MODULATION RECOGNITION USING ARTIFICIAL NEURAL NETWORKS

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ABSTRACT

In this paper the artificial neural networks (ANNs) approach as another solution for the modulation recognition process is describe in some detail. This work demonstrates the success of the ANN, it the modulation recognition process. Due to the simplicity of the ANN structure, it can be used for on/line analysis. To use the ANNs for modulation recognition for on/line analysis, the main requirement is that the classifier structure be adjusted beforehand; i.e. to finish the training phase off/line using this network in the on/line analysis.

1 INTRODUCTION

The fundamental principles of ANNs in the signal-processing context have been previously described by many authors, e.g. Lippmann, Hush and Horne. Furthermore, ANNs are successful in many practical applications including control, signal processing, pattern recognition and manufacturing processes. This paper demonstrates the success of the ANN in the modulation recognition process.

2 STRUCTURE FOR ANN MODULATION RECOGNISER

The neural network based modulation recognition process involves trying different architectures, learning techniques and training parameters in order to achieve acceptable decision accuracy. The constraint that different inputs lead to the same output may lead to a network with hidden layers to learn certain mappings from input to output. This is the situation in the modulation recognition process, especially for the analogue types such as the AM signals with different modulation depths that classify as AM, FM signals with different modulation indices that classify as FM, and combined (AM-FM) modulated signals with different modulation depths and different modulation indices that classify as combined modulation. The chosen ANN structure is different according to the group of modulation types under consideration - analogue only, digital only or both analogue and digital. The selection of the network parameters are based on choosing the structure that gives the minimum sum-squared errors (SSE) in the training phase, and the maximum probability of correct decisions in the test phase.

The modulation recognisers based on the ANN approach are composed of the three main blocks, These are: 1) pre-processing in which the input key features are extracted from every signal realization in addition to signal isolation and segmentation, 2) training and learning phase to adjust the classifier structure, and 3) test phase to decide about the modulation type of a signal.

The four key features are used for the ANN analogue modulation recognition algorithms. They are:

- γ_{max} - represents the maximum value of the spectral power density of the normalized-centered instantaneous amplitude of the intercepted signal.
- σ_{ap} - is the standard deviation of the absolute value of the centered non-linear component of the instantaneous phase, evaluated over the non-weak intervals of a signals segment.
- σ_{dp} - is the standard deviation of the centered non-linear component of the direct instantaneous phase, evaluated over the non-weak intervals of a signals segment.
- The fourth key feature is used for measuring the spectrum symmetry around the carrier frequency, and it is based on the spectral powers for the lower and upper sidebands of the signal.

The objective of training a network is to find the optimum weights and biases to minimise the error between the network output and the correct response. There are many types of learning methods to achieve the minimum error. These are error-correction learning (back propagation), Hebbian learning, competitive learning, and Boltzman learning. Both the back propagation as well as the supervised learning paradigm are used in all the developed ANN modulation recognition algorithms. The chosen ANNs are adaptively trained using momentum back propagation learning. In these algorithms, three network types are considered: 1) ANNs with no hidden layers, 2) ANNs with single hidden layer, and 3) ANNs with two hidden layers. All the networks used in the modulation recognition algorithms are adaptively trained to reduce the sum squared error, *SSE,* defined in terms of the difference between the calculated output corresponding to the data used in the training and the actual target.

The outputs of the training phase are the weight and biases of the output layer of the trained network that will be used in the test phase. Generally the training phase comprises the following steps:

- Initialize the network weights and biases
- Adaptive training stage
- Presentation phase
- Back propagation learning

3 ANALOGUE MODULATION RECOGNITION ALGORITHMS

The modulation types that can be classified by the ANN recogniser are: AM, DSB, VSB, LSB, USB, combined, and FM signals. In this paper is presented the algorithms with two hidden layers. The structure of the ANN recogniser is described in Fig. 1

The tested network contains a 4-node input layer, a 7-node output layer and two hidden layers with 10 nodes in each of hidden layers.

The results of simulation of the ANN recogniser for real signals are presented in the table 1.

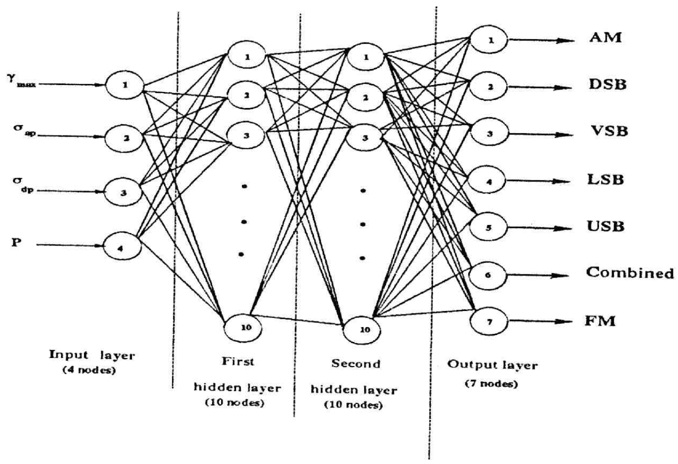

Fig. 1: *Two hidden layers ANN architecture for ANN recognizer*

Simulated Modulation Type	Deduced Modulation Type					
	AM	DSB	VSB	LSB	USB	FM
AM	82%	18%				
DSB	8%	92%				
VSB			78%		22%	
LSB				86%	14%	
USB				18%	82%	
FM						100%

Tab. 1: *Confusion matrix for the ANN algorithm (based on 1000 realizations for the real signals)*

4 CONCLUSIONS

Two types ANN algorithms – no hidden layer, and two hidden layer – have been simulated and considered for the same data sets. The algorithm using two hidden layers have been used as well as the optimal structure for analogue modulation recognition of real signals.

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