MADALINE RULE II: A TRAINING ALGORITHM FOR NEURAL NETWORKS.

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A new algorithm for training muti-layer fully connected feed-forward networks of ADALINE neurons has been developed. Such networks cannot be trained by the popular back-propagation algorithm since the ADALINE uses the nondifferentiable signum function for its nonlinearity. The algorithm is called MRII for MADALINE Rule II.

Previously, MRII sucessfully trained the adaptive descrambler portion of a neural network system used for translation invariant pattern recognition[1]. Since then, studies of the algorithm's convergence rates and its ability to produce generalizations have been made. These were conducted by training networks with MRII to emulate fixed networks.

A fixed network, acting as a teacher, provides desired responses for the net being trained. MRII trains the adaptive net to emulate the input-output mapping of the teacher. This training is conducted using only a small number of the patterns available in the input space. Once trained, the adaptive net's responses to patterns it has not been trained on are compared to the fixed net's responses to see if it has truly generalized. MRII has demonstrated its ability to produce useful generalizations when trained on as little as one percent of the input space patterns.

The basic operation of the MRII algorithm is contained in the principle of *minimal disturbance.* During training, the algorithm makes no changes to the network when it responds correctly to an input. When an error occurs, a minimum amount of change in the network's weights is made to correct the erroneous response. New patterns are accommodated in a way that least disturbs the solution established by previous input patterns.

When correcting errors in a two layer network, MRII begins by adjusting the first layer ADALINEs. Those first layer ADALINEs whose responses are least confident are put through a series of trial adaptations in which their current outputs are reversed. The trial adaptations start by reversing the output of one ADALINE at a time, beginning with the least confident one. If a trial adaptation reduces the number of output errors, the weights are changed to implement the trial. If no reduction in errors occur, the response of the trial unit is returned to its previous value. If errors remain after all possible single unit trials are made, the ADALINEs are trial adapted two at a time. If errors remain after the exhaustion of pairwise trials, 3-wise, 4-wise, etc., trials are made. After doing as well as can be done on the first layer, any remaining errors are corrected by adapting the second layer ADALINEs.

This paper will present the principles and experimental details of the MRII algorithm. Typical learning curves will show the algorithm's efficient use of training data. Architectures that take advantage of MRII's quick learning to produce useful generalizations will be reported.

[1] B. Widrow, R. Winter, R. Baxter, "Learning phenomena in layered neural networks," in *IEEE First Annual International Conference on Neural Networks*, 1987.