

# A NONLINEAR SYNAPSE NEURAL NETWORK AND ITS APPLICATIONS

by

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1. Neural network
2. Artificial neural network

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*Dedicated to my mother  
who did not stay to see me earn my Ph.D.*

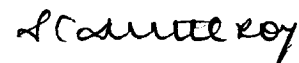
# Certificate

This is to certify that the thesis entitled 'A Nonlinear Synapse Neural Network and its Applications' submitted by Syed Atiqur Rahman, is worthy of consideration for the award of the degree of Doctor of Philosophy, and is a record of the original bonafide research work carried out by him under our guidance and supervision, and that the results contained in it have not been submitted in part or full to any other University or Institute for award of any other degree.

  
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## **Acknowledgment**

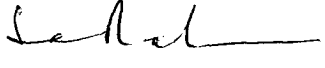
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(Syed Aliqur Rahman)

## **Abstract**

Rapid advances in computational power and techniques have in turn stimulated manifold increase in the range and complexity of problems to be solved. Tasks like pattern recognition, combinatorial optimisation, and aerodynamic simulation have tested the limits of conventional serial computation. Artificial Neural networks, a highly parallel architecture, emerged as a new paradigm for solving computationally intensive tasks, using collective computation in a network of neurons.

Feedback neural networks were extensively explored after the concept of Lyapunov or 'energy' functions, as a means of computation, was introduced by the work of Hopfield and Tank in the 1980's. Their architecture, called the Hopfield Network, had a single layer of nonlinear neurons with linear feedback. It was implemented in hardware and became very popular, especially as a model of analog circuit computation. However, attempts to apply Hopfield Networks in practical applications have revealed many difficulties. These include convergence to infeasible solutions and the requirement of a large number of neurons and interconnection weights. These drawbacks led us to explore alternative neural network architectures.

In this thesis, we have developed a new class of neural networks, which employ nonlinear feedback, and is termed as Nonlinear Synapse Neural Network (NOSYNN). The use of nonlinear synapse leads to a NOSYNN 'energy' function that involves transcendental functions, which is fundamentally different from the earlier quadratic form of energy function associated with Hopfield Network and its variations. Moreover the neuron states lie in the interior of hypercube, rather than at its corners. The use of a

real valued neuron output allows very compact and novel representations in the context of combinatorial optimisation problems.

The proposed network, NOSYNN, has been applied to classical computational problems such as Graph Colouring and Ranking. A graph colouring network that uses  $N$  neurons to solve an  $N$  node graph, has been developed. This is to be compared with the requirement of  $N^2$  neurons in Hopfield networks. The proposed network has been implemented in hardware and always converges to feasible solutions. With the objective of improving the solution quality, another colouring network belonging to the NOSYNN class, but with synapses having greater hardware complexity has been proposed. The increased cost of hardware is justified by the reduction in the number of colours. Another application of NOSYNN, for ranking  $N$  numbers using a network of  $N$  neurons, ideally converges in  $O(1/N)$  time. In the presence of non-idealities, ranking is achieved in  $O(1)$  or constant time for large  $N$ .

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