

Guest Editors' Introduction: Neural Networks for Signal Processing

PROGRESS in the theory and design of neural networks has expanded on many fronts during the past ten years. Much of that progress has a direct bearing on signal processing. In particular, the nonlinear nature of a neuron that constitutes the basic building block of neural networks—the ability of neural networks to learn from their environments in supervised as well as unsupervised ways and the universal approximation property of neural networks—make them highly suited for solving difficult signal processing problems. Applications of neural networks include

- nonlinear signal modeling, detection and estimation, and pattern classification;
- system identification, adaptive filtering, and blind adaptation;
- image and speech processing;
- unconventional applications.

From a signal processing perspective, it is imperative that we develop proper understanding of neural network-based signal processing algorithms and how they impact the above-mentioned applications. We need to assess the impact of neural networks on the performance, robustness, and cost-effectiveness of signal processing systems and develop methodologies for integrating neural networks with other signal processing algorithms. Another important issue is how to evaluate neural network paradigms, learning algorithms, neural network structures, and identify those that work and those that do not work reliably for solving signal processing problems. The issues raised herein demand detailed attention, innovative ways of thinking, and above all, honest answers.

This special issue offers a unique forum for researchers and practitioners in this field to present their views on these important questions. The response to the initial call for papers was overwhelming—a total of 101 manuscripts were submitted from all over the world. All guest editors worked hard to keep up with the schedule while maintaining the same high standard as that applied to other manuscripts submitted to the IEEE TRANSACTIONS ON SIGNAL PROCESSING. Each manuscript was reviewed by two to four anonymous reviewers, and then, the reviewers' recommendation, as well as the manuscript itself, were examined by two guest editors before a final decision was made. Based on the subject area of interest, the accepted papers are grouped into the following categories:

- nonlinear signal learning and processing: theory and algorithms;
- signal prediction and filtering;
- blind source separation and channel equalization;
- pattern classification.

The first group of papers, which contain five papers and two correspondence items, concerns the theory and algorithms

for nonlinear signal learning and processing. In “NL_q Theory: Checking and Imposing Stability of Recurrent Neural Network,” the authors discuss the stability of discrete-time recurrent neural networks for nonlinear modeling applications. In “Mixture of Experts Regression Modeling by Deterministic Annealing,” the authors present an annealing approach for the design of regression models based on the mixture of experts architecture. In “Self Evolving Neural Networks for Rule Based Processing of Data,” a multiple-shaped radial basis network architecture is proposed to efficiently represent the distribution in the input space. In “Comparing Support Vector Machines with Gaussian Kernels to Radial Basis Function Classifiers,” an experimental comparison of a support vector (SV) learning algorithm to the k-means clustering algorithm for the training of radial basis networks is presented. In “Bi-Directional Recurrent Neural Networks,” an extension to a regular recurrent neural network is presented, which makes it possible to train the network in forward and backward time directions simultaneously. There are also two correspondence articles: “Statistical Convergence Analysis of Rosenblatt's Perceptron Algorithm as a DS-Spread Spectrum Detector,” and “Multiresolution Learning Paradigm and Signal Prediction.”

The second group of six papers focuses on the applications of neural networks to nonlinear signal prediction and filtering. In “Delta-NARMA Neural Networks—A New Approach to Signal Prediction,” a simple nonlinear extension of the ARMA model is proposed, which leads to the development of an efficient univariant signal prediction network called Delta-NARMA. In “Neural Network Modeling and Identification of Nonlinear Channels with Memory,” the authors study the statistical transient and convergence behavior of a neural network structure (filter-nonlinearity-filter) that adapts its parameters using a modified back-propagation algorithm. In “A Delay Damage Model Selection Algorithm for NARX Neural Networks,” a delay (internal memory) pruning method is proposed to enhance the performance of the nonlinear autoregressive models with exogenous inputs (NARX) neural network. In “Nonparametric Regression Analysis Achieved with Topographic Maps Developed in Projection Pursuit Learning: An Application to Density Estimation and Adaptive Filtering of Gray Scale Images,” a novel topographical map using maximum entropy learning and projection pursuit learning is proposed. In “Optimum Nonlinear Filtering,” the authors survey the optimum nonlinear filtering methods and explore the impact of recent applications of (discrete-time) neural networks to nonlinear filtering. In “Solving Inverse Problems by Bayesian Iterative Inversion of a Forward Model with Ground Truth Incorporation,” the authors use a Bayesian framework to incorporate multiple knowledge sources in order to solve the inverse problem in remote sensing.

The third group of papers is devoted to applications of neural networks to signal source separation and channel equalization. It contains three papers and one correspondence item. In "Blind Source Separation-Semi-Parametric Statistical Approach," a semi-parametric model is used to formulate the problem of blind source separation. In "Neural Networks for Blind Decorrelation of Signals," the authors analyze and extend a class of adaptive networks for second-order blind decorrelation of instantaneous signal mixtures. In "Fast Adaptive Digital Equalization by Recurrent Neural Networks," the authors develop a discriminative learning algorithm for recurrent neural networks. The correspondence item is, "A Decision Feedback Recurrent Neural Equalizer as an Infinite Impulse Response Filter."

Finally, there are a number of novel applications of neural networks to pattern classification tasks. This group consists of eight papers and three correspondence items. In "Neural-Fuzzy Classification for Segmentation of Remotely Sensed Imageries," remote sensing image segmentation is accomplished using an adaptive resonance theory (ART) classifier, followed by a clustering of signals. In "Classification of Seismic Signals by Integrating Ensembles of Neural Networks," an integrated classification machine (ICM) consisting of a hierarchy of neural networks is used to distinguish natural earthquakes from man-made explosions. In "Classification of Underwater Mammals Using Feature Extraction Based on Time-Frequency Analysis and BCM Theme," a Bienenstock, Cooper, and Munro (BCM) neuron is used to classify the time-frequency representations of underwater mammal sounds. In "Bird Song Recognition Using Backpropagation and Multivariate Statistics," the application of neural networks to recognize bird species using recordings of bird songs is reported. In "Unsupervised Statistical Neural Networks for Model-Based Object Recognition," an objective recognition problem is posed as a maximum likelihood estimation of hierarchical mixture of experts problem followed by regularization using smoothing terms. In "Coding and Comparison of DAG's as a Novel Neural Structure with Applications to On-Line Handwriting Recognition," the direct acyclic graph (DAG) is used as a novel representation of ordered continuous signal streams to solve the handwriting recognition problem. In "Discriminative Metric Design for Robust Pattern Recognition," an advanced formalization of discriminative feature extraction called discriminative metric design is proposed, and

applications to speech recognition are demonstrated. In "Self-Organizing Feature Maps and Hidden Markov Models for Machine-Tool Monitoring," the self-organizing feature map is used as a feature extractor for a hidden Markov model classifier with applications to machine tool monitoring. The three correspondence items include "Extracting Useful Higher Order Features for Condition Monitoring Using Artificial Neural Networks," "Neural Networks For Signal Detection in Non-Gaussian Noise," and "High-Performance Low-Complexity Word-Spotting Using Neural Networks."

We would like to extend our sincere appreciation to all the authors who submitted manuscripts to this special issue. We thank all the reviewers for their timely and highly constructive reviews. The guest editors also would like to express their gratitude to the present and former members of Neural Network for Signal Processing Technical Committee of the IEEE Signal Processing Society for their support and assistance throughout this project. We thank the Editor-in-Chief of IEEE TRANSACTIONS ON SIGNAL PROCESSING, Prof. Jose Moura, as well as all the associate editors, for their support, encouragement, and guidance throughout this project. Finally, we hope that you enjoy this special issue.

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