Phys. and Astronomy, Brigham Young Univ., N 283 ESC, Provo, UT 84602, alexbrownbass@gmail.com), Micah Shepherd, and Tracianne B. Neilsen (Phys. and Astronomy, Brigham Young Univ., Provo, UT)

The motivation for this presentation is to demonstrate that vocal percussion, or "beatboxing," can be a rich method of teaching and demonstrating various introductory acoustical concepts. Beatboxing can be an entertaining way to demonstrate the different acoustical sources of energy—namely burst, noise, and voice—and how they can be combined to create familiar and unfamiliar phonemes, such as the "PF" snare. It also provides an engaging way to introduce the anatomy of the vocal tract as the students can see and hear how vibrating different parts of the mouth and throat (e.g., vocal cords, epiglottis, vestibular folds, lips, etc.) alter the sound. Finally, beatboxing can be used to demonstrate the source-filter model of speech production through altering the sound source in the throat and displaying how to change your mouth shape to produce different formant-altering effects, such as the rapid formant shifting that gives a record scratch its characteristic sound. Beatboxing provides an entertaining and effective way to demonstrate technical concepts to students in an artistic format which captures the attention, especially of younger audiences. [Undergraduate research supported by the College of Physical and Mathematical Sciences, at Brigham Young University.]

8:55

3aED2. An artistic approach is taken that uses principles in quantum mechanics to understand the signature sound created by granular synthesis in an undergraduate course on music synthesis techniques. Jill A. Linz (Phys., Skidmore College, 815 N Broadway, Saratoga Springs, NY 12866, jlinz@skidmore.edu)

Music Synthesis Techniques is an advanced undergraduate course that explores how various methods are used to create and manipulate synthesized sounds used in sound design and audio production. Students explore their understanding through the creation of a series of short, one-minute compositions that utilize each technique. This paper focuses on that of granular synthesis. Granular synthesis is a music synthesis technique that is used to create unique and alluring sounds that has captivated modern music listeners. For audio engineers and sound designers, the term granular synthesis has always held an aura of mystery surrounding it. Recent developments in plugins for digital audio workstations allow them to easily create its signature sound, which have created a way to use granular synthesis as an art form. Unlike other methods, granular synthesis is rooted in the laws of quantum mechanics. The Heisenberg Uncertainty Principle is explored to understand how granular synthesis creates its signature sound, which in turn is then used to create artistic compositions through the manipulation of the variables. Several examples from student work as well as collaborative work will be included.

9:15

3aED3. Emotion equalization app: The effectiveness of dynamic music therapy approaches. Man Hei Law (Comput. Sci. and Eng., Hong Kong Univ. of Sci. and Technol., The Hong Kong University of Sci. and Technol., Clear Water Bay, Kowloon, Hong Kong, mhlawaa@connect.ust.hk) and Andrew B. Horner (Comput. Sci. and Eng., Hong Kong Univ. of Sci. and Technol., Hong Kong, Hong Kong)

A recent study explored how static music playlists of relaxing or uplifting music can improve our mood. Unlike static playlists that rely exclusively on relaxing, uplifting, or consoling music, this study explores eight distinct methods to curate playlists. These approaches include transitions from one dimension to another (e.g., Angry-to-Relaxing, Angry-Uplifting, Relaxing-Uplifting, Relaxing-

Natural, Sad-Relaxing, Sad-Uplifting, Uplifting-Relaxing, and Uplifting-Natural). To evaluate the effectiveness of these playlists, online experiments were conducted, wherein participants were surveyed before and after music listening to monitor changes in valence and arousal. The results reveal that Sad-Relaxing, Relaxing-Uplifting, Relaxing-Natural, and Uplifting-Natural playlists give positive changes in participants' valence levels, indicating mood improvement. As for the arousal level, the Angry-Relaxing playlist made people feel calmer. Correspondingly, the Relaxing-Uplifting playlist made people feel more energetic. Moreover, this study has identified specific pathways on a two-dimensional plane where both arousal and valence values could be profitably to good effect, including transitioning from Angry to Relaxing to Uplifting especially for arousal, and Sad to Relaxing or Uplifting especially for valence. These findings highlight how dynamic music can give rise to distinct emotional responses and influence our energy levels, and give guidelines on how to use music therapy playlists for mood enhancement.

9:35–9:50 Break

Contributed Paper

9:50

3aED4. Extended playing techniques as a source of unusual acoustic phenomena to explore with music students. Montserrat Pàmies-Vilà (Dept. of Music Acoust. - Wiener Klangstil (IWK), Univ. of Music and Performing Arts Vienna, Anton-von-Webern-Platz 1, mdw - Inst. 22, Vienna 1030, Austria, pamies-vila@mdw.ac.at)

When teaching acoustics, instructors typically consider musical instruments to introduce students to the science of sound. Common examples, such as the flute as an open pipe or the behavior of a string fixed at both ends, are often used to illustrate the acoustics of musical instruments. In addition, when teaching acoustics to advanced musicians, one could take advantage of the precise prior knowledge that students have regarding both conventional and extended playing techniques. When using extended techniques, musicians may incorporate unusual ways of producing sound with their instruments, as is often found in contemporary classical compositions. This unusual sound production might even result in a counterexample to the classical textbook case. For example, the so-called slap-tongue technique on the saxophone or clarinet produces a free (and highly damped) oscillation of the reed, which contrasts with the self-sustained oscillations of the reed if the instrument is blown as usual. Based on insights gathered during an introductory course in musical acoustics at the mdw—University of Music and Performing Arts Vienna, this paper highlights how extended techniques not only challenge our understanding of musical acoustics but also serve as interesting phenomena to explore interactively with students in the lecture room.

Invited Paper

10:05

3aED5. Fantastic acoustics: A magazine describing the importance and the scope of acoustics research in Québec. Olivier Robin (Université de Sherbrooke, 2500, bd de l'université, Faculté de Génie - Dpt Génie Mécanique, Sherbrooke, QC J1H1L2, Canada, olivier.robin@usherbrooke.ca), Tamara Krpic, Alexis Carrion, François Proulx (Université de Sherbrooke, Sherbrooke, QC, Canada), Michel Demuynck, Lucie Gallerand (Mech. Eng., ETS (Ecole de technologie superieure), Montréal, QC, Canada), Valérian Fraisse, Christopher Trudeau, Cynthia Tarlao (McGill Univ., Montreal, QC, Canada), Cécile Perrier de la Bathie, Coralie Bernier-Breton (Institut des Sci. de la mer (ISMER), Université du Québec à Rimouski (UQAR), Rimouski, QC, Canada), Thomas Dupont, Olivier Doutres, Jeremie Voix (Mech. Eng., ETS (Ecole de technologie superieure), Montréal, QC, Canada), Pierre Cauchy, Guillaume St-Onge (Institut des Sci. de la mer (ISMER), Université du Québec à Rimouski (UQAR), Rimouski, QC, Canada), and Catherine Guastavino (McGill Univ., Montreal, QC, Canada)

It's often difficult for the general public and young people to grasp the importance of acoustics in everyday life and its many branches and fields of application. However, it's equally complex for people working or studying acoustics to communicate to this audience while avoiding the same focus on detail as scientific publications. Science communication skills are seldom taught, and multidisciplinary approaches are little used. This paper describes the work carried out as part of the 'Fantastique acoustique—Fantastics acoustics' project, which aims to raise awareness of the acoustics-related research at four Québec universities and train students in science communication. Eight student teams were partnered with cartoonists to produce 3-page comic strips and an associated corpus (including references and videos). The steps involved in producing the magazine are described, as are some of the final works. In particular, a survey including the students and the artists identifies the main positive points and the most significant challenges of such a partnership.

Contributed Paper

10:25

3aED6. What's that sound? Real world observations as teaching opportunities. John A. Case (Graduate Program in Acoust., Penn State, 201 Appl. Sci. Bldg., University Park, PA 16802, jac7175@psu.edu)

In our day-to-day lives, we encounter numerous interesting acoustic events that can offer a starting point for a rich learning experience. In the past, making recording and performing signal analysis took expensive equipment and expert knowledge. Now, smart phones offer a readily available measurement tool to capture interesting phenomena in the world around us. A simple phone video file can provide audio for introducing signal processing techniques as well as a motivating visual context, and readily available signal processing tools enable for the investigation of these events. Several examples of such events will be presented and discussed. These examples are used as a motivation for discussion and signal processing analysis, trying to uncover the underlying physics behind each example.

10:40–11:15
Panel Discussion

Session 3aMU

Musical Acoustics, Physical Acoustics and Computational Acoustics: Applications of Physical Modeling of Musical Instruments

Vasileios Chatziioannou, Cochair
Department of Music Acoustics, University of Music and Performing Arts Vienna, 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—8:30

Invited Papers

8:35

3aMU1. An open-source project for wind instrument modeling using digital waveguides. Gary Scavone (Music Res., McGill Univ., 555 Sherbrooke St. West, Montreal, QC H3A 1E3, Canada, gary.scavone@mcgill.ca)

Digital waveguide methods for time-domain modeling of acoustic structures comprised of interconnected piece-wise one-dimensional cylinders, cones and toneholes have been well reported in the past. In this work, an open-source Matlab class is presented that can be used to model arbitrary wind instrument air column structures, defined by length, radii and hole geometric parameters, using digital waveguide methods. Fractional-delay filtering can be enabled or disabled, with support for both Thiran and Lagrange filter types of specified order. Thermoviscous losses can be modeling using either a discrete-time least squares or a shelf-filter fit, both of arbitrary order. Three different tonehole model options are provided (two-port, three-port or wave digital filter). End boundary conditions include closed, anechoic, ideally open, open flanged and open unflanged. The class object can be used either in single-sample iterative contexts (for example, with an attached excitation model) or with arbitrarily-sized input signals (for example, to compute a reflection function or impedance). The modeled geometry can be constructed manually by iteratively adding segments or holes, or a complete geometry can be specified in a file. This project is bundled together with a parallel and previously reported open-source project for frequency-domain transfer matrix modeling of air columns (https://github.com/garyscavone/acmt).

8:55

3aMU2. Time-domain simulation of a recorder using the model of a jet allowed to deflect overall. Seiji Adachi (School of Marine Sci. and Technol., Tianjin Univ., 92 Weijin Rd., Nankai District, Tianjin 300072, China, seiji_adachi@yahoo.co.jp)

A sound production model of the flute-like instrument which allows the jet to deflect overall has been proposed recently. The overall deflection is introduced to satisfy flow consistency at the instrument's window (embouchure hole or mouth), i.e., the condition that the volume velocity swept by the oscillating jet should be equal to that through the window. The full oscillation of the jet is the sum of the deflection and the oscillation caused by fluid dynamical sinuous instability. This model can correctly reproduce the reflection function of a recorder's head as seen from the resonator. The next question is whether the model can predict the sound level of the flute-like instrument correctly. To answer the question, the model was first formulated in the time domain. In this formulation, measures were taken to prevent the oscillation from drifting. Using the time-domain model, physical modeling simulation of a recorder was performed to obtain sound levels produced for various blowing pressures. Artificial blowing experiments with a real instrument are in progress to compare the simulation results with the actual sound levels.

9:15

3aMU3. Spectral analysis of the air flow pattern near the labium of a recorder. Nicholas Giordano (Phys., Auburn Univ., College of Sci. and Mathematics, Auburn, AL 36849, njg0003@auburn.edu)

Navier-Stokes-based simulations of the air flow through a recorder allow detailed tests of analytic theories of how the pattern of flow—specifically the creation and time evolution of vorticity near the labium—gives rise to the sound of the instrument. A new spectral analysis algorithm has been developed to extract the flow pattern at the fundamental frequency for a soprano recorder playing a steady tone. This analysis allows the flow pattern at the fundamental frequency to be separated from the flow patterns at other frequencies and from the uniform flow pattern, i.e., the time independent flow associated with the air jet emerging from the flue. This gives an especially clear elucidation of the time dependent process in which vortices are created and evolve during the course of a musical tone. This analysis technique can also be used to extract the flow patterns at the frequency of the second partial and at the frequency of the recently discovered half harmonic [1], which show a geometrical structure that is distinctly different from that found at the fundamental frequency. Our spectral analysis technique should allow more detailed tests of the theory of vortex produced sound for a flue instrument than have been possible to date. N. Giordano and K. L. Saenger, J. Acoust. Soc. Amer. **154**, 2917 (2023). [Work supported by NSF under Grant No. PHY2306035.]

9:35

3aMU4. Physical modeling and time-domain simulation of a piano. Eiji Tominaga (Res. and Development Div., Yamaha Corp., 10-1 Nakazawa-cho, Chuo-ku, Hamamatsu, Shizuoka-prefecture 430-8650, Japan, eiji.tominaga@music.yamaha.com) and Masanao Sato (Res. and Development Div., Yamaha Corp., Hamamatsu, Shizuoka-prefecture, Japan)

The elaborate method to simulate the sound produced by a piano is presented, using the physical model that considers almost all parts of the piano with wood complex elastic orthotropy and manufacturing stress, but excluding action parts. The purpose of this work is to improve the efficiency of piano development by clarifying the causal relationship between the design and the produced sound. The completed piano is modeled as a 3D coupled system consisting of "nonlinear systems including hammers and strings" and "a linear coupled body-air system." The hammer felt property are represented by the double layer nonlinear generalized Maxwell model. For the strings with geometrical nonlinearity and their support end anisotropy, the Galerkin method with the component mode synthesis (CMS) method is applied. And also, for the large-scale linear coupled body-air system, the complex CMS method via nonlinear eigenvalue analysis is used. The simulated sounds, including the ringing and body sounds, are so realistic that they help piano designers predict the actual sounds before making heavy prototypes. The method presented here can be applied to other musical instruments that consist of strings and a body, such as guitars and violins.

9:55–10:10 Break

10:10

3aMU5. Towards better copies of guitars: Compensate material variability with geometry. Pierfrancesco Cillo (Inst. of Eng. and Computational Mech., Univ. of Stuttgart, Stuttgart, Germany), Pascal Ziegler (Inst. of Eng. and Computational Mech., Univ. of Stuttgart, Pfaffenwaldring 9, Stuttgart 70569, Germany, pascal.ziegler@itm.uni-stuttgart.de), and Peter Eberhard (Inst. of Eng. and Computational Mech., Univ. of Stuttgart, Stuttgart, Germany)

Luthiers have been trying to copy the sound of iconic instruments like Torres guitars for many years. Though precise geometric copies were manufactured, audible differences were found which can be attributed largely to the natural variability of wood. We were able to present a methodology allowing non-destructive material identification based on which a shape optimization was performed to compensate material variablility with specific geometric variations, allowing a much more exact copy of a guitar soundboard in terms of eigenfrequencies. We will present a generalization of this methodology to full guitars including almost arbitrary geometric adaptions and consideration of mode shapes in the optimization. A mesh morphing strategy allows to simultaneously define very general geometric adaptions and comparing mode shapes without re-meshing. Further, a parameterized reduced order numerical model will be presented in which all possible global geometric variations are mapped to the individual elements of the underlying finite-element model in symbolical form. This symbolical representation is then carried over to the assembled finite-element matrices resulting in an extremely efficient reduced model keeping the symbolic relationships. This is the absolute core requirement of an efficient shape optimization. The approach will be presented for hexahedral elements.

Contributed Papers

10:30

3aMU6. Influences of electric guitar pickup magnetic force on string vibrations. Takuto Yudasaka (Res. & Development, Yamaha Corp., 10-1, Nakazawa-cho, Naka-ku, Hamamatsu, Shizuoka 4300912, Japan, takuto.yudasaka@music.yamaha.com), Gary Scavone (Music Res., McGill Univ., Montreal, QC, Canada), and Kenta Ishizaka (Res. & Development, Yamaha Corp., Hamamatsu, Default Choice, Japan)

The design of a magnetic pickup has a significant impact on the tone of an electric guitar. In particular, the magnetic force from the pickup can influence the string vibrations and cause a beating effect, depending on the strength of the magnetic force and the amplitude of the string vibrations. To understand this behavior, we performed experiments and simulations. We measured and modeled the transversal string restoring force at various displacements from the magnetic pickup in directions both parallel and perpendicular to the guitar body. We observed that the magnetic force distribution is asymmetric in the perpendicular direction but symmetric in the parallel direction, which distorts the frequency of vibrations in opposite ways for the two directions and causes a resultant beating. This effect increases with larger string amplitudes or greater magnetic force and also varies over the duration of a plucked tone.

10:45

3aMU7. Aeroacoustic modeling of blown-closed free reeds. Ninad V. Puranik (Music Res., McGill Univ., 550, Rue Sherbrooke Ouest, Area (Ste. 500), Montreal, QC H3A1E3, Canada, ninad.puranik@mail.mcgill.ca) and Gary Scavone (Music Res., McGill Univ., Montreal, QC, Canada)

We present ongoing work on the development of an aeroacoustic model of blown-closed free reeds used in a hand harmonium. Physics-based models of free reed instruments involve modeling of the oscillating free reed, the air-flow in the upstream region and around the reed, and the interaction between these two systems. The minimal model of free reeds by Millot and Baumann (2007) assumed the reed as a damped spring-mass system and approximated the air flow field by two discrete zones representing the flow near the reed and the upstream region respectively. Our recent work included the adaptation of the minimal model to match the physical setup and control parameters of the hand harmonium and the development of a distributed clamped-bar model of the free reed. These updates resulted in a closer agreement of the parameters for simulation and the observed physical variables. To address limitations of this model, we present a revised modeling of the air flow as a continuous potential flow and discuss implications for numerical stability, accuracy and real-time sound synthesis.

11:00

3aMU8. Results from a time domain clarinet model: Effects of nonharmonic air column resonances. Stephen C. Thompson (Graduate Program in Acoust., Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, sct12@psu.edu)

A time domain model of a clarinet-like system was previously reported [S. C. Thompson, *J. Acoust. Soc. Am.*, **150** A98 (2021)] . That model has been used to investigate the improvement in playing behavior when the instrument air column has accurately harmonic input impedance peaks. Two tube models were designed with an effective length to produce a 400 Hz first resonance frequency. Both tubes are terminated at the "closed" end by a SDOF reed with a reasonably high resonance frequency. The first tube is purely cylindrical terminated at the "open" end by a tone hole lattice with a cutoff frequency of 1500 Hz. This tube has two resonances below cutoff whose peaks differ from true harmonicity by approximately 7%. The second tube has a small region of slightly increased bore radius positioned to

provide resonances whose inharmonicity is reduced to less than 1%. These tubes have very similar playing behavior in the model at low playing amplitude, but increasingly differ as the playing level is increased. The model has also been upgraded to include a mechanical hard stop for the reed position as it closes against the mouthpiece. Preliminary results with the beating reed will be presented.

11:15

3aMU9. Sound synthesis applications using a physical model of a single-reed woodwind instrument. Vasileios Chatziioannou (Dept. of Music Acoust., Univ. of Music and Performing Arts Vienna, Anton-von-Webern-Platz 1, Vienna 1030, Austria, chatziioannou@mdw.ac.at), Alex Hofmann, and Montserrat Pàmies-Vilà (Dept. of Music Acoust., Univ. of Music and Performing Arts Vienna, Vienna, Austria)

Physical modeling can be used to analyze and predict the vibrations of a musical instrument. This also enables to numerically synthesize sounds as if they were produced by a real instrument. Focusing on single-reed woodwind instruments, a physical model should incorporate the actions of the player in order to synthesize realistic sounds. This interaction mostly takes place at the instrument mouthpiece—toneholes opened by the player's fingers may be approximated by changing the instrument geometry. A physical model is presented that is able to take embouchure effects into account, in order to reliably simulate note transitions. Regarding physical modeling synthesis, the numerical efficiency of the underlying algorithms should also be considered. Capturing as many physical phenomena as possible may lead to models that require longer running times. Omitting less significant phenomena may lead to models suitable for real-time performance, while retaining most of the sound characteristics of the real instrument. In either case, it is of utmost importance to prove that the simulation algorithms are numerically stable. Sound examples are presented in an attempt to imitate real recordings, as well as in a live performance setting (examples available at https://iwk.mdw.ac.at/sound-synthesis/)

WEDNESDAY MORNING, 15 MAY 2024 — ROOM 205, 8:00 A.M. TO 11:45 A.M.

Session 3aNSa

Noise, Architectural Acoustics, Engineering Acoustics, and Physical Acoustics: Assorted Topics on Noise I

Aaron B. Vaughn, Chair
Structural Acoustics Branch, NASA Langley Research Center, 1 NASA Drive, Hampton, VA 23666

Contributed Papers

8:00

3aNSa1. Solving noise issues: Understanding feasible and effective temporary and permanent noise control options. Matt Cott (Behrens & Assoc., Environ. Noise Control, 9536 E I-25 Frontage Rd., Longmont, CO 80504, mcott@baenc.com)

Development projects, especially in densely populated areas, face a critical challenge in managing noise impact levels resulting in an increase in specification of noise regulations in bid documents. Uncontrolled noise issues carry the potential for offsite receiver complaints and regulatory actions, necessitating a strategic approach to compliance with project noise level specifications and municipal noise ordinances while understanding what feasible mitigation solutions are readily available are key to compliance and minimizing community disruption while working with project budgets. The presentation will focus on ways to work with the project owner and acoustical consultant to find solutions that are effective, feasible, readily available and take costs into consideration.

8:15

3aNSa2. Adaptive zone based active noise control for a moving target. Wintta Ghebreiyesus (Aerosp. Eng., Toronto Metropolitan Univ., 350 Victoria St., Toronto, ON M5B 2K3, Canada, wghebrei@torontomu.ca), Sifat Hasan (Aerosp. Eng., Toronto Metropolitan Univ., Toronto, ON, Canada), and Fengfeng (Jeff) Xi (Aerosp. Eng., Toronto Metropolitan Univ., Toronto, ON, Canada)

This study focuses on enhancing active noise control (ANC) in room enclosures, specifically targeting zones of quiet (ZoQ) around aircraft passenger seats. By integrating virtual sensing and motion tracking techniques, we aim to dynamically adapt the ZoQ to moving targets. Key to our approach is the strategic placement of actuators and sensors, forming the core of the ANC system. Our methodology includes virtual sensing for ANC analysis, ZoQ optimization for varied applications, and in-depth case studies. We introduce an innovative combination of a speaker gimbal system, a vision system, and custom software for precise motion tracking, significantly improving ZoQ localization. The findings offer insights into maintaining effective ZoQs for multiple input multiple output (MIMO) local ANC configurations, laying the groundwork for adaptive ZoQ control about sound sources and desired cancellation locations. This research marks a significant step towards more effective and adaptable noise cancellation in enclosed spaces.

8:30

3aNSa3. Bowling alleys in residential buildings—Noise control and measurements. Guangsheng (Sam) Du (Valcoustics Canada Ltd., 25-30 Wertheim Court, Richmond Hill, ON L4B1B9, Canada, sam@valcoustics.com), Mark Levkoe, Jessica Tsang, and Qiang (Richard) Li (Valcoustics Canada Ltd., Richmond Hill, ON, Canada)

In the competitive world of residential development, developers are striving to construct residential buildings that will be more desirable to occupants by providing a diverse range of amenity spaces, such as a bowling alley. Understandably, noise concerns from the addition of bowling alleys in residential buildings were raised during the design stage of various projects. To address the issues, a jack-up floating floor system was proposed for the bowling alley to mitigate the noise impact from the pin setting machine, initial ball impact on the bowling alley lanes, rolling on the lanes, and ball impact with the pins. Apparent Impact insulation class (AIIC) and heel drop testing were completed at various stages during the floating floor construction to confirm the impact sound isolation performance of the floating floor system. Testing results concluded that the implemented floating floor system reduced impact noise significantly and satisfactory sound levels resulted in the closest occupied spaces.

8:45

3aNSa4. Challenges in urban data center design. Scott Hamilton (Stantec, 233 S Wacker Dr #5300, Chicago, IL 60606, scott.hamilton@stantec.com)

The data center market is experiencing significant growth, with each new facility requiring increased power density and cooling needs. This growth brings new challenges, including noise pollution and its impact on nearby communities, which becomes excessively difficult in urban environments. This presentation will explore the issues faced by data centers in urban environments and discuss potential solutions to create quieter facilities. Key points include:—Physical challenges: Every site design faces numerous physical constraints, including limited rooftop and equipment room space, tight and complex adjacencies of neighboring sites, and design and performance standards for equipment.—Political issues: Every site and community have a different set of laws and regulations that a site needs to meet, and often go beyond to ensure that the community will accept the site.—People issues: Data centers must navigate contentious relationships with neighbors and address noise concerns to maintain a positive reputation. By addressing these challenges, data centers can minimize noise pollution and maintain positive relationships with surrounding communities, ensuring a sustainable future for the industry in urban environments.

9:00

3aNSa5. Survey of background noise levels inside classrooms on a college campus. Laura Ruhala (Mech. Eng., Kennesaw State Univ., 840 Polytechnic State University, Rm. Q319, MD 9075, Marietta, GA 30060, lruhala@kennesaw.edu), Richard J. Ruhala, Antonio Patino, and Charles Packer (Mech. Eng., Kennesaw State Univ., Marietta, GA)

Sound level measurements were made for 18 classrooms and learning spaces on the Marietta Campus of Kennesaw State University, Georgia, USA. Excessive background noise in learning spaces diminishes the speech intelligibility from the speaker to the listeners. The noise measured was in empty or nearly empty classrooms with no one talking. The primary background noise source was observed to be due to heating, ventilation, and air-conditioning equipment. The results are compared with a student survey to see if the noise complaints correlate with the noisiest classrooms in terms of their average A-weighted decibel levels. In addition, conformance with ANSI-ASA S12.60-2010/Part 1 (Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools) is evaluated.

9:15

3aNSa6. Background noise and reverberation time in a college classroom. Richard J. Ruhala (Mech. Eng., Kennesaw State Univ., 840 Polytechnic Ln., KSU - Mech. Eng. Dept. Rm. Q131, Marietta, GA 30060, rruhala@kennesaw.edu), Laura Ruhala, Charles Packer, and Antonio Patino (Mech. Eng., Kennesaw State Univ., Marietta, GA)

A sound survey of noise levels in unoccupied classrooms on the Marietta Campus of Kennesaw State University identified one classroom as the most problematic in terms of background noise levels. This level is mostly associated with heating, ventilation, and air-conditioning equipment. Excessive background noise in learning spaces diminishes the speech intelligibility from the speaker to the listeners and can cause stress and fatigue. The overall A-weighted average sound levels are compared with ANSI-ASA S12.60-2010/Part 1 (Acoustical Performance Criteria, Design Requirements, and Guidelines for Schools). In addition, frequency analysis of the background sound and time variations are studies. Binaural headset microphone measurements are compared to the single microphone measurements. Reverberation time is measured using the engineering survey method and compared to the ANSI guidelines.

9:30

3aNSa7. Development and verification of a method to simulate non-stationary vehicle interior wind noise. Jinghe Yu (Ray W. Herrick Labs., Purdue Univ., 3879 Amber Ln., West Lafayette, IN 47906, yu1140@purdue.edu) and Patricia Davies (Ray W. Herrick Labs., Purdue Univ., West Lafayette, IN)

As speeds and directions of the vehicle and wind change, the time-varying flow creates variations in wind noise, which can be referred to as non-stationary wind noise. To investigate people's perceptions of non-stationary wind noise inside the vehicle, a method to simulate the non-stationary wind noise is needed. Previously, a method was developed that used stationary wind noise recordings taken at several constant wind speeds and directions to form functions that relate the 1/3 octave sound pressure level with wind speed and direction. These functions are used to create time-varying filters based on provided time histories of wind speed and direction. To reduce the cost of taking many stationary measurements, an improved method was investigated. At each yaw angle, one speed sweep wind tunnel measurement was used to estimate the relationship between sound pressure level and wind speed. Two partially correlated white noise signals were then filtered to simulate binaural sounds that had a similar coherence structure between the left and right ear sounds to that observed in binaural measurements in the vehicle. The accuracy of the simulations was validated by comparing wind noise simulations to vehicle interior noise measured in the wind tunnel and on the road.

9:45–10:00 Break

10:00

3aNSa8. Identifying noise control strategies for variable air volume (VAV) boxes in acute care hospital design. Jessica Carolina (Acoust., bkl Consultants Ltd., 3999 Henning Dr., Burnaby, BC V5C 6P9, Canada, carolina@bkl.ca)

Variable air volume boxes are frequently used within new acute care hospital design of heating, ventilation and air conditioning systems in Canada. Spatial and room-use noise limits as defined within the project requirements [PM1] are often necessarily onerous to provide acoustical conditions that promote well-being and patient recovery, with appropriate noise control design crucial to the success of meeting the project requirements. Additionally, the desire for fiber-free linings to ductwork exacerbates the noise control limitations. This paper will review the available noise control strategies, the acoustic performance of fiber-free variable air volume box types with and without an attenuator and identify cost-benefits to the Design-Builder. This study will demonstrate how the implementation of a variety of variable air volume box models, sizes, operating conditions, pressure drops are affecting the noise performance. This study will summarize the appropriate variable air volume box types and design conditions that meet the project noise limits used in Canadian healthcare standards such as CSA Z8000, LEED and other provincial technical guidelines.

10:15

3aNSa9. Simulink modeling of carbon nanotube thin film thermophones for applications in active noise control. Kourtney Libenow (Acoust., Graduate Program in Acoust., The Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, kra5346@psu.edu) and Andrew Barnard (Acoust., Penn State, University Park, PA)

Carbon Nanotube (CNT) Thin Film Thermophones are transducers that operate by varying the input voltage to rapidly heat and cool the thin film, resulting in a local fluid pressure variation which results in radiation of sound. These devices are promising for active noise control in HVAC due to being able to withstand higher ambient heat, requiring no rare earth materials, and being able to stretch into many different configurations. An important step to future HVAC implementation is to model an ANC system using CNT thermophones as the canceling speaker. CNT thermophones have a nonlinear response due to the proportionality between input electrical power and output pressure. In order to use them in active noise control applications, preprocessing techniques such as DC offset have been used. A traditional FXLMS system with preprocessing is simulated using Simulink, with an aim to evaluate different nonlinear control structures in the future.

10:30

3aNSa10. Quantifying crowd engagement with machine learning. Jason D. Bickmore (Phys., Brigham Young Univ., N283 ESC, Provo, UT 84602, jdb387@byu.edu), Mitchell C. Cutler, Mark K. Transtrum (Phys. and Astronomy, Brigham Young Univ., Provo, UT), and Kent L. Gee (Dept. of Phys. and Astronomy, Brigham Young Univ., Provo, UT)

Inferring a crowd's engagement at a sporting event using only acoustic signals is difficult for humans to do precisely, but it may be a great job for machine learning. This presentation will summarize the results of using acoustic data from crowds at four types of college sporting events to train a random forest machine-learning model to identify behaviors such as cheering, chanting, and distracting the opposing team. The model uses spectral data and other features derived from acoustic measurements such as spectral slope, spectral kurtosis, and zero cross rate to quantify the level of crowd engagement. This presentation will then discuss an ongoing investigation of how the model performs at predicting crowd engagement from acoustic data collected with a new data-collection system. It will discuss specific challenges and opportunities associated with incorporating new data into an existing machine-learning pipeline.

10:45

3aNSa11. Construction noise modelling—A comparison of equipment noise emissions data sources. Sam Zokay (1004 Middlegate Rd #1100, Mississauga, ON L4Y 1M4, Canada, samz@aercoustics.com)

The accuracy of any environmental noise impact model depends on the quality and application of its input data, typically consisting of at-source emission levels, propagation factors, and receiver characteristics. In the realm of construction noise modelling, this starts with the determination of the noise emission level for each construction activity or item of equipment. This data can be procured from a variety of sources including manufacturer data, standards and guideline documents, or proprietary measurements. This study explores how emission levels from different data sources can be utilized to assess noise impacts against project criteria, and aims to validate the reliability through real-world case studies.

11:00

3aNSa12. Case study of construction noise and vibration monitoring at an elementary school. Galen Wong (Stantec Consulting Ltd., 300 - 1331 Clyde Ave., Ottawa, ON K2C3G4, Canada, galen.wong@stantec.com)

Construction noise and vibration monitoring was performed for long-term construction activities occurring directly adjacent to an elementary school and playground area. Noise and vibration limits were determined based on measurements taken indoors and outdoors during preliminary construction activities, and in discussions with the school. Noise and vibration alerts during monitoring were provided in real-time to the construction managers during the activities, and notices of exceedances provided as methods of administrative controls. Various temporary noise mitigation barriers erected on-site were also assessed.

11:15

3aNSa13. Active cancellation of oblique noise entering a window. Robert Nelson (Graduate Program in Acoust., Penn State, 201 Appl. Sci. Bldg., State College, PA 16802, rwn5136@psu.edu) and Stephen C. Thompson (Graduate Program in Acoust., Penn State, University Park, PA)

Environmental noise propagating through an open window may be cancelled by a sparse array of transducers placed in the window frame. This approach towards global noise cancellation mitigates noise pollution at its source while retaining the light and ventilation received from an open window. Heretofore the array's performance has been studied with a normally incident noise source; however, oblique noise sources must be considered to fully illustrate the array's viability as a commercial product. Analytical and finite element models were used to perdict the array's global noise cancellation capabilities with regards to oblique noise sources, and these results were verified via experimental implementation. Flaws inherent to the current array, including cross bar vibrations and nonoptimal transducer placement, will be discussed along with how they will be circumvented in a future array iteration.

11:30

3aNSa14. Mapping past and future shipping noise in European seas. Roberto Racca (JASCO Appl. Sci., 2305 - 4464 Markham St., Victoria, BC V8Z 7X8, Canada, roberto.racca@jasco.com), Michael A. Ainslie (JASCO Appl. Sci., Den Haag, Netherlands), Johan Bosschers, Marjolein Hermans, Thomas Lloyd (MARIN, Wageningen, the Netherlands), Alexander MacGillivray (JASCO Appl. Sci., Victoria, BC, Canada), Federica Pace (JASCO Appl. Sci., Rotterdam, Netherlands), Max Schuster (DW-ShipConsult, Schwentinental, Germany), Özkan Sertlek (JASCO Appl. Sci., Den Haag, the Netherlands), and Michael Wood (JASCO Appl. Sci., Droxford, United Kingdom)

Against the backdrop of a steadily increasing demand for sea transport of goods and people, the development of a reliable marine shipping soundscape model is an essential planning requirement to assess the effect on ocean noise of operational and technological changes aimed at mitigating the environmental impact of the shipping sector. The NAVISON (Navis Sonus) project, conducted with the support of the European Maritime Safety Agency, employs a specially developed parametric vessel source model with the objective of producing shipping sound maps in European seas for past, present, and potential future conditions over a time span from 2016 to 2050. The source model is combined with historical ship tracking data from the automated identification system (AIS), or projected shipping densities and mitigation scenarios, to calculate spatial ship noise emissions data for input to a sound mapping tool. The mapping tool computes underwater sound propagation using the parabolic-equation method, drawing upon ocean-scale databases of bathymetric, oceanographic, and sediment properties. Project outputs are provided as map layers of sound pressure level and sound energy according to vessel type, season, region, year, and operational conditions; from these layers, maps can be generated for user-specified combinations of mitigation measures. Maps are presented in two frequency bands (centred at 63 Hz and 125 Hz) selected for assessing Good Environmental Status in the context of the European Union's Marine Strategy Framework Directive.

Session 3aPAa

Physical Acoustics, Underwater Acoustics and Acoustical Oceanography: Meteorological Acoustics

Roger M. Waxler, Cochair
Univ. of Mississippi, P.O. Box 1848, University, MS 38677

Jelle D. Assink, Cochair
R&D Seismology and Acoustics, KNMI, Utrechtseweg 297, Utrecht, 3731GA, Netherlands

Natalia Sidorovskaia, Cochair
Physics, Univ. of Louisiana at Lafayette, P.O. Box 44210, Lafayette, LA 70504-4210

Contributed Papers

8:00

3aPAa1. Influence of refracting atmospheric profiles on trace velocity and arrival time. Michael J. White (U.S. Army Engineer Res. and Development Ctr., Champaign, IL, michael.j.white@usace.army.mil) and Matthew G. Blevins (U.S. Army Engineer Res. and Development Ctr., Champaign, IL)

The influence of the atmospheric profile on the trace velocity and arrival time has received little attention, although these properties of sound propagation are important for direction finding and localization. The refracting temperature profile causes the received sound to be delayed or advanced in time compared to that for the temperature at ground height, and the situation is made anisotropic in the presence of wind. We consider refraction by linear temperature and logarithmic wind profiles on the trace velocity and arrival time for distant impulses received at the ground, and use this information in small arrays for direction finding and large arrays for localization.

8:15

3aPAa2. Verifying turbulence models in the atmospheric boundary layer by acoustical means. D. Keith Wilson (Cold Regions Res. and Eng. Lab., U.S. Army Engineer Res. and Development Ctr., U.S Army ERDC-CRREL, 72 Lyme Rd., Hanover, NH 03755-1290, D.Keith.Wilson@usace.army.mil), Vladimir E. Ostashev, Carl R. Hart, and Matthew J. Kamrath (Cold Regions Res. and Eng. Lab., U.S. Army Engineer Res. and Development Ctr., Hanover, NH)

The impacts of turbulence on sound propagation in the atmospheric boundary layer (ABL) are important in many practical applications such as acoustic source localization, sonic boom propagation, and auralization of flying aircraft. However, turbulence impacts can vary dramatically in response to changing meteorological conditions. To address this issue, a turbulence spectral model has been introduced that captures the complexities of turbulence generation by wind shear, buoyancy instabilities, and ground blocking in the ABL. An experiment on vertical and slanted sound propagation through the ABL was conducted to verify the model. Various statistical characteristics of sound signals, including variances of the log-amplitude and phase fluctuations, coherences, and signal probability distributions were measured and compared to theoretical predictions. The dependence of the statistics on meteorological conditions was found to be accurately predicted in conditions of well-developed turbulence, as occurs in windy conditions and the daytime. Predictions in conditions of weak and intermittent turbulence, as often occur at night and around sunrise and sunset, remain challenging.

Invited Paper

8:30

3aPAa3. The statistical characteristics of the atmospheric anisotropic inhomogeneities and their effect on the intensity fluctuations of infrasound field. Igor P. Chunchuzov (Atmospheric Dynam., Obukhov Inst. of Atmospheric Phys., 3 Pyzhevsky Per, Moscow 119017, Russian Federation, igor.chunchuzov@gmail.com), Sergey Kulichkov, Oleg Popov, and Vitaly Perepelkin (Atmospheric Dynam., Obukhov Inst. of Atmospheric Phys., Moscow, Russian Federation)

The influence of anisotropic wind velocity and temperature inhomogeneities on the attenuation of infrasound field intensity with increasing distance from a point source and on its altitude distribution is studied. The field is calculated as a function of receiver height and horizontal distance from the source using method of the pseudo-differential parabolic equation for the atmosphere with model realizations of anisotropic effective sound speed fluctuations. These realizations are obtained from the nonlinear shaping model for the gravity wave perturbations which produces the fluctuations with both the vertical and horizontal spectra consistent with the observed spectra. When propagating in the stratospheric and thermospheric wave guides the multiple scattering of infrasound field from the anisotropic fluctuations results in certain vertical wave number spectra and probability density functions of infrasound intensity fluctuations in the stratospheric (altitudes 30–40 km) and mesospheric layers (50–70 km). The statistical characteristics of the intensity fluctuations as a function of distance from the source (up to 2200 km) were studied. The same characteristics were obtained for the infrasound field scattered from the inhomogeneities whose vertical profile was retrieved from the infrasound signals from surface explosions detected in the shadow zone.

Contributed Paper

8:50

3aPAa4. On the possibility of acoustic solitons in open air. Michael S. McBeth (Res. and Appl. Sci., Naval Information Warfare Ctr. Atlantic, NASA Langley Res. Ctr., 22 West Taylor St., M.S. 060, Hampton, VA 23681, michael.s.mcbeth@navy.mil)

Sugimoto *et al*. reported on the generation and propagation of acoustic solitary waves in an air-filled tube with an axially connected periodic array of Helmholtz resonators [Phys. Rev. Lett. **83**, No. 20, 4053–4056 (1999)]. The generation and propagation of acoustic solitons in open air has been discounted due to the nondispersive nature of the speed of sound in air. However, the sound speed is known to be dispersive at certain levels of humidity. Over the ocean there often exists a water vapor density gradient known as an evaporation duct. Here we show that humidity driven frequency dispersion and nonlinearity can combine to allow acoustic solitons in open air. For certain water vapor density gradients found over the ocean there are elevations at which acoustic soliton generationa and propagation are possible. If these open air acoustic solitons can be experimentally verified it could lead to applications including evaporation duct sensing and acoustic communications.

Invited Paper

9:05

3aPAa5. Probing atmospheric waves and the middle atmosphere dynamics using infrasound. Patrick Hupe (Federal Inst. for Geosciences and Natural Resources (BGR), Stilleweg 2, Hannover 30655, Germany, patrick.hupe@bgr.de), Christoph Pilger (Federal Inst. for Geosciences and Natural Resources (BGR), Hannover, Germany), Alexis Le Pichon (CEA, DAM, DIF, Arpajon, France), and Lars Ceranna (Federal Inst. for Geosciences and Natural Resources (BGR), Hannover, Germany)

Infrasound is defined as pressure fluctuations with frequencies between acoustic cut-off (5 min) and human-hearing frequency threshold of sound (16 Hz). Low-frequent infrasonic waves can travel long distances, ranging from hundreds to thousands of kilometres. The middle atmosphere dynamics mainly control the presence of atmospheric waveguides where energy transmission loss is low. These properties are utilized to record atmospheric explosions at highly sensitive pressure sensors (micro-barometers). A global network of 60 infrasound stations was designed as part of the International Monitoring System (IMS) for the Comprehensive Nuclear-Test-Ban Treaty. IMS infrasound stations can record small pressure fluctuations of a few millipascals, which can originate from numerous atmospheric infrasound sources, including meteorological phenomena. In this study, the capability of IMS infrasound arrays for capturing a broad spectrum of atmospheric wave phenomena is highlighted; for instance, mountain-associated infrasonic waves show features that seem to be correlated with orographic gravity waves. Moreover, the interaction of ocean waves produces quasi-continuous infrasound, so-called microbaroms. Infrasonic signatures from microbaroms can be used for probing the middle atmosphere dynamics and assessing atmospheric circulation models. For opening the unique global infrasound network of the IMS for meteorological applications, we also present open-access BGR infrasound data products of two decades and highlight selected case studies.

Contributed Paper

9:25

3aPAa6. Calculating the acoustic and internal gravity wave dispersion relations in Venus's supercritical lower atmosphere. Gil Averbuch (Appl. Ocean Phys. and Eng., Woods Hole Oceanographic Inst., 266 Woods Hole Rd., MS #11, Woods Hole, MA 02543-1050, gil.averbuch@whoi.edu) and Andi Petculescu (Dept. of Phys., Univ. of Louisiana at Lafayette, Lafayette, LA)

There is a growing interest in quantifying Venusian seismic events through their infrasonic signatures detected by balloon-borne sensors at $\sim$ 55 km altitude. The extreme pressure and temperature at Venus's surface correspond to supercritical conditions in the planet's deep atmosphere. Therefore, an appropriate real-gas equation of state (EoS) must be used to study the acoustic properties and thermodynamics in the Venusian lower atmosphere. In previous work, the Peng-Robinson (P-R) EoS was used to obtain the acoustic sound speed and attenuation coefficient in the lower atmosphere of Venus. Here, the P-R EoS is coupled with the fluid dynamics equations in order to derive the acoustic and internal gravity wave (IGW) dispersion equations. Results show that in Venus's deep atmosphere, the acoustic cut-off frequency corresponds to a period of $\sim$480 s (0.0020 Hz), and the buoyancy frequency corresponds to a period of $\sim$600 s (0.0016 Hz). By comparison, the values in Earth's lower atmosphere are $\sim$310 and $\sim$340 s, respectively. These differences in acoustic and IGW propagation characteristics will be useful in later efforts to discriminate between the various waves detected by high-altitude sensors.

9:40–10:00 Break

Invited Papers

10:00

3aPAa7. How can acoustic measurements help us understand severe weather phenomena such as lightning? Thomas Farges (DAM, DIF, CEA, Arpajon 91290, France, thomas.farges@cea.fr), François Coulouvrat, and Damien Bestard (Institut Jean Le Rond d'Alembert, Sorbonne Université, Paris, France)

Lightning is an indicator for monitoring severe weather events like heavy precipitation, flash floods, hail… It is also a climate variable for monitoring global warming. Lightning emits light, sound and radioelectromagnetic fields, allowing remote detection and analysis. Acoustic measurements can be used to, for instance, track global warming over more than 70 years via the keraunic level (the

number of thunderstorm days per year in a specific location), or detect and monitor severe weather events such as cyclones, e.g. the Medicanes, or characterize optical phenomena such as sprites associated with violent thunderstorms, or highlight temporal changes in the upper layers of the atmosphere, such as the semi-annual oscillation of stratospheric winds in tropical zones. At closer ranges, less than 30 km, acoustic network measurements complement electromagnetic observations to reconstruct the 3D structure of cloud-to-ground and intra-cloud discharges. Recently, it has been shown possible to provide the 3D structure of acoustic power within the lightning source. From flash to flash, this power shows four orders of magnitude variations, similarly to electromagnetism or optics. Moreover, it outlines that large variations of power also exist even within a lightning flash, reflecting heterogeneities in conductivity within the discharge.

10:20

3aPAa8. Low frequency sounds from tornadoes. Aaron Alexander, Douglas Fox, Real J. KC (Mech. and Aerosp. Eng., Oklahoma State Univ., Stillwater, OK), and Brian R. Elbing (Mech. and Aerosp. Eng., Oklahoma State Univ., OSU-MAE, 201 General Academic Bldg., Stillwater, OK 74078, elbing@okstate.edu)

It has been well established that tornadic storms can generate infrasound (i.e., sound at frequencies below human hearing) signals, but the mechanism of sound generation is still a mystery. There is speculation that these infrasound signals have the potential to serve as an alternative method for alerting and/or tracking of life-threatening tornadoes. Yet, until the mechanism for infrasound generation is understood, it remains a possibility that the infrasound signals are present due to other storm effects and would be improper to use for tornado warning or tracking. One possible explanation for the infrasound signals is an amplification of turbulent fluctuations due to latent heat production. This presentation will detail laboratory efforts to isolate noise production from turbulent structures with and without latent heat production due to condensation of water in saturated warm air. [This work was supported by the Gordon and Betty Moore Foundation, grant DOI 10.37807/gbmf11559.]

Contributed Paper

10:40

3aPAa9. A theory for the emission of infrasound from Tornadoes. Bin Liang (Univ. of MS, Oxford, MS), Roger M. Waxler (Univ. of MS, P.O. Box 1848, University, MS 38677, rwax@olemiss.edu), and Paul Markowski (The Penn State Univ., University Park, PA)

Tornadoes have been shown to radiate infrasound to great distances, however convincing fundamental sound mechanisms are still absent. After using vortex sound theory to study sound generated by two numerical tornadoes, we found that there is a significant low-frequency signal between 0.1 Hz and 1 Hz. The sound is closely related to rotation of the non-axisymmetric vorticity field and its frequency depends on the rotational frequency. The non-axisymmetric vorticity field is represented by a Kirchhoff vortex-like flow in baseline tornado model and by multiple-vortex flow in eddy injection tornado model. Interestingly, there also exist high-frequency components in the later model which are hypothesized to originate from vortex merging process. Field detection data of tornado infrasound provides some support for the low-frequency sound.

Invited Paper

10:55

3aPAa10. A study of acoustic array signal processing applied to tornado tracking. Garth Frazier (NCPA, Univ. of MS, NCPA, University of MS, P.O. Box 1848, Oxford, MS 38677, frazier@olemiss.edu) and Bin Liang (National Ctr. for Physical Acoust., Oxford, MS)

In low signal-to-noise ratio (SNR) applications it is often necessary to integrate array measurement data over an extended temporal period to achieve satisfactory estimates of source bearings-of-arrival (BOA), especially in the case of multiple sources. For example, in popular frequency-domain methods such as MUSIC and its variants, the number of so-called snapshots (temporal windows) can be increased to improve performance. However, this improvement is achieved under the assumption that the bearing-of-arrival is not changing during the integration period. In this presentation, a study of the estimation performance of two algorithms (a MUSIC variant and a maximum-likelihood based method) is performed as a function of the number of snapshots, and the result of application of these algorithms to infrasound data recorded during the presence of tornadic storms (moving sources) is presented. Additionally, a method for integration over time using a moving source model is introduced.

Contributed Paper

11:15

3aPAa11. Discussion of infrasonic detection of tornadoes in the Southeastern United States. Roger M. Waxler (NCPA, Univ. of MS, P.O. Box 1848, University, MS 38677, rwax@olemiss.edu), Garth Frazier, Carrick Talmadge (NCPA, Univ. of MS, Oxford, MS), Claus Hetzer (NCPA, Univ. of MS, Tempe, AZ), Hank Buchanan, Bin Liang (NCPA, Univ. of MS, Oxford, MS), Naveen Thirunilath (NCPA, Univ. of MS, University, MS), Chip Audette (Benchtop Eng. LLC, Springfield, VT), and Islam Hamama (NCPA, Univ. of MS, University, MS)

It has been established that tornadoes emit an infrasonic signal that is regularly detected in the 1 to 10 Hz band, although the actual band is expected to be wider. The physical mechanism through which this signal is generated is not yet fully understood and is the subject of current research. Here we discuss some of our experimental efforts, past and present. During the tornado seasons of 2017, 2018, and 2019, we deployed a network of infrasound sensor arrays in northern Alabama, southern Tennessee, and northwestern Georgia. We performed detailed analysis of one particular storm front that spawned at least eight identified tornadoes in northwestern Alabama during its passage. For that storm we find that when propagation modeling and wind noise analyses suggest that the signal should have been detected at a given array it always was. A long term monitoring effort is now underway in Mississippi. The Mississippi network deployment strategy relied on statistical analyses of tornado touchdown probability, signal transmission loss, and local wind noise studies. The network and array design for our Mississippi network was heavily informed by our experiences in Alabama and, we believe, represents the current state-of-the-art. In this presentation we will give an overview of what was learned from our previous deployments in Alabama, what strategies were used for the current deployment in Mississippi, and the current state of our data collection and analysis.

WEDNESDAY MORNING, 15 MAY 2024 — ROOM 202, 9:45 A.M. TO 12:00 NOON

Session 3aPAb

Physical Acoustics, Engineering Acoustics, Structural Acoustics and Vibration, and Signal Processing in Acoustics: Characterization of Electronic Materials, Components, Devices, and Batteries

Michael R. Haberman, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet Rd, Austin, TX 78758

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

Haley N. Jones, Cochair
Materials Science and Engineering, Penn State University, N-225 Millenium Science Complex, State College, PA 16802

Lauren Katch, Cochair
The Pennsylvania State University, 212 Earth and Engineering Sciences Building, State College, PA 16802

Chair's Introduction—9:45

Invited Papers

9:50

3aPAb1. Air-coupled ultrasound for testing of batteries and components. Tomas Gomez Alvarez-Arenas (ITEFI, CSIC, Serrano 144, Madrid 28006, Spain, t.gomez@csic.es)

This work describes the use of an air-coupled and through transmission ultrasonic (0.2–1.5 MHz) technique, both at normal and oblique incidence, for the characterization and test of pouch-cell Li-ion (and similar types) batteries and components. Time domain measurements show that it is possible to measure ultrasonic velocity in the battery. Frequency domain measurements reveal the generation of thickness resonances. From them, solution of the inverse problem permit to extract: ultrasound velocity and attenuation (and variation with frequency), thickness and density. At normal incidence, these resonances provide information about the compressional wave.

At oblique incidence, it is first observed that there is a range of incidence angles where propagation is no permitted. This response can be explained in terms of the battery layered structure, once these angles are exceeded, the shear wave is generated, propagated and observed, giving rise to the generation of thickness resonances. Shear wave propagation is strongly anisotropic: lower velocity in the direction of the battery plane, compared with a higher velocity in the direction normal to the battery plane. No limit angle for the shear wave is observed. Possibilities of this technique for the testing of new batteries, continuous state monitoring and battery sorting for re-use or recycling are discussed.

10:10

3aPAb2. Cryogenic acoustic microscopy and evaulation of electronic components. Steven Doran (Phys. and Astronomy, Iowa State Univ., 2323 Osborn Dr., Ames, IA 50011-1026, doran@iastate.edu), Leonard J. Bond (Aerosp. Eng., Iowa State Univ., Ames, IA), Daniel Barnard (Ctr. of Nondestructive Evaulation, Iowa State Univ., Ames, IA), Navaneeth Poonthottathil (Phys., IIT Kanpur, Kanpur, India), Amanda Weinstein, Yue Feng, Sijith Edayath, Hariom Sogarwal, and Frank Krennrich (Phys. and Astronomy, Iowa State Univ., Ames, IA)

Electronics operating at cryogenic temperatures are essential in fields like space exploration and particle physics. The Deep Underground Neutrino Experiment (DUNE), a next generation particle physics experiment, will rely on tens of thousands of custom designed application specific integrated circuits (ASICs) operating directly in liquid argon (87 K) for decades without repair or replacement. Ensuring circuit functional reliability throughout the duration of the experiment is mission critical. Both functional and nondestructive testing are employed to safeguard circuit quality and reliability. Part of this work involves the design, testing, and data analysis of a cryogenic acoustic microscope (CryoSAM) operating at 15 MHz. The CryoSAM is capable of interrogating ASICs at both room temperature (300 K) and in liquid nitrogen (77 K), identifying acoustic anomalies likely arising from thermal stress and manufacturing-related defects, using a powerful correlation analysis technique. These anomalies can lead to functional degradation and suboptimal electronic performance of the circuit sensors. Image analysis and correlations are used to compare differences seen before and after cryogenic temperature cycling. Data are reported that were collected at both room temperature and when cooled using liquid nitrogen. Designs and challenges of operating the instrument at cryogenic temperatures are also discussed.

Contributed Papers

10:30

3aPAb3. Measurements of nonlinear electric-acoustic interactions in lead zirconium titanate. Robert Lirette (Communications Technol. Lab., National Inst. of Standards and Technol., 325 Broadway, MS67201, Boulder, CO 80305, robert.lirette@nist.gov), Tomasz Karpisz (Communications Technol. Lab., National Inst. of Standards and Technol., Boulder, CO), Małgorzata Musiał (Mater. Measurement Lab., National Inst. of Standards and Technol., Boulder, CO), Gabriela Petculescu (Univ. of Louisiana at Lafayette, Lafayette, LA), Aaron Hagerstrom, Nathan Orloff, and Angela C. Stelson (Communications Technol. Lab., National Inst. of Standards and Technol., Boulder, CO)

When electric and acoustic waves simultaneously pass through a piezoelectric material, nonlinearities can arise. The electric and acoustic waves can mix, generating a signal consisting of both sum and difference spectral components. Here we present a method of directly measuring the nonlinearly mixed electric-acoustic signal using a vector network analyzer (VNA). In normal VNA operation, sources and receivers operate at the same frequency. In our measurements, we employ a frequency offset mode, where receivers in the VNA can be tuned to a frequency different from the source frequency. Here, we measure at the expected mixing product frequency of the electrical and acoustic signals we introduce into the measurement to capture nonlinear electric-acoustic mixing. We present measurements of electric-acoustic mixing in a block of lead zirconium titanate (PZT) mounted on top of an electric co-planar waveguide connected to the VNA. The results show the presence of many coupled electric-acoustic modes. To interpret these modes, we characterized the PZT block with modal analysis and finite element simulations. Some of the observed nonlinear electric-acoustic modes directly correlated with the mechanical modes of the block, while others did not. Overall, this method allows for direct probing of non-linear electric-acoustic mixing in materials and devices.

10:45

3aPAb4. Micro-electromechanical systems sensor characterization for acoustic prognostic health management. Ruth Willet (Penn State, 201 Old Main, University Park, PA 16802, raw5930@psu.edu) and Karl Reichard (Penn State, State College, PA)

Prognostic Health Management (PHM) is the process used to optimize machinery use by detecting faults and predicting failures and a machine's remaining useful life. PHM is especially important to electro-mechanical systems in order to maximize a system's availability and effective operation. The use of Micro-Electromechanical Systems (MEMS) accelerometers and microphones for PHM analysis is beneficial because it enables nondestructive acoustic testing with reduced cost, reduced size, and more efficient vehicle integration with other electronics than current methods. This research quantitatively studies a variety of MEMS sensors to understand how they measure acoustic data in a lab setting and on a truck with a diesel engine compared to piezoelectric accelerometers and condenser microphones. Diesel engines are common in many vehicles and hybrid-electric power systems, so the results will be applicable to a variety of situations. By applying signal processing techniques and PHM condition indicators to the data, standardized metrics can be developed to determine the best sensor for different PHM analyses.

11:00

3aPAb5. Degradation monitoring of multilayer ceramic capacitors during high accelerated lifetime testing using ultrasound. Haley N. Jones (Mater. Sci. and Eng., Penn State Univ., N-225 Millenium Sci. Complex, State College, PA 16802, hnj5051@psu.edu), Andrea P. Arguelles (Eng. Sci. and Mech., Penn State Univ., State College, PA), and Susan Trolier-McKinstry (Mater. Sci. and Eng., Penn State Univ., University Park, PA)

Multilayer ceramic capacitors (MLCCs) are vital circuitry components where long-term stability at high temperature and fields is critical to device operation. High accelerated lifetime testing (HALT) statistically investigates reliability and lifetime of MLCCs through exposure to temperatures and voltages exceeding normal operating conditions. The long-term reliability of the dielectric layers in MLCCs strongly depends on potential variability in the dielectric microstructure, such as cracking, which can be challenging to detect. Nondestructive ultrasonic evaluation is sensitive to microstructural changes through measurements of wave scattering. This work uses high frequency (100 MHz) focused ultrasonic scattering methods to nondestructively monitor structural and microstructural changes in MLCCs from the pristine to the failed state during HALT to understand structural origins of electrical failure. Printed circuit board mounted MLCCs were electrically and ultrasonically characterized in a pristine state and during various degraded states before and after electrical failure under HALT. Evidence of damage pre-HALT was ultrasonically indicated by high attenuation regions on the ultrasonic maps suggesting that the mounting process

may induce damage. The high attenuation regions in the pristine samples evolved throughout HALT indicating that the damage in the pristine state might be the spatial origin of part failure, which underscores the impact and importance of detection of structural defects on the reliability of MLCCs.

11:15

3aPAb6. Ultrasonic C-scan for micro-crack inspection on semi-flexible solar modules. Dicky Silitonga (George W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., Metz, France), Pooja Dubey (George W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., 2 Rue Marconi, Georgia Tech-Europe, Metz 57070, France, pooja.dubey@gatech.edu), and Nico Declercq (George W. Woodruff School of Mech. Eng., Georgia Inst. of Technol., Metz, France)

Solar photovoltaic modules are versatile power sources in diverse materials and configurations, including compact and flexible variants for portable electronic devices. Ensuring the reliability of these modules is crucial for sustaining the functionality of the devices they power. Manufacturing or handling-induced defects, such as cracks or scratches, pose a threat to the performance of solar modules. Hence, non-destructive inspection becomes essential in the quality control process. Ultrasonic C-scan has been an established inspection technique within various industries; however, its application on solar modules remains uncommon. On the other hand, Scanning Acoustic Microscopy (SAM) has been implemented for observing defects in solar cells, yet employing SAM for comprehensive module scanning is inefficient. This study aims to assess the capability of ultrasonic c-scan in detecting micro-cracks within semi-flexible solar panels and to evaluate the effects of frequency selection on the results. This work investigates the specimen with an Ultrasonic C-Scanner at different frequencies. Subsequently, the outcomes are validated by comparing them with the results from the SAM. The potential of using a widely known ultrasonic technique for this purpose, while understanding its limitations, such as the c-scan, will enable a more straightforward integration of the technique into the solar module quality control process.

11:30

3aPAb7. Probing layer interface behavior in Lithium-ion batteries via concurrent ultrasonic and modal measurements. Alexandra Litvinov (Walker Dept. of Mech. Eng., The Univ. of Texas at Austin, 204 E. Dean Keeton St., Texas, TX, alitvinov@utexas.edu), Tyler McGee, Ofodike A. Ezekoye, and Michael R. Haberman (Walker Dept. of Mech. Eng., The Univ. of Texas at Austin, Austin, TX)

Lithium-ion batteries are pivotal in various technological applications, from powering electric vehicles to supporting renewable energy storage systems. Understanding and monitoring the intricate chemo-mechanics within lithium-ion cells is imperative for ensuring their reliability and performance over time. Previous research has shown that both ultrasonic and vibrational measurements provide a measure of a cell's state of charge (SOC) and state of health (SOH) and provide indications of existing or previous thermal or electrical abuse. Recent work suggests that ultrasonic and modal analysis may provide complementary insights into the evolution of layer interfaces during early-life aging due to charge-discharge cycling [J. Acoust. Soc. Am., **154**, A284 (2023)]. This work presents the results of concurrent ultrasonic and modal measurements over multiple charge-discharge cycles. Namely, we monitor concurrent changes in the ultrasonic time-of-flight and signal amplitude and the resonance frequency of a clamped-clamped 10 Ah Nickel–Manganese–Cobalt pouch cell as a function of electrical cycling. The evolution of these metrics paired with analytical and numerical models of the cell will be used to understand changes in the material properties at layer interfaces and potential structural alterations within the battery which may be important indicators of SOC and early-life aging mechanisms.

11:45

3aPAb8. Assessing spatial non-uniformities in lithium-ion battery state of charge using ultrasound immersion testing. Mac Geoffrey Ajaereh (Mech. Eng., Univ. of Bath, Claverton Down, Bath, Bath BA2 7AY, United Kingdom, mgoa20@bath.ac.uk), Olivia J. Cook (Penn State, University Park, PA), Haley N. Jones (Mater. Sci. and Eng., Penn State Univ., State College, PA), Nathan Kizer (Penn State Univ., University Park, PA), Lauren Katch (The Penn State Univ., State College, PA), Christopher Wheatley (Penn State, State College, PA), Chris Vagg, Charles Courtney (Mech. Eng., Univ. of Bath, Bath, United Kingdom), Christopher M. Kube (Eng. Sci. and Mech., The Penn State Univ., University Park, PA), and Andrea P. Arguelles (Eng. Sci. and Mech., Penn State Univ., State College, PA)

Enhancing the performance, safety and reliability of battery management systems is crucial for advancing the state of the art in battery electric vehicles. Current research explores the potential of ultrasound to monitor state of charge (SoC) changes in individual cells. Understanding spatial variations in SoC is essential, as non-uniformities could lead to sub-optimal performance, premature ageing, and possible safety risks. This study uses ultrasound immersion C-scans to map wave speed and attenuation at different SoC levels during battery cycling. Results indicate non-uniform wave speed and attenuation suggestive of SoC spatial variations within single cells, emphasising the importance of addressing this issue. Acoustic measurements under various C-rates and relaxation periods are discussed, providing insights into lithium-ion rearrangement in graphite particles. Potential causes of structure and manufacturing variations of the cell are discussed, highlighting the need to address these issues to prevent overcharging or overdischarging in specific battery areas.

Session 3aPP

Psychological and Physiological Acoustics: Temporal Processing, Aging, and Hearing Loss: Research Inspired by Christian Fullgrabe

G. Christopher Stecker, Chair
Center for Hearing Research, Boys Town National Research Hospital, 555 N 30th St., Omaha, NE 68131

Chair's Introduction—8:00

Contributed Papers

8:05

3aPP1. Modeling the relationship between listener factors and signal modification: A pooled analysis spanning a decade. Varsha H. Rallapalli (Commun. Sci. & Disord., Northwestern Univ., 2240 Campus Dr., Evanston, IL 60208, varsha.rallapalli@northwestern.edu), Jeff Crukley (Univ. of Toronto, Toronto, ON, Canada), Emily Lundberg, James M. Kates, Kathryn Arehart (Speech Lang. and Hearing Sci., Univ. of Colorado Boulder, Boulder, CO), and Pamela E. Souza (Northwestern Univ., Evanston, IL)

The overarching goal of our work is to understand how listeners respond to hearing aid processing and consequently inform individualized hearing aid treatment. Our previous work demonstrated that individual cognitive abilities, age, and hearing loss contribute to variability in response to cumulative signal modifications introduced by hearing aid processing and background noise. Specifically, older individuals with poorer working memory and more hearing loss were more susceptible to signal modifications introduced by hearing aid processing. These relationships were established in independent studies involving systematic manipulations of compression, digital noise reduction, frequency lowering, or microphone directionality. In this study, we present a hierarchical pooled analysis of data collected from six previous studies to develop a unified statistical model of the relationships between response to signal modification and individual listener variables. Across studies, signal modification is quantified using a cepstral correlation metric that accounts for cumulative envelope distortions arising from hearing aid processing and background noise. The statistical model will determine how working memory, age, and degree of hearing loss mediate the relationship between signal modification and speech intelligibility in noise across a large dataset. Both inferential and predictive applications of the combined data and model will be discussed. [Work supported by NIDCD.]

8:20

3aPP2. Physiological characterization of a macaque model of presbycusis. Swarat S. Kulkarni (Hearing and Speech Sci., Vanderbilt Univ., 111 21st Ave. S, Nashville, TN 37240, swarat.s.kulkarni@vanderbilt.edu), Amy N. Stahl, Troy Hackett, and Ramnarayan Ramachandran (Hearing and Speech Sci., Vanderbilt Univ., Nashville, TN)

Age-related hearing loss (presbycusis) is the leading cause of hearing loss worldwide, but current human studies do not separate this pathology from lifetime noise exposure. Laboratory macaques live in environments with minimal noise-induced hearing trauma and have long lifespans, making them optimal presbycusis models. We describe age-related auditory changes using two clinical, non-invasive physiological measures in aging macaques: distortion product otoacoustic emissions (DPOAEs) and auditory brainstem responses (ABRs). ABRs and DPOAEs were measured in anesthetized young (6–9 years old, $n = 36$ ears) and aging (26–35 years old, $n = 20$ ears) *Macaca mulatta*. ABR and DPOAE thresholds were elevated in aging subjects compared to young macaques at all tested frequencies. ABR thresholds were significantly correlated with age for frequencies >8 kHz, but DPOAE thresholds were not, a pattern likely attributable to a high-frequency ceiling effect for DPOAE measures. For frequencies <8 kHz, DPOAE thresholds showed significant correlation with age. However, this was not observed with ABR thresholds, suggesting differential sensitivity to age-related changes for auditory nerve and brainstem function compared to cochlear outer hair cell function. Ongoing analysis on temporal processing/adaptation metrics will further elucidate age-related changes. Future work will correlate these findings with histological analysis. [Work Supported by NIH R01-DC-015988.]

8:35

3aPP3. Perceptual benefits of implicit auditory learning of rule-based nonspeech sound patterns in younger and older adults. Brian Gygi (Nottingham Hearing Biomedical Res. Unit, Martinez, CA), Christian Füllgrabe (MRC Inst. of Hearing Res., Chicago, IL), and Valeriy Shafiro (Commun. Disord. and Sci., Rush Univ. Medical Ctr., 600 South Paulina St., 1015 AAC, Chiago, IL 60612, Valeriy_Shafiro@rush.edu)

Sounds in everyday environments typically precede and follow one another in systematic ways determined by the properties and interactions of corresponding sound sources. Familiar and predictable contextual relationships between consecutive sounds are known to provide perceptual benefit under adverse listening conditions. Previous work has demonstrated implicit learning of arbitrary rule-based sound patterns by young normal hearing adults. However, the role of such rule-based learning on identification of individual sounds within a sound pattern and the effect of listener age has not been investigated. Here younger and older adults with age-appropriate hearing were first familiarized with a set of rule-based nonspeech sound sequences produced by a finite-state machine. Subsequently, they identified individual target sounds within sequences under a range of signal-to-noise ratios (0 to -15 dB). The test sequences were (a) familiar, rule-based; (b) novel, rule-based; or (c) novel, non rule-based. The results for both younger and older listeners revealed superior sound identification in sequences versus in isolation, and a greater overall accuracy of rule-based versus non rule-based sequences. Younger listeners significantly outperformed older listeners. Implicit learning benefit did not correlate with measures of working memory processing. Current findings have implications for audiologic rehabilitation and auditory display design.

8:50

3aPP4. Age-related changes in gap detection thresholds in adult cochlear-implant users: Effects of stimulus level and electrode-to-neural interface. Miranda Cleary (Hearing and Speech Sci., Univ. of Maryland-College Park, 7251 Preinkert Dr., Ste. 0100 Lefrak Hall, College Park, MD 20742, micleary@umd.edu) and Matthew J. Goupell (Hearing and Speech Sci., Univ. of Maryland-College Park, College Park, MD)

Aging is associated with reduced sensitivity to brief temporal gaps in auditory stimuli. Although gap detection is a relative strength among late-deafened cochlear-implant users, aging and electrode-to-neural interface (ENI)

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factors may contribute to temporal processing difficulties. Because aging may negatively impact perception particularly at very low and very high input levels, we hypothesized larger gap detection thresholds (GDTs) at poor-ENI electrodes and an interaction between age and level such that GDT improvement with increased level would be less evident in older listeners. GDTs were measured on three electrodes selected to span a range of good-to-poor ENI based on electrically-evoked compound action potential amplitude growth or threshold sensitivity to increased pulse rate. GDTs were assessed using constant-amplitude single-electrode 1000-pps pulse trains presented at 40/60/80/100% dynamic range. In preliminary data (N = 4), GDTs averaged 3 ms at 100%DR and 40 ms at 40%DR. Listeners with better average ENI metrics displayed better GDTs. Within-subject, an advantage for best-ENI electrode over poorer-ENI electrodes was evident only at low levels. Finding an interaction between age and level such that temporal processing is impaired at both low and high (but not mid) levels for older listeners may help elucidate the contributions of peripheral versus central factors.

9:05

3aPP5. Effects of auditory processing ability on the phonological and acoustic processing of Mandarin tone by Thai speakers: An ERP study. Yu Zou (English Dept. & Lang. and Cognit. Neurosci. Lab, School of Foreign Studies, Xi'an Jiao Univ., No. 28 Xianning Rd. (W), Xi'an, Shaanxi 710049, China, zouyu_02@stu.xjtu.edu.cn), Bing Cheng (English Dept. & Lang. and Cognit. Neurosci. Lab, School of Foreign Studies, Xi'an Jiao Univ., X'an, China), and Yang Zhang (Speech-Language-Hearing Sci., Univ. of Minnesota, Minneapolis, MN)

This study investigated how Mandarin-naïve Thai speakers' auditory processing ability affects their phonological and acoustic processing of Mandarin tone. The participants were 20 native Mandarin speakers and 19 Mandarin-naïve Thai speakers. A 10-step computer synthesized Tone 1 (T1)–Tone 2 (T2) continuum was manipulated for identification task. The stimulus 1, 3, 5, 7, 9 from the T1–T2 continuum were used in a multi-feature passive oddball ERP paradigm, encompassing within-category and across-category stimuli with equivalent large-scale and small-scale acoustic intervals. We used pitch discrimination, melody reproduction, and rhythm reproduction to assess participants' auditory processing ability. The identification results showed that Mandarin-naïve Thai speakers' exhibit a weaker categorical perception (CP) of Mandarin tones compared to the native Mandarin speakers, a pattern consistent with ERP results observed at both sensor and source levels. Further analysis revealed higher auditory processing ability leads to enhanced CP of Mandarin tone for learners from Thai, and the same improvement is observed in the melody memory for acoustic processing of Mandarin tone. These findings add to our understanding on how individual differences influence phonological and acoustic processing of Mandarin tone during the initial stage of second speech learning.

9:20

3aPP6. Estimating the high-frequency extent of binaural sensitivity to temporal fine structure across listeners. Matthew J. Goupell (Hearing and Speech Sci., Univ. of Maryland-College Park, College Park, MD), Anhelina Bilokon (Dept. of Hearing and Speech Sci., Univ. of Maryland, College Park, MD), Brittany T. Williams (Boys Town National Res. Hospital, Omaha, NE), Daniel J. Tollin (Physiol., Univ. of Colorado School of Medicine, Aurora, CO), and G. Christopher Stecker (Ctr. for Hearing Res., Boys Town National Res. Hospital, 555 N 30th St., Omaha, NE 68131, cstecker@spatialhearing.org)

Füllgrabe *et al*. [2017, Int. J. Audiol. 56:926-35] developed a novel procedure to estimate the frequency dependence of listeners' sensitivity to temporal fine structure in the form of interaural phase differences (IPD). Whereas traditional approaches fixed tone frequency and varied IPD, the new "TFS-AF" test fixed the IPD and varied frequencies adaptively so as to estimate the upper frequency limit (UFL) of IPD sensitivity, even in listeners who struggle with traditional tests. UFL estimates for young normal hearing listeners were consistently 1200–1400 Hz, with notable exceptions of lower UFL (e.g. 800–1000 Hz) in a small subset. The consistency of UFL and abrupt loss of IPD sensitivity above it remain among the most puzzling aspects of binaural hearing, unexplained by the (rather shallow) frequency dependence of audibility, neuronal phase locking, or internal noise in this region. Recently, our group adapted a version of the TFS-AF test to measure UFL as a function of sound level, comparing the resulting slope to predictions of candidate mechanisms. The limitation closely matches the upper edge of an auditory filter centered at ~700 Hz, suggesting that IPD sensitivity is mediated exclusively by neurons tuned to that frequency or below. [Work supported by NIH R01DC014948, R01DC016643, and R01DC017924.]

9:35–9:50 Break

9:50

3aPP7. Behavioral evidence of the modulation filterbank in an avian animal model of complex-sound perception. Kenneth S. Henry (Otolaryngol., Univ. of Rochester, 601 Elmwood Ave., Box 629, Rochester, NY 14642, kenneth_henry@urmc.rochester.edu), Kristina Abrams (Neurosci., Univ. of Rochester, Rochester, NY), and Margaret Youngman (Otolaryngol., Univ. of Rochester, Rochester, NY)

Behavioral detection of amplitude modulation (AM) can be adversely affected by competing AM "noise" present in the acoustic environment. Called AM masking, human studies suggest the existence of a modulation filterbank that separates sounds (signal from noise) based on differences in AM frequency. The modulation filterbank is an important theoretical advancement in hearing science because in addition to explaining AM masking, the model successfully predicts differences in speech perception across noisy listening environments with different AM statistics. Currently, there are no behavioral animal models of the modulation filterbank, presenting a serious impediment to understanding neural underpinnings. We trained budgerigars, a parakeet species, to detect AM frequencies from 64 to 400 Hz in the presence of narrowband AM maskers applied to a 2.8-kHz carrier signal. AM masker center frequencies spanned a >2 octave range centered on the target AM frequency. Behavioral AM sensitivity was evaluated with operant conditioning, a single-interval two-alternative discrimination task, and two-down one-up adaptive threshold tracking procedures. Budgerigar AM masking functions had a band-pass characteristic, consistent with the modulation filterbank and with human AM masking results for the same stimuli. To our knowledge, these are the first behaviorally estimated modulation filter shapes in a nonhuman species. [Funding: NIDCD R01-DC017519.]

10:05

3aPP8. Low gain hearing aids use and benefit: A viable management option for those with hearing sensitivity within the normal range. Alyssa Davidson (Walter Reed National Military Medical Ctr., 4954 North Palmer Rd., Bldg 19, Rm 5506, Bethesda, MD 20889-5630, alyssa.j.davidson.civ@health.mil), Gregory M. Ellis (Audiol. and Speech Pathol., Walter Reed National Medical Military Ctr., Bethesda, MD), and Douglas Brungart (Walter Reed National Military Medical Ctr., Bethesda, MD)

Low (or mild) gain hearing aids (LGHAs) are increasingly considered for individuals with normal peripheral hearing but self-reported auditory complaints. The Tinnitus and Hearing Survey-Hearing Subscale (THS-H) offers a normative cutoff, aiding identification of significant self-reported hearing difficulties (SHD). This research assesses the benefits of LGHAs as a management option for individuals with normal hearing sensitivity and significant SHD, comparing LGHA use and benefit to individuals without SHD and those with peripheral hearing loss. 186 participants across four groups, including those with or without SHD and peripheral hearing loss were recruited. Participants completed questionnaires that addressed hearing aid usage, benefit, SHD and tinnitus. Individuals with significant SHD and hearing sensitivity within the normal range (NHT) reported higher LGHA usage and benefit than individuals with normal hearing difficulties (NHD) and NHT. Comparable use and benefit were noted between groups with significant SHD regardless of peripheral hearing loss status. The findings support LGHAs as a suitable management option for individuals with NHT and SHD, as indicated by hearing aid use and benefit. Quantifying the level of perceived auditory processing deficits (i.e., SHD), notably with the THS-H, enhances sensitivity in identifying those who may benefit from this management option.

Session 3aSA

Structural Acoustics and Vibration, Education in Acoustics and Physical Acoustics: My Favorite Homework Problems in Structural Acoustics in Vibrations

Samuel P. Wallen, Cochair
Applied Research Laboratories, The University of Texas at Austin, 10000 Burnet RD, Austin, TX 78758

Andrew Barnard, Cochair
Acoustics, Penn State, 201C Applied Sciences Building, University Park, PA 16802

Kathryn Matlack, Cochair
University of Illinois at Urbana-Champaign, 1206 W Green St., Urbana, IL 61801

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

Contributed Papers

10:15

3aSA1. Fundamental acoustics concepts taught through the development of an impedance tube. Nathan P. Geib (Appl. Res. Labs., The Univ. of Texas at Austin, 1587 Beal Ave Apt 13, Ann Arbor, MI 48105, geib@umich.edu), Allan Pham, and Christina Naify (Appl. Res. Labs., The Univ. of Texas at Austin, Austin, TX)

As part of its mission to educate students, Applied Research Laboratories, The University of Texas at Austin (ARL:UT) employs student technicians to assist on a variety of ongoing research projects. Recently, an undergraduate student technician was tasked with the design and fabrication of a low-cost impedance tube for use in characterizing acoustic materials. To assist the student in developing a set of design requirements, and to determine whether preliminary data were being accurately collected and processed, a set of homework problems were developed to teach the student the fundamental concepts in acoustics necessary for impedance tube development. Homework problems required utilizing both travelling- and standing-wave solutions to the one-dimensional (1D) Helmholtz equation, as well as a basic understanding of the relationships between pressure, particle velocity, and acoustic impedance. Homework solutions were compared with 3D finite element simulations and with experimental data collected using the impedance tube. We felt that these homework problems were effective at conveying basic ideas in acoustics to a student with no prior knowledge in the subject, and how those concepts could be used to solve real-world problems.

10:30

3aSA2. Don't say "modal analysis:" A backdoor introduction to vibrations via programming and numerical methods. Samuel P. Wallen (Appl. Res. Labs., The Univ. of Texas at Austin, 10000 Burnet Rd., Austin, TX 78758, sam.wallen@utexas.edu)

As an undergraduate degree requirement, The Walker Department of Mechanical Engineering at the University of Texas at Austin teaches a lower-division, introductory course on computer programming and numerical methods. The enrollment consists primarily of second-year mechanical engineering (ME) students, approximately half of whom enter the course with no prior programming experience. Due to its relatively early position in the ME curriculum, the course presents the unique challenge of teaching students to apply numerical methods to ME-relevant problems, with little background about the physics involved or the contexts in which they are likely to occur in practice. This talk presents an end-of-term project in which students use two numerical methods discussed earlier in the course, singular value decomposition and Runge-Kutta methods, to construct, simulate, and benchmark a reduced-order, dynamic model of a vibrating guitar string. In addition to reinforcing course outcomes associated with programming, mathematics, and data visualization, this project provides an introduction to acoustics, vibration, and modal analysis at a level that belies its position in the overall curriculum.

10:45

3aSA3. Evaluating years in hours. Robert W. Smith (PSU/ARL, P.O. Box 30, State College, PA 16804, rws100@arl.psu.edu)

The Graduate Program in Acoustics (GPA) at Penn State requires prospective Ph.D. candidates to pass a qualifying exam consisting of written and oral components. Objectives are to evaluate mastery and integration of some key concepts, and to determine if students have developed a fluency with acoustic concepts. The over-riding goal is to evaluate if the students have emergent qualities and understanding to potentiate success as researcher. Most of the exam is focused on the content of two required graduate courses—one primarily on vibrations in solids, and the second in fluids; these provide a common foundation to supplement the diverse undergraduate backgrounds of students, characteristic of students attracted to attend the GPA. We strive to avoid esoterica, but problems are often intentionally unfamiliar and often inspired by applications encountered in research. The author has participated as one of four on the committee that administers the exam for the past 7 years; each member is charged with developing two problems for the exam, typically offered twice per year. This talk will describe some illustrative problems developed by the author and some of the acoustic concepts they probe we think are important. Some discussion of observations of students' difficulties will be discussed.

11:00

3aSA4. Lord Rayleigh versus Chladni and KFC Sanders: Who is correct about tuning forks? Daniel A. Russell (Graduate Program in Acoust., Penn State Univ., 201 Appl. Sci. Bldg, University Park, PA 16802, dar119@psu.edu)

The tuning fork is one of my favorite pieces of acoustical apparatus (as evidenced by three published papers in the *American Journal of Physics* and an article in *Acoustics Today)*. A favorite problem (formerly used on final exams, and currently used as a hands-on activity) for the first-year graduate

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structural vibrations course I teach, requires students to read excerpts from four textbooks which make a statement about the boundary conditions for the tines of a tuning fork. Lord Rayleigh and Barton describe a tuning fork as two fixed-free bars joined at the base, while Chladni and Kinsler, Frey, Coppens, and Sanders describe a tuning fork as free-free bar bent into a U-shape. Who is correct? Students are required to measure the frequency spectrum of a tuning fork and match the resulting frequency ratios to what they would obtain by solving the boundary condition problem by treating the fork tines as a free-free or fixed-free bar undergoing flexural vibrations. This talk will work through the problem and will illustrate some of the pitfalls that often trip up students. And yes, the question of who is correct will be answered!

11:15

3aSA5. Applying intuition to Fourier analysis by rendering images with vibration. Tre DiPassio (Elec. and Comput. Eng., Univ. of Rochester, 402 Comput. Studies Bldg., 160 Trustee Rd., Rochester, NY 14627, tredipassio@rochester.edu)

It has been said that "Everything in life is vibration." While this may seem dramatic, it is true that we can describe any shape as a superposition of a structure's bending modes using Fourier decomposition. In this session, I present an assignment that involves the rendering of images and artwork using only a subset of a rectangular membrane's mode shapes. This assignment allows students to engage with fundamental concepts such as Fourier analysis and the modal nature of structural vibrations in a way that allows them to see and interact with the results of their work. A natural extension is to simulate the response of a plate to an external stimulus using the Fourier series, and to verify the results of their simulation experimentally using tools such as laser vibrometry. While exciting complex patterns in the vibrational response of a real plate is difficult in practice, this assignment provides a memorable and engaging baseline for understanding the modal composition of induced structural vibrations.

WEDNESDAY MORNING, 15 MAY 2024 — ROOM 203, 8:00 A.M. TO 11:15 A.M.

Session 3aSC

Speech Communication, Architectural Acoustics, Psychological and Physiological Acoustics, and Education in Acoustics: Classroom Acoustics and Speech Communication

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

Reanne Pernitsky, Cochair
84 Hilldowns Dr, Spruce Grove, T7X 0J1, Canada

David S. Woolworth, Cochair
Roland, Woolworth & Associates, 356 CR 102, Oxford, MS 38655

Contributed Papers

8:00

3aSC1. Understanding speech in everyday conditions—Effects of room acoustics and noise. Heui Young Park (Graduate Program in Acoust., The Penn State Univ., 201 Appl. Sci. Bldg., University Park, PA 16802, hkp5188@psu.edu), Navin Viswanathan (Dept. of Commun. Sci. and Disord., The Penn State Univ., University Park, PA), and Michelle C. Vigeant (Graduate Program in Acoust., The Penn State Univ., University Park, PA)

Understanding speech in noisy, indoor settings is a considerable challenge for listeners. Room acoustics, such as reverberation and heating, ventilation, and air conditioning (HVAC) noise, all contribute to such challenges. In the current study, the effects of different backgrounds were examined in anechoic versus reverberant conditions at two different signal-to-noise ratios (SNRs) were examined. 60 monolingual American English listeners transcribed spoken English sentences under different noisy conditions. Overall, we tested two acoustic conditions: anechoic and reverberant, reverberation time = 1.5 s, with four speech conditions (target speech only, or combined with HVAC noise, two-talker babble, or both) and two different SNRs (0 dB and -3 dB). Both the target and babble speech were female voices speaking in English. Complex backgrounds resulted in decreased performance, and the detrimental effects of such masking were accentuated by reverberation and lower SNR. This study serves as a basis for future research exploring the effects of room acoustics on speech intelligibility to gain a more wholistic understanding of speech perception under realistic conditions.

8:15

3aSC2. Impact of background noise and dysphonia on elementary students' listening comprehension and listening effort. Silvia Murgia (Speech and Hearing Sci., Univ. of Illinois - Urbana Champaign, 901 South Sixth St., Champaign, IL 61820, smurgia2@illinois.edu), Mary M. Flaherty (Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, Champaign, IL), Kara Federmeier (Dept. of Psych., Univ. of Illinois Urbana Champaign, Champaign, IL), and Pasquale Bottalico (Dept. of Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, Champaign, IL)

This project investigated how background noise and dysphonic voice impact elementary students' listening comprehension and effort. Listening comprehension is essential for academic success, and this study explored the extent to which adverse conditions hinder sentence comprehension and the mental resources utilized. The experiment used speech material recorded by an actress with normal and dysphonic voice quality. Nineteen 8–12 year-old children participated, using a computer in a laboratory with a talkbox for stimuli and loudspeakers for classroom noise at two signal-to-noise ratios (SNRs) of + 6 dB and 0 dB. Listening effort was measured subjectively on a 5-point scale and objectively through response time, the seconds taken to select a figure onscreen. Executive functions like working memory, attention, and inhibitory control were also assessed. Results showed that lower SNR and dysphonia significantly affected comprehension accuracy and increased perceived listening effort. Inhibitory control correlated with increased perceived effort. Similarly, both factors significantly lengthened response times. However, no significant correlations with executive functions were observed for comprehension or response time. In conclusion, background noise and dysphonia significantly affect listening comprehension and effort among elementary students. These findings emphasize the need for educators and policymakers to mitigate these factors for optimal classroom learning conditions.

8:30

3aSC3. Building a real-time convolution system for assessing vocal health of teachers. Bethany Wu (Dept. of Phys. & Astronomy, Brigham Young Univ., N284 ESC, Provo, UT 84602, bwu98@student.byu.edu) and Brian E. Anderson (Phys. & Astronomy, Brigham Young Univ., Provo, UT)

Due to prevalent vocal health issues in teachers, the acoustics of K-12 classrooms has become a common topic of study in acoustics. One way to understand the impact of a classroom's acoustics on speech is through real-time convolution of speech with a binaural room impulse response (BRIR). This is done by having a talker seated in an anechoic chamber and their vocal effort can be assessed while using the real-time convolution system to simulate the acoustics of a variety of classroom conditions. Keeping the talker in one physical space provides more control over the testing environment. A system that can successfully execute convolution in real-time requires parameters to be fine-tuned, an optimized algorithm, and appropriate hardware. Current efforts and lessons learned during the development of this system are shared. Goals for a finished real-time convolution system include specific testing to determine the effects of background noise and reverberation on a teacher's vocal effort.

Invited Papers

8:45

3aSC4. Perceptual consequences of reverberant environments on spatial unmasking. Gabriel S. Weeldreyer (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, 1110 S 67th St., Omaha, NE 68182, gweeldreyer2@unl.edu), Lily M. Wang (Durham School of Architectural Eng. and Construction, Univ. of Nebraska - Lincoln, Omaha, NE), and Z. Ellen Peng (Boys Town National Res. Hospital, Omaha, NE)

Spatial hearing provides access to auditory spatial cues that promote speech perception in noisy listening situations. However, reverberation degrades auditory spatial cues and limits listeners' ability to utilize these cues for segregating target speech from competing babble. Hence, spatial unmasking—an intelligibility benefit from a spatial separation between a target and masker—is reduced in reverberant environments as compared to free field. To understand the perceptual consequences of poorer spatial unmasking in reverberation, we assessed three aspects of functional spatial hearing in virtual reverberant environments: perceived auditory source width, auditory spatial acuity, and spatial unmasking. Three auditory environments were simulated and auralized using ODEON to vary interaural coherence (IC): (1) a control anechoic environment, (2) a classroom designed to meet classroom acoustics standards (IC = 0.58), and (3) a classroom of the same size with more severe reverberation (IC = 0.37). Individually measured head-related transfer functions were used to binaurally reproduce the auralized signals over headphones. We hypothesize that interaural decorrelation, the result of increasing reverberation, will broaden the perceived auditory source width with a cascading effect of reduced auditory spatial acuity and subsequently poorer spatial unmasking. Preliminary data from normal-hearing adults will be presented. [Work supported by NIH R21DC020532.]

9:05

3aSC5. Effect of reverberation and informational masking on speech perception by adolescents and young adults with cochlear implants. Z. Ellen Peng (Boys Town National Res. Hospital, 555 North 30th St., Omaha, NE 68131, ellen.peng@boystown.org) and Abbie A. Mollison (Boystown National Res. Hospital, Omaha, NE)

Children with severe to profound hearing loss fitted with cochlear implants (CIs) can develop speech with degraded auditory inputs. Little is known about how speech perception by CI users who developed speech through electrical hearing is affected by realistic reverberation—a source of additional degradation in acoustic inputs to the CI speech processor. Moreover, how these young CI users handle competing maskers with high informational masking, such as two-talker babble, in speech-in-noise perception is not well characterized. Both reverberation and competing maskers are relevant factors in everyday classroom listening scenarios. In this work, we studied a cohort of adolescents and young adults with early fitting of CIs. Speech reception thresholds (SRTs) were measured in five types of maskers: speech-shaped noise (SSN), SSN modulated by a speech envelope, two-talker babble in English and in French, and time-reversed two-talker English babble. SRTs from each masker type were repeated in an anechoic condition and two reverberation conditions mimicking a classroom meeting classroom acoustics standard versus a lecture hall. When compared with a group of age-matched normal-hearing listeners, young CI users showed steeper increase of masked SRTs by increasing reverberation but comparable release from informational masking. [Work supported by the Hearing Health Foundation.]

9:25–9:40 Break

9:40

3aSC6. Achieving "Good" acoustical conditions for speech communication in active university classrooms. Young-Ji Choi (Kangwon National Univ., 1 Ganwondaehak-gil, Gangwon-do 24341, Korea (the Democratic People's Republic of), youngjichoi@kangwon.ac.kr)

This paper discusses acoustical parameter values for achieving 'good' acoustical conditions for speech communication in active university classrooms. Both room acoustics and background noise influence desirable conditions in classrooms for speech communication. The useful-to-detrimental sound ratio ($U_{;50}$) and speech transmission index (STI) values were calculated from both measured clarity ($C_{;50}$) and signal-to-noise ratio (SNR) values in the active classrooms. To investigate the combined effects of room acoustics ($C_{;50}$) and background noise (SNR) on speech intelligibility, multiple regression analyses were performed regressing both predictors of speech intelligibility, $U_{;50}$(125-4k) and STI, on the combinations of $C_{;50}$(125-4k) and SNR(125-4k) values. If the room has a $C_{;50}$(125-4k) value of 6.3 dB or greater, a SNR(125-4k) value of 10 dBA or greater is required for achieving 'Good' or 'Excellent' acoustical conditions for both measures, $U_{;50}$ and STI, in active university classrooms. However, the required $C_{;50}$(125-4k) value is slightly different for both measures if the room has higher or lower SNR(125-4k) values of 10 dBA.

Contributed Paper

10:00

3aSC7. Enhancing speech comprehension in large classrooms: Addressing alignment delay in assistive listening. Thomas Kaufmann (Dept. of Speech and Hearing Sci., Arizona State Univ., 976 S Forest Mall, Tempe, AZ 85281, tkaufmann@asu.edu), Mehdi Foroogozar, Julie Liss, and Visar Berisha (Dept. of Speech and Hearing Sci., Arizona State Univ., Tempe, AZ)

This study investigated the impact of alignment delay between assistive listening audio signals and acoustic signals from loudspeakers in large classrooms. Focusing on speech-in-noise comprehension, subjective comprehension confidence, and listening effort, the research aimed to illuminate auditory processing challenges and suggests improvements for assistive listening technology. Using a modified QuickSIN speech-in-noise hearing test in a simulated large auditorium setting, 53 participants with normative hearing experienced varying signal-to-noise ratios and alignment delays. The findings reveal a significant and progressive impact of alignment delay on speech comprehension. The study emphasizes the importance of compensating for alignment delay in assistive listening system design in large classrooms to enhance speech comprehension and comprehension confidence while minimizing listening effort. These insights are crucial for individuals with hearing disabilities, who likely face greater challenges than listeners with normative hearing. The study advocates for improved standards in assistive listening system design to ensure auditory accessibility and comfort in educational settings.

Invited Papers

10:15

3aSC8. "I feel like a pack a day smoker": Teacher and student voices from noisy classrooms. Pam Millett (Deaf and Hard of Hearing Program, York Univ., 104 Winters College, 4700 Keele St., Toronto, ON M3J 1P3, Canada, pmillett@edu.yorku.ca)

Concerns about the effects of poor classroom acoustics on student learning (particularly on students who are deaf or hard of hearing) have been expressed since the 1950s, yet research continues to indicate that poor classroom acoustics are both common, and related to poorer student outcomes in academic achievement, attention, behavior, and most recently, mental health. Teachers are not immune to the detrimental effects of noise; for them, research indicates a higher incidence of voice problems, absenteeism and job stress. However, little is reported about what teachers and students themselves have to say about their experiences attempting to learn under adverse listening conditions, and what changes for them when acoustical conditions improve. Their voices are largely missing from the research literature but they illuminate the problem in ways that quantitative data does not always capture. This presentation by an educational audiologist with over 35 years of experience in classrooms will provide an overview of the research on learning under adverse listening conditions, with a focus on representing teacher and student voices through qualitative research and anecdotal reports. The title is a quote from a teacher describing her voice problems and fatigue after a day of teaching.

10:35

3aSC9. Long- and short-term implicit talker familiarity: Effects on children's word and sentence recognition. Mary M. Flaherty (Speech and Hearing Sci., Univ. of Illinois at Urbana-Champaign, 901 S Sixth St., Champaign, IL 61820, maryflah@illinois.edu)

While previous research has highlighted the positive effects of talker familiarity on children's word recognition in quiet, its role in challenging listening conditions remains poorly understood for this age group. Additionally, the amount of familiarity required to yield benefits remains unclear. The current study explored implicitly acquired short and long-term talker familiarity effects in school-age children (8–12 years), utilizing speech or noise maskers. Experiment 1 assessed open-set sentence recognition in a two-talker-female masker, with the child's mother's voice serving as the target or masker speech. Experiment 2 measured closed-set word recognition in a noise masker, both before and after a 5-day exposure to a female talker. Results from Experiment 1 indicate that children benefit from familiarity when their mother is the target talker, but not when she is the masking speech. In Experiment 2, children exhibited familiarity effects after only a 5-day exposure period to a previously unfamiliar voice, demonstrating a significant impact of implicit short-term familiarity. Working memory and selective attention did not predict performance or benefit. Together, these findings underscore the importance of talker familiarity in children's speech recognition in challenging listening situations. The implications of these findings for understanding the mechanisms underlying familiarity effects will be discussed.

10:55

3aSC10. Summary of National Standards on classroom acoustics: The data collection. Virginia Tardini (Dept. of Industrial Eng., Univ. of Bologna, Viale Risorgimento 2, Bologna 40136, Italy, virginia.tardini2@unibo.it), Giulia Fratoni, and Dario D'Orazio (Dept. of Industrial Eng., Univ. of Bologna, Bologna, Italy)

Improving acoustic comfort in classrooms is paramount for enhancing intelligibility, fostering student concentration, and alleviating the vocal strain on teachers. The global discourse on acoustic quality in educational buildings has intensified in recent decades, with each country establishing its unique set of building codes, standards, guidelines, and voluntary point protocols to delineate acoustic quality parameters. Geometrical and architectural classroom variations, influenced by cultural and historical contexts, further contribute to the diversity of approaches. The present work provides a summary that investigates and compares local standards across various countries worldwide, aiming to offer a holistic understanding of the classroom acoustic landscape. The motivation for this summary lies in finding regulations that are not easily searchable on Scholar or Scopus. It involves human interpretation and consideration of building codes, often in local languages. More than 70 experts, distributed across continents, were queried about his local standards, their enforceability, room criteria, design rules; and non-acoustic factors like classroom geometry, average occupancy, and flexibility of learning spaces. By synthesizing insights from diverse regions, this study aspires to provide a global perspective on the state of acoustic quality in educational settings, shedding light on potential areas for improvement.

WEDNESDAY MORNING, 15 MAY 2024 ROOM 213, 8:00 A.M. TO 11:35 A.M.

Session 3aSP

Signal Processing in Acoustics, Acoustical Oceanography, Physical Acoustics, Computational Acoustics, and Underwater Acoustics: Bayesian and Machine Learning in Acoustics I

Paul J. Gendron, Cochair
ECE, University of Masschusetts Dartmouth, 285 Old Westport Rd., Dartmouth, MA 02747

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

Yangfan Liu, Cochair
Purdue Univ., Ray W. Herrick Laboratories, Purdue University, 177, South Russell Street, West Lafayette, IN 47907-2099

3a WED. AM

Chair's Introduction—8:00

Invited Papers

8:05

3aSP1. Performance evaluation of decision trees and multilayer perceptrons in seabed classification. Diego Rios, Jack Tokuda (Dept. of Mathematical Sci., New Jersey Inst. of Technol., Newark, NJ), and Zoi-Heleni Michalopoulou (Dept. of Mathematical Sci., New Jersey Inst. of Technol., 323 M. L. King Boulevard, Newark, NJ 07102, michalop@njit.edu)

Accurate knowledge of the oceanic propagation medium, and, thus, seabed properties, is of paramount importance in source localization, especially of weak targets. In this work, we employ machine learning techniques to perform seabed identification and classification using impulse responses of different media; supervised learning is employed. We first design a decision tree architecture that relies on features selected from the impulse responses corresponding to the different media. Examples of these features are kurtosis, skewness, and strength of the signal. Training sets are created by identifying features from noisy signals and testing follows after extracting corresponding features from a different data set. Performance is evaluated as a function of Signal-to-Noise Ratio. A principal component analysis is also implemented for the investigation of the potential for dimensionality reduction. Subsequently, multilayer perceptrons are employed using identical data both for training and testing and the two machine learning techniques are compared; advantages and disadvantages of each are identified and discussed in this work. [Work supported by ONR.]

8:25

3aSP2. Parallel tempering in trans-dimensional Bayesian inversion for seabed geoacoustic models with many parameters per layer. Stan Dosso (School of Earth and Ocean Sci., Univ. of Victoria, School of Earth and Ocean Sci., University of Victoria, Victoria, BC V8W 2Y2, Canada, sdosso@uvic.ca), Charles W. Holland (Elec. and Comput. Eng., Portland State Univ., Portland, OR), Jan Dettmer (Earth, Energy, and Environment, Univ. of Calgary, Calgary, AB, Canada), and Yong-Min Jiang (School of Earth and Ocean Sci., Univ. of Victoria, Victoria, BC, Canada)

Trans-dimensional (trans-D) Bayesian inversion is a powerful tool for estimating seabed geoacoustic models from ocean-acoustic data, combining quantitative model selection with parameter/uncertainty estimation. The approach applies reversible-jump Markov-chain Monte Carlo methods to sample probabilistically over the number of seabed layers and the corresponding geoacoustic parameters for each layer. Layers are added and removed during sampling, referred to as birth and death moves, respectively, changing the dimension of the model. However, the probability of accepting birth and death moves can approach zero for formulations that include many parameters per layer. This paper considers the use of parallel tempering to mitigate this degradation in efficiency. Parallel tempering employs a series of interacting Markov chains with successfully-relaxed acceptance criteria, achieved by raising the likelihood to powers of 1/T, with T greater than or equal to 1 referred to as the sampling temperature. While only the $T = 1$ chain provides unbiased sampling, probabilistic interchange between chains provides a robust ensemble sampler that mixes more readily over the trans-D model space. The approach is illustrated for wide-angle reflection-coefficient inversion including compressional and shear parameters in the seabed model, resulting in a total of 5 unknown parameters per layer.

8:45

3aSP3. Probabilistic multiphysics inference with flexible coupling and data covariance estimation. Jan Dettmer (Earth, Energy, and Environment, Univ. of Calgary, Dept. of Geoscience, University of Calgary, Calgary, AB, Canada, jan.dettmer@ucalgary.ca), Pejman Shahsavari, and Jeremy Gosselin (Earth, Energy, and Environment, Univ. of Calgary, Calgary, AB, Canada)

We consider combining complementary information contained in multiple data types recorded from distinct physical processes interacting with the Earth's subsurface. Such multiphysics inference of non-invasive geophysical observations can improve the resolution of Earth structure and processes, but is plagued by many subjective choices that practitioners are commonly required to make. We present the method of probabilistic multiphysics inference that employs Bayesian statistics to overcome several requirements for subjective choices. To ensure appropriate data weights, full data covariance matrices are estimated during Markov chain Monte Carlo sampling. The layering structure of the subsurface is estimated with flexible coupling, where the number of homogeneous layers is treated as unknown and the number of geophysical parameters for each layer are unknown. The latter permits flexible coupling such that parameters for different physical processes are not required to share the same layering structure, which avoids over-parametrization. We consider two examples with elastic and electromagnetic waves. In the first example, the thicknesses of shallow (tens of meters) active and permafrost layers are better constrained by probabilistic multiphysics inference. The second example resolves cratonic structure, with reduced uncertainty of a sedimentary basin and for the depth of the lithosphere-asthenosphere boundary. [Work supported by an NSERC Discovery Grant.]

9:05

3aSP4. Uncertainty quantification for acoustical problems. Peter Gerstoft (Univ. of California, San Diego, 9500 Gilman Dr., La Jolla, CA 92093, gerstoft@ucsd.edu) and Ishan D. Khurjekar (Univ. of California, San Diego, La Jolla, CA)

Acoustical parameter estimation is a routine task in many domains and is typically done using signal processing methods. The performance of existing estimation methods is affected due to external uncertainty and yet the methods provide no measure of confidence in the outputs. Hence it is crucial to quantify uncertainty in the estimates before real-world deployment. Conformal prediction is a simple method to obtain statistically valid prediction intervals from an estimation model. In this work, conformal prediction is used for obtaining statistically valid uncertainty intervals for various acoustical parameter estimation tasks. We consider the tasks of DOA estimation and localization of one or more sources in an acoustical environment. The performance is validated on plane wave data with different sources of uncertainty including ambient noise, interference, and sensor location uncertainty, using statistical metrics. Results demonstrate that conformal prediction is a suitable and easy-to-use technique to generate statistically valid uncertainty quantification for acoustical estimation tasks.

9:25

3aSP5. Bayesian optimization for geoacoustic inversion. William F. Jenkins (Scripps Inst. of Oceanogr., UC San Diego, 9500 Gilman Dr., La Jolla, CA 92093, wjenkins@ucsd.edu), Peter Gerstoft, and Yongsung Park (Scripps Inst. of Oceanogr., UC San Diego, La Jolla, CA)

Geoacoustic inversion of high-dimensional parameter spaces is a computationally intensive procedure, often necessitating thousands of forward model evaluations to accurately estimate the geoacoustic environment, such as Markov chain Monte Carlo sampling. This study introduces Bayesian optimization (BO), an efficient global optimization technique, to estimate geoacoustic parameters with significantly fewer evaluations, typically on the order of hundreds. BO involves an iterative search within the parameter space to locate the global optimum of an objective function; in this study, the Bartlett power is used. BO consists of fitting a Gaussian process surrogate model to existing evaluations of the objective function, followed by selecting a new data point for evaluation using a heuristic acquisition function. The effectiveness of BO is showcased through its application to both simulated and real-world data from a shallow-water environment for multidimensional parameter space encompassing source location, array tilt, and seabed properties.

9:45–10:00 Break

10:00

3aSP6. Performance of a computational Bayesian approach for active localization of a mobile scatterer in a refractive ocean environment. Paul J. Gendron (ECE, Univ. of Masschusetts Dartmouth, Dartmouth, MA) and Abner C. Barros (ECE, Univ. of Masschusetts Dartmouth, 285 Old Westport Rd., Dartmouth, MA 02747, abarros1@umassd.edu)

Underwater active acoustic systems that employ limited aperture arrays suffer from reduced processing gain and poor angular resolution, thereby hindering inferential objectives such as localization and tracking. Accurate localization is further challenged by the short conventional coherence-time associated with mobile bodies and dynamic environments. A computational Bayesian approach is presented and expanded here, for joint inference of range, depth, and speed of a submerged mobile scatterer in a refractive and multipath environment [Barros and Gendron, JASA-EL, 2019]. The Gibbs-sampling based approach infers the joint posterior probability density (PPD) of the pressure field wave vectors associated with the angle/Doppler spread arrivals and then maps their joint PPD to the target state joint PPD through acoustic ray interpolation. Performance analysis at high frequencies and relevant ranges using simulated acoustic fields are presented. The posterior uncertainty is investigated as a function of aperture and SNR, and we summarize the PPD using posterior credible intervals. A bound on posterior variance due to uncertainty in sound speed is provided and explored using profiles from the HYCOM database.

10:20

3aSP7. A new seperation method for rotationg and static sound source localization. Ning Chu (Res. Ctr., Zhejiang Shangfeng Co., Renminxi Rd. No1818, Shao Xing, Zhejiang Province 310024, China, chuning1983@sina.com) and Ali Djafari (Res. Ctr., Zhejiang Shangfeng Co., Shao Xing, China)

Traditional sound source localization methods encounter significant challenges in simultaneously locating rotating and static sources. These challenges arise from the differing motion patterns of these two types of sound sources, and they are typically not situated on the same plane. To address this issue, a method based on Modal Composition Beamforming (MCB) and the equivalent source method is proposed for separating rotating and static sound sources that can fully utilize priori knowledge of the spatiotemporal properties of the sources. The proposed approach involves establishing a Rotating-Static Sources Power Propagation (R-S2P) model, utilizing the relationship between the beamforming output of equivalent sources and the actual beamforming output. Solving this model allows for matching the contributions of rotating and static equivalent sources. Simulations for three cases with different source strengths are presented, and the R-S2P model is solved using the Least Absolute Shrinkage and Selection Operator (LASSO). This method enables accurate separation and localization of rotating and static sources on different planes with varying relative intensities, even if the background noise is strong

10:40

3aSP8. Dissipation estimation for the impedance tube measurement using Bayesian inference. Ziqi Chen (Graduate Program in Architectural Acoust., Rensselaer Polytechnic Inst., 110 8th St., Troy, NY 12180, chenz33@rpi.edu) and Ning Xiang (Graduate Program in Architectural Acoust., Rensselaer Polytechnic Inst., Troy, NY)

Although air dissipation is usually neglected in the impedance tube measurement, it affects the accuracy of the measurement results. Multiple effects contribute to the sound dissipation in an impedance tube, like the boundary layer effect or relaxation effect. This work formulates a transfer function model incorporating different dissipation. Bayesian inference is applied to estimate the acoustic dissipation in an impedance tube. Critical parameters in dissipation models are estimated based on the transfer function measured from an empty impedance tube. Nested sampling is applied to get an accurate approximation of parameters. The results of the analysis demonstrate that the critical parameters estimated by the Bayesian method are accurate. The accurate estimated dissipation helps improve the accuracy of impedance measurement with the material under test.

11:00

3aSP9. Parameter estimation and sensitivities of a Bayesian source localization method in an urban environment. Aaron Meyer (US Army Engineer Res. and Development Ctr., 72 Lyme Rd., Hanover, NH 03755, aaron.c.meyer@erdc.dren.mil), Adrian Doran, D. Keith Wilson, and Matthew J. Kamrath (US Army Engineer Res. and Development Ctr., Hanover, NH)

Acoustic signals propagating in urban environments are influenced by rough-surface scattering, multipath reflections, and diffraction. The performance of conventional source localization algorithms often suffers when these effects are present. Bayesian approaches, however, are particularly well suited to incorporating physics-based statistical models for the signal propagation. Previously, we found that the complex Wishart distribution, which describes fully saturated scattered signals across a network of receivers, can be readily employed in a Bayesian framework. In this presentation, a new source localization algorithm based on the Wishart distribution signal model is described and tested on real acoustic data. The experimental data were collected within a mock urban environment as part of a NATO urban acoustics-seismics experiment in Walenstadt, Switzerland. Four acoustic arrays recorded signatures from gunshots and ground vehicles. The present study uses the measured signals to investigate the sensitivity and relative importance of the model parameters, including source and noise amplitudes, frequency band, prior signal sampling, and sensor-sensor correlation behavior. Results are presented in the form of source location probability maps and localization error metrics. Interpretations of the study, including strengths and weaknesses of the new method, are discussed.

Contributed Paper

11:20

3aSP10. Performance of an approximate Bayes factor based detector for environmentally informed active sonar. Kenneth Bowers (Univ. of Massachusetts Dartmouth, 285 Old Westport Rd., Dartmouth, MA, kbowers@umassd.edu) and Paul J. Gendron (ECE Dept., Univ. of Masschusetts Dartmouth, Dartmouth, MA)

Developed here are a space of approximate Bayes Factor (BF) inference processors for high frequency broadband active sonar with short vertical arrays operating in shallow water ocean waveguides that exploit relatively depth invariant modes of propagation. The relevant information regarding the refractive media, rough surface and volume reverberation are incorporated to build the marginal likelihoods under each of the composite hypotheses of null and alternative. Acoustic scattering from a mobile object of interest under depth uncertainty characterizes the compound alternative hypothesis. Approximations are presented and inferences regarding the presence of the mobile body of interest are determined against a composite null hypothesis of reverberation and ambient acoustic noise. The approximate BF processor is shown to be a time-varying quadratic form of array observations over the beam-delay space. We demonstrate the sub-space processing of depth invariant modes at range and illustrate the BF inferential approach on a few representative waveguides. Performance in classic terms of probability of detection as a function of false alarm rate are presented. [This work supported by the Office of Naval Research.]

WEDNESDAY AFTERNOON, 15 MAY 2024 ROOM 201, 1:00 P.M. TO 1:45 P.M.

Session 3pAA

Architectural Acoustics: Soundscape Simulation: Opportunities and Challenges II

Catherine Guastavino, Cochair
CIRMMT & School of Information Studies, McGill University, McGill University, School of Information Studies, 3661 Peel, Montreal, H3A 1X1, Canada

Josep Llorca-Bofi, Cochair
Institute for Hearing Technology and Acoustics, RWTH Aachen University, Kopernikustrasse 5, Aachen, 52074, Germany

Andre Fiebig, Cochair
Engineering Acoustics, TU Berlin, Einsteinufer 25, Berlin, 10587, Germany

Contributed Papers

1:00

3pAA1. What is realistic enough? Design considerations for soundscape simulators. Richard Yanaky (Information Studies, McGill Univ. / Ctr. for Interdisciplinary Res. in Music Media and Technol., 3661 Peel St., Montreal, QC H3A 1X1, Canada, richard.yanaky@mail.mcgill.ca) and Catherine Guastavino (Information Studies, McGill Univ. / Ctr. for Interdisciplinary Res. in Music Media and Technol., Montreal, QC, Canada)

Urban soundscapes reflect life and behaviours in a city. Given the dynamic and ever-changing behaviours of people, this introduces many complexities for soundscape simulators. We focus on bottom-up simulators, wherein every aspect of an environment can potentially be simulated, including 3D models of spaces, people's behaviours, sound sources, weather, nature, lighting, and the physics behind them to create the illusion of navigating a real space. How much realism is necessary in such virtual environments though? This work discusses realism through the lenses of plausibility, hyperrealism, and ecological validity. Is it ok to *just* be a plausible reality? Should reality be exaggerated? How faithful should it be and from which perspective (e.g. matching physical or cognitive "realities")? These questions were considered during the development of our in-house soundscape simulator, City Ditty. City Ditty seeks to be operable by non-sound professionals and support integration into urban projects with minimal expertise and resources, thus encouraging more diverse urban professionals and city users to contribute to how their cities will sound through participatory approaches. Given these requirements, we discuss how suitable levels of realism can be attained to fit people's needs at technical, practical, and theoretical levels by considering these three lenses for design.

1:15

3pAA2. Case study: Computer modeling the noise produced by a future food court radiated to nearby existing offices. Hong Tong (MJM Acoust. Consultants inc., 753 Ste-Helene St., Longueuil, QC J4K 3R5, Canada, htong@mjm.qc.ca)

Lately, there's an increase in the co-existence of spaces of different usage with acoustical challenge. Throughout 2016 to 2018, the 2nd floor of the Complexe Les Ailes, in Montreal, underwent a fit-out to become a food court. At its center, there is an elliptical atrium where all levels are can be viewed. There are existing offices above the food court separated by a glass pane. The purpose of this study was to evaluate the noise generated by

human activities in the future food court to the adjacent offices and recommend noise control elements if needed. Multiple sound samples were taken at existing food courts to quantify the sound level. Simulations were done with ODEON, a room acoustic software, to evaluate the sound level produced by different activities. On-site measurements were conducted to calibrate the existing conditions with the 3D ODEON model. Finally, noise reduction tests were undertaken to determine the sound levels that would be radiated in the offices by the activities in the food court. To reduce noise disturbance in the offices, acoustical treatment under the ceiling of the food court was recommended and the 3rd and 4th floor glass panes composition would have to be improved.

1:30

3pAA3. Comparing subjective similarity ratings and quantitative errors for the evaluation of free-field binaural panning techniques. Zane T. Rusk (The Penn State Univ., 104 Eng. Unit A, University Park, PA 16802, ztr4@psu.edu), Matthew Neal (Otolaryngol. and Comm. Disord., Univ. of Louisville and Heuser Hearing Inst., Louisville, KY), and Michelle C. Vigeant (The Pennsylvania State Univ., University Park, PA)

A free-field sound source can be accurately rendered over headphones via direct convolution with head-related impulse responses (HRIRs). Using binaural panning techniques, a free-field source can be approximated, which can be thought of as *HRIR reconstruction*. However, a loss of fidelity occurs related to the panning algorithm's spatial resolution. Previously, perceptual comparisons of noise bursts were made between panned sources and direct convolution with measured HRIRs. Reconstructions were generated using five different binaural panning methods, both with and without time-alignment of the HRIRs with separate application of the interaural time delay (ITD). To further explore the listening test results, the quantitative differences between the reconstructed and original HRIRs were investigated alongside the perceptual data. Several perceptually-motivated error metrics were evaluated, including errors in both ITD and interaural level difference. The fidelity of the reconstructed HRTF magnitude response was evaluated using metrics that leveraged auditory modeling steps. Both subjective and objective results support that HRIR time-alignment reduces the number of filters needed for high perceptual accuracy. A principal component-base rendering filter set produced the best subjective accuracy with only a small number of required filters (16-25). The ability to predict perceptually detectable degradation via quantitative errors will be discussed.

WEDNESDAY NOON, 15 MAY 2024 — ROOM 215, 12:55 P.M. TO 2:00 P.M.

Session 3pAO

Acoustical Oceanography: Munk Award Lecture

Andone C. Lavery, Chair
AOPE, Woods Hole Oceanographic Institution, 98 Water Street, Woods Hole, MA 02543

Chair's Introduction—12:55

Invited Paper

1:00

3pAO1. Inference of geoacoustic model parameters from acoustic field data: Perspectives on Geoacoustic Inversion. Ross Chapman (Univ. of Victoria, University of Victoria, 3800 Finnerty Rd., Victoria, BC V8P5C2, Canada, chapman@uvic.ca)

Estimation of parameters of geoacoustic models from acoustic field data has been a central research theme in acoustical oceanography and ocean acoustics. During the past several decades, highly efficient numerical inversion techniques have been developed that provide model parameter estimates and their uncertainties based on statistical inference methods. However, the methods are model-based and the inversions are prone to errors related to model mismatch. In any event, the inversions can generate only effective models of the true structure of the ocean bottom, which is generally highly variable over relatively small spatial scales in range and depth. There are also questions about the theory for modelling sound propagation in porous sediment media that raise doubt about the validity of inversion results. In most inversions, a visco-elastic theory is used, but is this the most appropriate propagation model? Another question is about the impact of neglecting shear waves in geoacoustic models. Most inversions assume a fluid model of the ocean bottom. This paper revisits issues that have raised questions about limitations of geoacoustic inversion methods, and discusses the impact of various mitigation measures that have been applied. The paper concludes with musings about new inversion techniques based on machine learning.

Session 3pED

Education in Acoustics: Acoustics Education Prize Lecture

Chair's Introduction—1:00

Invited Paper

1:05

3pED1. Building the acoustics program at Brigham Young University. Scott D. Sommerfeldt (Brigham Young Univ., N283 ESC, Brigham Young University, Provo, UT 84602, scott_sommerfeldt@byu.edu)

The history of acoustics at Brigham Young University dates well back into the first half of the twentieth century. Nonetheless, at the end of the twentieth century the program was on the verge of dying off. The author was hired in the Department of Physics and Astronomy at that time, in the hopes of revitalizing the acoustics program. Various steps were taken at opportune times to continuously rebuild the program to where it has become well known again – both nationally and internationally. The acoustics program is characterized by both a very strong undergraduate program in acoustics, as well as a thriving graduate program that has produced over 70 graduate theses and dissertations and even more undergraduate theses and capstone papers. This presentation will overview the growth and development of the acoustics program since 1995, highlighting lessons learned that may be useful for others looking to develop or strengthen their programs.

Session 3pID

Interdisciplinary: Keynote Lecture: Vibrotactile Perception of Music

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

Chair's Introduction—2:15

Invited Paper

2:20

3pID1. Vibrotactile perception of music. Frank A. Russo (Toronto Metropolitan Univ., Dept. of Psych., Toronto, ON M5B 2K3, Canada, russo@torontomu.ca)

While music is primarily experienced through audition, many aspects of music can also be experienced through somatosensation. Vibrotactile stimulation occurs when a tactile stimulus displaces the skin at a specific carrier frequency. When the carrier is frequency modulated, it can create a complex waveform and when it is amplitude modulated, it can create a rhythmic pulse. These vibrotactile aspects of music have long been recognized as important by music performers, providing a valuable source of non-auditory feedback that may support musical expression. Critically, these same vibrotactile aspects of music may also support the perception of music and voice in individuals with hearing loss. This paper will provide an overview of research conducted over the last decade that has clarified the aspects of music and voice that may be perceived through somatosensation along with some insight into neural underpinnings of these perceptions. Specific features of music considered will include pitch, rhythm, and timbre. Also considered will be the manner by which sensitivity to these features may change as a function of hearing loss, experience, and the properties of stimulation.

3p WED. PM

Session 3pNS

Noise: Assorted Topics on Noise II

Aaron B. Vaughn, Cochair
Structural Acoustics Branch, NASA Langley Research Center, 1 NASA Drive, Hampton, VA 23666

S. Hales Swift, Cochair
Sandia National Laboratories, P.O. Box 5800, MS 1082, Albuquerque, NM 87123-1082

Contributed Papers

1:00

3pNS1. Ongoing confirmation of an objective criterion predicting annoyance linked to wind turbines. William K. Palmer (76 Sideroad 33-34, RR 5, Paisley, ON N0G 2N0, Canada, trileaem@bmts.com)

The 2023 CAA Acoustics Week in Canada introduced a criterion based on an objective acoustic measure to predict annoyance subjectively identified by residents living in the vicinity of wind turbines. That evidence was gathered primarily at a site near constant speed, stall regulated wind turbines. This paper presents subsequent investigations confirming that the criterion is also effective at a site with variable speed pitch regulated wind turbines. The results arise from the analysis of over 400 days of sampling at a site 787 m from the nearest wind turbine, with 18 turbines within 3 km. Verification of the study data was shown by comparison to data collected by an acoustic contractor employed by the provincial Ministry of the Environment. That data was collected through over 70 recording periods to analyze times residents at the site identified annoyance during a Ministry audit. These samples were obtained through a Freedom of Information request purchase. Analysis of the samples confirms the annoyance criterion identified at the CAA 2023 conference applies also for a different turbine type to objectively predict the annoyance subjectively identified by residents. The implications of this confirmation will be discussed.

1:15

3pNS2. A review of the modelling of impulsive noise. Donal Finnerty (Aercoustics Eng. Ltd., 1004 Middlegate Rd #1100, Mississauga, ON L4Y1M4, Canada, donalf@aercoustics.com)

It is generally acknowledged that impulsive noise can be perceived to be more annoying than steady noise with the same equivalent continuous sound level. This increased level of annoyance is often reflected in the regulations of noise emissions, in the form of applied penalties or specific modelling and measurement requirements for impulsive sources. To ensure that facilities that emit impulsive noise comply with those regulations, accurate modelling of impulsive noise is necessary. The modelling of impulsive noise is commonly performed using the same software and methodologies established to predict the impact of steady noise, such as ISO 9613-2. This paper seeks to evaluate the effectiveness and accuracy of these propagation methods when predicting the impact of impulsive noise.

1:30

3pNS3. Ontario Class 4 classification. Giuseppe Garro (Noise, Vib., and Acoust., Stantec, 1331 Clyde Ave. #300, Ottawa, ON K2C 3G4, Canada, giuseppe.garro@stantec.com)

The Ministry of Environment, Conservation, and Parks introduced the Class 4 noise area classification for land-use planning applications in 2013. A Class 4 classification is used in special cases where new noise sensitive developments are proposed in proximity to existing, lawfully established stationary noise source(s). This infrequently used classification is typically applied for in-fill developments in urban settings where land-use compatibility concerns are common. This work summarizes the Class 4 design criteria and discusses the practical implementation of the classification in the context of land-use planning.

Session 3pPP

Psychological and Physiological Acoustics: Auditory Neuroscience Prize Lecture

Sarah Verhulst, Chair
Ghent University, Technologiepark 126, Zwijnaarde, 9052, Belgium

Chair's Introduction—1:00

Invited Paper

1:05

3pPP1. The sing-song of old man human ear. Christopher Shera (Departments of Otolaryngol. and Phys. & Astronomy, Univ. of Southern California, 1969 Allen Ave., Altadena, CA 91001, christopher.shera@usc.edu)

Otoacoustic emissions evoked from the inner ear are the barely audible, signature by-product of the delicate hydromechanical amplifier that evolved within its bony walls. Compared to the sounds evoked from the ears of common laboratory animals, otoacoustic emissions (OAEs) from human ears have exceptionally long delays, typically exceeding those of cats, guinea pigs, and chinchillas by a factor of two to three. This presentation asks "Why are human OAE delays so long?" and reviews efforts to find answers in the mechanical frequency selectivity of the inner ear. The road to understanding species differences in OAE delay has led to the identification of new invariances and the emergence of new questions.

Plenary Session and Awards Ceremony

Stan E. Dosso
President, Acoustical Society of America

Annual Membership Meeting

Presentation of Certificates to New Fellows

Ahmad T. Abawi – For contributions to modeling underwater sound propagation and scattering

William C. Alberts, II – For contributions to tactical infrasound and battlefield acoustics

Simone Baumann-Pickering – For contributions to passive acoustic monitoring of beaked whales

Ana M. Jaramillo – For service to the Society, outreach to Spanish speakers, and acoustics education

Jungmee Lee – For contributions to auditory processing of simple and complex signals

Michael L. Oelze – For contributions to quantitative ultrasound tissue characterization

Introduction of Award Recipients and Presentation of Awards

Science Writing Awards to Francesco Aletta, David George Haskell, and Ute Eberle

Walter Munk Medal of The Oceanography Society to N. Ross Chapman

Rossing Prize in Acoustics Education to Scott D. Sommerfeldt

Medwin Prize in Acoustical Oceanography to Julien Bonnel

William and Christine Hartmann Prize in Auditory Neuroscience to Christopher Shera

Silver Medal in Acoustical Oceanography to Stan E. Dosso

Wallace Clement Sabine Medal to Peter D'Antonio

R. Bruce Lindsay Award to Christopher Kube

Helmholtz-Rayleigh Interdisciplinary Silver Medal to D. Keith Wilson

Gold Medal to Ingo R. Titze

Vice President's Gavel to Ann Bradlow

President's Tuning Fork to Stan E. Dosso

Canadian Acoustical Association

Umberto Berardi

President, Canadian Acoustical Association