applied sciences

MDPI

Editorial

Special Issue on Ultrasound Technology in Industry and Medicine

Krzysztof J. Opieliński

Department of Acoustics, Multimedia and Signal Processing, Faculty of Electronics, Photonics and Microsystems, Wroclaw University of Science and Technology, Wyb. Wyspianskiego 27, 50-370 Wroclaw, Poland; krzysztof.opielinski@pwr.edu.pl

Citation: Opieliński, K.J. Special Issue on Ultrasound Technology in Industry and Medicine. *Appl. Sci.* **2023**, *13*, 1455. https://doi.org/10.3390/app13031455

Received: 4 January 2023
Revised: 11 January 2023
Accepted: 18 January 2023
Published: 22 January 2023

As early as 1774, the application of ultrasound in the animal world was noted by the Italian naturalist Lazzaro Spallanzani, who discovered that bats move using ultrasonic waves. The first ultrasonic generator was developed by Leonard Savory in 1830, and then in 1876, a blade squeaker was constructed by Francis Galton to produce ultrasonic waves; using this, Galton first determined the upper threshold of human hearing in 1883. Galton's squeaker was the only model source of ultrasound until the discovery of piezoelectricity by Jacques and Pierre Curie in 1880. Indeed, not everyone knows that Wilhelm Röntgen was pursuing work in ultrasound before he discovered X-rays. The rapid development of ultrasound dates from this discovery in 1895.

After the Titanic disaster of 1912, great interest in the industrial application of ultrasound emerged. In 1916, Paul Langevin developed a method of underwater communication and submarine localization, which led to the development of a category of devices called Sonar (SOund Navigation And Ranging) during World War II. In 1920, Walter Cady, George Pierce, and Alexander Nicolson developed the piezoelectric crystal resonator, which was widely used in the radio communications industry. The emergence of industrial ultrasonic diagnostics for the nondestructive testing of materials was first discerned in 1928–1931, with Sergei Sokolov and Otto Mühlhäuser.

In 1930, Raimar Pohlmann discovered and began the development of ultrasound's active application in medicine in the field of ultrasound therapy. In 1950, Warren P. Mason introduced the inverted exponential horn as a method of concentrating ultrasonic waves. At the same time, Blake, Willard, and Neppiras were developing research on the phenomenon of ultrasonic cavitation and the use of high-intensity ultrasound to treat materials.

The first diagnostic applications of ultrasound in medicine appeared in 1942 in the form of a device used for examining the displacement of the cerebral hemispheres (echoencephalograph), developed by the Austrian neurologist and psychiatrist Karl Theo Dussik. The first ultrasound B-mode scanner, produced with quartz transducers, was developed in 1949. The first ultrasound scanners to use barium titanate piezoceramic transducers were applied in 1950 by the Scottish gynecologist Ian Donald, who is considered to be a pioneer of medical ultrasound. Donald's article, "Investigation of Abdominal Masses by Pulsed Ultrasound", published on 7 June 1958 in The Lancet medical journal, defined the use of ultrasound-guided technology and laid the foundation for prenatal diagnosis.

In 1954, Douglass Howry and Joseph Holmes developed the Type III B-mode ultrasonic scanner. In their experiment, the patient was placed in a bathtub of water and a transducer, 6 cm in diameter, was moved around him in a linear wheel fashion. The image was obtained on an oscilloscope with a long glow time and the degree of gray determined the visualization of the difference in the acoustic impedance. Then, in the 1960s, the method for ultrasonic scanning was improved; this new method used a transducer placed behind the diaphragm and moving in a semi-rotating motion in oil (for cyst detection and liver examination). The two-dimensional visualization later led to the development of echocardiography. Ultrasound medical applications began to develop intensively after the development of the Godfrey Hounsfield X-ray computed tomography (EMI scanner) in 1985; this was a method of imaging blood flow in blood vessels using the Doppler phenomenon (1985), three-dimensional B-type ultrasound imaging (1999–2001), 4D imaging (i.e., 3D in pseudo-real time), as well as 3D + Color Doppler imaging, Fusion 3D (2003–2004).

Today, the number of ways in which ultrasound is applied in industry and in medicine is growing rapidly, and new innovative methods and devices are continuously being developed. The purpose of this Special Issue was to collect and present research on developments related to the broadly innovative application of ultrasound in both industry and medicine. In this issue, a total of thirteen valuable and interesting papers were published, investigating a range of novel and innovative methods, devices, and applications of ultrasound technology in industry and medicine. The papers will cover the following topics: medical diagnostics utilizing shear wave elastography (SWE) methods [1,2], photothermal and photoacoustic effects in materials [3]; shaping the frequency-response characteristics of ultrasonic transducers for use in various applications [4]; ultrasound tomography [5,6], underwater communication systems using the quadrature phase-shift keying method (QPSK) [7]; the ways in which to use standard B-mode ultrasound scanners in precise 3D imaging [8]; the use of the acoustic field beamforming (AFB) method in ultrasonic handheld scanners [9]; a system for locating and tracking objects in the air using ultrasonic detection technology [10]; the full-matrix ultrasonic non-destructive imaging of multi-layer structures [11]; the Doppler ultrasound blood flow monitoring circuit system with a single element transducer [12], and the scanning of a dental implant using an intraoral high-frequency ultrasonic prototype device [13].

Almutairi et al. [1] revealed that discrepancies in the method of measuring the point shear wave elastograhy (pSWE) have been reported due to differences in the body organ, the probes used, or the sample sizes that have been examined; these could provide inaccurate findings and, therefore, affect the reliability of the diagnosis. The authors of this paper sought to assess the reliability and accuracy of pSWE measurements at a range of depths in an elasticity phantom. Cacko and Lewandowski [2] demonstrated that it is possible to implement the SWE modality by applying a portable and cost-optimized system, without a significant loss in the image quality. The developed system and processing algorithm were experimentally validated, thus proving the suitability of the proposed solution for research purposes. This is the first compact and portable solution that implements the SWE technique; thus, it could pave the way for novel point-of-care scanners that are equipped with elasticity imaging. The primary aim of the study presented by Xia et al. [3] was to better understand the absorption and conversion process of short-pulsed light energy, and appreciate the resulting photothermal and photoacoustic effects that this process creates. The authors introduced a theoretical model that displayed the complete process of analyzing the absorbed energy conversion for the refractive index perturbation, induced by both the thermal effect and the photoacoustic pressure; indeed, the authors' numerical simulations agreed excellently with the results of the experiments. Gudra and Banasiak [4] propounded the prospects and advantages of employing a genetic algorithm to shape the characteristics of the transfer functions; these are of particular importance in the search for the greatest bandwidth of a transducer that is intended for pulse operation in a particular medium. The primary advantage of the proposed method is the optimal selection of materials to match layers among materials that physically exist. This approach is fundamentally distinct the existing methods used to match layer selection. Franceschini et al. [5] complied with the expectation that public data sets must test inverse scattering-based approaches; they designed an experimental multiple-input–multiple-output ultrasound tomographic database whose acquisitions were performed by an air-matched internal system. The developed scenarios may provide interesting options for the initial testing of tomographic imaging approaches in non-destructive testing and medical imaging applications. The authors of the paper [6] presented the results of in vivo breast imaging studies on a hybrid ultrasound breast tomography scanner that they had developed for the early detection of cancer. Their resultant measurements and calculations demonstrated how the refraction of ultrasound beam rays on the breast immersed in water affected the quality of the images reconstructed from the measurements of the pulse transit times. The authors discovered that the refraction causes the highest measurement errors in the area of the water/breast interface, and that these can be reduced by adjusting the water temperature and varying the breast geometry. The objective of the paper [7] by B. Szlachetko was to develop a simplified method for the implementation of the underwater communication system, based on quadrature phase-shift keying (QPSK). The experiments performed with the prototype modems allowed the study to attain a 4 kbps data rate on a distance of approximately 18 m. Such modems can be exceedingly attractive in the field of underwater robotics in their ability to send simple commands, status, and position, among others. Moreover, each transmitted frame can be treated as an ultrasound probing pulse, so that it can deliver information regarding obstacles in the vicinity of the robot. Sabiniok et al. [8] proved that three-dimensional automated breast ultrasound (ABUS) systems are not especially popular, due to their cost and exceptionally narrow application; the authors also demonstrated the universal multi-angle conventional 3D ultrasound compound imaging method (MACUI), which is intended for use with standard B-mode scanners in order to reduce cost but preserve the advantages of ABUS systems. The results discussed in the paper elucidate the perceived benefits to quality improvement and the scanning area obtained with the application of tilted and shifted probes, as well as the advantages of using a relatively simple convex probe that does not incorporate software beam steering instead of more advanced devices. Hu et al. [9] proposed the use of the generalized coherence factor (GCF) technique, based on acoustic field beamforming (AFB), instead of the conventional delay-and-sum (DAS) method for handheld ultrasound; this was applied in order to reduce electricity consumption, and avoid battery and unwanted heat problems. The efficacy of the proposed method has been verified by the authors with simulation data, experimental results, and in vivo tests exhibiting an improved imaging quality. Juan et al. [10] implemented an object location and tracking system using an ultrasonic sensing technique with improved algorithms, consisting of one ultrasonic transmitter and five receivers, and applying the principle of measuring the ultrasonic range in order to locate the target object. The experimental results verified the performance of the proposed system and demonstrated that it has a considerable degree of accuracy and stability for object location and tracking. Yu et al. [11] reported that the efficiency of the total focusing method (TFM), applied to non-destructive full matrix capture (FMC)-based ultrasonic imaging systems, is limited, especially in multilayered structures. They proposed a modified wavenumber method for the full-matrix imaging of multilayered structures with an oblique array incidence, which can deal with any incident angle without a loss of precision. The simulation and experimental results indicated that the proposed method performs better in terms of accuracy and efficiency than the TFM. Park and Um [12] proposed a proof-of-concept ultrasound blood flow monitoring circuit system, consisting of a single element ultrasonic transducer, an analog interface circuit and a field-programmable gate array (FPGA), and employing a new automatic range-gate position scheme. The system was successfully tested on a flow phantom model with two vessel-mimicking channels. The purpose of the in vitro study presented by Bohner et al. [13] was to evaluate the trueness of a dental implant, scanned using an intraoral high-frequency ultrasound prototype, developed at the Department of Medical Engineering, Helmholtz Institute, RWTH Aachen University in Germany, compared to conventional optical scanners. In conclusion, the high-frequency ultrasound scanner exhibited a similar trueness to optical scanners for the impression of digital implants.

Funding: This research received no external funding.

Acknowledgments: Thanks to all the authors and peer reviewers for their valuable contributions to this Special Issue "Ultrasound Technology in Industry and Medicine". I would also like to express my gratitude to all the staff and people involved in this Special Issue.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Almutairi, F.F.; Abdeen, R.; Alyami, J.; Sultan, S.R. Effect of Depth on Ultrasound Point Shear Wave Elastography in an Elasticity Phantom. *Appl. Sci.* **2022**, *12*, 6295. [CrossRef]
2. Cacko, D.; Lewandowski, M. Shear Wave Elastography Implementation on a Portable Research Ultrasound System: Initial Results. *Appl. Sci.* **2022**, *12*, 6210. [CrossRef]
3. Xia, Z.; Ni, B.; Hou, R.; Zhang, Y.; Hou, L.; Hou, J.J.; Marsh, J.H.; Liu, X.; Xiong, J. Temporal Evolution of Refractive Index Induced by Short Laser Pulses Accounting for Both Photoacoustic and Photothermal Effects. *Appl. Sci.* **2022**, *12*, 6256. [CrossRef]
4. Gudra, T.; Banasiak, D. Multiparameter Analysis of the Ultrasonic Transducer Transfer Function Using a Genetic Algorithm. *Appl. Sci.* **2022**, *12*, 5325. [CrossRef]
5. Franceschini, S.; Ambrosanio, M.; Gifuni, A.; Grassini, G.; Baselice, F. An Experimental Ultrasound Database for Tomographic Imaging. *Appl. Sci.* **2022**, *12*, 5192. [CrossRef]
6. Opieliński, K.J.; Bułkowski, M.; Gabryel, A.; Wiktorowicz, A. Analysis of the Refraction Effect in Ultrasound Breast Tomography. *Appl. Sci.* **2022**, *12*, 3578. [CrossRef]
7. Szlachetko, B. Low-Cost Underwater Communication System: A Pilot Study. *Appl. Sci.* **2022**, *12*, 3287. [CrossRef]
8. Sabiniok, M.; Opieliński, K.J. Different Types of Ultrasound Probes Usage for Multi-Angle Conventional 3D Ultrasound Compound Imaging: A Breast Phantom Study. *Appl. Sci.* **2022**, *12*, 2689. [CrossRef]
9. Hu, C.-L.; Li, C.-J.; Cheng, I.-C.; Sun, P.-Z.; Hsu, B.; Cheng, H.-H.; Lin, Z.-S.; Lin, C.-W.; Li, M.-L. Acoustic-Field Beamforming-Based Generalized Coherence Factor for Handheld Ultrasound. *Appl. Sci.* **2022**, *12*, 560. [CrossRef]
10. Juan, C.-W.; Hu, J.-S. Object Localization and Tracking System Using Multiple Ultrasonic Sensors with Newton-Raphson Optimization and Kalman Filtering Techniques. *Appl. Sci.* **2021**, *11*, 11243. [CrossRef]
11. Yu, B.; Jin, H.; Mei, Y.; Chen, J.; Wu, E.; Yang, K. A Modified Wavenumber Algorithm of Multi-Layered Structures with Oblique Incidence Based on Full-Matrix Capture. *Appl. Sci.* **2021**, *11*, 10808. [CrossRef]
12. Park, H.-T.; Um, J.-Y. Image-Free Ultrasound Blood-Flow Monitoring Circuit System with Automatic Range-Gate Positioning Scheme: A Pilot Study. *Appl. Sci.* **2021**, *11*, 10617. [CrossRef]
13. Bohner, L.; Habor, D.; Radermacher, K.; Wolfart, S.; Marotti, J. Scanning of a Dental Implant with a High-Frequency Ultrasound Scanner: A Pilot Study. *Appl. Sci.* **2021**, *11*, 5494. [CrossRef]