Combining Genetic Algorithms and Fuzzy Logic for Improved Robotics Control

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Abstract

Reliable control of robots in a changing environment may include a lengthy training process, resulting in specialising expected behaviour. This removes autonomy, a trait desired in robotic installations to enable rapid decision-making when assessing varying inputs. Investigating the combination of Genetic Algorithm learning with Fuzzy Logic control, a theoretically sound Fuzzy Logic system is tested at failure points before being improved using a rudimentary Genetic Algorithm. As a final test, the robotic movement controller successfully avoids six objects at varying distances and angles. Previous studies focus on creating movement controllers to fit constraints such as a limited on-robot processing capabilities [1] or include complex mathematic equations [2]. This paper focuses on the simplification of the Fuzzy Logic parameters in an effort to make a learning robot controller more accessible to users without a computer science background. The resulting research may be applied to real-life situations requiring reliable movement where the full range of test scenarios may be either too time consuming or difficult to assess. This research focuses on the example of training robotic object avoidance behaviour on a FIRA Mirosot robot soccer field. OpenGL graphics in combination with Box2D physics ensures high quality testing which is comparable to real-life training.

1. Introduction

The current state of genetic algorithm based learning systems immediately raises a barrier to individuals unfamiliar to Artificial Intelligence concepts. Creating a reliable fitness function is often a time consuming task, relying on trial and error with many complex intermediary calculations [2]. This project aims to test the feasibility of simplifying Genetic Algorithm componentry. This would enable robotic installations to be easily trained using a simple set of rules, while the simulated backend program fine-tunes the final Fuzzy System. The scope of this research will include two-wheeled robotic movement, specifically the avoidance of objects. While it is expected that a Genetic Algorithm based system could accommodate for external factors such as continued sensor interference or loss of traction, this project assumes that any physical implemented robot has accurate sensors and steady traction.

1.1 Objectives

The purpose of this project is to explore the feasibility of incorporating Genetic Fuzzy algorithm components with Fuzzy Logic control to create a self-correcting robotic movement controller.

The training environment should provide realistic physics, visual feedback and options to compare both hand-trained and genetic-trained controllers at runtime.

Ideally, the robotics controller should be able to train using basic instructions. Providing complex fitness functions which include weighted averages and complex-to-calculate distances or angles creates a well trained system, however this report will focus on the opposite – how well can the system train given very few parameters?
In a real robotic implementation, the robot may be given a rather simple rule set, for example “Don’t crash into the walls”. A rule set like this may be given a fitness function that simply counts the number of times a robot collides with the wall, and attempt to minimise this.

Using a simulated training environment enables all possible tests of a system to be analysed without physical damage to the robot or environment.

1.2 Problem Domain

This project will attempt to improve a hand-created Fuzzy Logic controller using the Genetic Algorithm training environment with a very simple fitness function.

The specific example that this project will implement is a robotic object avoidance system. Results from both stationary and moving objects will be analysed in order to judge the effectiveness of the collision avoidance, with the final conclusion noting the minimal amount training required.

1.3 Research Significance

Combining evolutionary algorithms with robotic behaviour is not a particularly new research field, as other papers have covered many different algorithms using various forms of implementation (see section 2) [2] [3] [4]. This research is significant due to the emphasis on simplifying the genetic components in order to make the genetic training aspects more accessible to end users.

Completing a robotic installation in a consumer or business environment requires complex training procedures specific to each environment [1]. A robot that navigates office hallways requires different object avoidance parameters compared to one that stacks shelves in a warehouse, for example. The end user – someone who does not necessarily have an Artificial Intelligence, physics or mathematics background, would likely need to adjust these parameters to create the highest quality controller specific to the environment.

The outcome of this research aims to determine if simplifying the genetic components still outputs an improved robotics controller. This would assist users in improving robotic installations by supplying a simple fitness function, such as “don’t collide with the other objects”.

Using a simulated testing environment, thousands of tests can be run on different genetic parameters to determine the best controller. This controller can then be implemented into the physical robot once processing has been completed, immediately improving the robot movement behaviour.

1.4 Research Scope and Limitations

- Test a theoretically sound Fuzzy Logic object avoidance controller at points of weakness
- Implement a simple genetic algorithm training solution to improve the robotic movement
- Limit genetic training to a small amount of processing time in order to further emphasise the controller improvements
- Reassess the genetically trained controller and provide any improvement in a measureable statistic
- Limit the current scope of the genetic algorithm to the Fuzzy Membership functions, focusing on robotic behaviour compared to speed or smoothness
- Assume the controller is enabled and disabled at the correct time, within a certain object distance or angle

6. Conclusions and Future Research

6.1 Final Conclusions

A hand-created Fuzzy Logic controller designed to avoid objects exhibits improved behaviour after training using a purposely-simple genetic fuzzy algorithm.

Providing the genetic algorithm with realistic simulation ensured high quality training data, able to improve a Fuzzy Logic system with a very simple fitness function. The fitness function, effectively “minimise the number of times a robot collides with an object”, delivers enough feedback to train the Fuzzy System relatively quickly without the use of complex mathematic equations.

Generating a Fuzzy Logic control system that provides a stronger emphasis on turning away from objects at a certain angle would be difficult and time consuming for a manually trained system to refine. The use of realistic computer simulations also enables the testing of many different situations, some which may not be possible to test in a real-life environment without a high time or financial cost.

These specific results obtained in this research further strengthen the feasibility of using such a system by training one system for a multitude of tests. Both the Dynamic Object testing and Static Object testing showed improvement, however only the dynamic layout was used for training. Once successfully trained, the same Fuzzy System was applied to the static layout – essentially a completely different test with similar positive results.

6.2 Future Research

Continuing the study and development of an accessible Genetic Fuzzy controller, the following ideas could be extended:

- Complete genetic representation of the Fuzzy System
- Fuzzy System Rule optimisation
- Standardised test layouts
- Simulated failures

Extending the genome to include the fuzzy membership associative matrix in addition to the membership rules will increase processing time as the Genetic algorithm has additional parameters to test. The benefit of increasing the gene size and training time compared to controller reactions would require comprehensive testing, as this would likely improve the smoothness of system reactions which would be difficult to measure in a simulation environment.

Optimising Fuzzy Rules could be an effective way to reduce the system size, for implementing on a smaller robotic controller – similar to Godjevacs’ study in section 2.2. This would be executed by proving a ‘weight’ of zero or one to each rule, adding these weights to the genome. Similar to the complete Fuzzy System representation above, this would increase the training time of the Genetic Algorithm. If system implementation to a smaller processor were required, the benefits of optimising the Fuzzy Rules would outweigh any addition to processing times.

Creating a standardised testing layout for the systems would be closely related to the specific implementation of a system. In this research, generic tests for object avoidance are used for training. The final test in section 6.1 demonstrates a specific test for this implementation of robot soccer. Different test layouts may be considered for movement controllers, for example navigating a warehouse with large shelving racks, or busy office environment with unpredictable environment movement.

Simulating failures, for example a loss of traction or systems failure may also be an interesting system extension. Due to the nature of genetic algorithms, a controller trained for long enough may develop a tolerance to a sustained handicap. An example may be a processing delay, requiring the controller to react faster with a stronger output, or a physical impairment such as a large turning radius. Intermittent issues such as a surface that is only sometimes slippery may require a more complex system if the expected behaviour is vastly different to the trained normal.

6.3 Summary of Achievements

- Proved the feasibility of improved Fuzzy Logic robotic movement control using a specifically-rudimentary Genetic Algorithm system
    - Use of simplistic fitness function
    - Improvements seen based on a theoretically sound ‘hand-created’ Fuzzy Logic system
- Used a high quality off-screen physics engine to provide realistic simulation for fast training
- Explored different Genetic Algorithm parameters, creating a balance between training time and expected output
- Implemented a bias into the Fuzzy Membership function, ensuring the robot always turns away from an object
- Designed a realistic display to visualise the training environment using OpenGL, integrating with the Box2D physics engine
- Designed a User Interface using the cross-platform rapid development tools of Qt Creator