Digital Object Identifier 10.1109/OJAP.2021.3057997

Guest Editorial: Special Section on Computational Intelligence in Antennas and Propagation: Emerging Trends and Applications

COMPUTATIONAL Intelligence (CI) is the theory, design, application and development of biologically and linguistically motivated computational paradigms. Machine Learning (ML), Fuzzy Inference Systems (FIS), and Evolutionary Computation (EC) have historically been the three principal pillars of CI. The use of CI has experienced an increasing impact on solving complex problems in antennas and propagation (AP).

Artificial Intelligence (AI) approaches and techniques, such as ML (of which deep learning and reinforcement learning are specific examples), are the new fundamental enablers for operating wireless networks more efficiently, for enhancing the overall end-user experience and for providing innovative service applications. ML represents a basic functionality to guarantee the efficiency of future wireless communication networks and, at the same time, can represent the enabling technology for several added-value applications and services. The utilization of ML in wireless communication nodes can enable several advanced services and quality of service functionalities for the proposed applications. Moreover, the use of ML techniques has the potential to provide a complete study and modeling of the radio environment.

Fuzzy Systems (FS) model linguistic imprecision using human language as a source of inspiration, and solve ambiguous problems based on a generalization of conventional logic that helps us to perform approximate reasoning. Fuzzy sets and structures, fuzzy clustering and classification, fuzzy controllers, linguistic summarization, fuzzy neural networks, and type 2 fuzzy networks, are all part of this research field.

Using biological evolution and swarm intelligence as a source of inspiration, by generating, evaluating and changing a population or swarm of possible solutions, the field of Evolutionary Computation (EC) has been developed to solve challenging optimization problems. Several Evolutionary Algorithms (EAs) have emerged in the past decades that mimic the behavior and evolution of biological entities. EAs are widely used to solve of single- and multi-objective optimization engineering problems. EAs have also been applied to a variety of microwave components, antenna design, radar design, and wireless communications problems. These techniques, among others, include Genetic Algorithms (GAs), Evolution Strategies (ES), Particle Swarm Optimization (PSO), Differential Evolution (DE), and Ant Colony Optimization (ACO). In addition, new innovative algorithms that are not only biology-based but also physics-based or chemistry-based have emerged. The above algorithms are having an increasing impact on antenna design and propagation problems. EAs have been combined on several occasions with numerical methods in electromagnetics, producing a plethora of significant and successful results.

Thus, CI techniques such as Nature-Inspired Algorithms, Decision Trees, Random Forests, Support Vector Machines, Extreme Learning Machines, Gaussian Processes, Artificial Neural Networks (ANNs), and Deep Learning Networks (DNNs) are gaining popularity in the AP community. Additionally, hybrid combinations of CI and problem specific methods are also emerging. For example, cutting-edge applications like the smart radio environment enabled by Reconfigurable Intelligent Surfaces (RISs) can become a reality using CI techniques.

In this Special Section, we explore new and transformative applications of CI methods in electromagnetics, antennas and propagation. The papers that follow demonstrate a range of approaches to a diverse set of application areas using different CI techniques, and with usage scenarios ranging from antenna design to biometric applications. While highly impactful, the body of work reported on here represents only a fraction of the current research, emerging trends and applications of CI. This special section consists of six research papers. The CI techniques used by the special section authors include Support Vector Machines (SVM), Naive Bayesian Classifiers (NBC), Multi-Objective Genetic Algorithms (MOGAs), the Coyote Optimization Algorithm (COA), Approximate Bayesian Computation (ABC), Deep Neural Networks (DNN), Recurrent Neural Networks (RNN), and the Social Network Optimization (SNO) algorithm.

A flexible shape generation technique combined with a multi-objective evolutionary optimization algorithm is presented by Whiting *et al.* in order to synthesize geometrically-diverse dielectric resonator antennas. The authors demonstrate that noncanonical shapes can improve gain and bandwidth when compared to conventional dielectric resonator antenna geometries. Moreover, the proposed approach is compatible with various feed designs, antenna performance parameters, and 3D printing techniques.

The prediction problem of the time evolution of field values in transient electrodynamics is addressed by Noakoasteen *et al.* in another paper. The authors develop an encoder-recurrent-decoder architecture, which is trained with finite difference time domain simulations of plane wave scattering from distributed, perfect electric conducting objects. They show that the proposed ML method can emulate a transient electrodynamics problem with more than 17 times speed-up in simulation time compared to traditional finite difference time domain solvers.

Nabulsi *et al.* explore the application of ML techniques for a biometric application. In this article, the authors generate a data set using an 8-antenna (Wi-Fi) system and by collecting microwave samples from human volunteers' forearms. They apply Support Vector Machines and Naive Bayesian to classify the data. Their results indicate that human identification via microwave signals is possible even with a subset of the above mentioned 8-antenna configuration.

Bharti *et al.* propose an estimation procedure for stochastic radio channel models from 60 GHz indoor measurement data using machine learning techniques. More specifically, the authors apply Approximate Bayesian Computation (ABC) and deep learning, for fitting stochastic channel models directly to data. The authors report that ML methods can learn the parameters of the model accurately in simulations.

The design problem of beam-scanning passive reflectarrays is addressed by Niccolai *et al.*using the Social Network Optimization (SNO) algorithm. The authors analyze all aspects of the optimization environment. They evaluate the proposed design procedure by comparing the SNO performance with other well established Evolutionary Algorithms.

Finally, Boursianis *et al.* design a multiband antenna for RF energy harvesting applications using the Coyote Optimization Algorithm. The obtained solution operates satisfactorily in the LoRaWAN (Long Range Wide Area Network) and in the cellular (GSM-1800 and UMTS) communication frequency bands. The authors report that the proposed antenna exhibits an acceptable performance (multiband frequency operation, maximum gain of 3.94 dBi, broadside operation) that make it a strong candidate for various RF energy harvesting applications.

In closing, the Guest Editors would like to thank the authors and reviewers for their efforts in making this section a timely one and hope that the work presented here will inspire new applications of CI in electromagnetics, antennas and propagation with opportunities that have not yet been explored. We would especially like to thank the IEEE Open Journal of Antennas and Propagation Editor-in-Chief and Senior Editor Prof. Nikita and Prof. Kiourti, respectively, for their valuable support that has made this Special Section possible.

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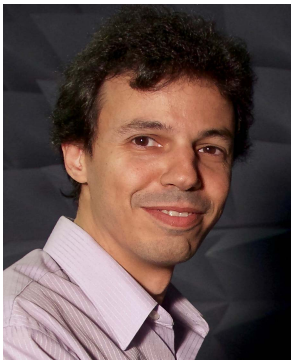

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