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Editorial: Advances in acoustic/elastic wave sensing for information processing

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Editorial on the Research Topic
Advances in Acoustic/Elastic Wave Sensing for Information Processing

Acoustic/elastic waves carry useful physical information in various fields. Such information in the physical world is processed in the digital world for physical knowledge and insights. In this sense, the convergence of the physical and the digital world is of great importance, which will be fully indebted to sophisticated sensing technology to seamlessly connect the two worlds. Conventional wave sensing approaches have some limitations. For example, these require multiple expensive or bulky sensors that disturb the wave field. Moreover, these approaches present challenges in the imaging of a subwavelength object in the far field, and suffer from poor sensitivity in the case of high impedance mismatch across two media.

Metamaterials have revolutionized research on acoustic/elastic wave control. Specifically, considerable progress has been made in imaging and sensing applications to address the challenges imposed by conventional sensing methods. Metamaterial-based sensing enables us to use smaller sensors by maximizing their interaction with waves. This can also reduce the number of sensors by implementing compressive sensing augmented by artificial intelligence, and allows far-field subwavelength imaging by converting the near-field information to the propagating field.

In this Research Topic, a total of five papers (three research papers and two review papers) are presented in various fields of metamaterials including photoacoustic waves of a fluidic elliptic cylinder, metamaterial characterization from far-field acoustic wave measurements, sensing with sound-enhanced acoustic metamaterials for fault diagnosis, coupled acoustic resonance for wave control and sensing, and spatial information coding with artificially engineered structures for acoustic and elastic wave sensing.

Ultrasound represents an important technology in biomedical imaging and treatment. For example, photoacoustic imaging has been widely used for the human body, including the three-dimensional visualization of vascular systems. To extend the technique for detailing the cross-section changes of blood microvessels, Zhang et al. reported the development of an analytic solution to study the photoacoustic wave generation from a fluidic cylinder based on the cylindrical models in blood vessel photoacoustic imaging. A finite element model is also established to verify the results and to investigate various physics processes. It is found that the angular dependence of photoacoustic power spectra may be used to track the shape changes of the elliptic blood vessels.

As resonances are a key component to subwavelength wave control, significant efforts has been devoted to resonant metamaterials for compact systems. In-depth understanding of coupled resonance systems are benefitical for gaining further insights. In this regard, Lee et al. reviewed key articles related to resonance coupling for wave control and sensing. Not only was the review discussing about relevant articles for various coupling phenomena, but also it was introducing future perspectives of coupled resonance systems.

Metamaterials enabling unprecendented control of waves have a property not found in nature. Characterizing the material properties of unknown media such as metamaterials is challenging even with typical wave-scattering methods. Cheong et al. presented an effective method to retrieve material properties by using far-field scattering waves of small samples and convolution neural networks for the scattering signal processing. This work proves synergestic effects of acoustic wave sensing and machine learning for metamaterial characterization.

Conventional wave sensing approaches generally require multiple expensive sensors and complex hardware systems due to the uniform spatial transmission characteristics of physical fields. Due to their extraordinary physical properties, artificially engineered structures such as metastructures can encode the physical field information by flexibly manipulating the transmission characteristics of acoustic and elastic waves. The fusion of information coding and wave sensing process breaks through the limitations of conventional sensing approaches and reduces the sensing cost. Jiang and He summarized enhanced spatial wave sensing with metastructures for weak signal detection and source localization, reviewed representative progress of computational sensing with artificially engineered structures in audio source separation, ultrasonic imaging, and vibration information identification, and discussed the open problems, challenges, and research prospects of the spatial information coding structures for acoustic and elastic wave sensing.

Cost-effective technology for condition monitoring and fault diagnosis is of practical importance for equipment maintenance and accident prevention. Huang et al. proposed a novel trumpet-shaped acoustic metamaterial (TSAM) with a high enhancement of sound wave selection to detect rotating machinery faults. An experiment was conducted based on an electrical fan to prove the effectiveness of the designed metamaterials. The results of the signal-to-noise ratio show more than 25% improvement, consistently demonstrating the potentiality of the designed acoustic metamaterials for enhancing the weak fault signal in acoustic sensing and the capabilities of contributing to a more cost-effective fault diagnosis technology.

Although submissions for this Research Topic have been closed, more in-depth research in the field of acoustic/elastic wave sensing for information processing continues to address the challenges we face today, such as high-speed mathematical operation and wave-based analog computing, resonant metamaterial lenses for small objects sensing.

Author contributions

TL is the lead author on this manuscript. All authors have contributed to the writing of this editorial.

Conflict of interest

TL was employed by Toyota Motor North America.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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