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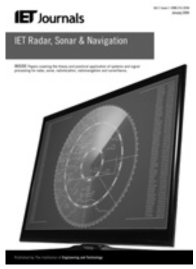
Special Section on Biologically-inspired radar and sonar systems



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Editorial

Biologically-inspired radar and sonar systems

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In the last century both radar and sonar active technology developed from inception to the point where high resolution images can be obtained from long ranges. The available technology can exploit Doppler effects, structural resonances, nonlinear scattering, synthetic aperture platforms, and sediment-penetrating modalities. Active sonar and radar share many common approaches, in part because of the similarities of the problems they address, both in the military and commercial research areas. Moreover, in the last two decades, research into both radar and sonar has explored biomimetic and bioinspired solutions [1–5], in recognition of the fact that whilst man-made systems have access to power and bandwidth far beyond that available to any living organism [6], some biological solutions have benefitted from millions of years of natural optimisation to evolve sensing capabilities and strategies and meet the challenges of survival (finding food and mates, avoiding predators, sensing and navigating to and within appropriate habitats, etc.) [7]. Problem solving for survival goes beyond the particular radiation used in sensing, covering also signal processing, detection and classification of targets, use of platforms, and strategies for deploying sensors and interpreting data [8–10]. Bio-inspired approaches follow logically when the problems facing manufactured technology resemble those addressed in nature. For example, in the last 15 years the arena for sonar challenge has changed from the passive detection of large quiet nuclear submarines in the deep, relatively quiet and uncluttered waters, to minehunting by active sonar in shallow coastal waters [11], a problem far closer to that faced by dolphins and bats in their natural environments [12,13].

Radar and sonar share another feature in common, which is that throughout the 20th century a substantial amount of the development arose through defence funded research to address defence issues. This provided investment in ‘blue skies’ research which balanced the requirements of commercial sonar and radar developers to generate income from research on the 3–5 year timescale.

The combined effect of decreasing budgets for research, and (particularly against a backdrop of a global financial crisis) the desire by politicians and sponsors to show that tax income is used to address societal problems, mean that Government research funders are often under pressure to direct research to specific products which will pay off in the short term. Lack of encouragement of the ‘blue skies’ research to offset this product development can result in incremental, as opposed to step-changing, advances in a technology [14]. The complexity of bio-inspired systems mean that it is particularly important to capitalise on real innovations and insight, before the glamour of the topic leads to an abundance of studies, which can eventually generate cynicism in the field because the real advances are buried in the clutter of less successful projects.

The call for this Special Issue was devised to bring together separate research into bioinspired radar and sonar in the spirit of identifying for each modality a fruitful area recognised by the other. The call identified areas of interest in bio-inspired waveforms; analysis of naturally occurring echolocation systems; bio-inspired methods for target detection and classification; bio-inspired transducers; cognitive signal processing inspired by natural systems; bio-inspired imaging; future research directions. In the event, eleven papers were received for consideration and seven of these were selected by the editorial and peer review processes for publication in the Special Issue. The resulting papers can be conveniently grouped into two categories:

- reviews
- applied hypothesis and experimentation

Together they provide an insight into the challenges and opportunities of following bioinspired research routes into remote sensing.

Reviews

The issue contains two reviews by world-leading authorities on the sonars of bats and dolphins [7]. Simmons and Gaudette [15] reviews the mechanisms that underpin echolocation by the Big Brown Bat (*Epesticus fuscus*). The authors describe the entire echolocation train, from the transmitting apparatus and the type of waveforms deployed, to the receiving system and the binaural processing of target echoes. They describe how the use of the harmonics can facilitate discrimination between targets and clutter and discuss differences, advantages and disadvantages between man-made sonar systems and echolocating bats.

Au and Martin [6] examine in depth the above-mentioned discrepancy between the outstanding performance achieved by dolphin biosonar compared to man-made sonar, which exists in spite of the dolphin sonar appearing to lack any great advantage when parameterised in terms of sonar hardware. This discrepancy reveals the limitations of such parameterisation that the authors explore by reference to experiments on target discrimination.

Applied hypothesis and experimentation

Balleri *et al.* [16] present an analysis of the information content of acoustic echoes from unpollinated flowers of a bat pollinated plant species, namely the *Cobaea scandens*. They investigate how their echo-acoustic signatures change as the flower degrades and hence stop attracting potential pollinating bats, and quantify these differences by assessing the performance of typical radar and sonar classifiers.

Schillebeeckx *et al.* [17] investigate biosonar 3D binaural target localisation. This is commonly achieved by either processing relative time and intensity differences between two receivers or by deploying a number of receivers which is greater than two. Bats largely rely on additional binaural spectral cues generated by the bat pinna. The authors explore the advantages behind the presence of the pinna and they identify the features that are responsible for improved performance with respect to traditional transducers. This paper offers an understanding of the localisation strategies evolved by bats and provides a technical insight into the design of much simpler bioinspired in-air sonar systems with high 3D localisation performance.

Li *et al.* [18] address the problem of edge detection and extraction from Synthetic Aperture Radar (SAR) images. They propose an algorithm that takes inspiration from the mechanisms of strengthening and positioning the image edges adopted by the human eyes and they test it against simulated and real SAR images. They compare the performance of their proposed algorithm with that of traditional methods and show that better results can be achieved.

Two papers [19, 20] build upon the proposal [21] that some odontocetes might exploit nonlinearities in the scattering of pulse pairs to discriminate genuine targets from the pervasive and potent clutter generated by bubbles produced, for example, by breaking waves. Although nonlinear processing of one form of sonar pulse was subsequently shown to work in the wakes of car ferries [22] and container ships [23], there is no conclusive evidence that any odontocete uses such pairs [22]. Very similar pairs have been detected, and Finfer *et al.* [19] review the detection of such pulses from a range of species. They discuss whether the evidence allows categorical assertions that received pulse pairings are the result of surface reflections or are generated by the odontocete at source. Chua *et al.* [20] revisit whether a variant of the nonlinear processing scheme for consecutive pulses which resemble those made by some odontocetes could enhance target detection and classification amongst bubble clutter.

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His research interests include radar signal processing, biologically inspired radar and sonar systems, radar and sonar target classification (HRRPs and micro-Doppler signatures), target feature identification and extraction, multi-static radar systems, echolocating natural systems and radar sea and wind farm clutter.

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