Guest editorial: recent advances in synthetic aperture sonar technology

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Compared to traditional sidescan sonar, synthetic aperture sonar (SAS) or Interferometric synthetic aperture sonar (InSAS) systems can provide much higher resolution images across the whole swath. Due to the high resolution and fast mapping rate at a given speed, SAS/InSAS technology is gaining increasing interest within the field of underwater engineering. Navigation, autonomous underwater vehicles (AUVs), sonar technolog and electronics have achieved great progress in recent years. Thanks to these developments, the SAS/InSAS has also been pushed into a new stage. Firstly, the lightweight and compact SAS can be mounted on ever smaller, highly flexible platforms. Secondly, current algorithms are computationally more efficient. Thirdly, the SAS/InSAS images are further improved based on various methods. Last but not least, SAS/InSAS technology is preferred by underwater mapping users due to its high resolution. The current Special Issue is focused on research ideas, articles and experimental studies related to "Recent Advances in Synthetic Aperture Sonar Technology" for development, operating mode, algorithms and applications the various aspects of SAS/InSAS in applications.

Introduction: Compared to traditional sidescan sonar, synthetic aperture sonar (SAS) or Interferometric synthetic aperture sonar (InSAS) systems can provide much higher resolution images across the whole swath. Due to the high resolution and fast mapping rate at a given speed, SAS/InSAS technology is gaining increasing interest within the field of underwater engineering. Navigation, autonomous underwater vehicles (AUVs), sonar technolog and electronics have achieved great progress in recent years. Thanks to these developments, the SAS/InSAS has also been pushed into a new stage. Firstly, the lightweight and compact SAS can be mounted on ever smaller, highly flexible platforms. Secondly, current algorithms are computationally more efficient. Thirdly, the SAS/InSAS images are further improved based on various methods. Last, but not the least, SAS/InSAS technology is preferred by underwater mapping users due to its high resolution. The current Special Issue is focused on research ideas, articles and experimental studies related to 'Recent Advances in Synthetic Aperture Sonar Technology' for development, operating mode, algorithms and applications the various aspects of SAS/InSAS in applications.

Papers in the special issue: In this Special Issue, we have received 18 papers, all of which underwent peer review. Of the 18 originally submitted papers, 12 have been accepted and 7 have been 'rejected', i.e. they did not meet the Electronics Letters criteria for rapid publication. Thus, the overall submissions were of high quality, which marks the success of this Special Issue.

The 12 eventually accepted papers can be clustered into three main categories, namely operating mode, algorithms and applications. The papers laying in the first category mainly present research achievements about InSAS, inverse synthetic aperture technique and MIMO SAS. The papers in this category are of Huang et al., Liu et al., Hansen et al., Thomas, et al. and Sæbø et al. The second category of papers exhibit novelties in algorithms about synthetic aperture technique. These papers are of Zhang et al., Wu et al., Jiang et al. and Brown et al. The last category discusses the applications of SAS/InSAS. These papers are of Emma et al. and Jean-Philippe et al. A brief presentation of each of the paper in this special issue follows.

Huang et al. discuss an adaptive filtering method combined with quality map to suppress the phase noise without loss of fringe edges. Their method can select window size adaptively according to quality map. It can remove noise and preserve edge details effectively.

Liu et al. introduce a joint estimation method of imaging plane and 3D structure based on ISAR image sequences to solve the problem of 3D reconstruction of nontriaxial stabilized space targets. Compared to the traditional method, their method can optimize the imaging plane vectors and obtain the 3D mesh of the target, and the surface information is more complete and accurate.

Hansen et al. discuss the benefits and limitations for a best case use of MIMO in SAS. Their findings are that MIMO SAS may be used in sparse scenes with strong targets of interest. The negative effect of cross-talk can then be controlled by choosing a large time-bandwidth product in the transmit waveforms. MIMO SAS does not allow for micronavigation or interferometry processing in speckle scenes. This is a rather fundamental drawback that must be taken into account when considering using MIMO for SAS imaging and mapping of the seabed.

Thomas et al. introduce an openly available simulated InSAS dataset of a ship wreck for assessing the performance of InSAS algorithms for a complex scene geometry with strong bathymetry. They intend for these data to be used within the InSAS community as a benchmark for developing, assessing and comparing bathymetry estimation algorithms.

Sæbø et al. propose a novel adaptive filtering in SAS interferometry by adapting the size of the correlation window (or filter) to estimate the phase difference and the coherence. Based on the test of real data, their method increases the valid area coverage when the SNR is marginal, at the expense of reduced horizontal resolution.

Zhang et al. present an imaging algorithm based on Chebyshev polynomials, which is sued for the deducing of approximated two-way slant range and series reversion method based point target reference spectrum. The performance of their method is superior to that of the traditional method by simulations.

Zhang et al. discuss a novel omega-k algorithm for multireceiver SAS by reformulating the Loffeld's bistatic formula into range-variant and range-invariant phases. Based on simulations, the presented method can also provide high-resolution result which is similar to that of the BP algorithm.

Wu et al. propose an improved existing chirp scaling algorithm based on the method of series reversion to mitigate the problem that the traditional method needs to approximate the range cell migration into a linear term of range and causes a larger range cell migration correction error. Compared to the traditional method, their method has more precise range cell migration correction, which comes from a new curvature factor they developed with their method.

Jiang et al. develop an improved synthetic aperture imaging algorithm to enhance the imaging performance in the azimuth missing data case by designing an effective phase compensation function based on the range cell migration correction echo and first reconstruct the complete range cell migration correction echo from the azimuth missing data. Their method overcomes the defect of plane wave assumption and obtains a better imaging result.

Brown et al. investigate the coherence breakdown of the phase centre approximation for near-range scattering observed by synthetic aperture sonar sensors through modelling with the van Cittert–Zernike theorem to predict the population coherence and point-based sonar scattering model to generate an ensemble of pings. Based on their work, the near-range coherence is impacted by the bistatic collection geometry of large arrays.

Shouldice et al. build upon interferometric phase statistics developed for Synthetic Aperture Radar (SAR) and present a method to differentiate between possible sources of decorrelation. Their work provides supporting evidence for the hypothesis that for single-pass interferometric SAS images phase statistics can be used to determine additional information about the source of decorrelation.

Malkasse et al. recall MVSP SAS offering key advantage of multiple views on every object and then focus on mine counter measures exploitation in understanding 3D objects. Images on targets and nontargets show that it results in time gain in sonar analysis and reduction of the false alarms of classification. Their work can give navy operators fast high confidence, close to pre-identification tools.

Summary: All papers presented in this Special Issue indicate that the synthetic aperture sonar (SAS) technique is very helpful for our exploration of ocean. With the development of new technology like lightweight and compact AUVs, the SAS technology would be easily realized, and it would bring much more benefits for our life.

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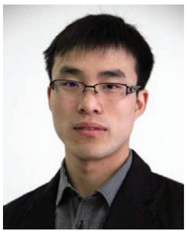

Xuebo Zhang (Senior Member, IEEE) received his B.Eng. degree in electronic engineering and the Ph.D. degree in underwater acoustic engineering in 2009 and 2014, respectively. Currently, he has been with Whale Wave Technology Inc., Kunming, China. Dr. Zhang is currently served as the Technology Committee Co-Chair for IEEE Oceanic Engineering Society. He is the Associate Editor for IEEE Access. Besides, he is the Editorial Board Member for Journal of Electronics & Information Technology and Current Engineering Letters and Reviews, and he has also been the Topical Advisory Member for Journal of Imaging, Journal of Marine Science and Engineering and Remote Sensing. Additionally, he is further the Section Editor for Recent Patents on Engineering. He is the Lead Guest Editor for Special Issues of Advances in Mechanical Engineering, Journal of Marine Science and Engineering, Electronics Letters, Recent Patents on Engineering and International Journal of Distributed Sensor Networks. His research interests include radar/sonar signal processing, noise modelling, image processing and so on.

Gary Heald has worked in the field of underwater acoustics and sonar research for over 40 years. He spent many years working at Dstl in the UK, where he was a Senior Principal Scientist, but recently partially retired from there. He has always maintiained close links with academia including a visiting Professorship at Heriot Watt University and a positon at the Institute of Sound and Vibration Research (ISVR - University of Southampton) and they have continued. His own PhD was obtained at Bath Univerisity, Physics department, investigating the use of high frequency underwater acoustic scattering for use in sediment classification. He has served on the Institute of Acoustics (IOA), Underwater Acoustics Group committee since 1994 and is the current chair. He is also an Executive Director of the Institute where he is also a fellow (FIOA). He is also a fellow of the Acoustical Society of America (FASA). Using his academic positions he has supervised 18 PhD students and has 4 current student. He has been involved in many conferences and chaired the IOA Synthetic Aperture in Sonar and Radar conference in 2014, 2018 and now in Sept 2023 (Lerici, Italy - 6–8 Sept 2023). In 2000 he was awarded the AB Wood medal for his research in Underwater Acoustic scattering from the seabed.

Anthony P. Lyons is currently a Research Professor in the Center for Coastal and Ocean Mapping and is the Associate Director for Research in the Center for Acoustics Research and Education. Anthony P. Lyons received the B.S. degree in Physics from Henderson State University, Arkadelphia, AR, in 1988. After receiving his PhD in Oceanography from Texas A&M University in 1995, Dr. Lyons worked in the Fine-Scale Acoustics and Oceanography Group at the SACLANT Undersea Research Centre, La Spezia, Italy, from 1995 to 2000 where he was involved in a variety of projects in environmental acoustics. Before taking his position at the University of New Hampshire, Dr. Lyons was a Senior Scientist at the Applied Research Laboratory at Penn State and a Professor of Acoustics in Penn State's Graduate Program in Acoustics. While on sabbatical, he worked in the Electrical and Computer Engineering Department at the University of Canterbury, Christchurch, New Zealand, in 2008. Dr. Lyons also worked for the US Office of Naval Research Global in 2008 and 2014. His research projects have included studies of shallow-water acoustic propagation, acoustic interaction with the seafloor, characterization of seafloor sediments and high-resolution oceanographic measurements. Dr. Lyons was awarded, with the recommendation of the Acoustical Society of America, the Institute of Acoustics' (U.K.) A.B. Wood Medal in 2003. He is a Fellow of the Acoustical Society of America (2007) and a member of the IEEE Oceanic Engineering Society.

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