8:25

1aBAa2. Small animal cerebral microvascular imaging with super-resolution ultrasound: Techniques and applications. Pengfei Song (Elec. and Comput. Eng., Univ. of Illinois Urbana-Champaign, 405 N. Mathews Ave., Beckman Inst. 4041, Urbana, IL 61801, songp@illinois.edu)

Super-resolution ultrasound (SR-US) is an emerging microvascular imaging technology that provides a micron-scale spatial resolution with tens of millimeters of depth of imaging penetration. The unmatched combination of high spatial resolution and deep imaging penetration opened new doors for many brain imaging applications that benefit from cerebrovascular biomarkers. Recently, SR-US has found its niche in small animal brain applications thanks to its unique capabilities of extending the optical-imaging-level spatial resolution to subcortical, deep brain regions. In this presentation, I will first introduce existing SR-US imaging techniques that are tailored to small animal brain imaging applications. Topics include fast SR-US methods, 3D SR-US imaging, and phase aberration correction for intact skull imaging. I will then focus on reviewing brain imaging applications that use SR-US to characterize cerebral mirovasculature in the aging, stroke, and Alzheimer's Disease brain. Finally, I will introduce the new functional super-resolution imaging technique that combines SR-US with functional ultrasound (fUS) to realize whole-brain neural activity recording at a micron-scale spatial resolution.

8:45

1aBAa3. Super-resolution imaging with modulation of point spread function. Jian-Yu Lu (Bioengineering, The Univ. of Toledo, 2801 West Bancroft St., Toledo, OH 43606, jian-yu.lu@ieee.org)

The spatial resolution of an imaging system using waves is limited by the spatial bandwidth of the point spread function (PSF) of the system, which is related to the wavelength. However, when the PSF is modulated either in amplitude or phase or in both, the resulting spatial bandwidth of the PSF is increased. In this study, the PSF-modulation method is used to obtain super-resolution imaging of objects and to distinguish wave sources that are closely located in space and are not normally separable due to diffraction limit. In imaging using waves, such as ultrasound, acoustics, optics, electromagnetics, radar, and sonar, the PSF can be modulated in their respective fields. For example, in ultrasound, shear wave in biological soft tissues has a low wave speed and thus has a small wavelength. A ring-shaped shear wave can be generated locally (remotely) deep in the tissue by the radiation force of a focused Bessel beam, X wave, or other limited-diffraction beam at their focuses [Lu, 2021 IEEE IUS, 2021 ASA POMA] to produce a sharp peak at the center of the ring (due to shear wave focusing with a small wavelength). This sharp peak of the shear wave modulates the center of a conventional focused beam transmitted after the shear wave ring is produced. The modulated focused beam is then used to scan through an object to obtain a super-resolution image after removing the contribution of the original beam. In this talk, the theory, computer simulation, and experiment results of the super-resolution method will be presented.

9:05

1aBAa4. Dynamic ultrasound localization microscopy. Jean Provost (Eng. Phys., Polytechnique Montreal, 2900 Boul Edouard-Montpetit, Montreal, QC H4B1Z1, Canada, jean.provost@polymtl.ca)

Ultrasound localization microscopy (ULM) can map the vasculature at large depth with unprecedented resolution by localizing millions of injected microbubbles in hundreds of thousands of images acquired over a few minutes. The current state of the art in ULM is to use low concentrations to achieve the best possible spatial resolution without providing temporal information, which limits the development of functional biomarkers such as pulsality or the imaging of moving organs like the heart. In this work, we will present dynamic ultrasound localization microscopy (DULM), which enables the generation of dynamic images of the vasculature of periodic phenomena by using a combination of enhanced image formation and processing techniques to drastically increase the number of microbubbles that can be detected in each image. Specifically, we will describe how the detection of microbubbles directly in space time along with novel aberration correction algorithms and a motion-invariant Lagrangian beamforming approach can be used to increase the concentration of microbubbles 5-fold with a limited degradation in resolution. Examples of application for the mapping of pulsatility in the brain and the dynamics of the intramyocardial blood flow in 2D + t and 3D + t will be shown.

9:25

1aBAa5. Nonlinear ultrasound imaging of the microcirculation. Matthew Bruce (Appl. Phys. Lab., Univ. of Washington, 8817 Interlake Ave. N, Seattle, WA 98103, mbruce@uw.edu), Jonah Harmon, Anton Arkadevitch, and Zin Khaing (Dept. of Neurosurgery, Univ. of Washington, Seattle, WA)

Blood flow at and near the tissue level is a physiological parameter of significant experimental and clinical importance, as it reflects the adaptive response of organs to their normal biological environment, to disease, trauma, and the malignant progression of cancer. The use of microbubbles gives ultrasound imaging access to microvascular hemodynamics, which are beyond the ability of Doppler ultrasound methods. However, expanded clinical use of microbubbles has been limited due in part to a lack of quantification and providing only relative differences in microvascular flow. Past and more recent approaches to the quantification of microvascular blood flow will be presented. Past approaches included the use of focused nonlinear pulsing sequences to isolate microbubble from tissue signals followed by analysis of bolus kinetics or flash replenishment dynamics. Although successfull to some extent, their clinical limitations prohibited extended use and the overall application of contrast enhanced ultrasound (CEUS). Newer approaches include higher frame-rate plane wave acquisitions combined with nonlinear pulsing schemes, which enable the tracking of microbubble flow through microvascular networks. Different approaches of these elevated frame-rate acquisitions will be presented, including use of ultrasound localized microscopy.

water temperature, salinity, and depth were concurrently measured with oceanographic probes. Additionally, cores were collected for point-estimates of seagrass biomass. Our work demonstrates that acoustic propagation offers a valuable alternative to experimental measurements of photosynthesis. [Work sponsored by NSF.]

11:25

1aAB11. Decadal scale trends in temperature, salinity, and sound speed in the Beaufort Sea since 1976. D. Benjamin Reeder (Oceanogr., Naval Postgrad. School, 833 Dyer Rd., Bldg. 232, SP-311B, Monterey, CA 93943, dbreeder@nps.edu) and John E. Joseph (Oceanogr., Naval Postgrad. School, Monterey, CA)

Profiles of conductivity and temperature as a function of depth (CTD) were collected in the Beaufort Sea during two U.S. Navy Ice Exercises in 2016, 2018, and 2020 (ICEXYY) in the month of March. The data show a significant departure from climatological values and significant variance at the interface between the Arctic Surface Layer (ASL) and the underlying Pacific Summer Water (PSW). Comparisons to older ICEX data collected over a 45 year period and to ice-tethered profiler (ITP) data since 2007 confirm both the subsurface warming trend and the variance at the ASL-PSW interface. Statistical analysis reveals a 0.4 degreeCelsius per decade increase in the near-surface temperature maximum (NSTM) near 75 m, which establishes two persistent acoustic propagation features beginning in the year 2000—a near-surface acoustic duct above 50 m and a subsurface acoustic duct, known as the Beaufort Lens, centered on 150 m water depth.

MONDAY MORNING, 8 MAY 2023 BELMONT, 8:00 A.M. TO 11:40 A.M.

Session 1aBAa

Biomedical Acoustics: Ultrasound Brain and Super-Resolution Imaging I

Chengzhi Shi, Chair
GWW School of Mechanical Engineering, Georgia Institute of Technology, 771 Ferst Dr NW, Atlanta, GA 30332-0001

Chair's Introduction—8:00

Invited Papers

8:05

1aBAa1. Motion model ultrasound localisation microscopy: Preclinical findings and clinical challenges. Fabian Kiessling (Experimental Molecular Imaging, RWTH Aachen Univ., Forckenbeckstrasse 55, n.a., Aachen 52074, Germany, fkiessling@ukaachen.de)

Superresolution ultrasound represents a major breakthrough for noninvasive tissue characterization. It mainly comprises ultrafast and motion model driven approaches. This talk will focus on motion model Ultrasound Localisation Microscopy (mULM), an approach working at frame rates of most clinical ultrasound devices. It realizes vascular tracks by subwavelength localization of microbubbles and estimating their probability to have moved from one voxel to another. mULM reliably depicts vascular pattern of different tumors and provides functional vascular characteristics that cannot be obtained by other imaging modalities. We will also report on our experiences in clinically translating mULM and applying it to track breast cancer response to neoadjuvant chemotherapy. Currently, we are exploring mULM for other indications, i.e., chronic kidney diseases preclinically and clinically. Here, it became obvious that microbubble dose and injection speed must be carefully adapted to each application to ensure that vascular architectures are sufficiently displayed and to avoid microbubble overload in the images, which complicates correct assignments of microbubbles to tracks. Motion compensation is another challenge for clinical translation, potentially demanding 3D transducers. Thus, we are highlighting the significant potential of superresolution ultrasound and pinpointing challenges that need to be addressed to make it a robust and reliable clinical tool.