Project Final Report

Society of Mind Robot

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by

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Society of Mind Robot

Abstract

This work presents an implementation of a cognitive architecture for control of an autonomous robot that is based on a theory of natural intelligence. The architecture is called Society of Mind and is a multi-agent system. Each agent in the system is responsible for a simple task and has limited intelligence. Through the interactions of these simple agents intelligent behaviour emerges. This project seeks to demonstrate this and show that the Society of Mind is a viable option as a controller for robots. It will also show the advantages and disadvantages of this architecture. Also presented in this work is a more advanced, although incomplete, version of the architecture called K-line architecture. This architecture allows for the custom creation of agents and would be the foundation for a Society of Mind robot that can learn.

Keywords: *autonomous robot, cognitive architecture, society of mind, multi-agent system*

1 Introduction

The purpose of this document is to explain the working of the Society of Mind architecture and demonstrate its functionality. This document is intended to be read by someone with basic knowledge of computer science and an interest in cognitive science, artificial intelligence, philosophy of mind and robotics.

The aim of this project is to create a society of mind robot; this is a collection of independent micro-agents, of limited intelligence, that work together allowing the robot to exhibit complex, intelligent behaviours. At the start this will require the creation of automata that cause the robot to exhibit simple behaviours such as approaching an object or avoiding an object. Automata in this context can be defined as Finite State Machines; they will be simple, having only a few states, reactive and will be self-operating. Once these are created they can be built upon by creating a simple agent that can turn specific ones, such as avoidance or approach, off and on in order to switch between behaviours. Then more agents can be added which are responsible for different tasks until the robot is capable of completing its goal in a given time frame.

1.1 Initial Brief

The original brief by D.N. Davis, as given in Appendix C, was as followed:

> *"This project will involve devising a Society of Mind controller for one of the simulated platforms. This could then be tested on real robots if time allows. There is room for negotiation on the specification with this project."*

This brief, as given in Appendix D, was modified to:

> *"This project will involve devising a Society of Automata that can be used as the basis for a Society of Mind controller for the Mobile Robotics platform (ARIA and MobileSim). If time allows this could then progress into the creation of a Society of Mind controller and testing on a real robot. The goal of the robot will be to find, identify and kick a ball. These three tasks require a set of robotic behaviours to be designed and implemented to achieve this. The requirement analysis will identify what behaviours are required. Testbed parameterisation will be used to evaluate the success of the implemented designs."*

The modifications made to the brief make it more specific, stating what platform will be used and give a better idea of how the project is intended to progress. It also now states the goal of the robot, how that goal will be achieved and how its success or failure will be evaluated.

1.2 Context

The general context for this project is robotics and artificial intelligence; two very closely related fields that have a lot of real world uses. The project itself demonstrates a theory of natural intelligence, developed by Marvin Minsky [MINSKY, 1988], that has been shown to work previously in other works and is very adaptable. It has been used to tackle the anchoring problem [GWATKINS, 2009] and to play a game of 5-a-side football [BOURGNE, 2003]. The basic idea behind the theory is "intelligent behaviour can be viewed as a combination of more simple behaviours" [VENKATAMUNI, 2008, p. 2] and that through the interactions of the simple behaviours emerges the intelligent behaviour. The simple behaviours are performed by agents that have limited intelligence. It is a key point in the theory that none of the agents themselves are intelligent because if one were then the theory would "end up resembling the nineteenth-century 'chessplaying machine' that was exposed by Edgar Allan Poe to actually conceal a human dwarf inside" [MINSKY, 1988, p. 23]. In other words, having an intelligent agent would not show that intelligent behaviour emerges from the interactions of simple agents but that it emerges from that one agent. This is why Minsky states that "whenever we find that an agent has to do anything complicated, we'll replace it with a subsociety of agents that do simpler things" [MINSKY, 1988, p. 23]. These subsocieties of agents are called Agencies [MINSKY, 1988]. The hierarchy of a society of mind is analogous to a human administrative organisation [MINSKY, 1980] in that on the large scale there are departments and divisions which are made up of simpler parts that are specialised for certain tasks and that when these simpler parts work to do their individual tasks the tasks of the department get done. This is another key part of a society of mind; that "if each does its own little job, the really big job will get done by all of them together" [MINSKY, 1988, p. 20]. Another key idea in the Society of Mind theory is K-lines. K-lines are how Minsky explains memories [MINSKY, 1980]. K-lines are a group of agents that "can be used to make records of what some of your brain-agents are doing at a certain moment" [MINSKY, 1988, p. 60] and that later by activating the same K-lines at a later date you restore the recorded agents to their previous state. This causes them to act like they did then which causes other parts of the mind to react as though the same events were happening [MINSKY, 1988] which would be the process we call "remembering". This can be seen illustrated in Figure 1.

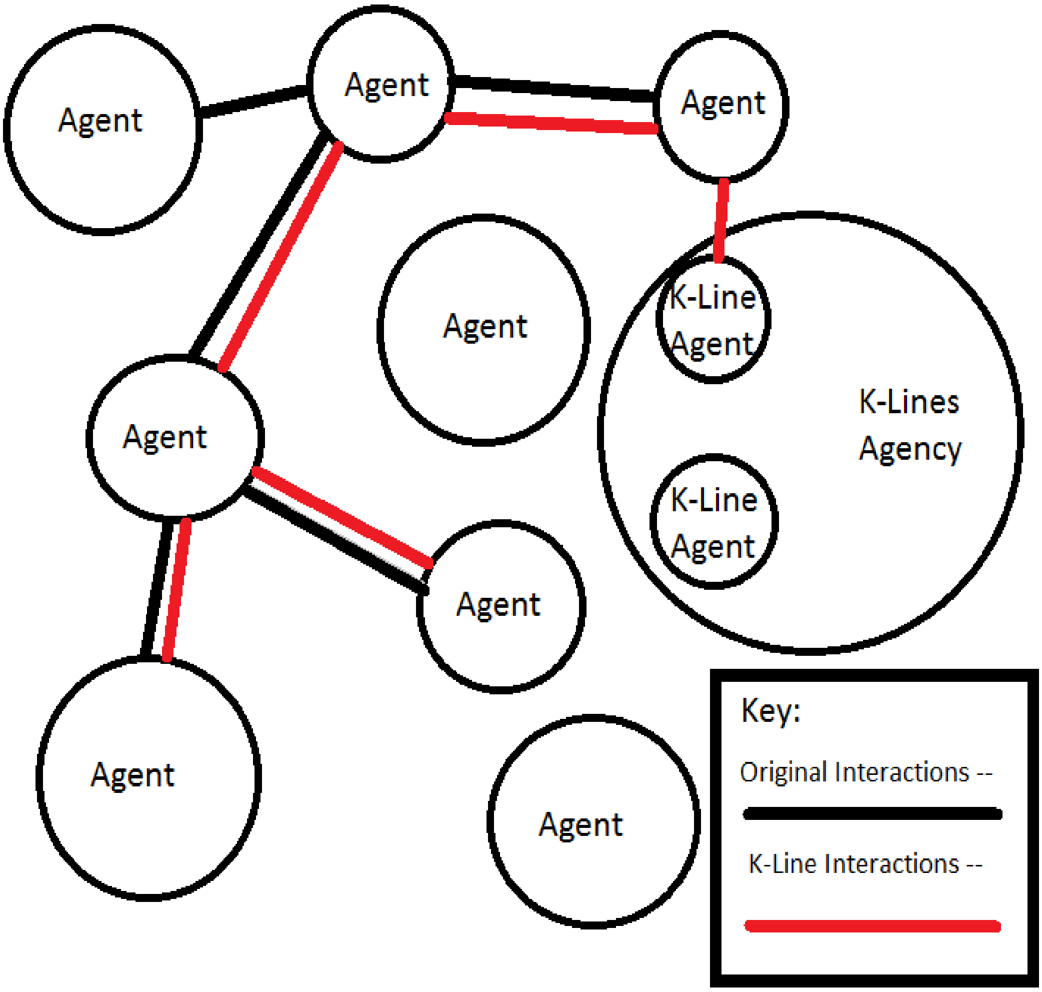

Figure 1. K-Line diagram

This work will not be innovative research but it will show practicable applications of the theory and the results should hopefully fit in with the results of others who have done similar work regarding a Society of Mind controller. Hopefully it will show that the Society of Mind controller can work to achieve its set goals in a reasonable time frame. It is very adaptable and very easy for others to build on it so this project can be used as the basis for a more complex system if desired.

1.3 Aim and Objectives

The aim of this project is to create a Society of Mind controller for a robot that is capable of finding a ball in a given environment. To test that this is achieved the robot will be placed into a bounded environment containing a barrier, another robot (turned off) and a ball. The robot will be expected to find the ball within fifteen minutes; if it does so then it has achieved its goal otherwise it has failed. It is important to note that because the simulation software is not very advanced the ball shall be represented by another robot. The simulation software also lacks physics simulation so when the society of mind robot does hit the other robot the effects of the hit shall be simulated by moving the robot representing the ball. Over the fifteen minute period the strength of each automata interaction will be recorded. This should allow for a graphical depiction of the robots flow of actions.

In order to achieve this goal it will have to achieve a series of lower-level objectives. One of these objectives is for the robot to be able to differentiate between what is a ball and what is not. This is important as the robot needs to correctly identify the ball in order to complete its main goal. If the robot cannot correctly differentiate between the ball and the other robot then it cannot be said that the robot has truly completed its goal of finding the ball if it does not know what it has found. This is because the robot could find the other robot and then behave like it had found the ball. From the robots perspective this would be seen as completing the goal but it is obviously a failure. If the robot were to find the ball in this scenario it would also appear as a success but still be a failure as the robot would have completed the goal of “find an object” and not “find the ball”; it would have just been lucky. Another objective that needs to be achieved is intelligent exploring or navigation. The robot needs to be able to navigate around its environment and not just go around in circles.

These objectives themselves will need lower-level objectives to be completed in order to be completed themselves. The differentiating-between-the-ball objective will require that the robot is capable of approaching, hitting, stopping, moving and observing whilst the navigation objective will require moving, stopping, approaching as well but also avoiding.

Each of the main individual sub-objectives will be tested in similar environments to the main one. They will be set up in either their own testbeds or the main testbed and run for a five minute period. Over the five minute period the strength of each automata interaction will be recorded for the sake of graphing the behaviour. This data can then be graphed and used to interpret the robots individual behaviours over the time period.

1.4 Report Structure

Following on from this section the report will cover the background of the project. This will talk about similar works in an attempt to give the reader a better understanding of the project. It will cover the research gone into the project and how this has affected the production of the software through discussing the technologies and algorithms used along with further elaborations on the theory behind it.

Next Chapter 3 will discuss the technical aspects of the project. This will include sections on the design of the software; what was required from it and designs for how this would be achieved along with how it will be tested. This will lead on to the actual testing of the software and an evaluation of the results.

The penultimate section, Chapter 4, is an evaluation of the project overall with focal points on how the project was managed, what was achieved and what else could be achieved that builds on this project.

Finally, the report will finish with a conclusion summarising everything up and concluding the report.

2 Project Background

This project is based on the theory of natural intelligence proposed by Minksy [MINSKY, 1988] as mentioned earlier. A simple summary of this theory is “that human intelligence and problem solving ability is derived from a large collection of independent affective, autonomous, cognitive and reactive actors…These actors handle atomic tasks within the biological or software system and interact with each other to handle more complex tasks” [ONG and WALCZAK, 2009, p. 1] or “views intelligence as emerging from the interactions of societies of simple, non-intelligent agents” [CANAMERO, 1997, p. 1]. For basic behaviours in this project there will be reactive agents such as the Avoidance agent. These are Braitenberg vehicles [BRAITENBERG, 1984] and an example can be seen in Figure 2. This is how most of the low-level agents work apart from the Observe Agent. The Observe Agents role is to observe changes in the environment and is in the system so that the robot can detect a moving ball. The Observe Agent uses standard deviation to detect significant changes.

This project is essentially about building a Multi-Agent System. An example of a Multi-Agent System would be OASIS [CIANCARINI and WOOLRIDGE, 2001] which is a system for scheduling aircraft and another is the BHS [HALLENBORG and RISAGER, 2007] which is a baggage handling system. These works are not inspired by the Society of Mind though. Some works that are inspired by the Society of Mind are Society of Agents Game Society [ONG and WALCZAK, 2009], A Society of Agents for Service Robots [AGIRRE IBARBIA, ESNAOLA and SMITHERS, 2010], the DUAL cognitive architecture [KOKINOV, 1994] and Modelling Motivations and Emotions as a basis for Intelligent Behavior[CANAMERO, 1997] . “The current implementation of the SOA Game Society is capable of playing: sudoku, kakuro, tic-tac-toe (TTT), three dimensional tic-tac-toe (3D-TTT), and work is progressing on caro” [ONG and WALCZAK, 2009, p. 2] shows that the Society of Mind approach has been implemented successfully and also successfully completes the goals it is given. Canamero’s work also shows some of the advantages of using a society of mind approach by saying “we will keep adding agents to our creature without modifying the existing ones – only their connections will grow more complex” [CANAMERO, 1997, p. 1]. The DUAL architecture is a hybrid symbolic/connectionist cognitive architecture which “is compatible with the Minsky’s Society of Mind metaphor” [KOKINOV, 1994, p. 1]. Similar to the society of mind it uses a number of small agents to produce the meaningful behaviour at a higher level but differs in the approach used [KOKINOV, 1994]. The DUAL architecture uses a hybrid approach which involves each agent having an L- and R-Brain which when “looking through an L-filter we see only he L-Brains of the agents and perceive the cognitive system as a symbolic machine, while looking through an R-filter we see only the R-Brains of the agent and perceive the cognitive system as a connectionist machine” [KOKINOV, 1994, p. 1]. It is, however, a multi-agent system similar to this project.

Other people have been working on implementing agent-based architectures to solve issues in robotics. MugiRo is a service robot that has its navigation system, called MiReLa, made up of a society of agents [AGIRRE IBARBIA, ESNAOLA and SMITHERS, 2010]. MiReLa can be seen as a success in that “Each of the agents developed for the MugiRo navigation system, can do very simple things, yet the result of them combined in a society, is a robot capable to navigate to different places in a workshop avoiding dynamic and static obstacles combining data from different sensor sources and capable to detect doors (closed or open) and go through them.” [AGIRRE IBARBIA, ESNAOLA and SMITHERS, 2010, p. 3519].

2.1 Comparison of Technologies

2.1.1 MobileSim and Mapper

MobileSim is the simulation software used in this project. It is a very straightforward program that is simple to use. Mapper is used to create a simple map with forbidden areas, lines for walls, starting areas for the robot(s) and goal(s). One of the main advantages of the software is that it was designed for use with the Amigo robot which, if time allows, will be the model of robot that the software will be embodied in. The main weakness with this software is the lack of physics simulation. The goal of this project requires the robot to hit a ball and observe the effects of this action. In an environment with no physics there will be no effect of hitting the ball which means the robot won't be able to tell the difference between hitting a wall and hitting a ball. This means that a way around this issue will have to be found such as using another robot as the ball and causing it to drive away when the robot hits it thus simulating the effect.

2.1.2 Microsoft Robotics Developer Studio

Microsoft Robotics Developer Studio is a package of software offering ways to program and test robots on a standard Windows PC. The main advantage and feature of this software is the simulation environment. It offers a 3D environment with working physics. This is advantageous for, as previously stated, the goal of the robot requires observing the effects of hitting a ball. The down side to this software is that is fairly complex and does not support the Amigo robot model although it does support a similar model made by the same company, the Pioneer robot, and offers the ability to create your own model [MICROSOFT, 2011].

2.2 Alternate Solutions

There are a lot of alternative architectures for basing a robot controller on such as EM-ONE, CAMAL and SOAR [VENKATAMUNI, 2008]. EM-ONE is perhaps the most interesting alternative options for a robot controller as it is "capable of reasoning about commonsense scenarios" [SINGH, 1998]. Theoretically this would allow the robot to achieve the goal set for this project but also allow for a team of robots to aid each other in finding a ball or playing a game of 5-a-side football. Another alternative solution is one that was used to play a game of 5-a-side football by using an affect-based multi-agent architecture [BOURGNE, 2003]. This used a similar approach but differed in the fact that it used a blackboard system and a coach agent to manage the other agents rather than having a collective of simple, limited intelligence agents that only interact with one another in a decentralised manner.

2.3 Comparison of Algorithms

There are a number of algorithms available for real-time obstacle avoidance and motion planning for robots. For example, there is a real-time obstacle avoidance modelled on the way locust escape danger [RIND et al, 2009] and Elastic Roadmaps which generate a path for the robot to follow in order to avoid obstacles [BROCK and YANG, 2009]. These were fairly complex solutions to the problems and computationally expensive. Another algorithm that could have been implemented was the sequence learning mechanism that "can be completed even by a small palmtop computer" [GOTO et al, 2010]. These are all fairly complex algorithms to solve the problems and, as the nature of the society of mind is to break everything down into its most simple forms, it was decided to go with more simple algorithms and use Braitenberg vehicles [BRAITENBERG, 1984]. For example, obstacle avoidance is done by slowing down the right wheel when an obstacle is detected too close on the left, and vice versa, as can be seen in Figure 2.

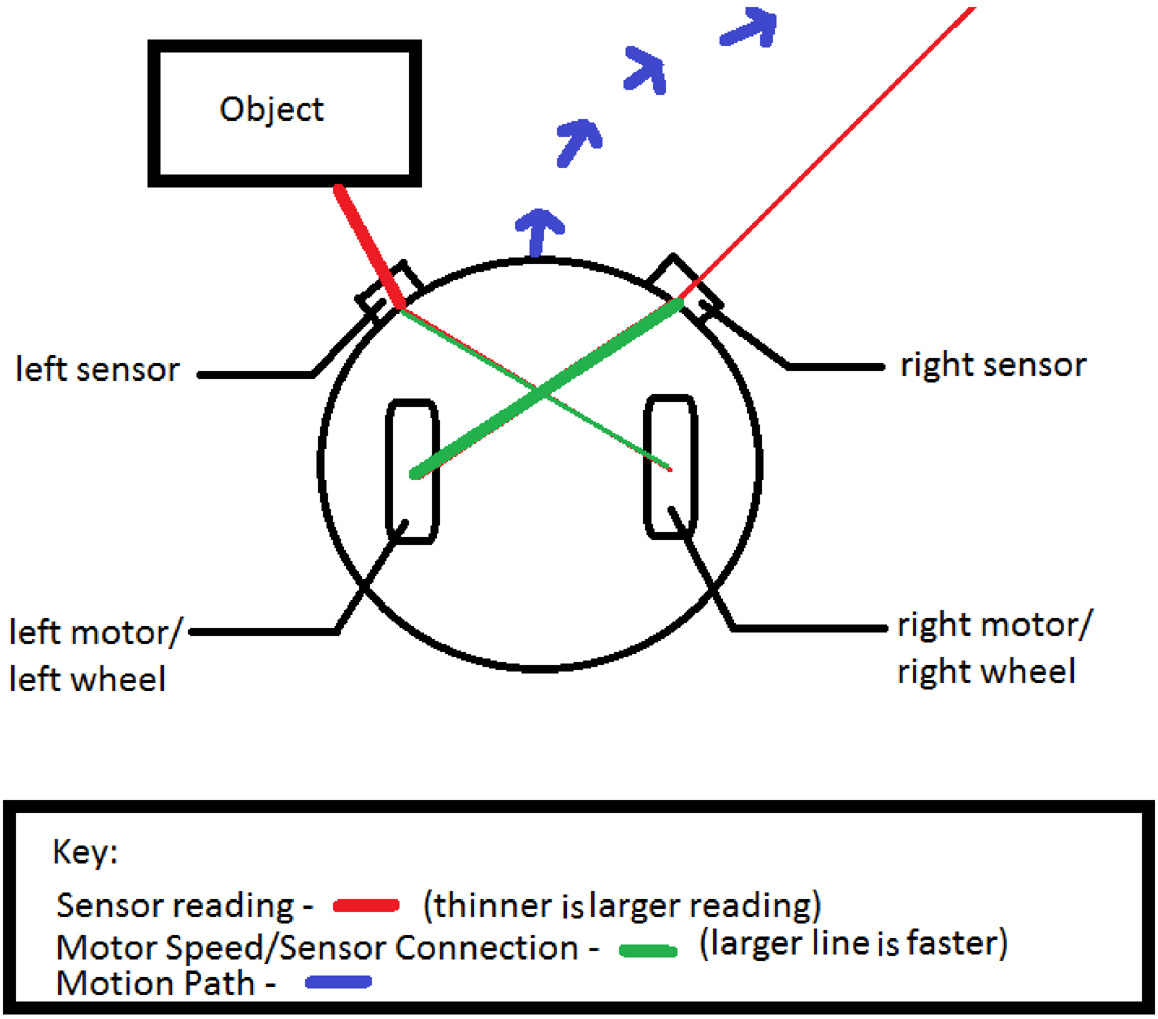

Figure 2. Avoidance Braitenberg Vehicle

Another algorithm that could have been chosen differently is the algorithm used for detecting changes in the environment. Originally implemented was an algorithm that kept a record of the five previous readings from each sensor and then checked to see if the current one differed. This failed to work though as noise from the sensors meant that the readings were always slightly different therefore the algorithm resulted in always detecting a change. Instead, a larger number of recordings were made and the standard deviation was used to decide if there was a change. Gaussian smoothing is a fairly common solution to this problem [DUDEK and JENKINS, 2000] but was not implemented due to time constraints.

3 Technical Development

3.1 Project Requirements

This project required the creation of many agents and figuring out how they would interact with one another to demonstrate the required behaviours. Due to the nature of the society of mind, none of the agents could be too intelligent and each had to be of limited intelligence. For this reason, whenever an agents design got too complex it was broken down into smaller agents. For example, the avoidance agent was broken down into a forward, rotate and stop agent. These agents then needed to be made to interact with one another so that they would display the agencies required behaviour. This required the designing of Braitenberg Vehicles for most agencies.

The Braitenberg vehicles that were required were as follows:

- Approach
- Avoidance

These vehicles required simple automata to function. The automata that was required for this project was:

- Forward
- Rotate
- Stop
- Reverse
- Accelerate

These simple automata and Braitenberg vehicles were then combined to create the required agents and agencies of:

- Hit
- Explore
- Observe

These all had requirements themselves. The observe agent required:

- recording readings from the robots sensors
- deduce from these recordings if a change had occurred
- differentiate between a change in environment and noise in sensors

The explore agent required:

- capable of travelling around an environment without getting stuck
- not travelling in circles

The hit agent required:

- to approach an object
- to record the distance between itself and the object
- to be able to tell when it had exceeded the distance to the object
- to know when to halt and observe for changes

These all also had the requirement of needing to be made up of simpler parts. So the hit agent, for example, required finding a way of making a hit behaviour and satisfying these requirements by turning other agents on and off.

3.2 System Design

3.2.1 Finite State Automata Designs

The automata designs can be seen in Appendix I. These were designed as finite state machines for the more complex automata such as observe, explore, avoidance and approach. These show how each agent is made up of more simple agents. For example, the explore agent can be seen to be made up of an avoidance agent and an approach agent. They also show how the agents can be reused in other agents illustrating how it is a society of agents and not strictly a hierarchy.

3.2.2 Braitenberg Vehicle Designs

The designs for the Braitenberg Vehicles can be seen in Appendix L. An alternate approach could have been to use fuzzy controllers to create the desired behaviours. Braitenberg Vehicles were chosen instead as they are simple agents. This tied in well with the society of mind as the idea is to have no single agent responsible for the intelligent behaviour so using these simple Braitenberg Vehicles seemed to be the best option. For example, the Braitenberg Vehicle for Avoidance in Appendix L is a very simple design. The speed of each motor is proportionate to the opposite sensor in this example.

3.3 System Implementation

The entire project has been implemented in C++ using the ARIA library. There are two versions of the project created. One is the preconfigured Society of Mind and the other is a K-Line implementation of the Society of Mind. The original project was the preconfigured Society of Mind, for which C++ was a fine choice, but once that was done it was further developed to be a K-line implementation for which C++ was not a good choice. With C++ there were some issues of circular logic where one agent's implementation involved another agent and that agent needed to use the former agent. In the preconfigured architecture this was easy to avoid but in the K-line architecture, where agents could be configured on the fly, this became a bigger issue.

In the preconfigured architecture it is not entirely obvious how the architecture operates. It starts by attempting to hit the nearest object and then, if it is not the ball, it begins to explore. The explore agent then switches between avoiding and approaching objects until it has been exploring for too long in which it then attempts to hit an object again.

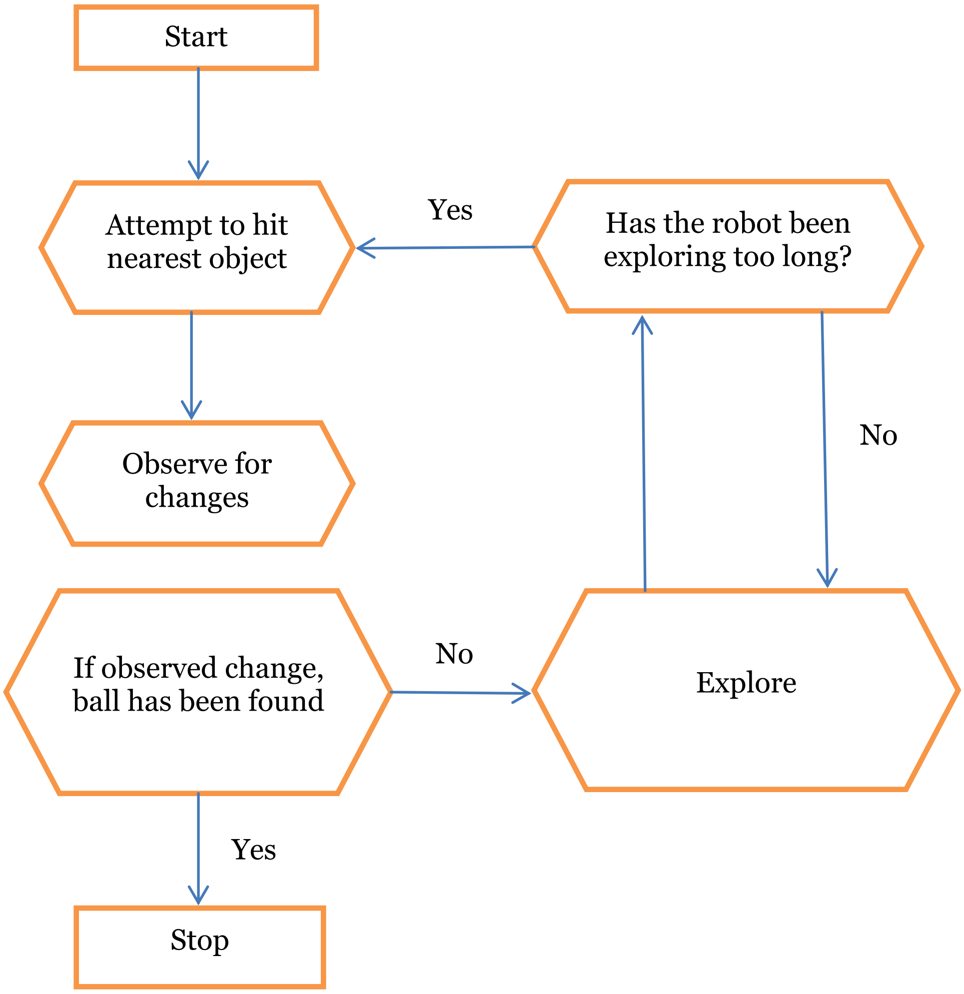

Figure 3. Flow chart of actions taken by the hit agent

The K-line architecture is slightly harder to understand how it operates. The k-line architecture is supplied with an agent, an architecture mode, an order mode, the strength of the agent and a list of subagents with their individual strengths. It then sets up the main agent, as can be seen in Append M, and supplies it with a list of subagents, the number of agents in that list and the strength unless it is a low-level agent in which it is only supplied with a strength value. Inside the constructor of each agent is the code that can be seen in Appendix M where the approach agent has been used as an example. This sorts through the list and creates a list specifically for that agent to use. If it finds itself in the main list then it removes itself from the main list by setting the type to an unknown type. It then passes on the main list to the agents it has created which do the same thing it has just done. This happens until all the agents in the list have been created and the list if filled with unknown types. Then, in the main body of the agent, the local list of subagents is cycled through to find the most, middle and least desired subagents. Currently subagents are only ordered by their strength so this can be thought of as the strongest, middle strongest and weakest agents. Then the code is similar to the preconfigured version except with the desired subagents replacing the preconfigured subagents. This can be seen in Appendix M under Approach Agent – K-line implementation with the preconfigured version as well.

There are some pieces of code that at first seem unnecessary but exist so that the robot can act appropriately. For example, in the hit agent there is the code that can be seen in Appendix M. This code checks whether the nearest object is in the left or right sensor and then essentially runs the same code, attempting to hit the object, with the only difference being which sensor is passed to the RecordDistance method. There for a few more instances similar to this in the code. One instance of this that C++ caused problems for was in the rotate agent. In Appendix M both the preconfigured and K-line implementation of the rotate agent can be seen. The difference here is that in the preconfigured version the robot is capable of rotating clockwise or anti-clockwise based on a Boolean variable. In the case of the approach agent, as can be seen in Appendix M, this is set to clockwise if the left sensor is lowest or anti-clockwise if it is the right. In the K-line architecture this is not possible due to the way C++ works and how the architecture was implemented. The k-line architecture was implemented by having a list of agents and calling these agents in order of their strengths. This meant that during runtime it is not possible to determine which agent is which and therefore cannot change the Boolean variable in the rotate agent. This was one of the main problems with using C++ for the K-line architecture.

3.4 System Testing

Testing was done on an agent by agent basis. Some agents, like the approach and avoidance agents, were tested in their own specific testbeds. These can be seen in Appendix K. The method of testing was primarily the use of test scenarios to see if the agent demonstrated the correct behaviour. When an agent needed to be tested it was added to the robot as the sole agent available, unless it had subagents then they too were added, in either the main testbed or its own specific testbed. Then the robot was left to run in the simulation until the tester was satisfied that it was behaving correctly.

3.4.1 Testbeds

The testbeds can be seen in Appendix K. In the approach testbed there is a single object for the robot to approach. The robot is supposed to be started near the object or so that the object is the nearer to the robot than the wall. The robot is expected to travel towards the object but never actually touch it.

In the avoidance testbed there are many objects in the environment. The robot is expected to avoid all of the objects. Once the robot is navigating through the obstacle course and not getting too close to any of the objects it is said to be working correctly.

All the other agents were tested in the main testbed which can also be seen in Appendix K. This was used for agents and automata such as the forward automata and the rotate automata. These tests were very simple in that, for the forward automata, if the robot travelled forward and didn't stop until it had collided with a wall or other obstacle then it was working correctly. Likewise, for the rotate automata, if it continually rotated for a few minutes without stopping then it was working correctly.

4 Experiments and Evaluation

The table of results for all the following tests can be seen in Appendix N.

4.1 Avoidance Testing

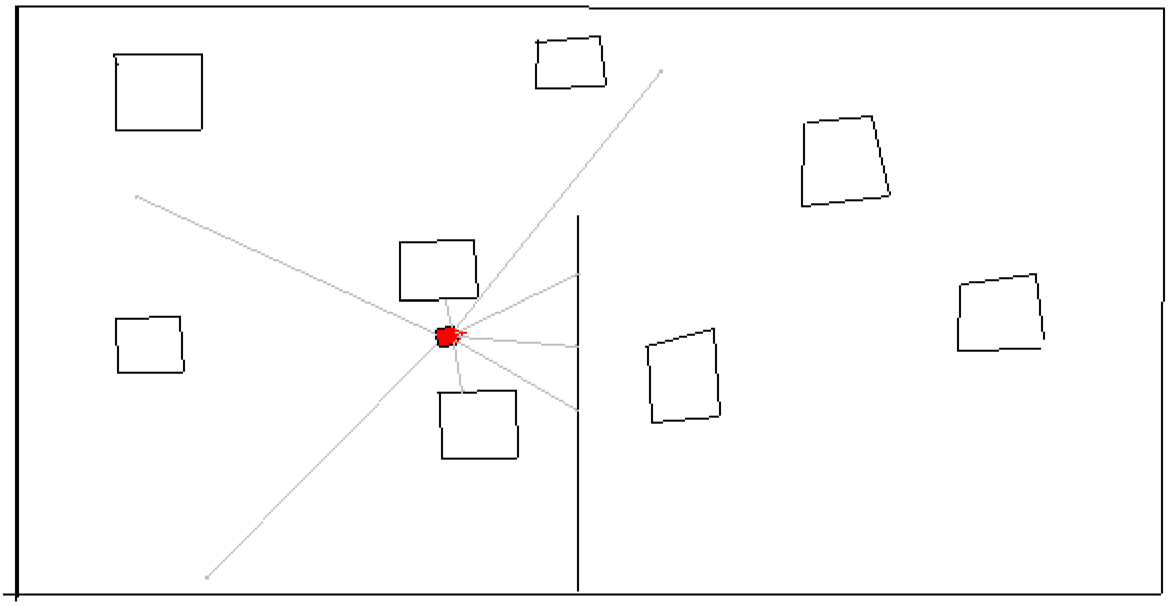

Figure 4. The robot running in MobileSim with only the avoidance agent and subagents

The robot was left to run in the avoidance testbed with only the avoidance agent and its required subagents active for five minutes. During this time the strength of each active agent was outputted to file. These outputs can be seen in figure 5.

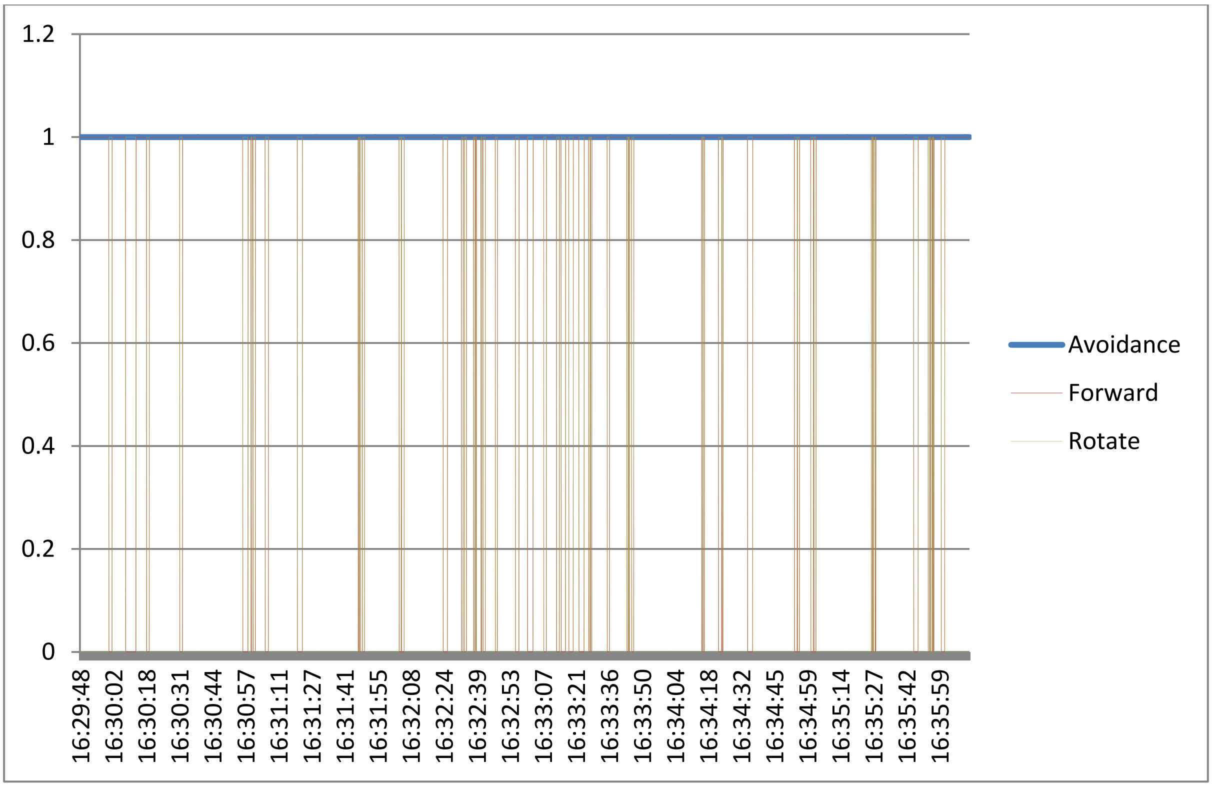

Figure 5. Strength of agents active over a five minute period

As can be seen in figure 5 the avoidance agent had moments where it didn't need to do anything and just travelled forwards. When the robot did need to avoid an obstacle the strength of the forward agent drops to zero and the strength of the rotate agent shoots up to one or full strength. There are many instances of this occurring with a large number of occurrences in the 16:32:24 and 16:33:36 range. This suggests a moment where the robot had a lot to avoid but avoided all the objects as it eventually stopped rotating and travelled forward uninterrupted from 16:33:50 to 16:34:18.

From the data gathered and from observations during the testing it can be said the avoidance agent works correctly as it avoided all objects.

4.2 Approach Testing

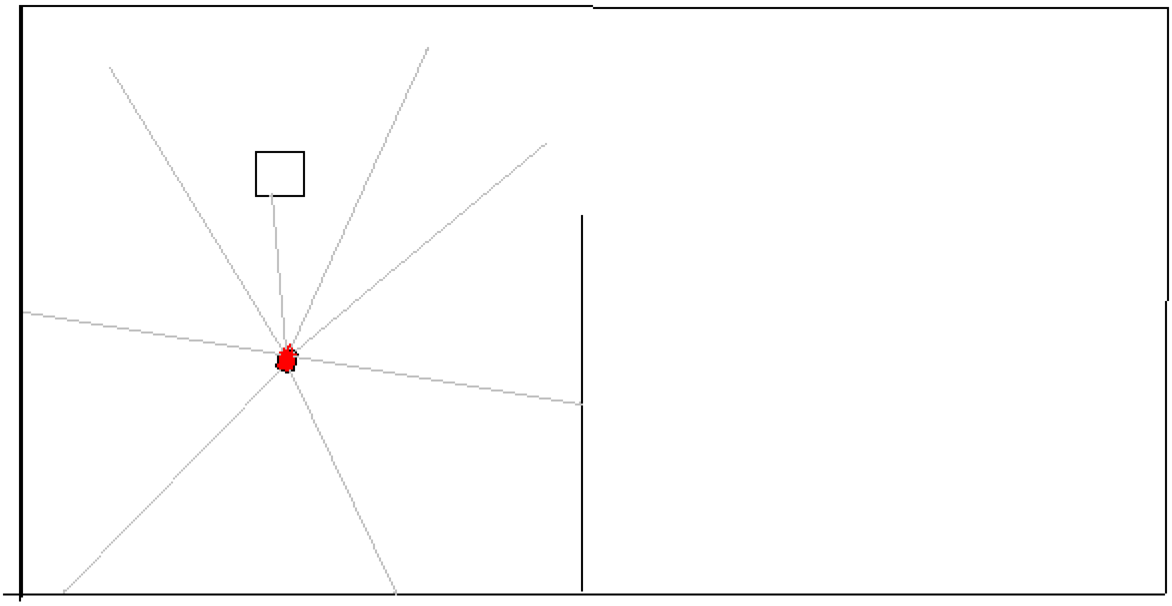

Figure 6. The robot before it approaches the object

The robot was left to run in the approach testbed, as can be seen in figure 6, for five minutes. When the robot had approached the obstacle, as in figure 7, it was moved back away from it. This was done four times.

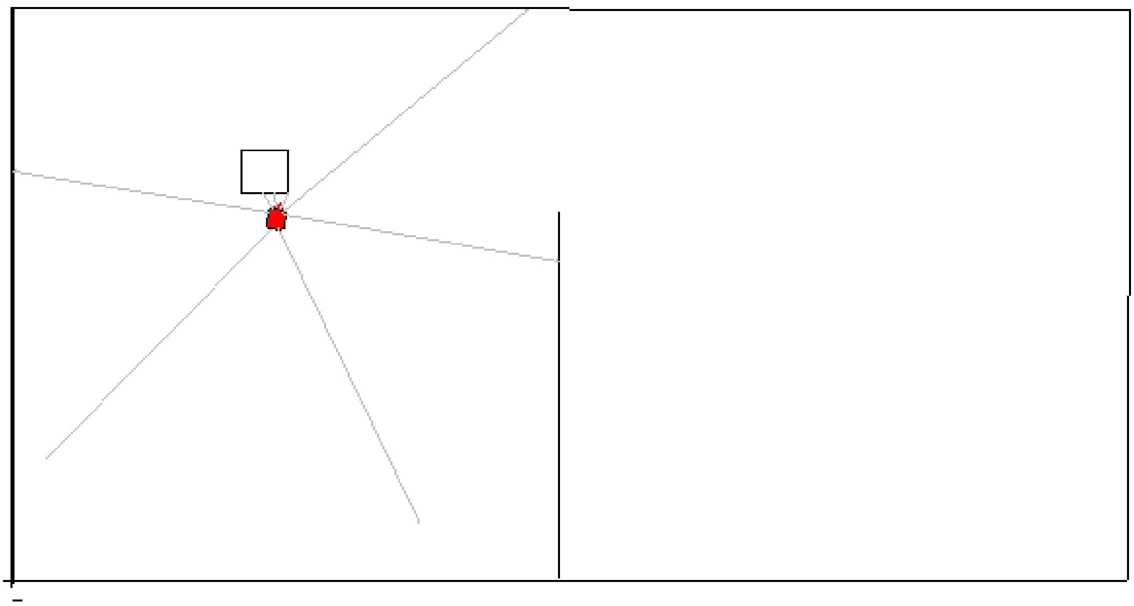

Figure 7. The robot after it has approached the object

During this time the strength of the active agents was recorded and can be seen as a graph in figure 8.

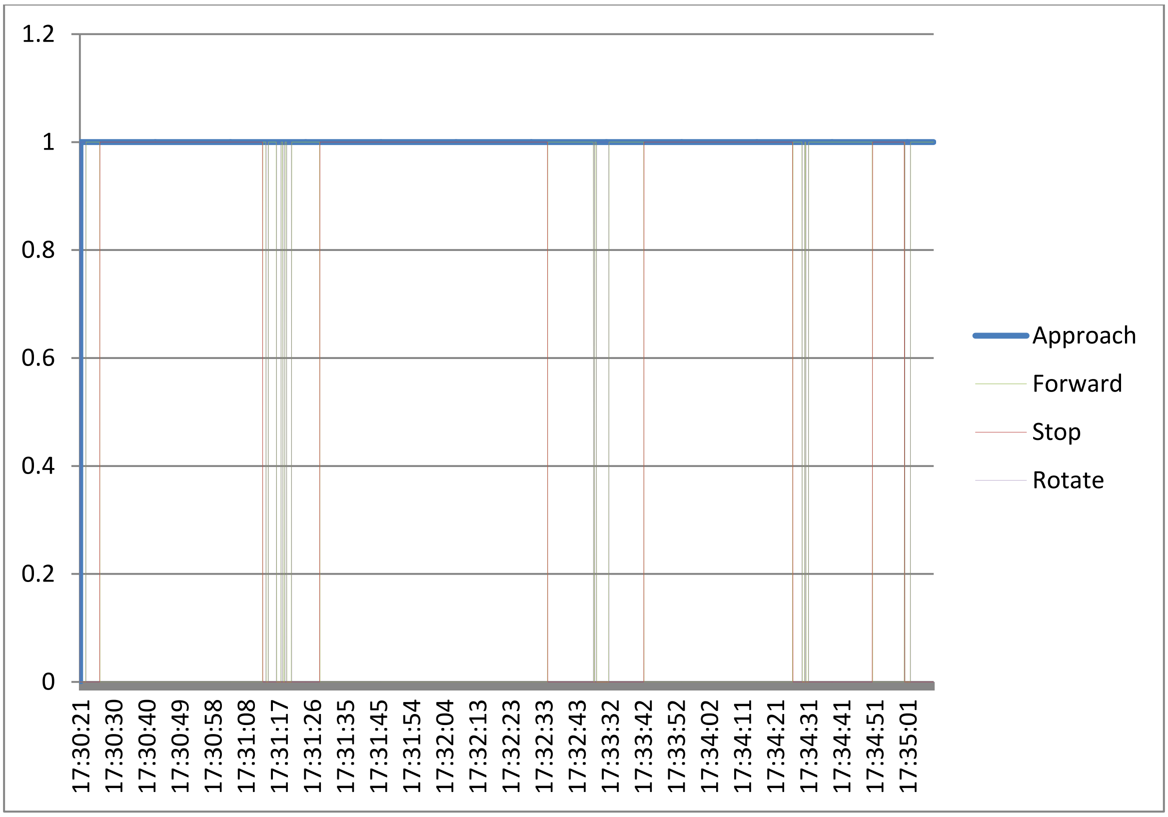

Figure 8. Strength of agents active over five period for the approach agent

As can be seen in figure 8 once the robot had approached close enough it stopped. This happened every time and the other agents only became active after the robot was manually repositioned. Once it was manually repositioned it began approaching objects once again. The manual repositioning of the robot can be seen in figure 7 at 17:31:08, 17:32:33, 17:34:21 and 17:35:01. In total the robot approached an object and stopped five times. This is the expected behaviour and shows that the approach agent is working correctly.

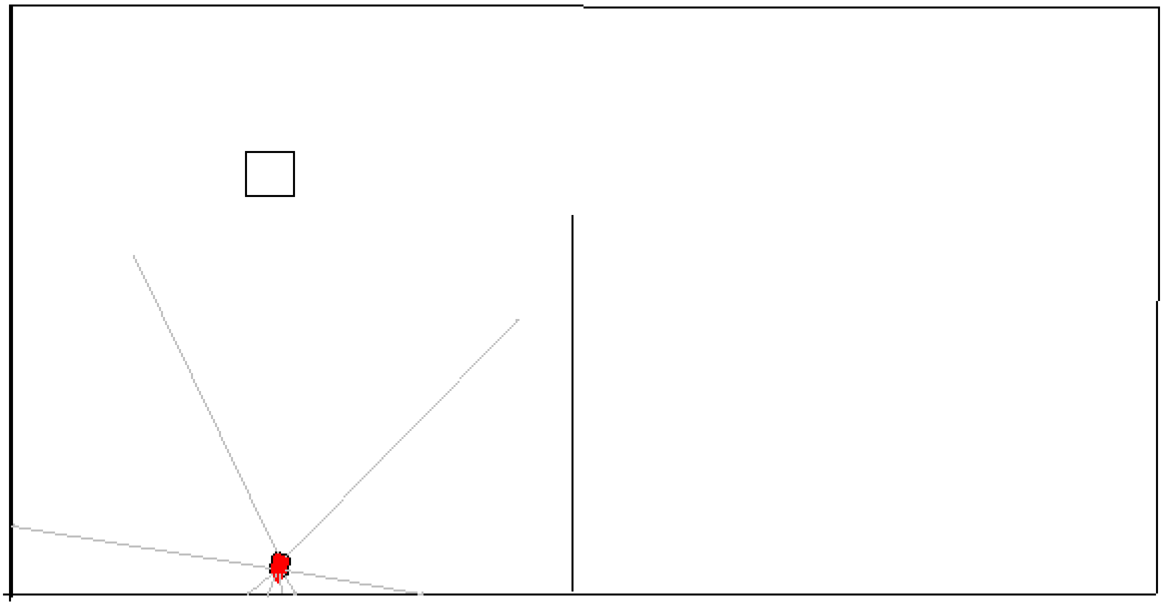

Figure 9. The robot approaching the wrong object

However, the testing did bring to light some issues with the agent. As can be seen in figure 9 the robot did approach an object but in this case it was the wall and not the object placed for it to approach.

4.3 Explore Testing

The testing for the explore agent was done by leaving the robot to run in the main testbed for five minutes.

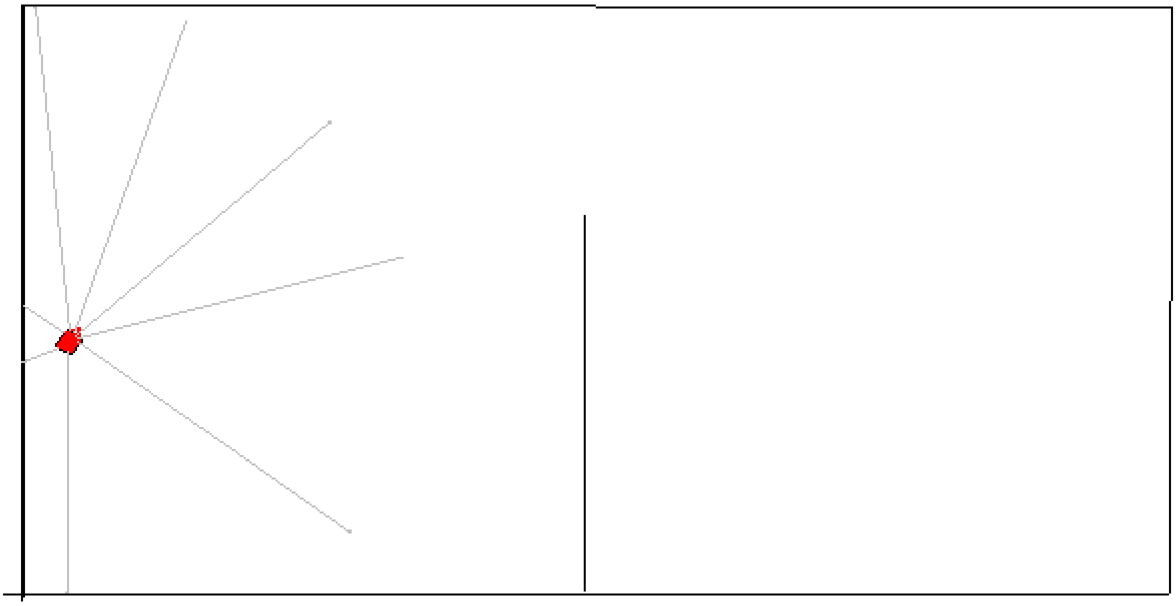

Figure 10. Robot exploring the area by avoiding obstacles

The robot was then observed to travel around its environment as can be seen in figures 10, 11 and 12.

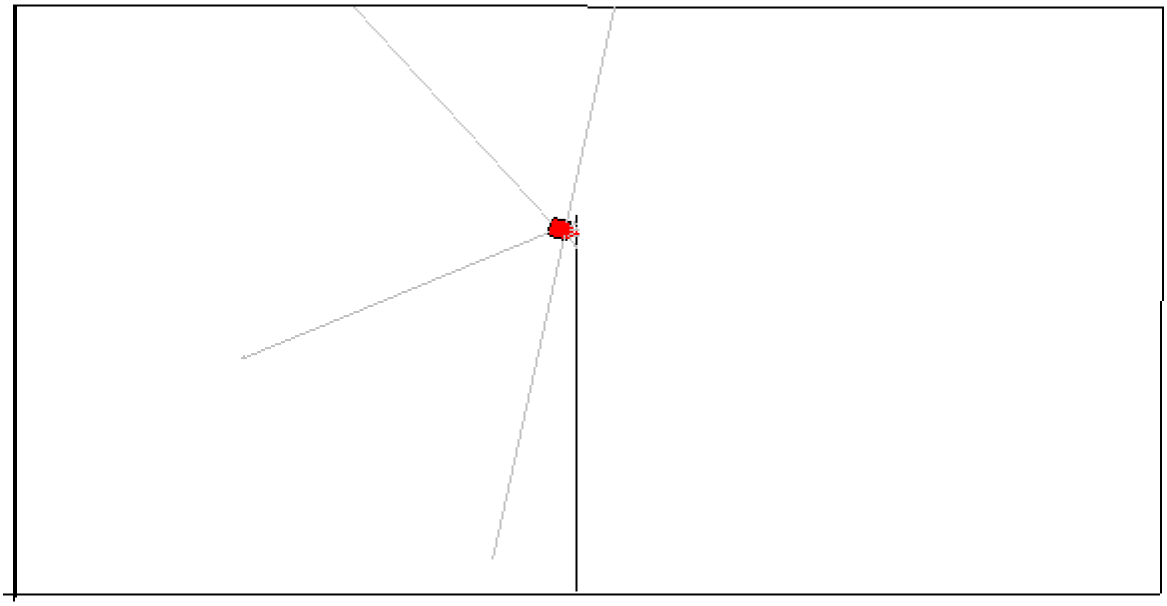

Figure 11. Robot exploring by approaching an object

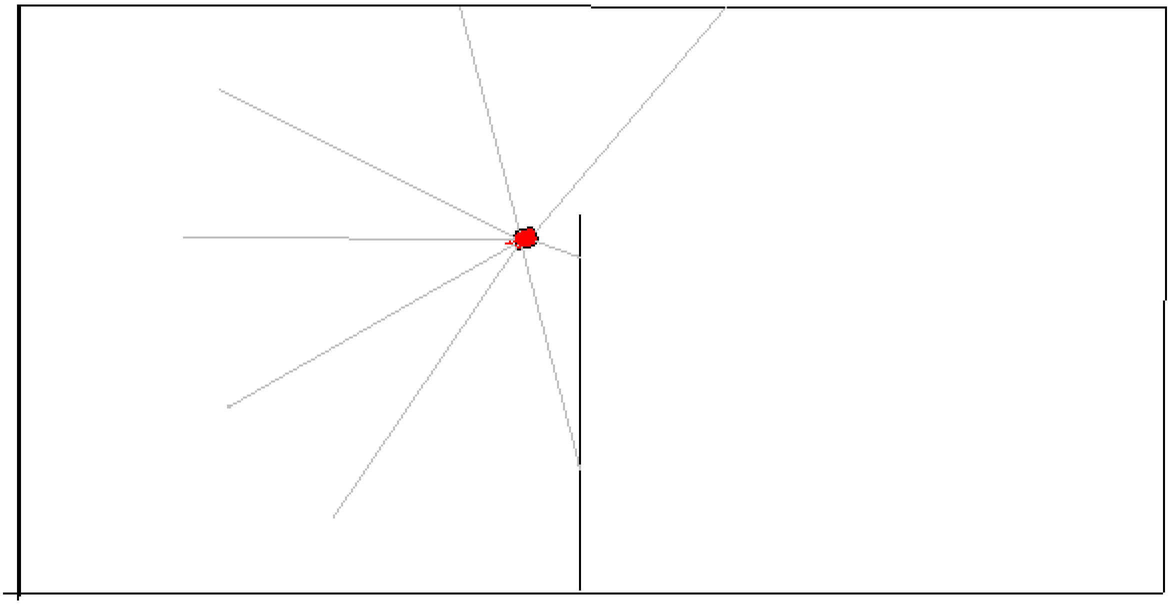

Figure 12. Robot exploring by avoiding after approaching an object

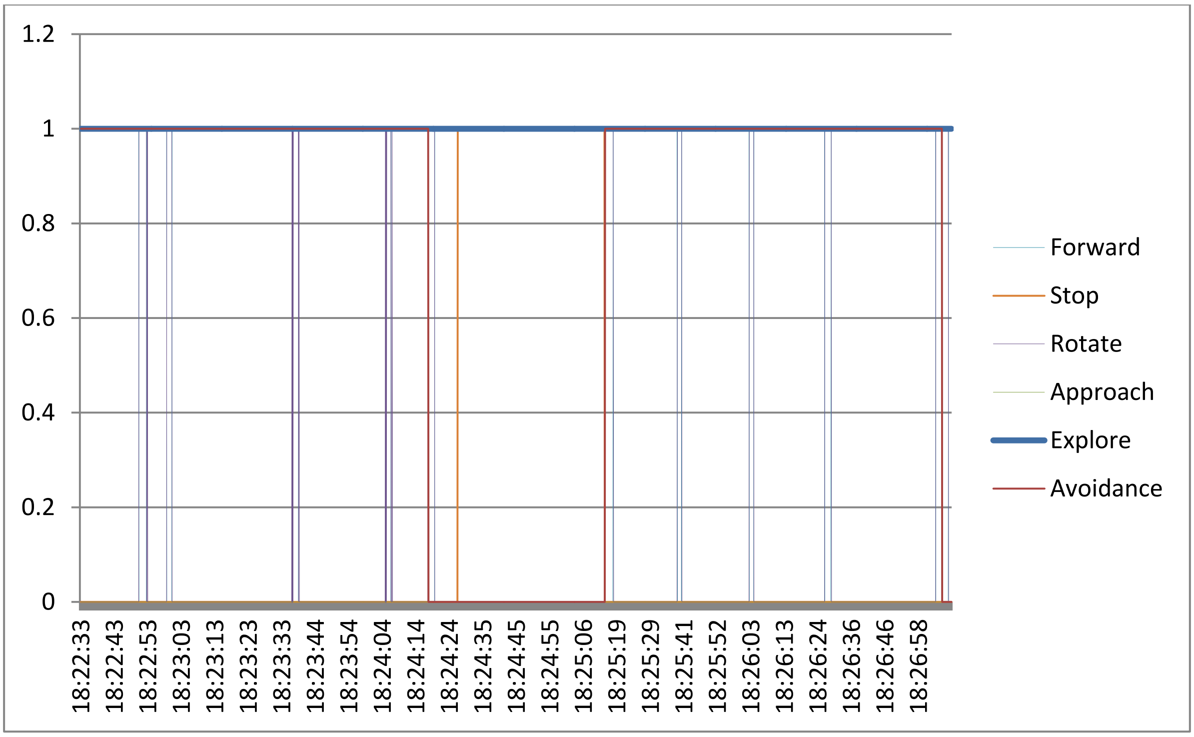

Figure 13. Strength of agents active in explore over a five minute period

Figure 13 shows that the robot was continuously active over the five minutes. Through observing the robot in the environment it can be said to be working correctly in that it moved around its environment, exploring it.

4.4 Observe Testing

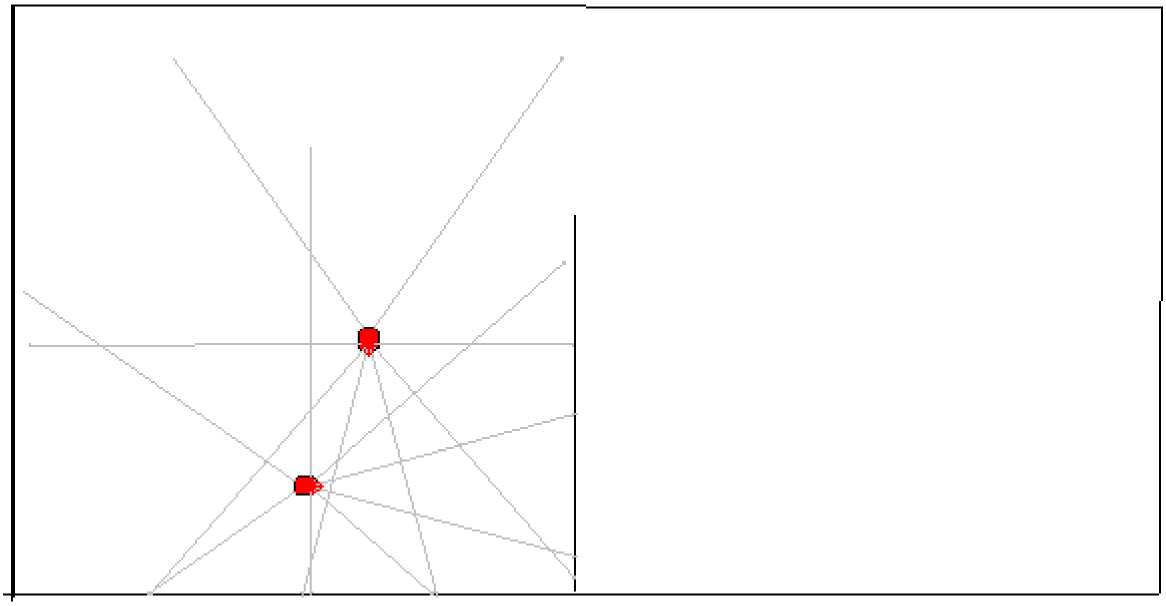

Figure 14. The setup for the observe testing

The testing for the observe agent was done by placing a teleoperated robot into the environment with the robot with the observe agent running on it. The observe agent robot remained inert whilst the teleoperated robot was moved through its sensors. This can be seen in figure 14 with the observe agent robot being the robot nearer the bottom of the screen.

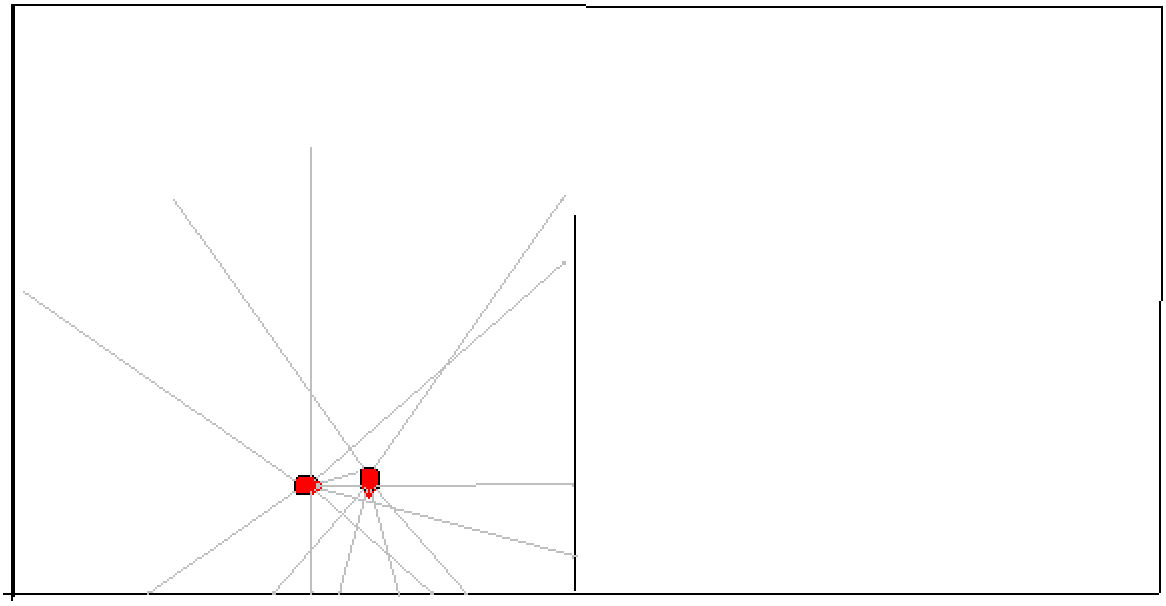

Figure 15. The teleoperated robot passing by the observing robot

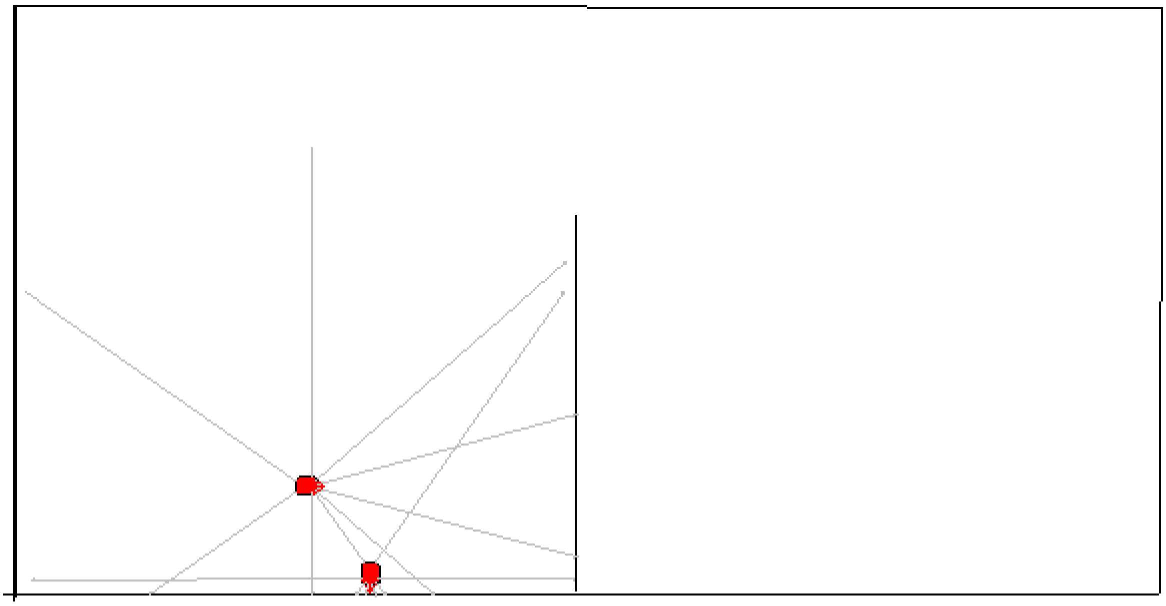

Figure 16. The teleoperated robot after passing by the observing robot

As can be seen in figures 15 and 16 the teleoperated robot was driven by the observing robot. This was repeated multiple times. If the observe agent worked correctly there would be no observable change but it would turn the stop agent on.

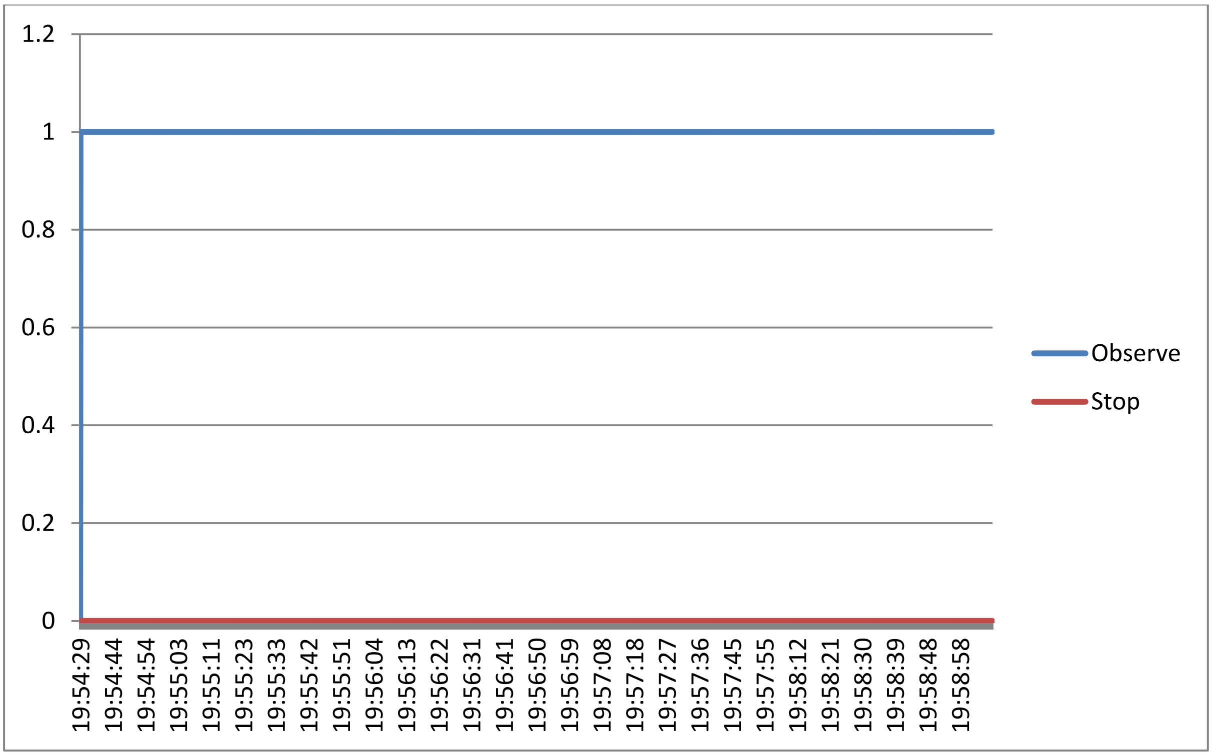

Figure 17. Strength of active agents during the observe testing

As can be seen in figure 17 there was no change in the strengths of the agents. When a change is observed the stop agent becomes active, because this is observed not to happen then it can only be concluded that the observe agent does not work correctly and has failed the test.

4.5 Hit Testing

The hit testing was done by leaving the robot to run in the main testbed for five minutes.

The robot was expected to explore the environment and occasionally hit the nearest object.

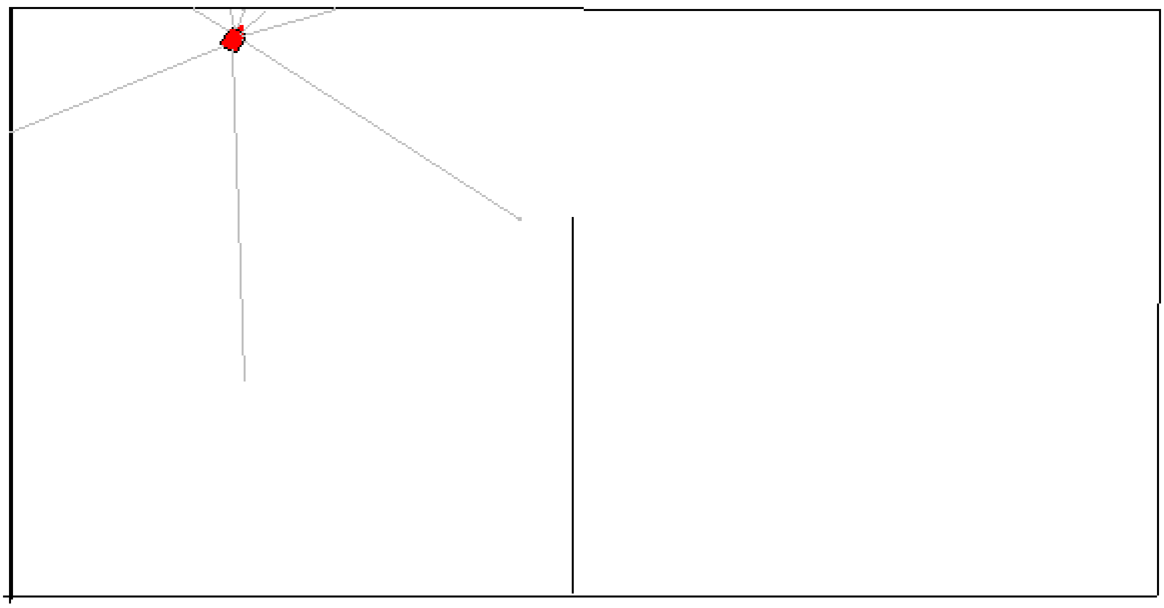

Figure 18. Robot hitting the wall

As can be seen in figure 18, the robot did successfully hit the nearest object, in this example the wall.

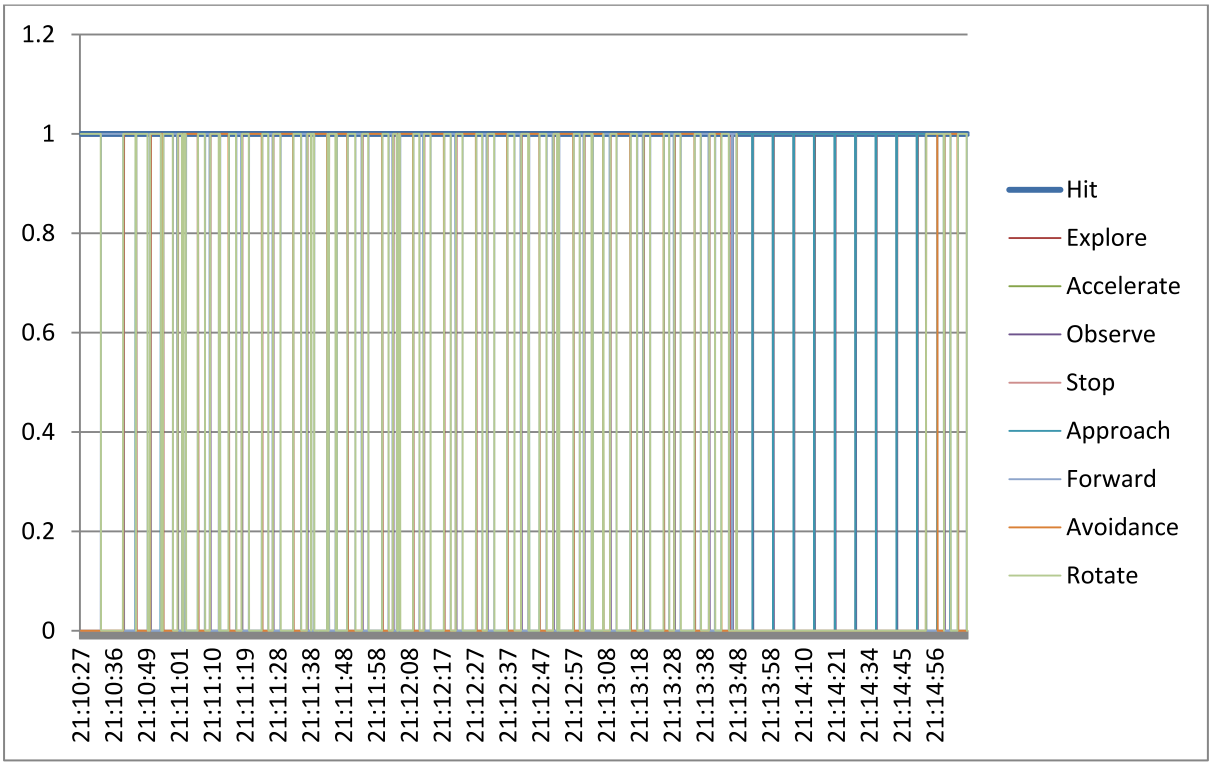

Figure 19. Strength of agents over the five minute period for the hit agent.

In figure 19 it can be seen that the agent was very active with lots of agents turning on and off over the five minute period. As the hit agent is always active it is not very clear as to when the robot did hit anything. Following an attempt to hit an object though the robot switches to the observe agent. In figure 19 the observe agent has a strength of 1 at multiple times, at 21:11:01 and 21:13:08 for example, indicating the robot hitting an object at multiple times. This is a success as the agent is working as intended.

4.6 Main Goal Testing

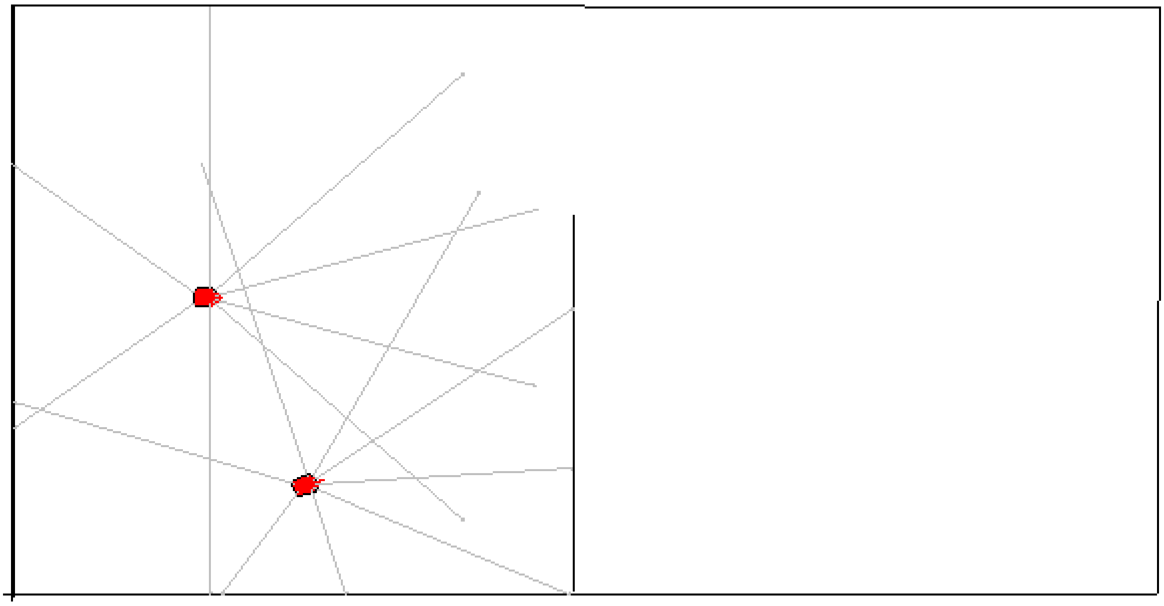

Figure 20. The robots at the start of the test in the main testbed.

The main goal test was setup as seen in figure 20. There was two robots placed in the main testbed, one robot running the preconfigured society of mind architecture and the other a teleoperated robot that remained motionless until the robot was seen hitting it. The experiment ran for fifteen minutes and the activity of the agents was recorded and can be seen in figure 21.

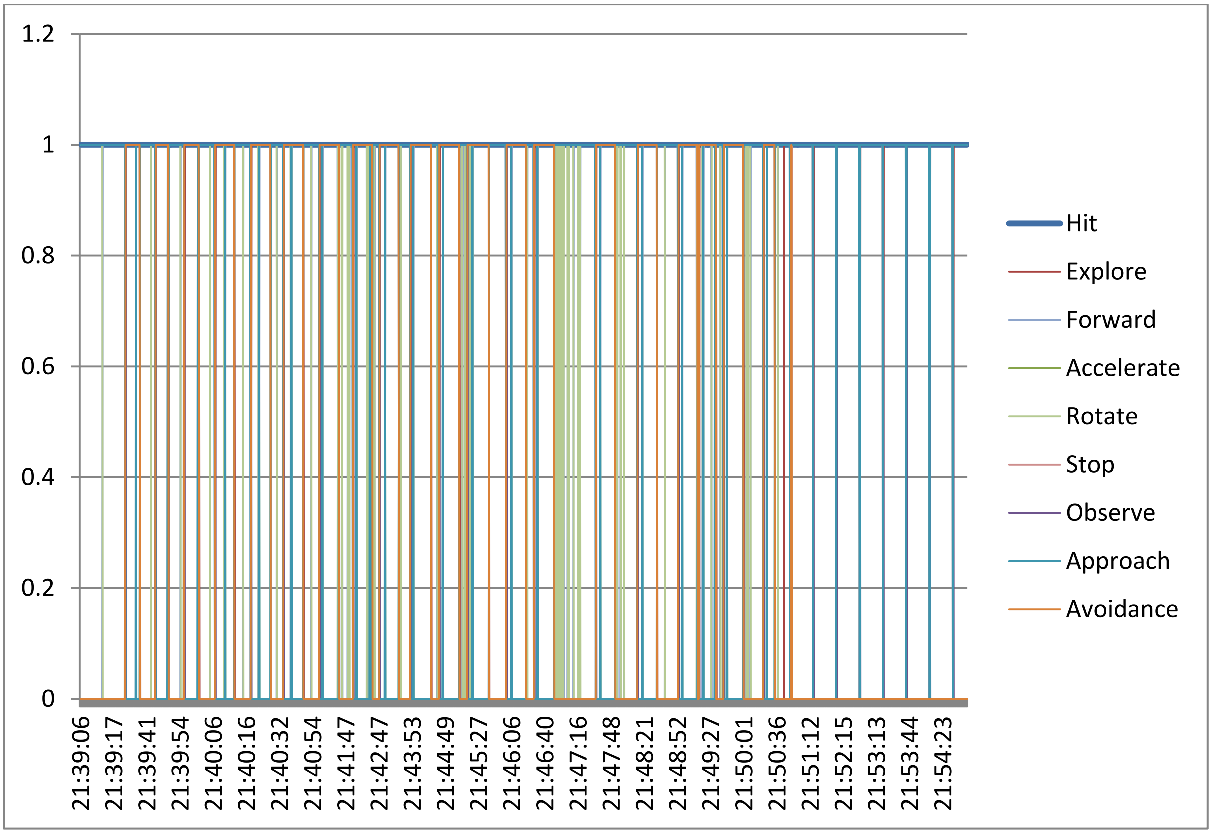

Figure 21. Strength of active agents during the main goal test

The aim of the main goal was for the robot to explore its environment in order to find a ball. A part of this was the requirement for the robot to be able to tell when it has found the ball. As the observe agent has been found to be faulty then this is not possible, so the main goal has been failed. However, in figure 22 it can be seen that the robot did find the ball and hit it. If the observe agent did work correctly then it would lead to reason that the main goal would succeed as well. As it stands though, because the robot cannot distinguish between the ball and an object that isn't a ball, it has failed the main goal test.

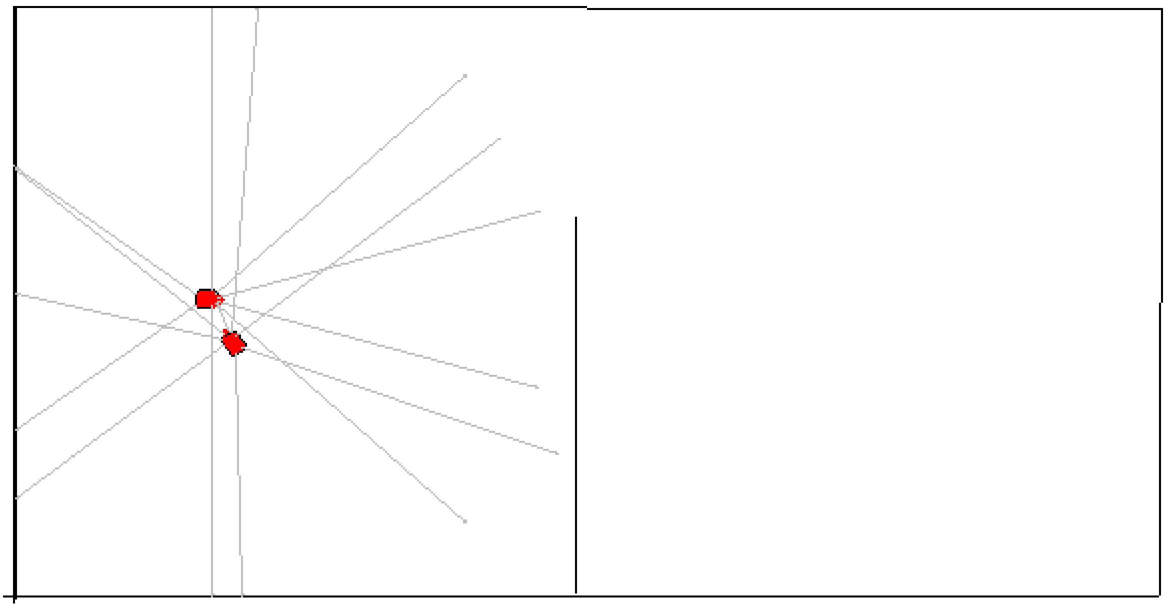

Figure 22. Robot hitting the other robot which is acting as the ball.

4.7 Analysis of Results

The results have shown that the principles behind the theory of a society of mind do work. All the behaviours worked apart from one and this is more likely due to a programming or design error than a failing of the theory. This is good evidence for the society of mind being a viable option for a robot controller. The testing did reveal some problems with the society of mind architecture such as the robot approaching the wall in figure 18. Perhaps with more development time this could have more agents added to it to make it more intelligent. The explore testing too revealed how the intelligent behaviour can be rather simplistic. It also demonstrated how two very simple braitenberg vehicles can be used together to form a more complex behaviour which is exactly what the society of mind theory is about.

5 Critical Evaluation

5.1 Project Management

The project went well but could have gone better. Underestimating how long the development of parts of the system would take, such as the automata, caused the project to go off plan quite a bit. As can be seen in appendix's A and B my time plan changed quite a bit. One of the reasons I was thrown off my time plan was underestimating how long it would take to truly understand the project. Starting off with a fuzzy understanding meant that I would create an agent and then need to go back and recreate it after I had bettered my understanding of what was required of it. Despite this most of the milestones were met within a reasonable timeframe. Another cause of delays in the project was due to not accounting for work that needed to be done outside of this project such as coursework projects and revision for exams.

5.2 Project Achievements

The main goal was for the robot to find, identify and kick the ball in its environment. I feel this goal has been partially met in that the robot was able to find an object in its environment and was only let down by the observe agent. The point of this goal was to demonstrate that the society of mind architecture could work and that it could be used as a controller for a robot that required natural-like intelligence. This, I feel, has been achieved in that the project demonstrates a working society of mind architecture and shows it successfully controlling a robot. All of the sub-objectives were completed apart from two. These are the navigation, or intelligent exploration, and observe sub-objectives. The navigation sub-objective has been partially met in that exploration was created and working but it was more of a limited intelligent exploration or simplistic exploration than intelligent exploration. That is to say the robot did not just go around in circles, which was what was wanted of it, but it also did not prioritise exploring open spaces or not explore places it had already been and found not ball.

5.3 Further Development

There are plenty of areas in this project that could do with further development. The main focus of further development would be on getting the observe agent to work correctly and use a Gaussian smoothing function. Developing this so that it works as intended should allow for the robot to work completely and satisfy the main goal. Further development still could be done to the explore agent so that it is more capable of intelligent navigation. This could be done by adding more agents and further developing the k-line architecture. The k-line architecture would ideally need to be redesigned completely from the start. This would allow for a society of mind robot that is capable of learning by adjusting the strengths, or weights, between each agent. This could also allow for the architecture to create its own custom agents by adjusting the strengths of agents into new patterns and possibly create entirely new behaviours. It could also be further developed to tackle the anchorage problem which would allow it to learn new behaviours or adjust its existing ones to suit its environment. For example, the ball could be replaced with a toy car and the robot could learn that its new goal is to find the toy car. An example of this is in Anchoring in a cognitive robot [GWATKINS, 2009]. It could also be improved to include the use of emotion as a means of motivation. To properly do this though the architecture would need to be redesigned from the ground up and use a more suitable language than C++.

Development could also be taken in another direction and have the architecture embodied into a real robot and the architecture expanded to allow for use on a variety of robots with differing hardware. This could allow for the robot to use visual devices such as a colour camera.

5.4 Personal Reflection

This project has taught me a lot about intelligence, cognitive science, robotics, and computer science. It has introduced me into a very interesting subfield of artificial intelligence and shown to me the cross-disciplinary skills needed for robotics. It has shown me how subjects can benefit from one another and how a subject, such as intelligence, can be viewed in many different ways.

This project has taught me a lot on managing my time between multiple projects and the amount of planning that needs to go into a large project. It has also taught me to plan safely. For example, I have learnt to leave more time than I think is necessary for production in order to allow for underestimating how long production of certain parts will take.

The society of mind required breaking down everything into smaller components. This showed me a very good way of looking at software design and problems; taking the larger problem and breaking it down into smaller problems.

6 Conclusion

This project aimed to demonstrate the society of mind as a controller for a robot, to create a society of automata that could be used as the basis for a society of mind and ultimately to create a controller for a robot that could find a ball. The former two of these were completed whilst the latter was only partially completed. This was not due to the theory though but the design or implementation of a single agent. The reason for this thinking is that the robot did demonstrate all the correct behaviours but was only let down when it came to observing its environment for changes. The lacking functionality of the observe agent was also shown in the observe agent testing that was done.

Overall the society of mind seems like good controller for a robot that can be customised to fit any situation. It is very adaptable as all that needs to be done is add agents to increase functionality. For example, this version could be expanded to allow for a robot to find a ball and then kick towards a football goal by adding agents that would use the hit agent to then navigate and hit the ball towards the goal line. This could be done by adding a navigate agent which uses the explore agent but for more intelligent exploration and some agents for identifying the goal posts. The architecture is also very versatile in that it can be made to do different actions or satisfy different goals depending on which agents are active within it. Carrying on with the football example, this would mean switching off most of the find-ball agents and turning on the find-goal-posts agents.

It is not the most efficient architecture as it breaks everything down into simple agents. This means that where it would be more efficient to keep some code together, to be true to the society of mind would require breaking it up into agents thus sacrificing efficiency. An example of this is in the Approach agent, as can be seen in Appendix M, there is a call to the SensorMore agent which is a function call that could just be a line of code instead but was made a function call to be a simple agent and break the approach agent down more. This function call adds overhead that is largely unnecessary and only exists due to trying to stick to the society of mind theory as strictly as possible. Another downside is the memory required with a large society of mind architecture. The more agents are added the more complex the behaviour can be but the more agents there are the more memory is needed in the robot. This project kept the society of mind rather small and so did not face these problems. However, if it did grow too large there could be a way around this problem by loading only the active agents into memory but this could cause more efficiency problems.

The society of mind seems like a good candidate as a controller for any robot as long as efficiency is not a key requirement but even if it is the efficiency problems could be tackled and reduced if needed. With its adaptability and versatility it can be used to tackle almost any problem or goal and can continually be improved by adding agents. It can also be made to support any hardware by adjusting the lowest level of agents to the hardware meaning it could run on any robot regardless of model or manufacturer.

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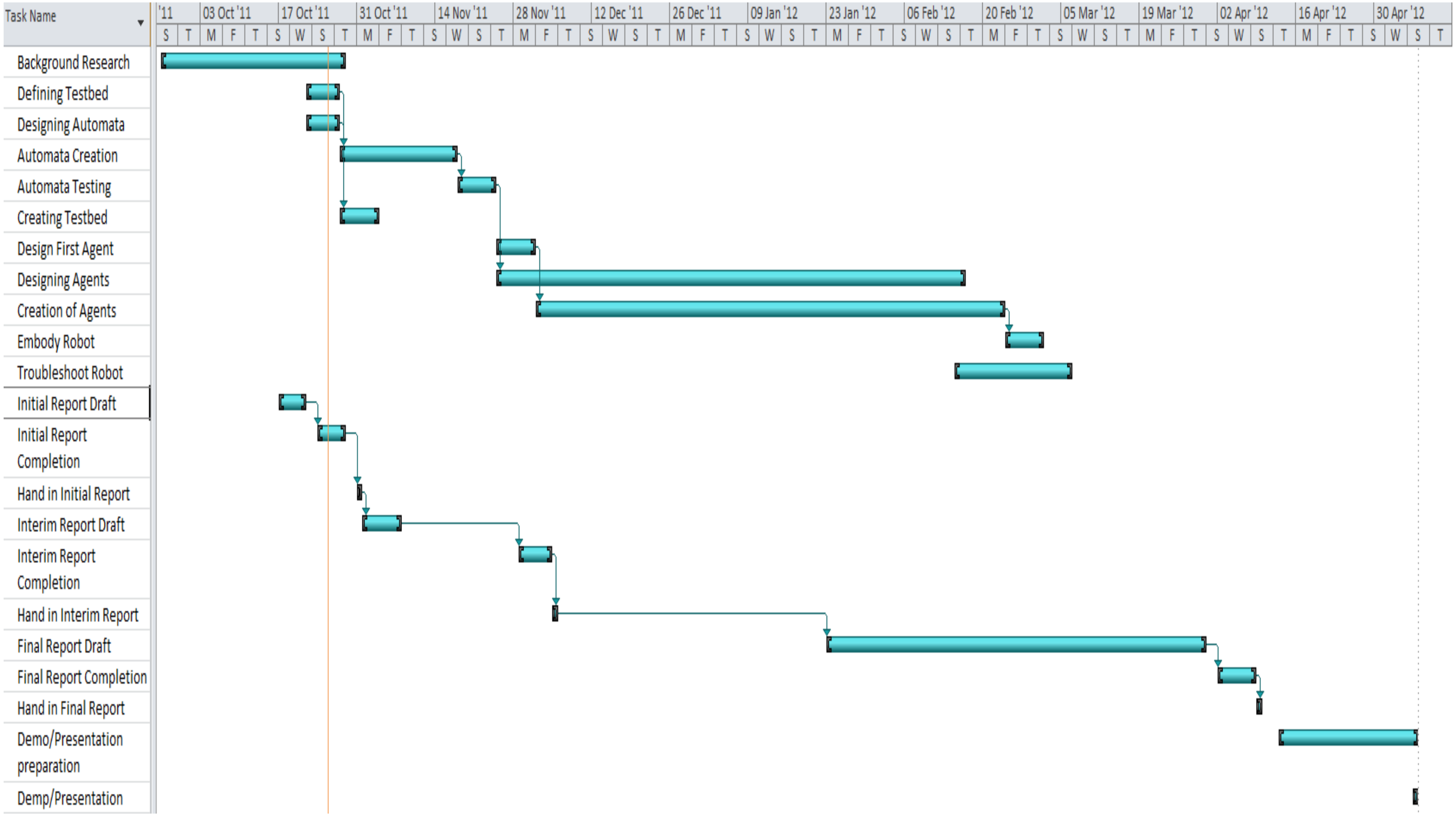
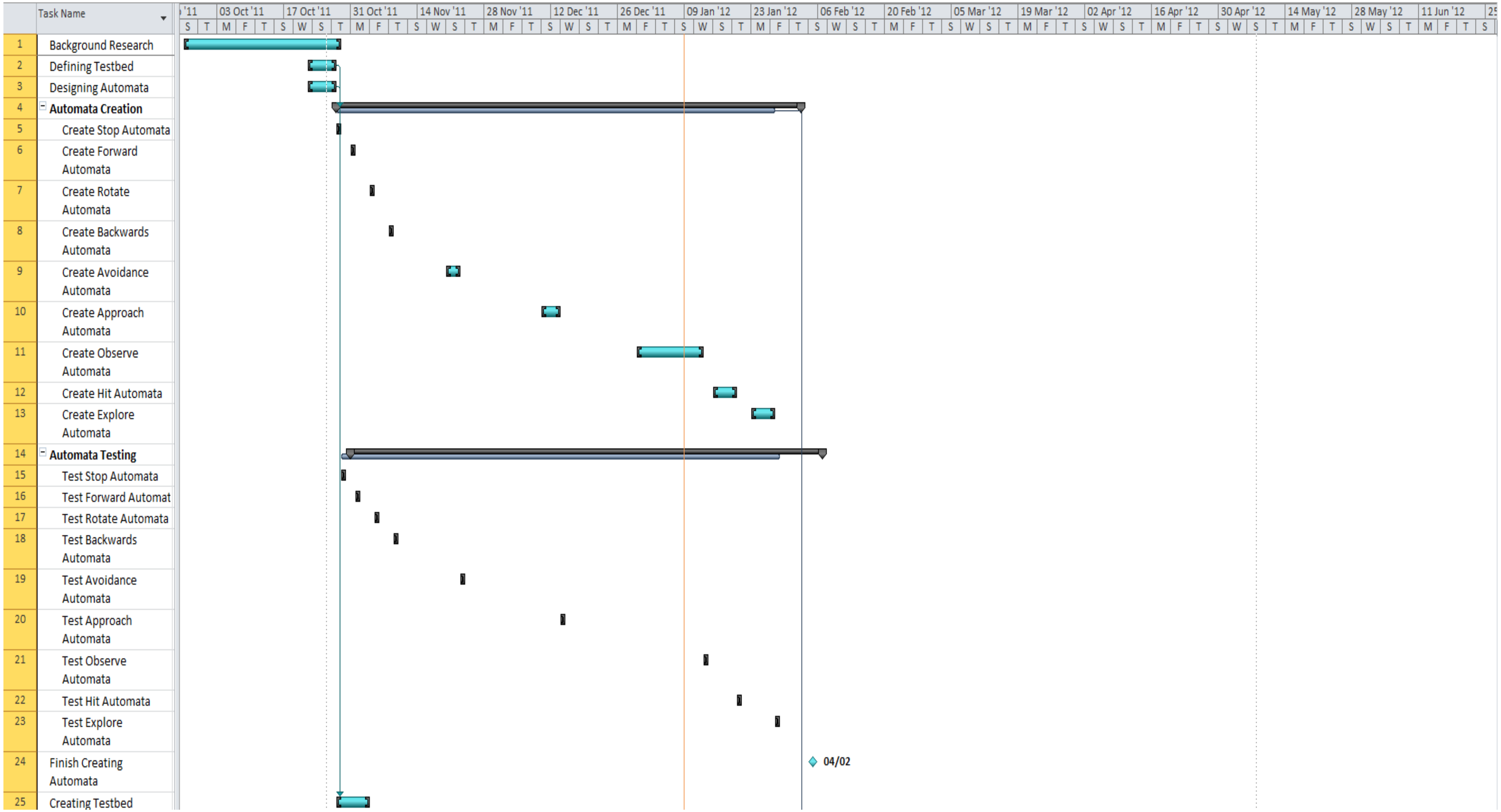
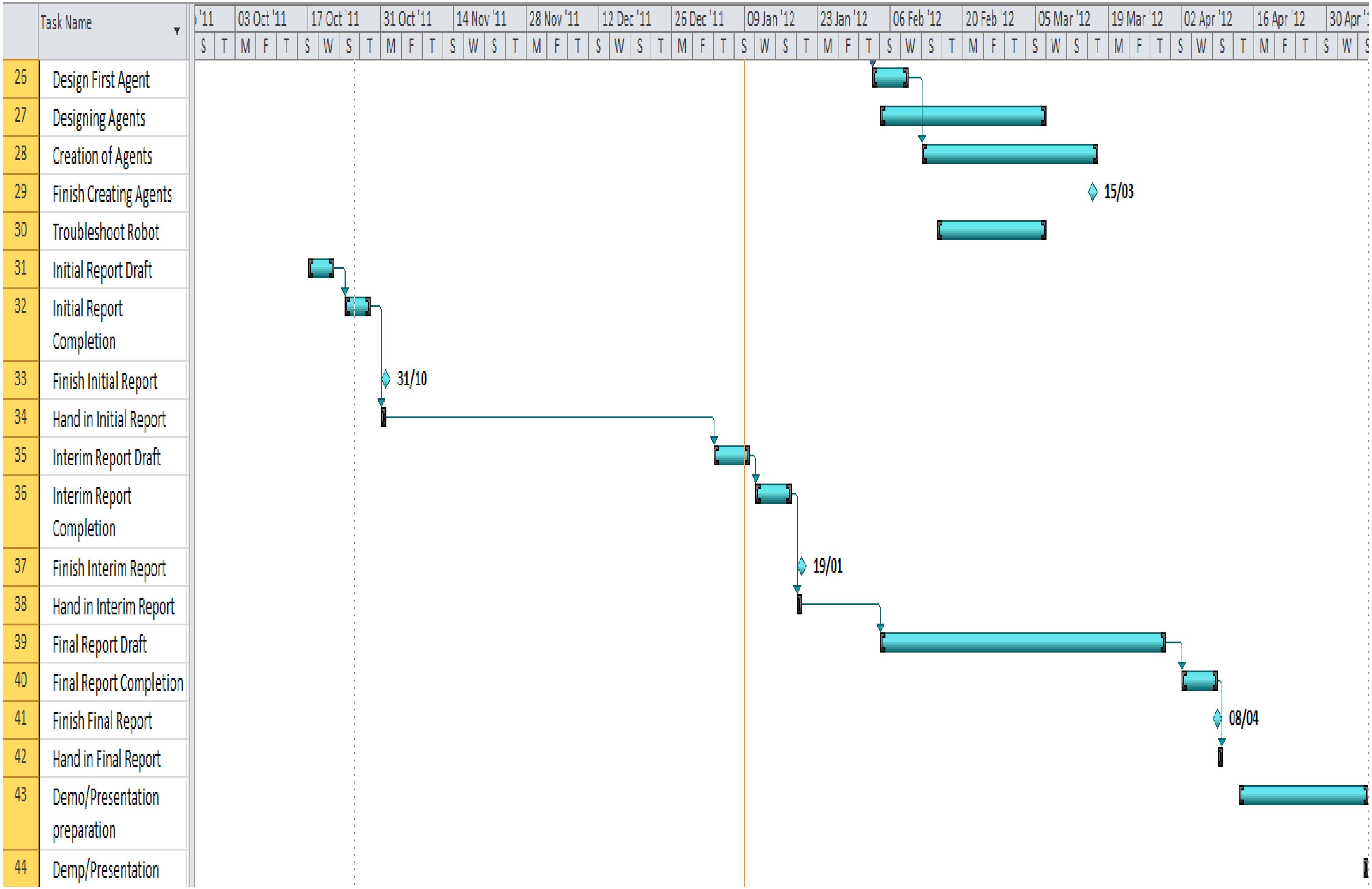
Appendix A. Original Time Plan



Appendix B. Revised Time Plan

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03 Oct '11
17 Oct '11
31 Oct '11
14 Nov '11
28 Nov '11
12 Dec '11
26 Dec '11
09 Jan '12
23 Jan '12
06 Feb '12
20 Feb '12
05 Mar '12
19 Mar '12
02 Apr '12
16 Apr '12
30 Apr '
26 Design First Agent
27 Designing Agents
28 Creation of Agents
29 Finish Creating Agents
15/03
30 Troubleshoot Robot
31 Initial Report Draft
32 Initial Report Completion
33 Finish Initial Report
31/10
34 Hand in Initial Report
35 Interim Report Draft
36 Interim Report Completion
37 Finish Interim Report
19/01
38 Hand in Interim Report
39 Final Report Draft
40 Final Report Completion
41 Finish Final Report
08/04
42 Hand in Final Report
43 Demo/Presentation preparation
44 Demp/Presentation

Appendix C. Original Project Description

Project Code: DND16
Title: Society of Mind Robot
Specification:
Microsoft Robotics (http://msdn.microsoft.com/en-us/robotics/default.aspx) is a (free) robotics test-bed that enables academic, hobbyist and commercial developers to easily create robotics applications across a wide variety of hardware. The virtual worlds and robot platforms that come with the test-bed include ones very similar to the physical robots in our robotics lab. An alternative toolkit is that available from Mobile Robotics (ARIA and MobileSim). Mobile Robotics are the manufacturer of the available robots, see

http://www.mobilerobots.com/researchrobots/researchrobots/amigobot.aspx

This project will involve devising a Society of Mind controller for one of the simulated platforms. This could then be tested on real robots if time allows. There is room for negotiation on the specification with this project.

Suitable Degree Programs:
Computer Science
Computer Systems Engineering
Computer Science with Games Development
Computer Software Development

System Environments and Hardware/Software requirements:
PC, Microsoft Robotics, C++ or /C#

Ratings:

Research:	3
Analysis:	2
Design:	3
Implementation Volume:	3
Implementation Intensity:	4
Significant Element of Mathematical Work:	Yes

Appendix D. Updated Project Description

Project Code: DND16-DM
Title: Society of Mind Robot
Specification:
Microsoft Robotics (http://msdn.microsoft.com/en-us/robotics/default.aspx) is a (free) robotics test-bed that enables academic, hobbyist and commercial developers to easily create robotics applications across a wide variety of hardware. The virtual worlds and robot platforms that come with the test-bed include ones very similar to the physical robots in our robotics lab. An alternative toolkit is that available from Mobile Robotics (ARIA and MobileSim). Mobile Robotics are the manufacturer of the available robots, see

http://www.mobilerobots.com/researchrobots/researchrobots/amigobot.aspx

This project will involve devising a Society of Automata that can be used as the basis for a Society of Mind controller for the Mobile Robotics platform (ARIA and MobileSim). If time allows this could then progress into the creation of a Society of Mind controller and testing on a real robot. The goal of the robot will be to find, identify and kick a ball.

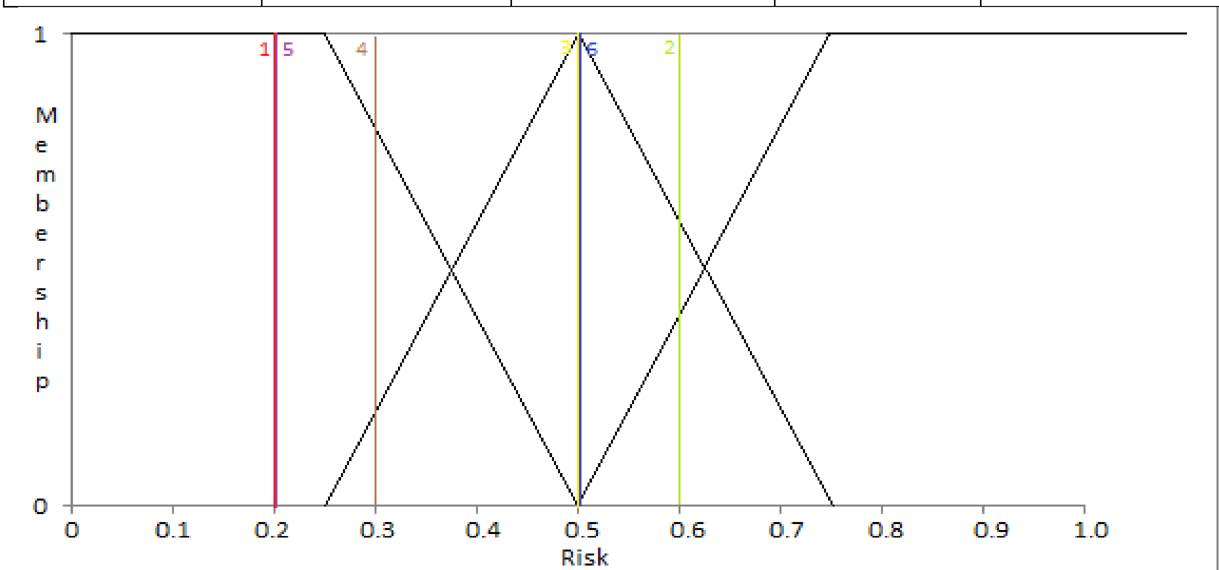
Suitable Degree Programs:
Computer Science with Games Development
System Environments and Hardware/Software requirements:
PC, Mobile Robotics Platform and C++

Ratings:

Research:	3
Analysis:	2
Design:	3
Implementation Volume:	3
Implementation Intensity:	4
Significant Element of Mathematical Work:	Yes

Appendix E. Risk Analysis

Threat	Severity	Probability	Significance	Measures that can minimize it
1. Computer Failure	0.4 – Medium	0.1 – Low	0.2 - Low	Daily backup of data
2. Task Overruns	0.8 – High	0.5 – Medium	0.6 – Medium	Allocate more than the expected time for the task
3. Unforeseen Complexity	0.4 – Medium	0.6 – Medium	0.5 – Medium	Create a detailed design
4. Sickness	0.6 – High	0.2 – Low	0.3 – Low	Email supervisor so that he is informed and can give extensions if necessary
5. Unsure of what to do next	0.4 - Medium	0.1 – Low	0.2 – Low	Create a plan
6. Accidental Deletion of work	0.9 – High	0.3 – Low	0.5 – Medium	Use version control to allow going back to latest version



Appendix F. Original Project Task List

Task Number	Task Name	Duration	Description
1	Background Research	5 weeks	Research on similar projects
2	Defining Testbed	1 week	Define the testbed to be used.
3	Designing Automata	1 week	Design the automata to be created.
4	Automata Creation	3 weeks	Create the automata
5	Automata Testing	1 week	Test the automata to make sure I have all the behaviours needed like approach
6	Creating Testbed	1 week	Create the testbed to be used
7	Designing Agents	12 weeks	Design the agents to be used
8	Creation of Agents	12 weeks	Create the agents to be used
9	Embody Robot	1 week	Transfer the robot into a real robot.
10	Troubleshoot Robot	3 weeks	Debug the robot and make it work properly.
11	Initial Report Draft	1 week	Write a draft version of the initial report
12	Initial Report Completion	5 days	Modify the draft version into the final version
13	Hand in Initial Report	1 day	Hand in the initial report
14	Interim Report Draft	1 week	Write draft version of interim report
15	Interim Report Completion	1 week	Modify draft version into final version
16	Hand in Interim Report	1 day	Hand in Interim report
17	Final Report Draft	5 weeks	Start draft version of final report
18	Final Report Completion	2 weeks	Turn draft version into final version
19	Hand in Final Report	1 day	Hand in Final Report
20	Demo/Presentation preparation	3 weeks	Prepare for the demonstration/presentation

Appendix G. Updated Project Task List

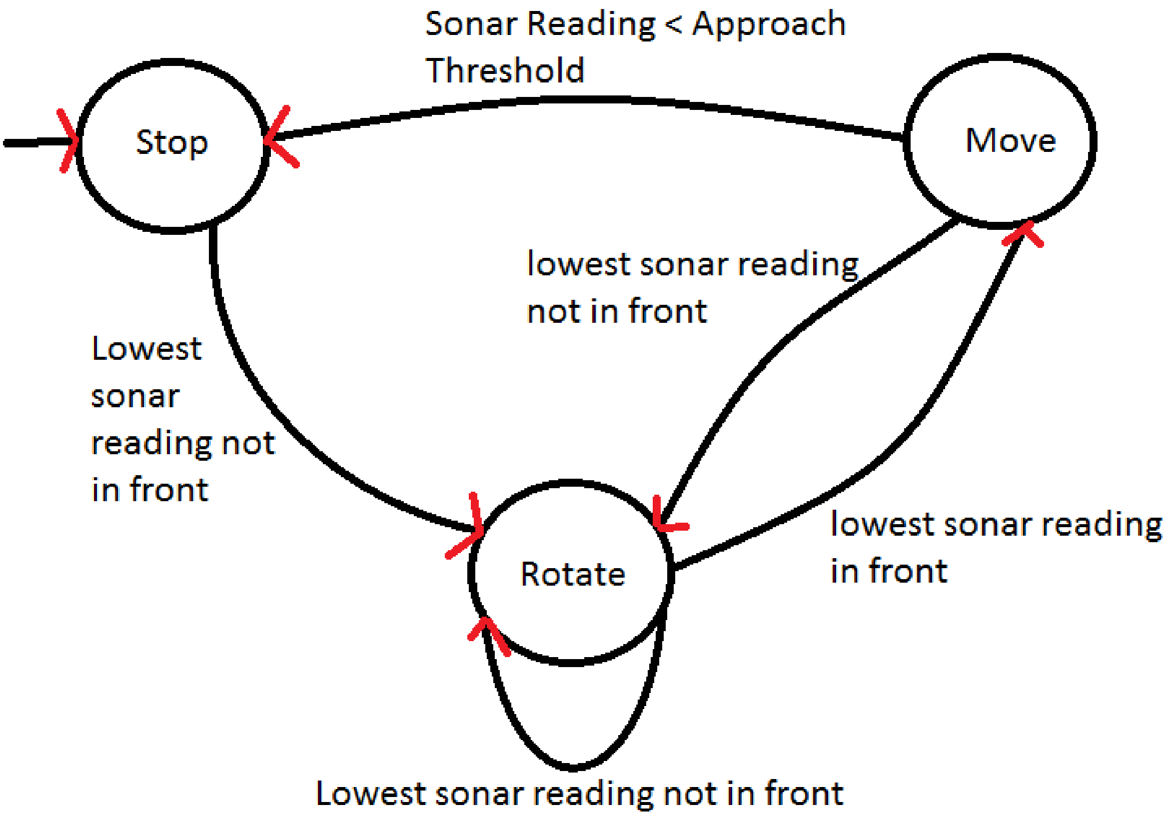
Task Number	Task Name	Duration	Description
1	Background Research	5 weeks	Research on similar projects
2	Defining Testbed	1 week	Define the testbed to be used.
3	Designing Automata	1 week	Design the automata to be created.
4	Automata Creation	14 weeks	Create the automata
5	Automata Testing	14 week	Test the automata to make sure I have all the behaviours needed like approach
6	Creating Testbed	1 week	Create the testbed to be used
7	Designing Agents	5 weeks	Design the agents to be used
8	Creation of Agents	5 weeks	Create the agents to be used
9	Initial Report Draft	1 week	Write a draft version of the initial report
10	Initial Report Completion	5 days	Modify the draft version into the final version
11	Hand in Initial Report	1 day	Hand in the initial report
12	Interim Report Draft	1 week	Write draft version of interim report
13	Interim Report Completion	1 week	Modify draft version into final version
14	Hand in Interim Report	1 day	Hand in Interim report
15	Final Report Draft	8 weeks	Start draft version of final report
16	Final Report Completion	2 weeks	Turn draft version into final version
17	Hand in Final Report	1 day	Hand in Final Report
18	Demo/Presentation preparation	3 weeks	Prepare for the demonstration/presentation

Appendix H. K-Line Architecture Definition

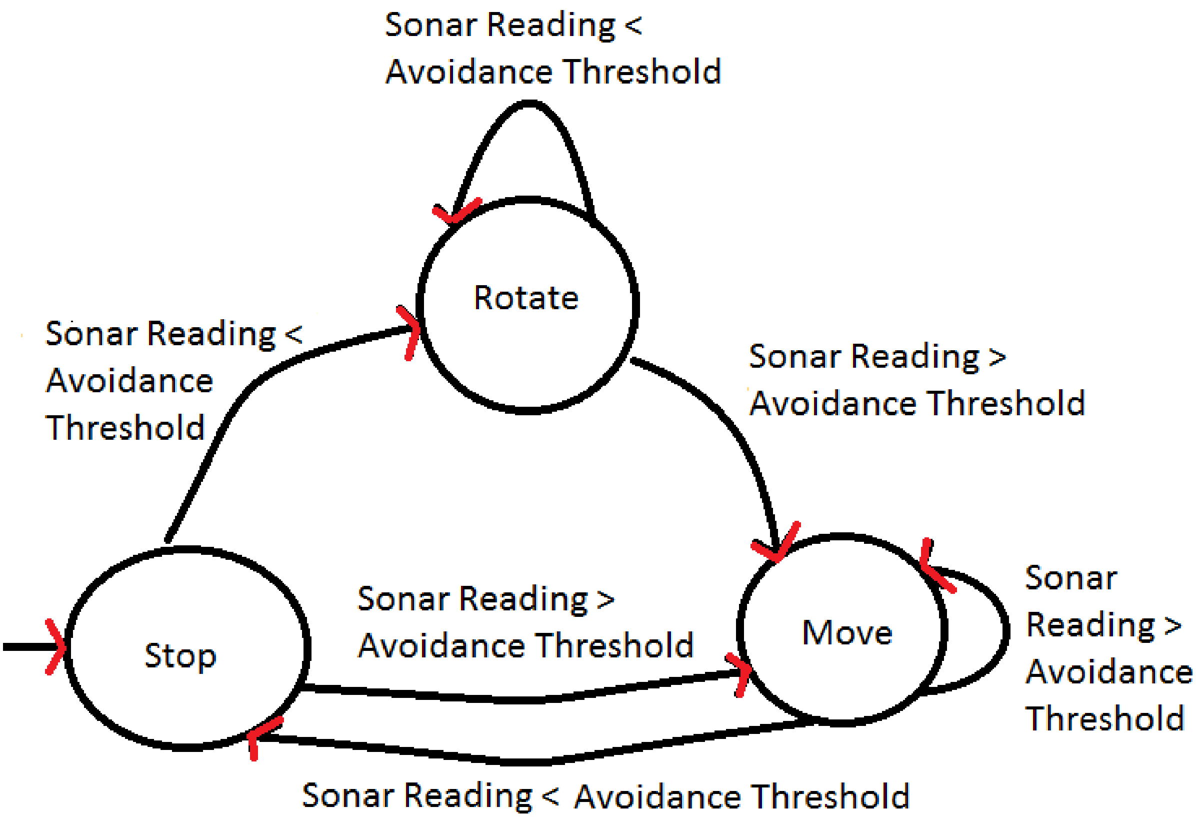
```
<K-Line> ::= <agent> <architecture> <strength> <subagents>
<architecture> ::= <mode> <order>
<mode> ::= <synchronous> | <asynchronous>
<order> ::= <weight> | <list-order> | <weight-order>
<subagents> ::= <agent> <strength> | <subagents>
<strength> ::= <NON-ZERO NUMBER>
```

Appendix I. Finite State Automata Designs

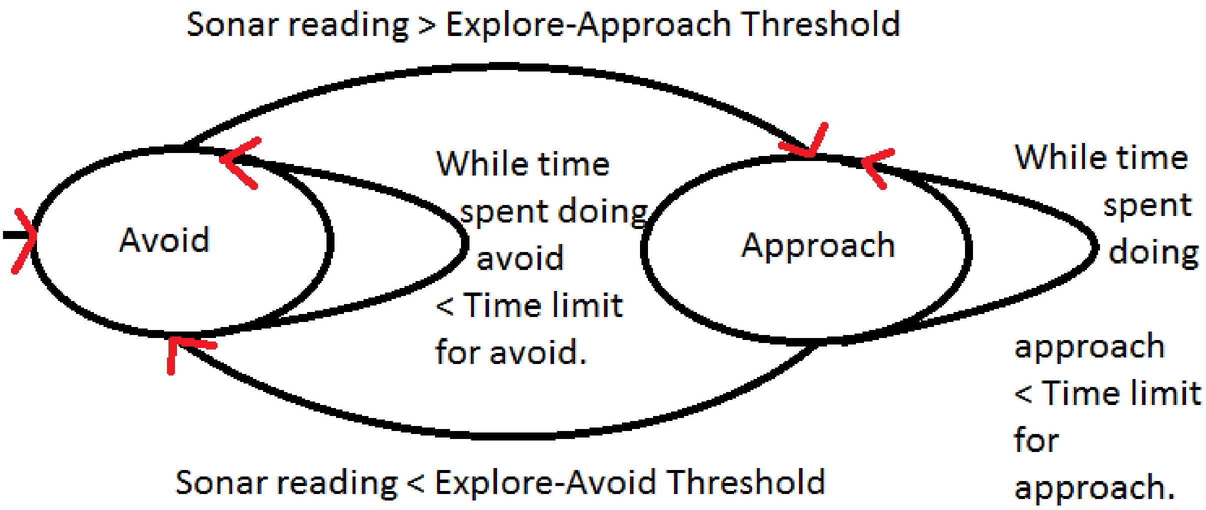
Approach Automata



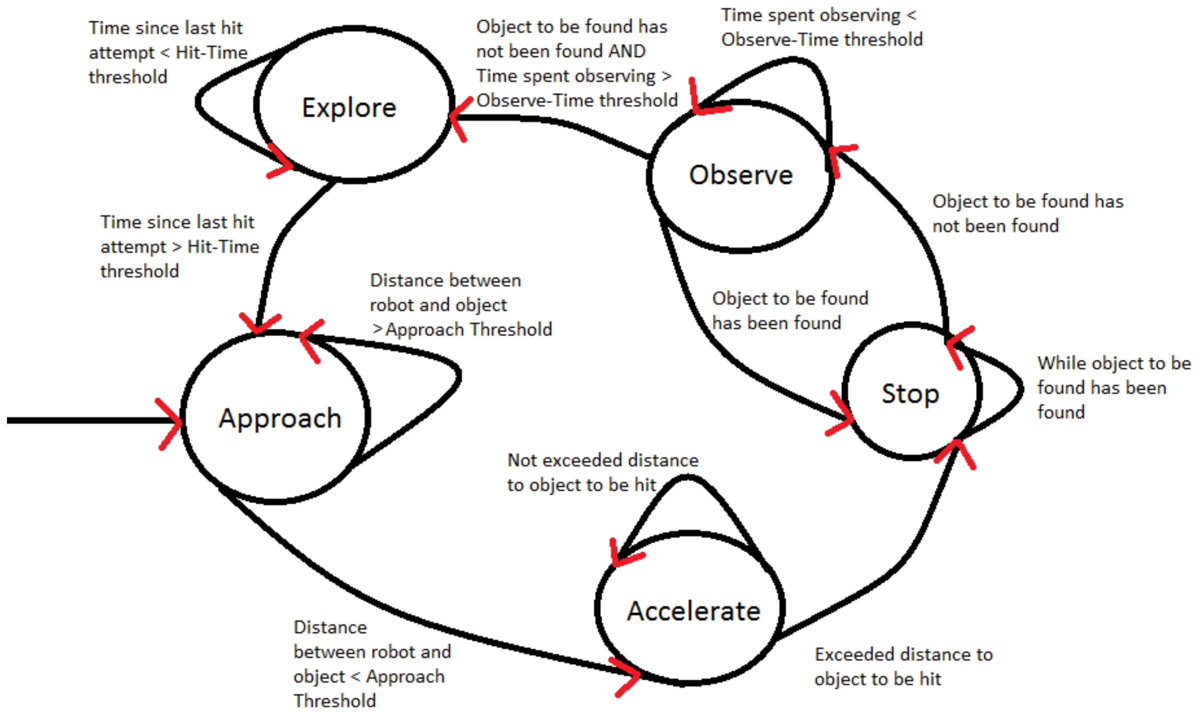
Avoidance Automata



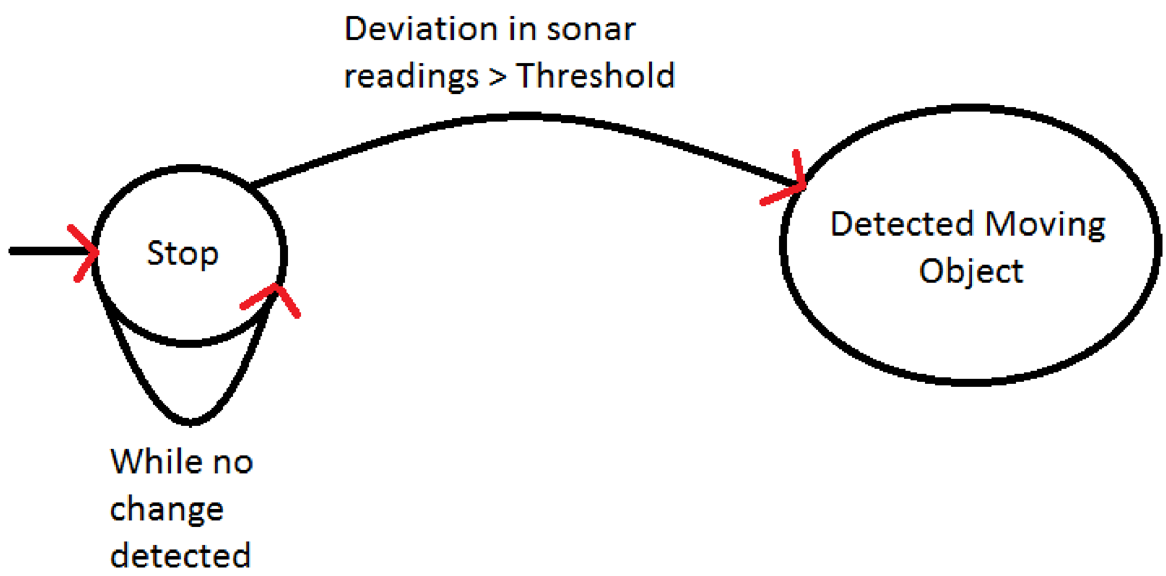
Explore Automata



Hit Automata



Observe Automata

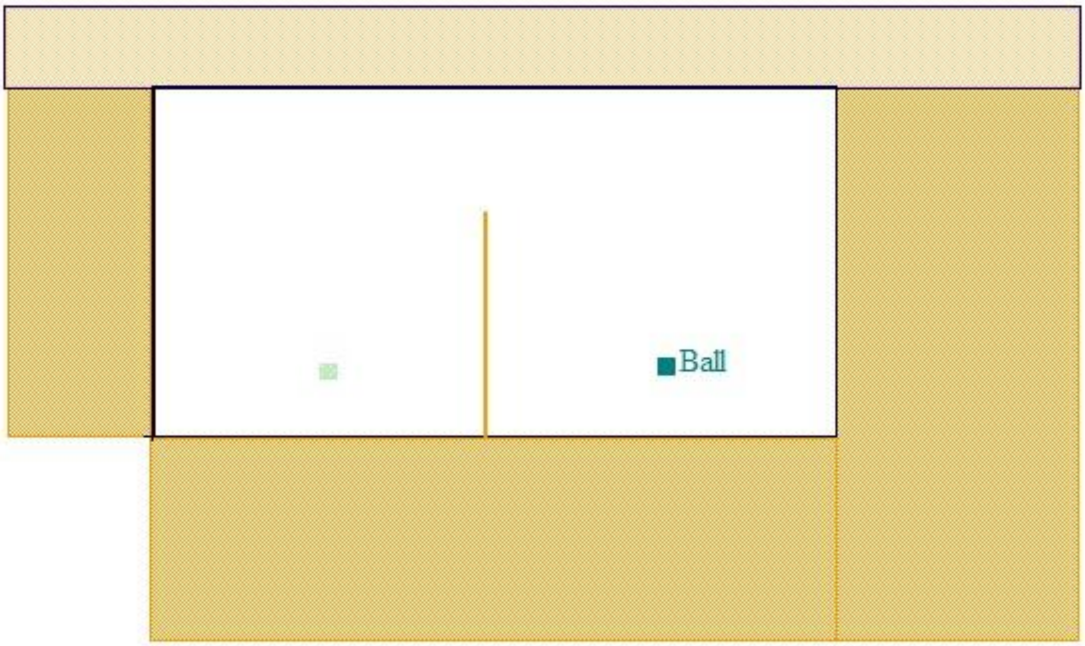


Appendix J. Testbed Definition

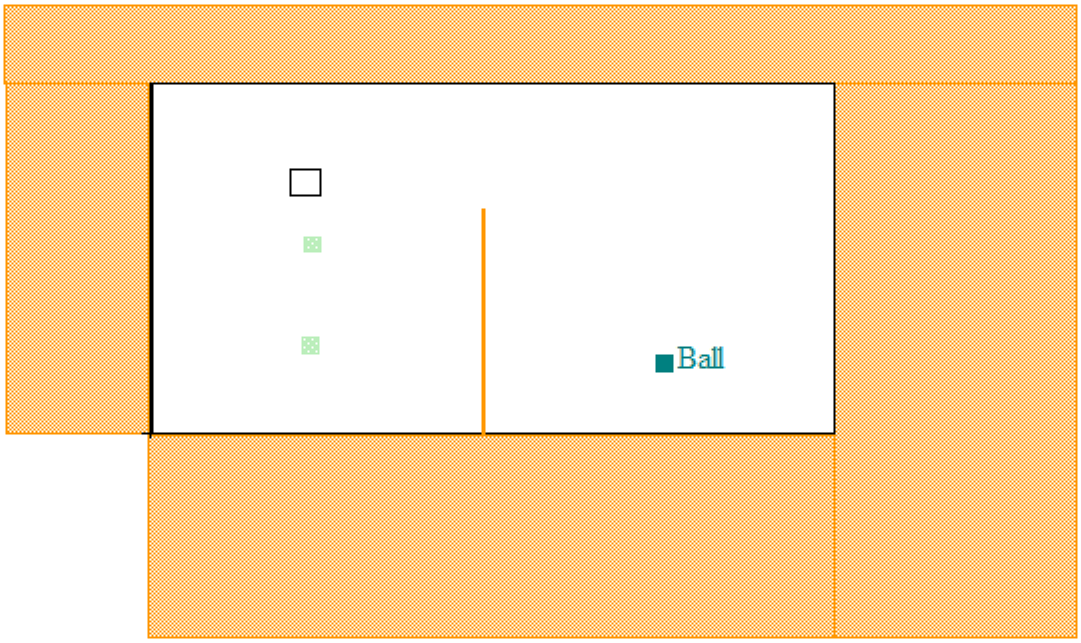
```
<objects> ::= <self> <ball><robot> barrier
<self> ::= <robot>
<robot> ::= <behaviours>
<behaviours> ::= <avoid> | <approach> | <hit> | <explore> | <observe>
<avoid> ::= move | stop | rotate
<approach> :: = move | stop | rotate
<hit> ::= <approach> | accelerate
<explore> ::= <avoid> | <approach>
<observe> ::= stop

<environment> ::= <wall> <wall> <wall> <wall> <objects> bounded
<wall> ::= barrier
```

Appendix K. Testbeds

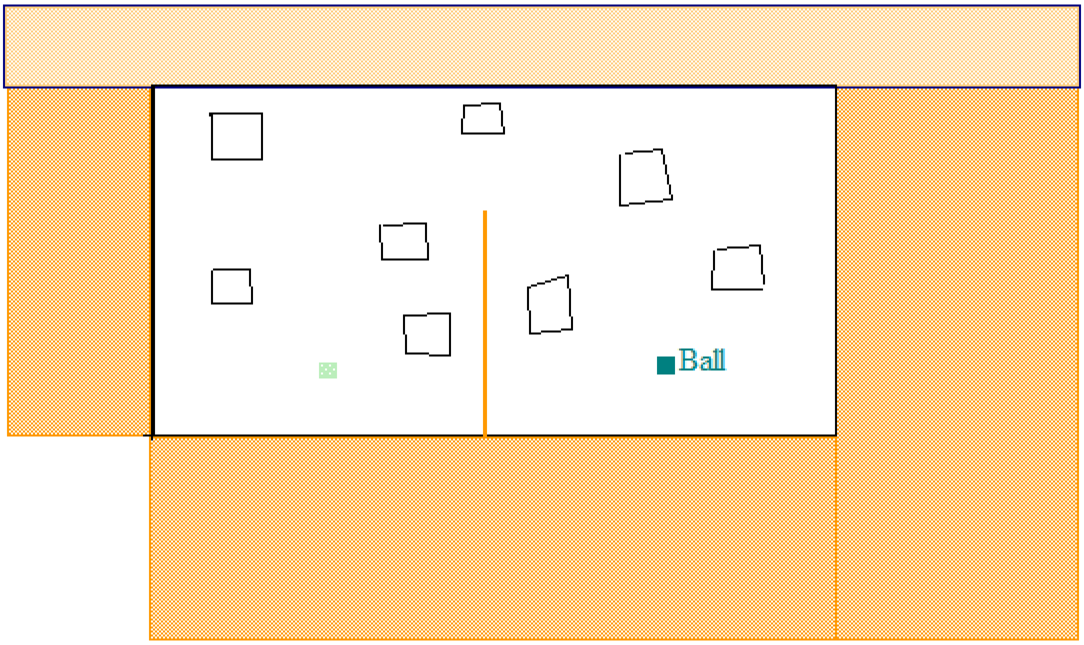
Main Testbed



Approach Testbed

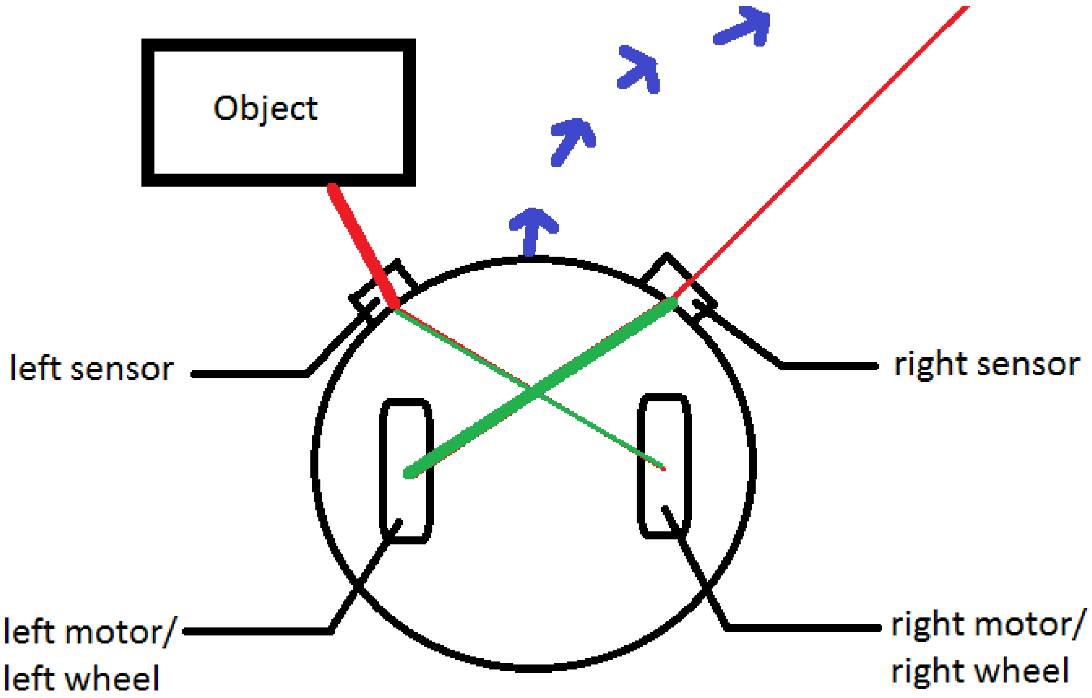


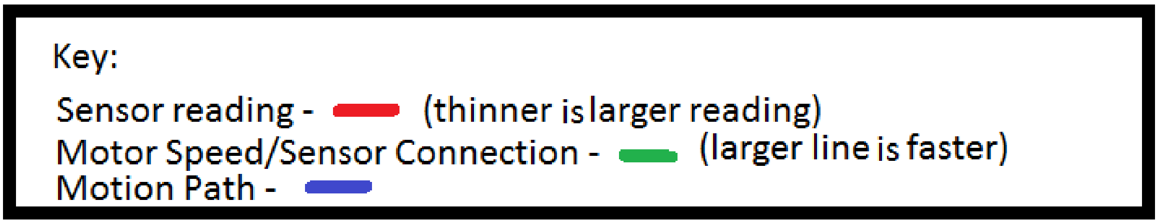
Avoidance Testbed



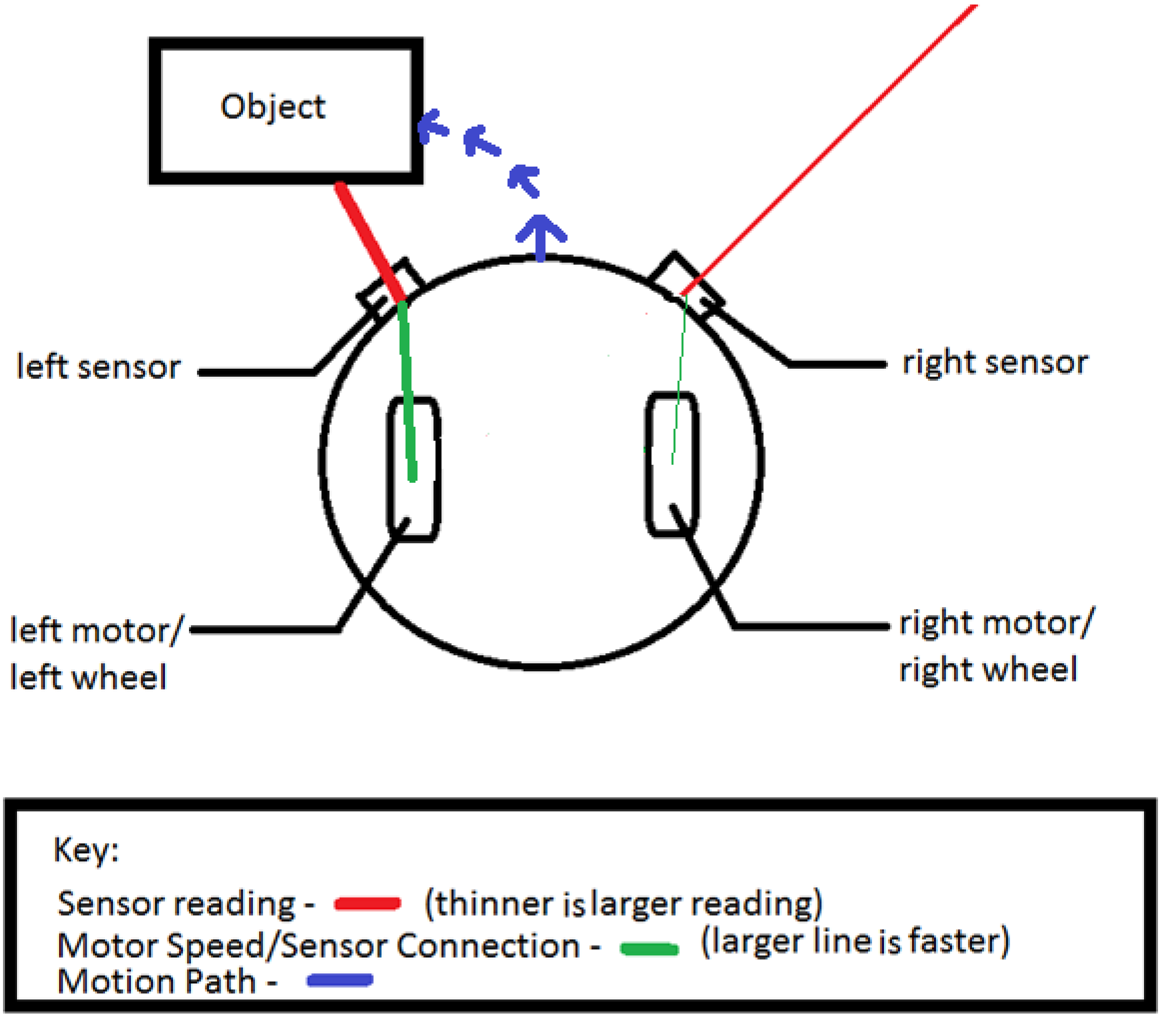
Appendix L. Braitenberg Vehicle Designs

Avoidance Braitenberg Vehicle





Approach Braitenberg Vehicle



Appendix M. Code Snippets

Main.cpp – K-line Implementation – setting up the main agent

```
switch (agent) {
	case ACCELERATE:
		robot.addAction(new Accelerate(strength), 50);
		break;
	case APPROACH:
		robot.addAction(new Approach(subagents, numOfSubagents, strength), 50);
		break;
	case AVOIDANCE:
		robot.addAction(new Avoidance(subagents, numOfSubagents, strength), 50);
		break;
	case EXPLORE:
		robot.addAction(new Explore(subagents, numOfSubagents, strength), 50);
		break;
	case FORWARD:
		robot.addAction(new Forward(strength), 50);
		break;
	case HIT:
		robot.addAction(new Hit(subagents, numOfSubagents, strength), 50);
		break;
	case OBSERVE:
		robot.addAction(new Observe(subagents, numOfSubagents, strength), 50);
		break;
	case REVERSE:
		robot.addAction(new Reverse(strength), 50);
		break;
	case ROTATE:
		robot.addAction(new Rotate(strength), 50);
		break;
	case STOP:
		robot.addAction(new Stop(strength), 50);
		break;
}
```

Approach Agent – K-line Implementation – Constructor setting up the subagents

```
for (int i = 0; i < numOfSubagents; ++i) {
      if (orginal_subagents[i]->type == APPROACH) {
            orginal_subagents[i]->type = -1;
      } else if (orginal_subagents[i]->type == HIT) {
            Subagents.push_back(new Hit(orginal_subagents, numOfSubagents, orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == EXPLORE) {
            Subagents.push_back(new Explore(orginal_subagents, numOfSubagents, orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == ACCELERATE) {
            Subagents.push_back(new Accelerate(orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == AVOIDANCE) {
            Subagents.push_back(new Avoidance(orginal_subagents, numOfSubagents, orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == REVERSE) {
            Subagents.push_back(new Reverse(orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == FORWARD) {
            Subagents.push_back(new Forward(orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == OBSERVE) {
            Subagents.push_back(new Observe(orginal_subagents, numOfSubagents, orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == ROTATE) {
            Subagents.push_back(new Rotate(orginal_subagents[i]->power));
      } else if (orginal_subagents[i]->type == STOP) {
            Subagents.push_back(new Stop(orginal_subagents[i]->power));
}

 Powers.push_back(orginal_subagents[i]->power);
}

NumOfSubagents = numOfSubagents;
```

Approach Agent – K-Line Implementation

```
int MostDesired = -1;
float MostPowerful = 0;
int LeastDesired = -1;
float LeastPowerful = 1;
int MidDesired = -1;
float MidPowerful = 0;
```

```

for (int i = 0; i < Subagents.size(); i++) {
      if (Powers[i] > MostPowerful) {
            MostPowerful = Powers[i];
            MostDesired = i;
      } else if (Powers[i] < LeastPowerful) {
            LeastPowerful = Powers[i];
            LeastDesired = i;
 } else if (Powers[i] > LeastPowerful && Powers[i] < MostPowerful) {
            MidPowerful = Powers[i];
            MidDesired = i;
      }
}

if (MostDesired >= 0) {
      //check if going in the correct direction
      if (LowestReadingInfront())
      {
            if (SensorLess(automata::LEFT_FRONT) && SensorLess(automata::RIGHT_FRONT)) //stop everything!
                  return Subagents[LeastDesired]->fire(currentDesired);
            else if (SensorMore(automata::LEFT_FRONT) && SensorMore(automata::RIGHT_FRONT))
            return Subagents[MostDesired]->fire(currentDesired);
      } else {
            return Subagents[MidDesired]->fire(currentDesired);
      }
}
```

Approach Agent – Preconfigured

```
if (LowestReadingInfront())
{
      //stop rotating/moving forward
      if (SensorLess(automata::LEFT_FRONT) && SensorLess(automata::RIGHT_FRONT)) //Close enough, now stop
            return stop->fire(currentDesired);
      else if (SensorMore(automata::LEFT_FRONT) && SensorMore(automata::RIGHT_FRONT))
            return forward->fire(currentDesired);
} else {
      //start rotating until lowestreading is infront
      int lowestReadingSensor = GetLowestReading();
```

```

    switch (lowestReadingSensor) {
            case automata::LEFT_FRONT:
            case automata::LEFT_FRONT_SIDE:
                    rotate->Clockwise = true;
                    break;
            case automata::RIGHT_FRONT:
            case automata::RIGHT_FRONT_SIDE:
                    rotate->Clockwise = false;
                    break;
    }

    return rotate->fire(currentDesired);
}
```

Hit Agent – Attempt to hit nearest object

```
if ( GetSensorReading(automata::LEFT_FRONT) < threshold ) {
    RecordPosition();
    RecordDistance(automata::LEFT_FRONT);

    if (ExceededDistance()) {
            AttemptedToHitRecently = true;
            return observe->fire(currentDesired);
    } else {
            return accelerate->fire(currentDesired);
    }
} else if (GetSensorReading(automata::RIGHT_FRONT) < threshold)
{
    RecordPosition();
    RecordDistance(automata::RIGHT_FRONT);

    if (ExceededDistance()) {
            AttemptedToHitRecently = true;
            return observe->fire(currentDesired);
    } else {
            return accelerate->fire(currentDesired);
    }
} else {
    return approach->fire(currentDesired);
}
```

Rotate Agent – Preconfigured

```
if (Clockwise)
 m_desire.setRotVel(velocity);
else
      m_desire.setRotVel(-velocity);
```

Rotate Agent – K-line Implementation

```
m_desire.setRotVel(velocity);
```

Approach Agent – Preconfigured – deciding which way to rotate

```
switch (lowestReadingSensor) {
      case automata::LEFT_FRONT:
      case automata::LEFT_FRONT_SIDE:
       rotate->Clockwise = true;
       break;
      case automata::RIGHT_FRONT:
      case automata::RIGHT_FRONT_SIDE:
 rotate->Clockwise = false;
            break;
}
```

Appendix N. Result Tables

Avoidance

Avoidance Agent Strength	Forward Agent Strength	Rotate Agent Strength	Time
1	1	0	16:29:48
1	1	0	16:29:49
1	1	0	16:29:50
1	1	0	16:29:51
1	1	0	16:29:52
1	1	0	16:29:53
1	1	0	16:29:54
1	1	0	16:29:55
1	1	0	16:29:56
1	1	0	16:29:57
1	1	0	16:29:58
1	1	0	16:29:59
1	0	1	16:30:00
1	1	0	16:30:02
1	1	0	16:30:03
1	1	0	16:30:04
1	1	0	16:30:05
1	1	0	16:30:06
1	1	0	16:30:07
1	0	1	16:30:09
1	0	1	16:30:10
1	0	1	16:30:11
1	0	1	16:30:12
1	1	0	16:30:14
1	1	0	16:30:15
1	1	0	16:30:16
1	1	0	16:30:17
1	1	0	16:30:18
1	0	1	16:30:19
1	0	1	16:30:20
1	1	0	16:30:21

1	1	0	16:30:22
1	1	0	16:30:23
1	1	0	16:30:24
1	1	0	16:30:25
1	1	0	16:30:26
1	1	0	16:30:27
1	1	0	16:30:28
1	1	0	16:30:29
1	1	0	16:30:30
1	1	0	16:30:31
1	0	1	16:30:32
1	1	0	16:30:33
1	1	0	16:30:34
1	1	0	16:30:35
1	1	0	16:30:36
1	1	0	16:30:37
1	1	0	16:30:38
1	1	0	16:30:39
1	1	0	16:30:40
1	1	0	16:30:41
1	1	0	16:30:42
1	1	0	16:30:43
1	1	0	16:30:44
1	1	0	16:30:45
1	1	0	16:30:46
1	1	0	16:30:47
1	1	0	16:30:48
1	1	0	16:30:49
1	1	0	16:30:50
1	1	0	16:30:51
1	1	0	16:30:52
1	1	0	16:30:53
1	1	0	16:30:54
1	1	0	16:30:55

1	1	0	16:30:56
1	0	1	16:30:57
1	0	1	16:30:58
1	1	0	16:30:59
1	1	0	16:31:00
1	1	0	16:31:01
1	1	0	16:31:02
1	1	0	16:31:03
1	1	0	16:31:04
1	1	0	16:31:05
1	1	0	16:31:06
1	0	1	16:31:07
1	1	0	16:31:08
1	1	0	16:31:09
1	1	0	16:31:10
1	1	0	16:31:11
1	1	0	16:31:12
1	1	0	16:31:13
1	1	0	16:31:14
1	1	0	16:31:15
1	1	0	16:31:16
1	1	0	16:31:17
1	1	0	16:31:18
1	1	0	16:31:19
1	0	1	16:31:20
1	0	1	16:31:21
1	1	0	16:31:22
1	1	0	16:31:23
1	1	0	16:31:24
1	1	0	16:31:25
1	1	0	16:31:26
1	1	0	16:31:27
1	1	0	16:31:28
1	1	0	16:31:29

1	1	0	16:31:30
1	1	0	16:31:31
1	1	0	16:31:32
1	1	0	16:31:33
1	1	0	16:31:34
1	1	0	16:31:35
1	1	0	16:31:36
1	1	0	16:31:37
1	1	0	16:31:38
1	1	0	16:31:39
1	1	0	16:31:40
1	1	0	16:31:41
1	1	0	16:31:42
1	1	0	16:31:43
1	1	0	16:31:44
1	1	0	16:31:45
1	1	0	16:31:46
1	0	1	16:31:47
1	1	0	16:31:48
1	0	1	16:31:49
1	1	0	16:31:50
1	1	0	16:31:51
1	1	0	16:31:52
1	1	0	16:31:53
1	1	0	16:31:54
1	1	0	16:31:55
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1	1	0	16:31:59
1	1	0	16:32:00
1	1	0	16:32:01
1	1	0	16:32:02
1	1	0	16:32:03

1	1	0	16:32:04
1	0	1	16:32:05
1	0	1	16:32:06
1	1	0	16:32:07
1	1	0	16:32:08
1	1	0	16:32:09
1	1	0	16:32:10
1	1	0	16:32:11
1	1	0	16:32:12
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1	1	0	16:32:17
1	1	0	16:32:18
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1	1	0	16:32:23
1	1	0	16:32:24
1	0	1	16:32:25
1	1	0	16:32:26
1	1	0	16:32:27
1	1	0	16:32:28
1	1	0	16:32:29
1	1	0	16:32:30
1	1	0	16:32:31
1	1	0	16:32:32
1	0	1	16:32:33
1	1	0	16:32:34
1	1	0	16:32:35
1	0	1	16:32:36
1	1	0	16:32:37

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1	1	0	16:32:59
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1	0	1	16:33:02
1	0	1	16:33:03
1	1	0	16:33:04
1	1	0	16:33:05
1	1	0	16:33:06
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1	1	0	16:35:24
1	1	0	16:35:25
1	1	0	16:35:26
1	0	1	16:35:27
1	1	0	16:35:28
1	0	1	16:35:29

1	1	0	16:35:30
1	1	0	16:35:31
1	1	0	16:35:32
1	1	0	16:35:33
1	1	0	16:35:34
1	1	0	16:35:35
1	1	0	16:35:36
1	1	0	16:35:37
1	1	0	16:35:38
1	1	0	16:35:39
1	1	0	16:35:40
1	1	0	16:35:41
1	1	0	16:35:42
1	1	0	16:35:43
1	1	0	16:35:44
1	1	0	16:35:45
1	0	1	16:35:46
1	0	1	16:35:47
1	1	0	16:35:48
1	1	0	16:35:49
1	1	0	16:35:50
1	1	0	16:35:51
1	1	0	16:35:52
1	1	0	16:35:53
1	0	1	16:35:54
1	0	1	16:35:55
1	1	0	16:35:56
1	1	0	16:35:57
1	1	0	16:35:59
1	1	0	16:36:00
1	0	1	16:36:01
1	1	0	16:36:02
1	1	0	16:36:03
1	1	0	16:36:04

1	1	0	16:36:05
1	1	0	16:36:06
1	1	0	16:36:07
1	1	0	16:36:08
1	1	0	16:36:09
1	1	0	16:36:10
1	1	0	16:36:11
1	1	0	16:36:12

Approach

Approach Agent Strength	Stop Agent Strength	Forward Agent Strength	Rotate Agent Strength	Time
1	0	0	1	17:30:21
1	0	0	1	17:30:22
1	0	1	0	17:30:23
1	0	1	0	17:30:24
1	0	1	0	17:30:25
1	0	1	0	17:30:26
1	1	0	0	17:30:27
1	1	0	0	17:30:28
1	1	0	0	17:30:29
1	1	0	0	17:30:30
1	1	0	0	17:30:31
1	1	0	0	17:30:32
1	1	0	0	17:30:33
1	1	0	0	17:30:34
1	1	0	0	17:30:35
1	1	0	0	17:30:36
1	1	0	0	17:30:37
1	1	0	0	17:30:38
1	1	0	0	17:30:39
1	1	0	0	17:30:40
1	1	0	0	17:30:41
1	1	0	0	17:30:42
1	1	0	0	17:30:43

1	1	0	0	17:30:44
1	1	0	0	17:30:45
1	1	0	0	17:30:46
1	1	0	0	17:30:47
1	1	0	0	17:30:48
1	1	0	0	17:30:49
1	1	0	0	17:30:50
1	1	0	0	17:30:51
1	1	0	0	17:30:52
1	1	0	0	17:30:53
1	1	0	0	17:30:54
1	1	0	0	17:30:55
1	1	0	0	17:30:56
1	1	0	0	17:30:57
1	1	0	0	17:30:58
1	1	0	0	17:30:59
1	1	0	0	17:31:00
1	1	0	0	17:31:01
1	1	0	0	17:31:02
1	1	0	0	17:31:03
1	1	0	0	17:31:04
1	1	0	0	17:31:05
1	1	0	0	17:31:06
1	1	0	0	17:31:07
1	1	0	0	17:31:08
1	1	0	0	17:31:09
1	1	0	0	17:31:10
1	1	0	0	17:31:11
1	1	0	0	17:31:12
1	1	0	0	17:31:13
1	0	0	1	17:31:14
1	0	1	0	17:31:15
1	0	1	0	17:31:16
1	0	0	1	17:31:17

1	0	0	1	17:31:18
1	0	0	1	17:31:19
1	0	0	1	17:31:20
1	0	0	1	17:31:21
1	0	1	0	17:31:22
1	0	1	0	17:31:23
1	0	1	0	17:31:24
1	0	1	0	17:31:25
1	0	1	0	17:31:26
1	0	1	0	17:31:27
1	0	1	0	17:31:28
1	1	0	0	17:31:29
1	1	0	0	17:31:30
1	1	0	0	17:31:31
1	1	0	0	17:31:32
1	1	0	0	17:31:33
1	1	0	0	17:31:34
1	1	0	0	17:31:35
1	1	0	0	17:31:36
1	1	0	0	17:31:37
1	1	0	0	17:31:38
1	1	0	0	17:31:39
1	1	0	0	17:31:40
1	1	0	0	17:31:41
1	1	0	0	17:31:42
1	1	0	0	17:31:43
1	1	0	0	17:31:44
1	1	0	0	17:31:45
1	1	0	0	17:31:46
1	1	0	0	17:31:47
1	1	0	0	17:31:48
1	1	0	0	17:31:49
1	1	0	0	17:31:50
1	1	0	0	17:31:51

1	1	0	0	17:31:52
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1	1	0	0	17:31:54
1	1	0	0	17:31:55
1	1	0	0	17:31:56
1	1	0	0	17:31:57
1	1	0	0	17:31:58
1	1	0	0	17:31:59
1	1	0	0	17:32:00
1	1	0	0	17:32:01
1	1	0	0	17:32:02
1	1	0	0	17:32:03
1	1	0	0	17:32:04
1	1	0	0	17:32:05
1	1	0	0	17:32:06
1	1	0	0	17:32:07
1	1	0	0	17:32:08
1	1	0	0	17:32:09
1	1	0	0	17:32:10
1	1	0	0	17:32:11
1	1	0	0	17:32:12
1	1	0	0	17:32:13
1	1	0	0	17:32:14
1	1	0	0	17:32:15
1	1	0	0	17:32:16
1	1	0	0	17:32:17
1	1	0	0	17:32:18
1	1	0	0	17:32:19
1	1	0	0	17:32:20
1	1	0	0	17:32:21
1	1	0	0	17:32:22
1	1	0	0	17:32:23
1	1	0	0	17:32:24
1	1	0	0	17:32:25

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1	1	0	0	17:32:27
1	1	0	0	17:32:28
1	1	0	0	17:32:29
1	1	0	0	17:32:30
1	1	0	0	17:32:31
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1	1	0	0	17:32:33
1	1	0	0	17:32:34
1	0	1	0	17:32:35
1	0	1	0	17:32:36
1	0	1	0	17:32:37
1	0	1	0	17:32:38
1	0	1	0	17:32:39
1	0	1	0	17:32:40
1	0	1	0	17:32:41
1	0	1	0	17:32:42
1	0	1	0	17:32:43
1	0	1	0	17:32:44
1	0	1	0	17:32:45
1	0	1	0	17:32:46
1	0	1	0	17:32:47
1	0	1	0	17:32:48
1	0	1	0	17:33:28
1	0	1	0	17:33:29
1	0	0	1	17:33:30
1	0	0	1	17:33:31
1	0	0	1	17:33:32
1	0	1	0	17:33:33
1	0	1	0	17:33:34
1	0	1	0	17:33:35
1	0	1	0	17:33:36
1	0	1	0	17:33:37
1	0	1	0	17:33:38

1	0	1	0	17:33:39
1	0	1	0	17:33:40
1	0	1	0	17:33:41
1	0	1	0	17:33:42
1	1	0	0	17:33:43
1	1	0	0	17:33:44
1	1	0	0	17:33:45
1	1	0	0	17:33:46
1	1	0	0	17:33:47
1	1	0	0	17:33:48
1	1	0	0	17:33:49
1	1	0	0	17:33:50
1	1	0	0	17:33:51
1	1	0	0	17:33:52
1	1	0	0	17:33:53
1	1	0	0	17:33:54
1	1	0	0	17:33:55
1	1	0	0	17:33:56
1	1	0	0	17:33:57
1	1	0	0	17:33:58
1	1	0	0	17:33:59
1	1	0	0	17:34:00
1	1	0	0	17:34:01
1	1	0	0	17:34:02
1	1	0	0	17:34:03
1	1	0	0	17:34:04
1	1	0	0	17:34:05
1	1	0	0	17:34:06
1	1	0	0	17:34:07
1	1	0	0	17:34:08
1	1	0	0	17:34:09
1	1	0	0	17:34:10
1	1	0	0	17:34:11
1	1	0	0	17:34:12

1	1	0	0	17:34:13
1	1	0	0	17:34:14
1	1	0	0	17:34:15
1	1	0	0	17:34:16
1	1	0	0	17:34:17
1	1	0	0	17:34:18
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1	1	0	0	17:34:20
1	1	0	0	17:34:21
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1	1	0	0	17:34:23
1	1	0	0	17:34:24
1	1	0	0	17:34:25
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1	0	1	0	17:34:27
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1	0	0	1	17:34:30
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1	0	1	0	17:34:33
1	0	1	0	17:34:34
1	0	1	0	17:34:35
1	0	1	0	17:34:36
1	0	1	0	17:34:37
1	0	1	0	17:34:38
1	0	1	0	17:34:39
1	0	1	0	17:34:40
1	0	1	0	17:34:41
1	0	1	0	17:34:42
1	0	1	0	17:34:43
1	0	1	0	17:34:44
1	0	1	0	17:34:45
1	0	1	0	17:34:46

1	0	1	0	17:34:47
1	0	1	0	17:34:48
1	0	1	0	17:34:49
1	0	1	0	17:34:50
1	1	0	0	17:34:51
1	1	0	0	17:34:52
1	1	0	0	17:34:53
1	1	0	0	17:34:54
1	1	0	0	17:34:55
1	1	0	0	17:34:56
1	1	0	0	17:34:57
1	1	0	0	17:34:58
1	1	0	0	17:34:59
1	1	0	0	17:35:00
1	0	0	1	17:35:01
1	0	0	1	17:35:02
1	0	1	0	17:35:03
1	0	1	0	17:35:04
1	0	1	0	17:35:05
1	0	1	0	17:35:06
1	0	1	0	17:35:07
1	0	1	0	17:35:08

Explore

Explore Agent Strength	Avoidance Agent Strength	Approach Agent Strength	Rotate Agent Strength	Forward Agent Strength	Stop Agent Strength	Time
1	1	0	0	1	0	18:22:33
1	1	0	0	1	0	18:22:34
1	1	0	0	1	0	18:22:35
1	1	0	0	1	0	18:22:36
1	1	0	0	1	0	18:22:37

1	1	0	0	1	0	18:22:38
1	1	0	0	1	0	18:22:39
1	1	0	0	1	0	18:22:40
1	1	0	0	1	0	18:22:41
1	1	0	0	1	0	18:22:42
1	1	0	0	1	0	18:22:43
1	1	0	0	1	0	18:22:44
1	1	0	0	1	0	18:22:45
1	1	0	0	1	0	18:22:46
1	1	0	0	1	0	18:22:47
1	1	0	0	1	0	18:22:48
1	1	0	0	1	0	18:22:49
1	1	0	0	1	0	18:22:50
1	1	0	1	0	0	18:22:51
1	1	0	1	0	0	18:22:52
1	1	0	0	1	0	18:22:53
1	1	0	0	1	0	18:22:54
1	1	0	0	1	0	18:22:55
1	1	0	0	1	0	18:22:56
1	1	0	0	1	0	18:22:57
1	1	0	0	1	0	18:2

						2:58
1	1	0	0	1	0	18:2 2:59
1	1	0	1	0	0	18:2 3:00
1	1	0	0	1	0	18:2 3:01
1	1	0	0	1	0	18:2 3:02
1	1	0	0	1	0	18:2 3:03
1	1	0	0	1	0	18:2 3:04
1	1	0	0	1	0	18:2 3:05
1	1	0	0	1	0	18:2 3:06
1	1	0	0	1	0	18:2 3:07
1	1	0	0	1	0	18:2 3:08
1	1	0	0	1	0	18:2 3:09
1	1	0	0	1	0	18:2 3:10
1	1	0	0	1	0	18:2 3:11
1	1	0	0	1	0	18:2 3:12
1	1	0	0	1	0	18:2 3:13
1	1	0	0	1	0	18:2 3:14
1	1	0	0	1	0	18:2 3:15
1	1	0	0	1	0	18:2 3:16
1	1	0	0	1	0	18:2 3:17
1	1	0	0	1	0	18:2 3:18

1	1	0	0	1	0	18:2 3:19
1	1	0	0	1	0	18:2 3:20
1	1	0	0	1	0	18:2 3:21
1	1	0	0	1	0	18:2 3:22
1	1	0	0	1	0	18:2 3:23
1	1	0	0	1	0	18:2 3:24
1	1	0	0	1	0	18:2 3:25
1	1	0	0	1	0	18:2 3:26
1	1	0	0	1	0	18:2 3:27
1	1	0	0	1	0	18:2 3:28
1	1	0	0	1	0	18:2 3:29
1	1	0	0	1	0	18:2 3:30
1	1	0	0	1	0	18:2 3:31
1	1	0	0	1	0	18:2 3:32
1	1	0	0	1	0	18:2 3:33
1	1	0	0	1	0	18:2 3:34
1	1	0	0	1	0	18:2 3:35
1	1	0	0	1	0	18:2 3:36
1	1	0	1	0	0	18:2 3:37
1	1	0	1	0	0	18:2 3:38
1	1	0	0	1	0	18:2

						3:39
1	1	0	0	1	0	18:2 3:40
1	1	0	0	1	0	18:2 3:41
1	1	0	0	1	0	18:2 3:42
1	1	0	0	1	0	18:2 3:43
1	1	0	0	1	0	18:2 3:44
1	1	0	0	1	0	18:2 3:45
1	1	0	0	1	0	18:2 3:46
1	1	0	0	1	0	18:2 3:47
1	1	0	0	1	0	18:2 3:48
1	1	0	0	1	0	18:2 3:49
1	1	0	0	1	0	18:2 3:50
1	1	0	0	1	0	18:2 3:51
1	1	0	0	1	0	18:2 3:52
1	1	0	0	1	0	18:2 3:53
1	1	0	0	1	0	18:2 3:54
1	1	0	0	1	0	18:2 3:55
1	1	0	0	1	0	18:2 3:56
1	1	0	0	1	0	18:2 3:57
1	1	0	0	1	0	18:2 3:58
1	1	0	0	1	0	18:2 3:59

1	1	0	0	1	0	18:24:00
1	1	0	0	1	0	18:24:01
1	1	0	0	1	0	18:24:02
1	1	0	0	1	0	18:24:03
1	1	0	0	1	0	18:24:04
1	1	0	0	1	0	18:24:05
1	1	0	1	0	0	18:24:06
1	1	0	0	1	0	18:24:07
1	1	0	0	1	0	18:24:08
1	1	0	0	1	0	18:24:09
1	1	0	0	1	0	18:24:10
1	1	0	0	1	0	18:24:11
1	1	0	0	1	0	18:24:12
1	1	0	0	1	0	18:24:13
1	1	0	0	1	0	18:24:14
1	1	0	0	1	0	18:24:15
1	1	0	0	1	0	18:24:16
1	1	0	0	1	0	18:24:17
1	1	0	0	1	0	18:24:18
1	0	1	1	0	0	18:24:19
1	0	1	1	0	0	18:2

						4:20
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1	0	1	0	1	0	18:2 4:22
1	0	1	0	1	0	18:2 4:23
1	0	1	0	1	0	18:2 4:24
1	0	1	0	1	0	18:2 4:25
1	0	1	0	1	0	18:2 4:26
1	0	1	0	1	0	18:2 4:27
1	0	1	0	0	1	18:2 4:28
1	0	1	0	0	1	18:2 4:29
1	0	1	0	0	1	18:2 4:30
1	0	1	0	0	1	18:2 4:31
1	0	1	0	0	1	18:2 4:32
1	0	1	0	0	1	18:2 4:33
1	0	1	0	0	1	18:2 4:34
1	0	1	0	0	1	18:2 4:35
1	0	1	0	0	1	18:2 4:36
1	0	1	0	0	1	18:2 4:37
1	0	1	0	0	1	18:2 4:38
1	0	1	0	0	1	18:2 4:39
1	0	1	0	0	1	18:2 4:40

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1	0	1	0	0	1	18:24:42
1	0	1	0	0	1	18:24:43
1	0	1	0	0	1	18:24:44
1	0	1	0	0	1	18:24:45
1	0	1	0	0	1	18:24:46
1	0	1	0	0	1	18:24:47
1	0	1	0	0	1	18:24:48
1	0	1	0	0	1	18:24:49
1	0	1	0	0	1	18:24:50
1	0	1	0	0	1	18:24:51
1	0	1	0	0	1	18:24:52
1	0	1	0	0	1	18:24:53
1	0	1	0	0	1	18:24:54
1	0	1	0	0	1	18:24:55
1	0	1	0	0	1	18:24:56
1	0	1	0	0	1	18:24:57
1	0	1	0	0	1	18:24:58
1	0	1	0	0	1	18:24:59
1	0	1	0	0	1	18:25:00
1	0	1	0	0	1	18:2

						5:01
1	0	1	0	0	1	18:2 5:02
1	0	1	0	0	1	18:2 5:03
1	0	1	0	0	1	18:2 5:04
1	0	1	0	0	1	18:2 5:05
1	0	1	0	0	1	18:2 5:06
1	0	1	0	0	1	18:2 5:07
1	0	1	0	0	1	18:2 5:08
1	0	1	0	0	1	18:2 5:09
1	0	1	0	0	1	18:2 5:10
1	0	1	0	0	1	18:2 5:11
1	0	1	0	0	1	18:2 5:12
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1	1	0	1	0	0	18:2 5:14
1	1	0	1	0	0	18:2 5:15
1	1	0	0	1	0	18:2 5:18
1	1	0	0	1	0	18:2 5:19
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1	1	0	0	1	0	18:2 5:21
1	1	0	0	1	0	18:2 5:22
1	1	0	0	1	0	18:2 5:23

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1	1	0	0	1	0	18:25:26
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1	1	0	0	1	0	18:25:28
1	1	0	0	1	0	18:25:29
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1	1	0	0	1	0	18:25:32
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1	1	0	0	1	0	18:25:35
1	1	0	0	1	0	18:25:36
1	1	0	0	1	0	18:25:37
1	1	0	0	1	0	18:25:38
1	1	0	1	0	0	18:25:39
1	1	0	0	1	0	18:25:41
1	1	0	0	1	0	18:25:42
1	1	0	0	1	0	18:25:43
1	1	0	0	1	0	18:25:44
1	1	0	0	1	0	18:2

						5:45
1	1	0	0	1	0	18:2 5:46
1	1	0	0	1	0	18:2 5:47
1	1	0	0	1	0	18:2 5:48
1	1	0	0	1	0	18:2 5:49
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1	1	0	0	1	0	18:2 5:51
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1	1	0	0	1	0	18:2 5:53
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1	1	0	0	1	0	18:2 5:55
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1	1	0	0	1	0	18:2 5:57
1	1	0	0	1	0	18:2 5:58
1	1	0	0	1	0	18:2 5:59
1	1	0	0	1	0	18:2 6:00
1	1	0	0	1	0	18:2 6:01
1	1	0	0	1	0	18:2 6:02
1	1	0	1	0	0	18:2 6:03
1	1	0	1	0	0	18:2 6:04
1	1	0	0	1	0	18:2 6:05

1	1	0	0	1	0	18:2 6:06
1	1	0	0	1	0	18:2 6:07
1	1	0	0	1	0	18:2 6:08
1	1	0	0	1	0	18:2 6:09
1	1	0	0	1	0	18:2 6:10
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1	1	0	0	1	0	18:2 6:18
1	1	0	0	1	0	18:2 6:19
1	1	0	0	1	0	18:2 6:20
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1	1	0	0	1	0	18:2 6:22
1	1	0	0	1	0	18:2 6:23
1	1	0	0	1	0	18:2 6:24
1	1	0	0	1	0	18:2 6:25
1	1	0	0	1	0	18:2

						6:26
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1	1	0	0	1	0	18:2 6:32
1	1	0	0	1	0	18:2 6:33
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1	1	0	0	1	0	18:2 6:35
1	1	0	0	1	0	18:2 6:36
1	1	0	0	1	0	18:2 6:37
1	1	0	0	1	0	18:2 6:38
1	1	0	0	1	0	18:2 6:39
1	1	0	0	1	0	18:2 6:40
1	1	0	0	1	0	18:2 6:41
1	1	0	0	1	0	18:2 6:42
1	1	0	0	1	0	18:2 6:43
1	1	0	0	1	0	18:2 6:44
1	1	0	0	1	0	18:2 6:45
1	1	0	0	1	0	18:2 6:46
1	1	0	0	1	0	18:2 6:47

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1	1	0	0	1	0	18:26:53
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1	1	0	0	1	0	18:26:55
1	1	0	0	1	0	18:26:56
1	1	0	0	1	0	18:26:57
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1	1	0	0	1	0	18:26:59
1	1	0	0	1	0	18:27:00
1	1	0	0	1	0	18:27:01
1	1	0	0	1	0	18:27:02
1	1	0	0	1	0	18:27:03
1	1	0	1	0	0	18:27:04
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1	0	1	1	0	0	18:27:06
1	0	1	1	0	0	18:27:07
1	0	1	1	0	0	18:2

						7:08
1	0	1	0	1	0	18:2 7:09

Observe

Observe Agent Strength	Stop Agent Strength	Time
1	0	19:54:29
1	0	19:54:30
1	0	19:54:31
1	0	19:54:32
1	0	19:54:35
1	0	19:54:36
1	0	19:54:37
1	0	19:54:38
1	0	19:54:39
1	0	19:54:40
1	0	19:54:41
1	0	19:54:42
1	0	19:54:43
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1	0	19:54:47
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1	0	19:54:54
1	0	19:54:55
1	0	19:54:56
1	0	19:54:57
1	0	19:54:58
1	0	19:54:59

1	0	19:55:00
1	0	19:55:01
1	0	19:55:02
1	0	19:55:03
1	0	19:55:04
1	0	19:55:05
1	0	19:55:06
1	0	19:55:07
1	0	19:55:08
1	0	19:55:09
1	0	19:55:10
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1	0	19:55:28
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1	0	19:56:02
1	0	19:56:03
1	0	19:56:04
1	0	19:56:05
1	0	19:56:06
1	0	19:56:07

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1	0	19:59:00
1	0	19:59:01
1	0	19:59:02
1	0	19:59:03
1	0	19:59:04
1	0	19:59:05
1	0	19:59:06
1	0	19:59:07
1	0	19:59:08

Hit

Hit	Explore	Accelerate	Observe	Approach	Avoidance	Forward	Stop	Rotate	Time
1	0	0	0	1	0	0	0	1	21:10:27
1	0	0	0	1	0	0	0	1	21:10:28
1	0	0	0	1	0	0	0	1	21:10:29
1	0	0	0	1	0	0	0	1	21:10:30
1	0	0	0	1	0	0	0	1	21:10:31
1	0	0	0	1	0	0	0	1	21:10:32
1	0	0	0	1	0	0	0	1	21:10:33
1	0	0	0	1	0	1	0	0	21:10:34
1	0	0	0	1	0	1	0	0	21:10:35
1	0	0	0	1	0	1	0	0	21:10:36
1	0	0	0	1	0	1	0	0	21:10:37
1	0	0	0	1	0	1	0	0	21:10:38
1	0	0	0	1	0	1	0	0	21:10:39
1	0	0	1	0	1	0	0	1	21:10:40
1	1	0	0	0	1	0	0	1	21:10:41
1	1	0	0	0	1	0	0	1	21:10:42
1	1	0	0	0	1	0	0	1	21:10:43
1	1	0	0	0	1	1	0	0	21:10:46
1	0	0	0	1	0	0	0	1	21:10:47
1	0	0	0	1	0	0	0	1	21:10:48
1	0	0	0	1	0	0	0	1	21:10:49

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1	1	0	0	0	1	0	0	1	21:10:52
1	1	0	0	0	1	0	0	1	21:10:53
1	1	0	0	0	1	0	0	1	21:10:54
1	1	0	0	0	1	1	0	0	21:10:56
1	0	0	0	1	0	0	0	1	21:10:57
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1	0	0	0	1	0	1	0	0	21:11:36
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1	1	0	0	0	1	1	0	0	21:11:42
1	1	0	0	1	0	0	0	1	21:11:43
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1	1	0	0	0	1	0	0	1	21:11:45
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1	0	0	0	1	0	1	0	0	21:11:52
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1	0	0	0	1	0	1	0	0	21:12:51
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1	1	0	0	0	1	0	0	1	21:12:53
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1	1	0	0	0	1	1	0	0	21:12:57
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1	0	0	0	1	0	0	0	1	21:12:59
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1	0	0	1	0	1	0	0	1	21:13:01
1	1	0	0	0	1	0	0	1	21:13:02
1	1	0	0	0	1	0	0	1	21:13:03
1	1	0	0	0	1	1	0	0	21:13:04
1	1	0	0	0	1	1	0	0	21:13:05
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1	1	0	0	1	0	0	0	1	21:13:07
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1	1	0	0	0	1	1	0	0	21:13:12
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1	0	0	0	1	0	0	0	1	21:13:36
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1	0	0	0	1	0	1	0	0	21:13:38
1	0	0	0	1	0	1	0	0	21:13:39
1	1	0	0	0	1	0	0	1	21:13:40

1	1	0	0	0	1	0	0	1	21:13:41
1	1	0	0	0	1	1	0	0	21:13:42
1	1	0	0	0	1	1	0	0	21:13:43
1	1	0	0	1	0	0	0	1	21:13:44
1	1	0	0	1	0	0	0	1	21:13:45
1	0	0	0	1	0	1	0	0	21:13:46
1	1	0	0	1	0	1	0	0	21:13:47
1	1	0	0	1	0	0	1	0	21:13:48
1	1	0	0	1	0	0	1	0	21:13:49
1	1	0	0	1	0	0	1	0	21:13:50
1	1	0	0	1	0	0	1	0	21:13:51
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1	1	0	0	1	0	0	1	0	21:13:57
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1	1	0	0	1	0	0	1	0	21:14:02
1	1	0	0	1	0	0	1	0	21:14:03
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1	1	0	0	1	0	0	1	0	21:14:06
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1	1	0	0	1	0	0	1	0	21:14:09
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1	1	0	0	1	0	0	1	0	21:14:12
1	1	0	0	1	0	0	1	0	21:14:13
1	1	0	0	1	0	0	1	0	21:14:14

1	1	0	0	1	0	0	1	0	21:14:15
1	1	0	0	1	0	0	1	0	21:14:16
1	1	0	0	1	0	0	1	0	21:14:17
1	1	0	0	1	0	0	1	0	21:14:18
1	1	0	0	1	0	0	1	0	21:14:19
1	1	0	0	1	0	0	1	0	21:14:20
1	0	0	1	1	0	0	1	0	21:14:21
1	1	0	0	1	0	0	1	0	21:14:22
1	1	0	0	1	0	0	1	0	21:14:23
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1	1	0	0	1	0	0	1	0	21:14:25
1	1	0	0	1	0	0	1	0	21:14:26
1	1	0	0	1	0	0	1	0	21:14:27
1	1	0	0	1	0	0	1	0	21:14:28
1	1	0	0	0	0	0	0	0	21:14:29
1	1	0	0	1	0	0	1	0	21:14:30
1	1	0	0	1	0	0	1	0	21:14:31
1	1	0	0	1	0	0	1	0	21:14:32
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1	1	0	0	1	0	0	1	0	21:14:35
1	1	0	0	1	0	0	1	0	21:14:36
1	1	0	0	0	0	0	0	0	21:14:37
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1	1	0	0	1	0	0	1	0	21:14:43
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1	1	0	0	1	0	0	1	0	21:14:45
1	1	0	0	1	0	0	1	0	21:14:46
1	1	0	0	1	0	0	1	0	21:14:47
1	1	0	0	1	0	0	1	0	21:14:48

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1	1	0	0	1	0	0	1	0	21:14:50
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1	1	0	0	1	0	0	1	0	21:14:52
1	1	0	0	1	0	0	1	0	21:14:53
1	1	0	0	0	1	0	0	1	21:14:54
1	1	0	0	0	1	0	0	1	21:14:55
1	1	0	0	0	1	0	0	1	21:14:56
1	0	0	0	1	0	0	0	1	21:14:57
1	0	0	0	1	0	0	0	1	21:14:58
1	0	0	0	1	0	0	0	1	21:14:59
1	1	0	0	0	1	0	0	1	21:15:00
1	1	0	0	0	1	0	0	1	21:15:01
1	1	0	0	0	1	1	0	0	21:15:03
1	1	0	0	0	1	1	0	0	21:15:04
1	1	0	0	0	1	1	0	0	21:15:05
1	1	0	0	0	1	1	0	0	21:15:06
1	0	0	0	1	0	0	0	1	21:15:07
1	0	0	0	1	0	0	0	1	21:15:08
1	0	0	0	1	0	0	0	1	21:15:09
1	0	0	0	1	0	1	0	0	21:15:10

<u>Main Goal</u>

Hit	Explore	Accelerate	Observe	Approach	Avoidance	Forward	Stop	Rotate	Time
1	0	0	0	1	0	0	0	1	21:39:06
1	0	0	0	1	0	0	0	1	21:39:07
1	0	0	0	1	0	0	0	1	21:39:08
1	0	0	0	1	0	0	0	1	21:39:09
1	0	0	0	1	0	0	0	1	21:39:10
1	0	0	0	1	0	0	0	1	21:39:11
1	0	0	0	1	0	0	0	1	21:39:12
1	0	0	0	1	0	0	0	1	21:39:13
1	0	0	0	1	0	0	0	1	21:39:14
1	0	0	0	1	0	1	0	0	21:39:15
1	0	0	0	1	0	1	0	0	21:39:16

1	0	0	0	1	0	1	0	0	21:39:17
1	0	0	0	1	0	1	0	0	21:39:18
1	0	0	0	1	0	1	0	0	21:39:19
1	0	0	0	1	0	1	0	0	21:39:20
1	0	0	0	1	0	1	0	0	21:39:21
1	0	0	1	0	1	0	0	1	21:39:26
1	1	0	0	0	1	0	0	1	21:39:27
1	1	0	0	0	1	0	0	1	21:39:28
1	1	0	0	0	1	0	0	1	21:39:29
1	1	0	0	0	1	0	0	1	21:39:30
1	1	0	0	0	1	0	0	1	21:39:31
1	1	0	0	0	1	0	0	1	21:39:32
1	1	0	0	0	1	0	0	1	21:39:33
1	1	0	0	0	1	0	0	1	21:39:34
1	1	0	0	0	1	1	0	0	21:39:38
1	1	0	0	0	1	1	0	0	21:39:39
1	0	0	0	1	0	0	0	1	21:39:40
1	0	0	0	1	0	0	0	1	21:39:41
1	0	0	0	1	0	0	0	1	21:39:42
1	0	0	0	1	0	1	0	0	21:39:43
1	0	0	0	1	0	1	0	0	21:39:44
1	0	0	1	0	1	0	0	1	21:39:45
1	1	0	0	0	1	0	0	1	21:39:46
1	1	0	0	0	1	0	0	1	21:39:47
1	1	0	0	0	1	0	0	1	21:39:48
1	1	0	0	0	1	1	0	0	21:39:51
1	0	0	0	1	0	0	0	1	21:39:52
1	0	0	0	1	0	0	0	1	21:39:53
1	0	0	0	1	0	0	0	1	21:39:54
1	0	0	0	1	0	1	0	0	21:39:55
1	0	0	1	0	1	0	0	1	21:39:56
1	1	0	0	0	1	0	0	1	21:39:57
1	1	0	0	0	1	0	0	1	21:39:58
1	1	0	0	0	1	0	0	1	21:39:59

1	1	0	0	0	1	0	0	1	21:40:00
1	1	0	0	0	1	1	0	0	21:40:02
1	1	0	0	1	0	0	0	1	21:40:03
1	0	0	0	1	0	0	0	1	21:40:04
1	0	0	0	1	0	0	0	1	21:40:05
1	0	0	0	1	0	1	0	0	21:40:06
1	0	0	1	0	1	0	0	1	21:40:07
1	1	0	0	0	1	0	0	1	21:40:08
1	1	0	0	0	1	0	0	1	21:40:09
1	1	0	0	0	1	1	0	0	21:40:10
1	1	0	0	0	1	1	0	0	21:40:11
1	1	0	0	0	1	1	0	0	21:40:12
1	1	0	0	1	0	0	0	1	21:40:13
1	0	0	0	1	0	0	0	1	21:40:14
1	0	0	0	1	0	0	0	1	21:40:15
1	0	0	0	1	0	1	0	0	21:40:16
1	0	0	0	1	0	1	0	0	21:40:17
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1	1	0	0	0	1	0	0	1	21:40:19
1	1	0	0	0	1	1	0	0	21:40:20
1	1	0	0	0	1	1	0	0	21:40:21
1	1	0	0	0	1	1	0	0	21:40:22
1	1	0	0	0	1	1	0	0	21:40:23
1	1	0	0	0	1	1	0	0	21:40:24
1	1	0	0	0	1	1	0	0	21:40:25
1	1	0	0	1	0	0	0	1	21:40:26
1	0	0	0	1	0	0	0	1	21:40:27
1	0	0	0	1	0	0	0	1	21:40:28
1	0	0	0	1	0	0	0	1	21:40:29
1	0	0	0	1	0	0	0	1	21:40:30
1	0	0	0	1	0	1	0	0	21:40:31
1	0	0	0	1	0	1	0	0	21:40:32
1	0	0	0	1	0	1	0	0	21:40:33
1	0	0	0	1	0	1	0	0	21:40:34

1	0	0	0	1	0	1	0	0	21:40:35
1	1	0	0	0	1	0	0	1	21:40:36
1	1	0	0	0	1	0	0	1	21:40:37
1	1	0	0	0	1	0	0	1	21:40:38
1	1	0	0	0	1	0	0	1	21:40:39
1	1	0	0	0	1	0	0	1	21:40:40
1	1	0	0	0	1	0	0	1	21:40:41
1	1	0	0	0	1	0	0	1	21:40:42
1	1	0	0	0	1	1	0	0	21:40:44
1	1	0	0	0	1	1	0	0	21:40:45
1	1	0	0	0	1	1	0	0	21:40:46
1	1	0	0	0	1	1	0	0	21:40:47
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1	1	0	0	0	1	1	0	0	21:40:49
1	1	0	0	0	1	1	0	0	21:40:50
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1	0	0	0	1	0	0	0	1	21:40:52
1	0	0	0	1	0	0	0	1	21:40:53
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1	0	0	0	1	0	1	0	0	21:40:55
1	0	0	0	1	0	1	0	0	21:40:56
1	0	0	0	1	0	1	0	0	21:40:57
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1	1	0	0	0	1	0	0	1	21:40:59
1	1	0	0	0	1	0	0	1	21:41:00
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1	1	0	0	0	1	0	0	1	21:41:02
1	1	0	0	0	1	1	0	0	21:41:03
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1	1	0	0	0	1	1	0	0	21:41:15
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1	0	0	0	1	0	1	0	0	21:42:39
1	0	0	0	1	0	1	0	0	21:42:40
1	0	0	0	1	0	1	0	0	21:42:41
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1	1	0	0	1	0	0	1	0	21:55:07