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Signals and Images in Sea Technologies

Edited by

Davide Moroni, Ovidio Salvetti

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Signals and Images in Sea Technologies

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About the Editors

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Editorial

Signals and Images in Sea Technologies

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Life below water is the 14th Sustainable Development Goal (SDG) envisaged by the United Nations and is aimed at conserving and sustainably using the oceans, seas and marine resources for sustainable development [1]. It is not difficult to argue that *Signals and Image technologies* may play an essential role in achieving the foreseen targets linked to SDG 14. Indeed, besides increasing general knowledge of ocean health by means of data analysis, methodologies based on signal and image processing can be helpful in environmental monitoring [2], in protecting and restoring ecosystems [3], in finding new sensor technologies for green routing and eco-friendly ships, in providing tools for implementing best practices for sustainable fishing, as well as in defining frameworks and intelligent systems for enforcing sea law and making the sea a safer and more secure place. Imaging is also a key element for the exploration of the underwater world for various scopes, ranging from the predictive maintenance of sub-sea pipelines and other infrastructures to the discovery, documentation and protection of the sunken cultural heritage.

The main scope of this Special Issue has been to investigate the techniques and ICT approaches, and in particular the study and application of signal- and image-based methods and, in turn, to explore the advantages of their application to the main areas mentioned above. After a careful review process, six papers were included in the Special Issue. Their thematic contributions are discussed in below.

As is well known, vision in the underwater environment is a much more complicated task than it is overland. Methods that achieve good performance in an outdoor scene may completely fail when applied to underwater optical images. The sun radiation only penetrates a few meters into the water medium, and it undergoes an attenuation process that reduces the radiation components in an irregular and non-homogeneous way, depending on the light wavelength, resulting in a severe distortion of the spectral content of the image. Therefore, in many cases, image enhancement is an essential step in several image processing and computer vision pipelines addressing the undersea world. This is precisely the scope of the paper "An Underwater Image Enhancement Algorithm Based on MSR Parameter Optimization" by Hu et al. [4]. Among the general-purpose image enhancement approaches, algorithms based on the so-called Multi-Scale Retinex (MSR) have achieved good results for overland images. However, they cannot be applied directly to the underwater domain since the general parameters cannot be adapted to the submerged scenario. The authors of the paper propose an underwater image enhancement optimisation (MSR-PO) algorithm, which uses the non-reference image quality assessment (NR-IQA) index as the optimisation index. To this end, they perform several experiments that make it possible to determine the appropriate parameters in MSR as the optimisation object. The reported results show that the proposed algorithm has unparalleled adaptability to disparate submarine scenes.

Image analysis plays an important role not only at sea but also for the characterisation of vessels and floating vehicles in water flume, an important topic in naval engineering. In this context, imaging can be used to determine the velocity field of bubbles, providing a non-intrusive technique for the kinematic study of the Free Surface Elevation of Water (FSEW). In the paper by Vargas et al. [5] entitled "On the Estimation of the Surface Elevation of Regular and Irregular Waves Using the Velocity Field of Bubbles", imaging is used to



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infer the wave velocities and forces acting on maritime infrastructure, one of the most challenging topics in the field of Coastal Engineering and Fluid Dynamics. In the study, a curtain of artificial bubbles was generated by a compressed air device placed at the bottom of the flume. Since the velocity of the bubbles can be considered as a proxy of the water velocity, particle imaging velocimetry (PIV) allows for an estimation of the velocity of the bubbles and in turn of the FSEW by using a transfer function.

Waves also intervene in ships dynamics and positioning. Indeed, the natural forces of induced nonlinear waves acting on a ship's hull interfere with the ship movements, possibly leading to sub-optimal routes, wrong positioning and safety concerns. There has been a growing interest in Dynamic positioning (DP) systems that consist of a complex network of sensors and actuators for obtaining accurate positioning. However, the sensor data is usually noisy, with scarce accuracy and reliability for reconstructing directional wave spectra; therefore, suitable filtering and signal processing appear to be necessary. The paper "Improving the Performance of Dynamic Ship Positioning Systems: A Review of Filtering and Estimation Techniques" by Selimović et al. [6] aims at presenting the reader with an overview of the state-of-the-art estimation and filtering techniques for providing optimum estimation states in DP systems, with a view towards safe and green routing.

Aspects related to the protection of the environment are also the main driver of the paper "Optimised Dislocation of Mobile Sensor Networks on Large Marine Environments Using Voronoi Partitions" by D'Acunto et al. [7]. In this paper, solutions are sought for the dynamic dislocations of sensors, mainly e-noses and other AUV-borne devices, in order to promptly detect and respond to pollution events, thus reducing the costs for real-time surveillance of large areas. Indeed, generally, the probability of the occurrence of a pollution event depends on the burden of possible sources operating in the areas to be monitored. The paper presents theoretical and simulated results inherent to a Voronoi partition approach for the optimised dislocation of a set of mobile wireless sensors with circular (radial) sensing power on large areas. The optimal deployment was found to be a variation of the generalised centroidal Voronoi configuration.

Protection against adversarial Underwater Acoustic Sensor Networks (UASN) is the central theme of the paper by Xiong et al. entitled "A Layout Strategy for Distributed Barrage Jamming against Underwater Acoustic Sensor Networks" [8]. Distributed barrage technology can be used to prevent a target from being detected. The paper focuses on the capacity of a limited set of jammers to achieve the best jamming effect by maximising the Cramér–Rao bound of multiple targets estimates. A heuristic algorithm is used to solve this optimisation model, which is demonstrated thanks to several numerical simulations. Stability of the results with respect to errors in the positioning of the jammers is also discussed since it is of vital importance for practical applications.

Acoustic signal processing is also the main subject of the last paper entitled "Robust Capon Beamforming against Steering Vector Error Dominated by Large Direction-of-Arrival Mismatch for Passive Sonar" by Hao et al. [9]. Arrays of sensors, that is, sets of sensors used in a particular geometric pattern, are used primarily when it is necessary to increase the performance of the sensor or add new dimensions to the observation estimating more parameters, for instance, the Direction-of-Arrival (DoA) of impinging waves. In this context, adaptive beamforming is often used in passive sonar arrays to improve the detectability of weak sources. Historically, the main push to this research topic has been military applications, in particular, the acoustic detection of submarines. In contrast, now new applications spur from environmental applications, such as the detection of whales and other sea creatures [10]. The paper discusses Capon beamforming (after the seminal work [11]) introducing a new robust approach. Indeed, since very often no accurate prior information of the direction of arrival of the target is available, Capon beamforming might suffer from performance degradation due to the steering vector error dominated by large DoA mismatch. The new approach can mitigate such an issue as shown in the experimental results.

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