APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS IN INSTRUMENTATION

by

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Dedicated to Almighty

for providing me great teachers, loving parents

and for being by my side always.....

Certificate

This it to certify that the thesis entitled "*Applications of Artificial Neural Networks in Instrumentation*" being submitted by Shakeb Ahmad Khan for the award of the degree of the **Doctor of Philosophy** to the Indian Institute of Technology, Delhi, is a record of the bonafide research work he has carried out under our supervision. The results contained in this thesis have not been submitted to any other University or Institute for the award of a degree or diploma.

17/2/05

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Abstract

An Artificial Neural Network (ANN) is an information-processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. ANNs, like humans, learn by example. An ANN is configured for a specific application, such as pattern recognition or data classification, through a learning process.

Neural networks, with its remarkable ability to process complex data using very simple methods, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. This expert can then be used to provide projections given new situations of interest and answer "what if" questions.

In this thesis an attempt has been made to investigate the application of ANN in following two important instrumentation situations;

(a) sensor linearization in the field of transducer instrumentation and

(b) advanced triggering in digital oscilloscopes for measurements involving complex waveforms.

In the first problem (a) above can be tackled by an ANN based inverse modeling technique for sensor response linearization. The choice of the order of the model and the number of the calibration points are important design parameters in this technique.

These important parameters were missing in earlier works. The thesis addresses this important and widely needed requirement by categorizing the wide range of sensors on the basis of extent of nonlinearity and gives guideline to chose the order of model and number of required training data points. An intensive study of the effect of the order of the model and number of calibration points on the lowest asymptotic Root Mean Square (RMS) error has been reported in this thesis. This thesis explains how to fix the order of the model, and the number of calibration points, based on the non-linearity of the sensor and the required RMS error. The number of epochs needed to calibrate the sensor (train the network), and thereafter the epochs needed to recalibrate in event of sensitivity or offset drifts are also presented to bring out the convergence time of the technique. More importantly, the advantages of the ANN technique over traditional regression based modeling are also discussed from the point of view of its advantage in hardware simplicity in micro-controller based implementation. Results presented in this thesis would be of interest to design engineers in the field of instrumentation.

The second problem presents a new scheme for oscilloscope triggering on complex waveforms that are challenging even today. Based on the Associative memory technique, and utilizing a new weighted Hamming distance parameter, this technique is capable of providing stable oscilloscope triggering even for complex waveforms where the commonly used voltage level triggering method fails to perform adequately. The proposed technique has been verified by exhaustive simulations using MATLAB® and Xilinx Foundation Series softwares. Further, the technique has been implemented and validated on XCV300EPQ240 Field Programmable Gate Array (FPGA) device, and has given successful initial results using several different kinds of test waveforms.

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