Evolutionary Wavelet Neural Networks in Data Classification and Dynamic Control

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Declaration of Authorship

Statement of Originality

I, Maryam Mahsal KHAN, hereby certify that the work embodied in the thesis is my own work, conducted under normal supervision.

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Abstract

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A wavelet neural network (WNN) is a combination of a neural network with wavelet functions, and belongs to a special class of neural networks in the field of machine learning. The interesting aspect of this type of network is that it has a single hidden layer. The advantages of such an inherent property are two-fold: fast convergence speeds and easy assessment of each neuron's contribution towards prediction.

Despite the above advantages of WNNs, the optimisation of their parameters and the estimation of the number of hidden neurons have significant effects on their performance. Not all WNN parameters are easily differentiable and are therefore usually excluded from the training process. Currently, standard gradient-based algorithms are used to optimise the different parameters of networks. Moreover, the initialisation of hidden neurons plays a critical role in capturing the variability of data.

Evolutionary algorithms have been used as a gradient-free optimisation method in many research problems where differentiability is unavailable or derivatives are unreliable or impractical to obtain. Thus, evolutionary algorithms was the effective choice for WNN parameter optimisation. Furthermore, in order to devise a bloat-free evolutionary programming method, a Cartesian genetic programming (CGP) model was used. Such models are based on the concept of using and evolving fixed resources

such as nodes and their connections links. This phenomenon proves beneficial where adaptability of hidden neurons is required, as its quantification varies from one system to another.

The proposed evolutionary WNN (EWNN) was first applied to a standard two-spiral task. This benchmark task provided a clear understanding of the operation and response of EWNNs, which highlights their potential for separating non-linear classes.

An EWNN was then applied to the classification of three publicly-available biomedical datasets on breast cancer and Parkinson's disease. The process of feature pruning during the evolutionary process, and the effects of training all of the network parameters, were studied in detail.

To further improve the classification performance of EWNNs, an ensemble EWNN (EWNN-e) was proposed. In this method, a genetic algorithm was used to prune trained EWNN classifiers for the three previously-investigated datasets. The EWNN-e was found to be even more accurate than the independent EWNN classifier.

The performance of EWNNs in learning patterns of control behaviour in a benchmark control problem —the acrobot— was the final focus of this thesis. The performance of any reinforcement learning algorithm is dependent on the space domain it operates in, i.e. discrete or continuous, whereby a discrete action space is significantly less challenging than a continuous one. In the context of EWNNs, both discrete and continuous action spaces were investigated. The performance of EWNNs were compared with the state-of-the-art deep RL algorithm. The EWNNs produced robust acrobot controllers that were independent of the type of action space domain.

Keywords: Wavelet neural networks, Cartesian genetic programming, prediction models, intelligent controllers.

Contents

List of Figures

List of Tables

List of Abbreviations

ANN	**A**rtificial **N**eural **N**etwork
CGP	**C**artesian **G**enetic **P**rogramming
CGPANN	**C**artesian **G**enetic **P**rogramming **A**rtificial **N**eural **N**etwork
DDSM	**D**igital **D**atabase of **S**creening **M**ammography
DNN	**D**eep **N**eural **N**etwork
EWNN	**E**volutionary **W**avelet **N**eural **N**etwork
EWNN-e	**E**volutionary **W**avelet **N**eural **N**etwork **E**nsembles
LCA	**L**atent **C**lass **A**nalysis
NEAT	**N**euro **E**volution of **A**ugmented **T**opology
NN	**N**eural **N**etwork
PD	**P**arkinson's **D**isease
RL	**R**einforcement **L**earning
SVM	**S**upport **V**ector **M**achine
TRPO	**T**rust **R**egion **P**olicy **O**ptimization
WNN	**W**avelet **N**eural **N**etwork
WT	**W**avelet **T**ransform