Evolutionary Networks for Multi-Behavioural Robot Control

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Abstract

Artificial Intelligence can be applied to a wide variety of real world problems, with varying levels of complexity; nonetheless, real world problems often demand for capabilities that are difficult, if not impossible to achieve using a single Artificial Intelligence algorithm. This challenge gave rise to the development of hybrid systems that put together a combination of complementary algorithms. Hybrid approaches come at a cost however, as they introduce additional complications for the developer, such as how the algorithms should interact and when the independent algorithms should be executed. This research introduces a new algorithm called Cascading Genetic Network Programming (CGNP), which contains significant changes to the original Genetic Network Programming. This new algorithm has the facility to include any Artificial Intelligence algorithm into its directed graph network, as either a judgement or processing node. CGNP introduces a novel ability for a scalable multiple layer network, of independent instances of the CGNP algorithm itself. This facilitates problem subdivision, independent optimisation of these underlying layers and the ability to develop varying levels of complexity, from individual motor control to high level dynamic role allocation systems. Mechanisms are incorporated to prevent the child networks from executing beyond their requirement, allowing the parent to maintain control. The ability to optimise any data within each node is added, allowing for general purpose node development and therefore allowing node reuse in a wide variety of applications without modification. The abilities of the Cascaded Genetic Network Programming algorithm are demonstrated and proved through the development of a multi-behavioural robot soccer goal keeper, as a testbed where an individual Artificial Intelligence system may not be sufficient. The overall role is subdivided into three components and individually optimised which allow the robot to pursue a target object or location, rotate towards a target and provide basic functionality for defending a goal. These three components are then used in a higher level network as independent nodes, to solve the overall multi-behavioural goal keeper. Experiments show that the resulting controller defends the goal with a success rate of 91%, after 12 hours training using a population of 400 and 60 generations.

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Chapter 1

Introduction

As the technological world further develops into unexplored territory due to consumer requirements or research breakthroughs in varying fields, additional requirements and constraints are placed upon computer systems for complicated behaviours, analysis or detection algorithms. Artificial Intelligence is a mainstream solution for these increasing requirements, however often the requirements set by these industries are beyond the scope of any single Artificial Intelligence algorithm. This limitation incites further research to develop hybrid algorithms or use a combination of multiple intelligent architectures to meet the expectations placed upon developers and researchers alike. Hybrid systems introduce considerations as to how these algorithms should interface with one another and using multiple intelligent systems to solve a problem introduces further decisions as to under which conditions these algorithms should be independently executed.

Genetic Network Programming was introduced by Katagiri et al.[5], this algorithm is a network of nodes connected to one another in a directed graph. These nodes can be either Judgements for branching and decision making, or Processing nodes for actions or interfacing with the environment they are designed for. This algorithm has found success in solving agent based systems[5, 6], double-deck elevator control systems[7] and some robotic applications[9, 10].

This Genetic Network Programming architecture has the ability to optimise the connections between these nodes and the node types themselves from a predefined library of potential node types. While this algorithm efficiently finds solutions for the required tasks the networks are designed for, the networks themselves are limited by the contents of the node library. The contents of the node library are specifically designed for the problem that the network is to achieve, increasing the required programmer development time to specialize nodes to this task. For complicated behaviours with a large number of objectives, the networks designed using this algorithm will become complicated for human interpretation.

The research discussed within this thesis proposes the Cascaded Genetic Network Programming architecture that is significantly modified from the original, to facilitate multiple layers of network structures with varying complexity, general purpose nodes reducing the need for problem specific node development and the optimisation of internal node data to exceed the limitations of predefined node libraries. This new architecture bridges the gap between different Artificial Intelligent systems, by treating them as independent nodes within a network and handles problem complexity, by allowing subdivision of any task into a new Cascaded Genetic Network Programming layer.

This new architecture is applied to the goal keeper behaviour in robot soccer, where the environment is repeatedly changing and the goal keeper must adhere to multiple objectives in order to efficiently defend the goal. The goal keeper problem is one possible case where multiple artificial intelligent systems are required to achieve the overall objective with a high success rate. To aid in the training optimisation a simulation environment is implemented to accurately represent the platform at Massey University, this is done by utilizing realistic physics and accurately representing the shape of the robot and environment. The goal keeper controller developed in conjunction with this research could be used in the Massey University robot soccer team for the FIRA MiroSot Middle League[12] competition.

1.1 Research Objectives

The primary objective of this thesis is to enhance the Genetic Network Programming architecture for environments that require multiple objectives, allowing it to extend to problems that are too complicated for the original. This new architecture should allow GNP to cascade into multiple sub-layers and allow more general purpose nodes to be developed by optimising the data internal to every node, these general purpose nodes will then be applicable to any problem thus reducing any required programming time. To test the capabilities of this new architecture a real life applicable, multi-behavioural goal keeper controller for the Massey University robot soccer platform is developed. It should have a high success rate when defending the goal, remain within the goal area so that it isn't left undefended and be able to reposition itself if knocked out of the goal area.

1. Develop a Cascading GNP architecture that facilitates subdivision of Artificial Intelligence problems into smaller, manageable tasks by allowing CGNP's to be contained within another in a complex multilayer network.

2. Investigate the current GNP architecture and make any changes required to allow a full object orientated design that can easily integrate any Artificial

Intelligence algorithm as either a processing or judgement node.

3. Develop a method to allow trained CGNP networks to be saved and imported into another CGNP network as a pre-trained Artificial Intelligence node for either processing or judgement.

4. Develop a method to represent all the node properties in a chromosome and provide an interface for future node development.

5. Develop a robot soccer simulation which accurately represents the FIRA MiroSot platform, using a full-fledged physics engine.

6. Build a platform independent C++ library for the new CGNP architecture.

7. Develop an interface that can bind the simulation environment with the CGNP architecture and allow modification to the CGNP properties for each node.

8. Prove that the CGNP architecture can be used to identify and fix issues in pre-existing AI systems.

9. Train and test the new architecture on a complex multi-behavioural controller such as the robot soccer goal keeper.

1.2 Significance of the Research

This research investigates the use of the Genetic Network Programming architecture for complex tasks where multiple objectives must be met and shows a modified implementation of the architecture that will significantly improve the development times of future AI research and allow trained AI systems to be reused in other applications. The GNP architecture can be used to solve problems or to improve existing solutions developed using any AI algorithm.

To aid in the re-usability of GNP systems a new approach is implemented to allow GNP to cascade into multiple layers of independent GNP systems, where a pre-trained system (or even untrained) can be treated as a node within another GNP, this allows complex behaviours to be designed and trained using predefined sub-behaviours. Since GNP is inherently a diverse algorithm, by using it to solve generic problems the resulting systems can be easily reused in other applications within the same scope, therefore there is no need to create a new controller to move a new robot if one has already been created for another.

This research is undertaken due to the recent research by Wenhan Wang[10] at Massey University, while he used the GNP architecture with Reinforcement Learning nodes he did not optimise data within Judgement nodes or other Processing nodes. Within his research long training times were encountered for a Target Pursuit with Wall Avoidance system. This research further extends on Wang's research by allowing all data within nodes to be optimised regardless of type, develops the new Cascading GNP architecture and develops a robot soccer goal keeper, which is considered to be a more complicated behaviour than Target Pursuit with wall Avoidance.

1.3 Scope and Limitations

This research is directly applicable to the FIRA MiroSot Middle League[12] environment however, with modifications the GNP architecture could be applied to any AI based application including but not limited to, stock markets, game development or other robot controllers.

Within the robot soccer simulation, only two dimensions are simulated and therefore does not take into consideration any situation where the ball or robot bounce or jump, nor in the situation where a robot is somehow pushed onto its side.

This research does not consider AI systems that transmit data to others, therefore all nodes act independently. Data transmission between nodes could be implemented and would be a useful feature, this is further discussed in the Further Research section (Section 8.2.1).

As Genetic Algorithms are used within the GNP architecture, there is no guarantee that the best solution will be received. However with a large enough population and number of generations, the optimisation algorithm will find a solution that can solve the problem assuming a well defined objective function is used.

1.4 Structure of the Thesis

This thesis begins with an introduction to two relevant intelligent systems; Fuzzy Logic and Genetic Algorithms, both of these are used regularly throughout the controller design process. Next a detailed review on the current Genetic Network Programming architecture, other approaches to complete the goal keeping behaviour and other relevant research. Then the software design and implementation is explained with descriptions and examples from the external libraries that are used in this application. Following this is a chapter that describes the simulation platform developed in conjunction with this research and specific design considerations.

Chapter 6 discusses the original GNP architecture and then all modifications required to produce the desired Cascaded GNP architecture. Chapter 7 covers the controller designs for Target Pursuit, Target Rotation, basic Goal Defending and the Multi-Behavioural Goal Keeper, this chapter discusses each component in detail and how they could be further improved. Lastly the conclusions of the research, a summary of the achievements made by this research and a series of future research topics using CGNP and other components of this research.