MATHEMATICAL MODELLING OF HIDDEN LAYER ARCHITECTURE IN ARTIFICIAL NEURAL NETWORKS

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Degree of Doctor of Philosophy

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief, it does not contain any material previously published or written by another person except where the acknowledgement made is made in the text.

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The above candidate has carried out the research for the PhD thesis under my supervision.

Signature of the supervisor: Date:

Dedicated to

My beloved Father and Mother

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Abstract

The performance of an Artificial Neural Network (ANN) strongly depends on its hidden layer architecture. The generated solution by an ANN does not guarantee that it has always been devised with the simplest neural network architecture suitable for modeling the particular problem. This results in computational complexity of training of an ANN, deployment, and usage of the trained network. Therefore, modeling the hidden layer architecture of an ANN remains as a research challenge. This thesis presents a theoretically-based approach to prune hidden layers of trained artificial neural networks, ensuring better or the same performance of a simpler network as compared with the original network.

The method described in the thesis is inspired by the finding from neuroscience that the human brain has a neural network with nearly 100 billion neurons, yet our activities are performed by a much simpler neural network with a much lesser number of neurons. Furthermore, in biological neural networks, the neurons which do not significantly contribute to the performance of the network will naturally be disregarded. According to neuroplasticity, biological neural networks can also solicit activations of neurons in the proximity of the active neural network to improve the performance of the network. On the same token, it is hypothesized that for a given complex-trained ANN, we can discover an ANN, which is much more simplified than the original given architecture.

This research has discovered a theory to reduce certain number of hidden layers and to eliminate disregarding neurons from the remaining hidden layers of a given ANN architecture. The procedure begins with a complex neural network architecture trained with backpropagation algorithm and reach to the optimum solution by two phases. First, the number of hidden layers is determined by using a peak search algorithm discovered by this research. The newly discovered simpler network with lesser number of hidden layers and highest generalization power considered for pruning of its hidden neurons. The pruning of neurons in the hidden layers has been theorized by identifying the neurons, which give least contribution to the network performances. These neurons are identified by detecting the correlations regarding minimization of error in training. Experiments have shown that the simplified network architecture generated by this approach exhibits same or better performance as compared with the original large network architecture. Generally, it reduces more than 80% of neurons while increasing the generalization by about 30%. As such, the proposed approach can be used to discover simple network architecture relevant to a given complex architecture of an ANN solution. Due to its architectural simplicity, the new architecture has been computationally efficient in training, usage and further training.

Keywords: Artificial neural networks, backpropagation algorithm, delta value, hidden layer architecture, neuroplasticity

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Abbreviations

ADALINE – Adaptive linear neuron

AI – Artificial Intelligence

ANN – Artificial neural network

Bi-search algorithm – Binary search algorithm

CNS – Central nervous system

$\gamma_{\delta_h,E}$ – Correlation coefficient of the sum of the delta values of h^{th} hidden layer and the output error

etc. – etcetera

i.e. – That is

LTD – long term depression

LTP – long term potentiation

MADALINE – Many ADALINE

MBP – Magnitude based pruning

MLP – Multilayer perceptron

MRI – The Magnetic Resonance Imagine

NN – Neural network

OBD – Optimal brain damage

OBS – Optimal brain Surgeon

PNS – Peripheral nervous system

PSA – Peak search algorithm

PSDV – Peak search and delta value algorithm (The proposed algorithm)

RBF – Radial basis function

SOM – Self Organizing Map

SVZ – Sub ventricular zone