Encouraging people to follow an autonomous robotic guide.

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Abstract

The motivation for this project is to design and build a guiding method that can encourage people to keep following it as it guides them. Two methods were designed by looking at other similar robots and different ways that person can be encourage to do something. Both methods were made and tested in a simulator before being integrated onto the STRANDS project robot Linda. Once the integrated methods were tested to make sure that they work, a user participation study was performed to determine which method was better at encouraging a person to follow. The outcome of the user study showed that the user is more encourage by a robot that uses both verbal and nonverbal forms of encouragement.

Table of Contents

List of tables and figures

Introduction

This report discusses the designing & developing of the artefact and how the project was managed. The reports firstly discusses the aims and objectives of this project, then the background research is discussed to show what has been done and what techniques and methods could be used for this project. The methodology parts of this report discuss how the project was managed, what software development life cycle was used and why as well as what tools where used in making the artifact and what methods were used in the research.

After that the report focuses on the designing, developing and testing of the artifact. The report continues onto the artefact's evaluation, which leads onto the conclusion were the report talks about if the project was successful or not. The final part of this report is about the project as a whole, what was bad or good and what would be changed if this project was to be attempted again.

Motivation

The motivation for this project is to design and build a guiding method that can encourage people to keep following it as it guides them. There have been several other robots that accomplish different parts of this, such as Gockley's Paper "*Encouraging Physical Therapy Compliance with a Hands-Off Mobile Robot*" where they had a robot give non-verbal encouragement to the user to them keep exercising (Gockley and MatariĆ, 2006), or Jinny the robot from "*The autonomous tour-guide robot Jinny*" (Kim et al., 2004). This robot is designed not only to guide visitors but to entertain them as well by playing a game with them and dancing to music. The entertainment aspect is not used to encourage people during the guide. In Shiomi's paper "A Larger Audience, Please! Encouraging people to listen to a guide robot" (Shiomi et al, 2010) they had their robot move backwards to get pedestrians to pay attention to it. Once someone showed an interest, the robot would try and guide them to a store, the robot performed non-verbal encouragement to encourage people to approach and interact with robot. They had the robot move backwards so it can keep eye contact with the follower. This robot did not try to keep them following once the guide had started. Therefore, it seems there are not many papers that are about robots that try to encourage people to keep following a robot guide.

So the motivation for this project is to build upon the current research and to make a robot guide that is able to determine those that need some encouragement to keep following the guide.

The main uses for this type of robot guide would be in care homes, where the elderly or those with some physical disability are guided around as part of their physical therapy. The robot would guide these people around a predefined route to get them their exercise, those that struggle to keep following or those that forget to follow will be encourage by the guide to keep following.

Aims and objectives

The aim of this project is to have Linda, the STRANDS project robot, be able to guide a person around a predefined route while using different forms of encouragement to keep the users following Linda. Different methods will use different forms of encouragement and the aim is to be able to determine which method is the most efficient and encouraging.

To accomplish this aim two methods were designed and developed to guide the user around. each tries to determine if the person following needs encouragement and if they do then the robot will give some form of encouragement to the user to keep them following. Two methods will be made, with the second method being based off the prior one, with the second method aiming to be a more complex version of the first. These methods were developed and tested with the ROS simulator. Once they worked in the simulator they were integrated on the robot. To find which method meets the aims of the project, a user group study was conducted, where each participant tests each method. After the tests they were each given questionnaire to get their thoughts about their experience with the robot. The data from the questionnaire was used to determine which method is the better one.

Objectives

- Design encouraging guide methods – two methods will be designed so that a robot guide will be able to determine if someone needs encouragement to follow and keeps them following.
- Integration of methods into simulator – these methods will be made in the ROS simulator, were they can be built without fear of damaging the real robot.
- Testing in simulator – Theses methods will be tested in the ROS simulator to remove most of the bugs and issues.
- Integrate with Linda – The methods will be integrated onto the robot Linda.
- Test with Linda – Test that the methods work on Linda, and fix any issues that might arise from the integration.
- Live testing – Have human participants testing methods. All the data relevant to the project will be collected at this stage.
- Evaluation – Evaluating the data collected from the live testing and determine which method was the most encouraging and quickest to complete the route out of all the methods developed.

Below are some basic requirement that the artifact must do:

- Must be able to determine if person is having problems keeping up.
- Must complete the route once started with follower.
- Robot must not be a hindrance to other walkers e.g. getting in the way of other walkers or obstructed them.

Background

Robot guides have been around for years, with one of the older ones being a guide dog robot called MELDOG, which was designed to guide blind people. (Tachi et al, 1985). This project is about guiding a human around an indoor environment and giving the follower encouragement to keep them following the robot when they need it. This section will look at different robot guides, different ways to encourage a human and what robots do currently to encourage humans to do something.

Over the years there has been several different methods of guiding a human around an indoor environment. Most of these have been in a museum environment and were used to show guests the different exhibits or give different tours. One of the simpler methods used was to have the robot go from one place to another. At each place, for example an exhibit, the robot would stop for a set amount of time to give some information about the location before moving on to the next. The robot would continue this process until it had finished the route and then in most implementations it would go back to the starting area. The Rhino (Burgard et al, 1999) from the paper "*Experiences with an interactive museum tour-guide robot*" and all three of the Mobots (Nourbakhsh et al, 2003) from the paper "*The mobot museum robot installations: A five year experiment*" do this method with some minor variants to each. Another robot that does this same method is Robox (Siegwart et al, 2003) from paper "*Design, implementation and exploitation of a new fully autonomous tour guide robot*" but instead of just giving out information at each place it will ask questions to the followers and wait for a response. This shows a simple guide method that could have been used as a baseline method.

There are complex methods of guiding a human, such as the method employed by the robot Cice (Macaluso et al, 2005) from paper "*Experiences with CiceRobot, a museum guide cognitive robot.*".
Cice will wait at a starting area for a user to input the place they would like to go to. The robot would then mostly follow the same method as the Mobots above, i.e. go from place to place giving information at each. The other major differences is that Cice will detect if there is a lot of people already present at the places, then Cice will plan a new route and come back to this place later. One of the problems with Cice is that it does not know if the people that are following are still following and if they are not then the robot is not guiding anyone. One way to combat this would be to have the robot check for a follower to make sure they are still following.

All the robots that have been discussed so far only wait for a humans to interact with it before trying to do anything with the humans, the robot Rackham (Clodic et al, 2006) from the paper

"*Rackham: Aninteractive robot-guide*" activity seeks out humans to see if they want a guide. Rackham will try and find a human that does not already have a guide, once one is found Rackham will approach and greet them then ask if they would like a guide. If the person ignores the robot or says no then Rackham will move on to find other people to guide but if the person response back to the robot and agree to a guide, then Rackham will guide that person around until dismissed or the tour ends. While the robot in this project will not be used in museums, this approach of greeting the user and seeing if they want some interaction with the robot could be used in a more advance method, e.g. move up to the user see if they respond and to greet the user see how they respond.

The more recent guiding robots use more complex methods of guiding, such as the robot in Santos paper "*Route learning and reproduction in a tour-guide robot*" (Alvarez-Santos et al, 2015) were they have designed a robot that will learn a route by following an instructor around that route. The robot is then able to reproduce that route to eventually be able to guide others on that route. The idea behind this kind of self-learning robot is that any "instructor" can add new routes to the robots guide without the need of an expert to "install" it. Another complex guide robot is Capi's robot, in his paper "*Guide robot intelligent navigation in urban environments*" (Capi et al, 2014) they say the robot is designed to guide visually impaired people in urban environments. The main difference from the other guide robots is that it is made to work in an outdoor environment, so their robot is able to change its navigation algorithm based on the environment.

The project is not just about a robot guiding a person, if the robot has determined that the person following is struggling to keep following then the robot will try and give them encouragement to keep at it. Getting humans to do something or keep doing something is nothing new, there are a lot of different studies in this area of research. This project is more focused on how to encourage a person to keep doing something. Dinkmeyer defines encouragement as "*the process whereby one focuses on the individuals resources in order to build that person self-esteem, self-confidence and fielding of worth*" (Dinkmeyer and Eckstein, 1995), in terms of the project we want to keep the person following even when they get a bit tired, if they start lagging behind the robot or they just lose motivation to follow.

In Guyatt paper "*Effect of encouragement on walking test performance*" (Guyatt et al, 1984) they show that using verbal encouraging phrases such as "You're doing well" or "Keep up the good work." increased the performance of the test group, which was receiving verbal encouragement compared to the other test group that was not. This positive verbal encouragement is also show to work in Nicolas Guéguen paper "*I am sure you'll succeed: When a teacher's verbal encouragement of success increases children's academic performance*", were they had 2 groups of children do a task, 1 group was given positive verbal encouragement and the other did not receive any encouragement. The results showed that the group that got encourage did better overall "*Results showed that more children succeeded in the verbal encouragement condition (82%) than in the control condition (47%)*." (Guéguen et al, 2015).These types of verbal encouragement phrases could be used as one of the methods to encourage people to keep following the robot.

There are also nonverbal forms of encouragement, such as images and body movement. In Erwin Geerts paper "*nonverbal support giving induces nonverbal support seeking in depressed patients*" (Geerts et al, 1997) they use nonverbal communication to encourage patients to keep talking to the interviewer. These include things like the interviewer nodding their head while the patient was speak and touch their arm. Some of the nonverbal encouragement could be used for one of the methods that will be designed to keep a person following the robot. It is worth noting that the robot will not be physically interacting with any of the participants but the robot can use "body language" (head movement, turning the body to face them, eye movements etc.) as forms of encouragement.

There are already robots that attempt to encourage humans in different ways. Most of these are to get the humans to do some exercise or encourage interaction between people. One of these robot is Robota, this robot was made to encourage children with autism to interact with other people using the robot as a mediator. The robot had two modes, dance toy - where the robot would dance and play music and puppet mode – where the experimenter would control the movement of the doll. The idea of this was to get the children familiar with robot while it was in its "toy" mode and then later use the puppet mode to start encouraging the child to interact with others. More can be read about Robota in Ben Robins & Kerstin Dautenhahn paper "*Encouraging social interaction skills in children with autism playing with robots*" (Robins and Dautenhahn, 2007). This paper shows one way to encourage humans is to get them first used to the robot and then they will be more likely to respond to the robots encouragement. This could be implemented in a way that the robot would greet the user first and perhaps interact with them before trying to encourage them to follow and keep following the robot.

In Adriana Tapus paper "*Socially Assistive Robots for Individuals Suffering from Dementia*" they use their robot to interact with individuals that suffer from dementia and to encourage them to perform their fitness program "*the robot will encourage the user to perform mild exercise, providing examples of simple movements and encouraging imitation*" (Tapus et al, 2008). The robot will imitate the users actions to both get the humans attention and as a form of encouragement. This form of encouragement could be used for one of the methods, though the imitation would not be practical for the robot to do while the robot was leading someone. It could be used to get the persons interest and encourage them to follow initially.

Methodology

Project Management

Any large project needs some form of management to keep the project from running out of time to complete. This section of the report discusses how this projects time was managed.

There were two main elements of this project, the documentation and building the artifact. Both parts equally require a lot of time and management. To make this easier both parts were broken into smaller manageable section. Documentation was broken into aims & objects, background and so forth. Not all of these smaller parts required the same amount of time or attention.

While the designing of the methods themselves did not take too much time, due to having good background research, the aspect of the regular meetings with the supervisor to discuss the designs for the methods did take a while. But this aspect is necessary as if this part is done incorrectly, the design could miss important aspects, or they could be designed incorrectly so that they do not achieve this projects goal.

Testing of the methods as a whole did required a lot of time and management, this was mainly due to the limited amount of time that the robot was available for live testing. This made the simulator testing all the more important as the time for that aspect was not limited. It was performed after each function was made. The testing in the simulator had to remove and fix a lot of the issues, so that the limited testing on the robot could be used to it full affect in removing and fixing integration issues.

The most demanding part of this project was the user study, while the time needed to do the study didn’t need as long as the testing or as the background research, it was the hardest to manage due to finding and gathering participants. In addition, managing how many will show up at one time, and then managing the time they took doing the tests and questionnaires; if they took too long or were late then it made the other participants waiting longer which could negatively impact there opinion on the tests. Thankfully most participants showed up when they were meant to and no one was wait long for their turn.

The project made use of a Gantt chart to help manage the timekeeping and resources of the different parts of this project (see appendix Item 6).
There were also regular meetings with the project supervisors to help keep the project on track. If they notice an issues with progress being made then steps could have be taken to change the plan to minimize the impact of the overall project.

Software Development

The Iterative software development approach (ISDA) was the methodology that this project followed. ISDA works best with this kind of project as it allow for the software to be built in iterative parts, each iteration aims to be better than the prior one. The first method was designed using the background to form a set of requirements and then the method was tested to see if it works and if it fits those requirements. If the requirements were not complete then a different method was improved and tested again. Once method 1 works in simulator and fits the requirements, design and development on the next method was started using the first method as a base.

There are other software development approaches that could have been used for this type of project. These include the waterfall model, agile and RAD. The Waterfall model is a phase by phase design, were each phase has to be completed fully before moving on to the next phase. The main problem with this model is that if any one of phases is incomplete, or if something needs to be changed in one of the previous complete phases; then the whole model has be restarted, from the beginning. RAD is another model that could be used but its speed of development and lack of planning will make it hard to keep the project on track and within scope.

Toolsets and Machine Environments

Linda the Strands project robot is the robot that all the methods where tested on. Linda was used because the robot has lot of functionality, from movement to people tracking, and since other are working on Linda all the time the list of functions Linda is able to do will grow.

Figure 1 Robot Linda (Lincoln Robotics, 2015)

Linda is a mobile robot, about average human height, that can move forward, backword and rotate her body; all the things that are need for a robot guide. Linda does have a head with two eyes and this head is encased in a clear plastic. The eyes themselves are not functional and are mainly used a focus point for humans. At the base of Linda, just above the wheels, there is a rubber bumper that if pressed or bumped cause Linda to stop moving; this is for the safety of the people around Linda and so Linda does not damage herself while moving. Figure 1 shows an image of Linda.

Linda is able to rotate her top camera and her head by 180^{o} as well tilting it up and down. Linda also has controllable blinking eyes, which are used in method 2. Linda has speaking capability as well as a touch screen on her back that can be used to display information as well as take input. Both the speaking and the screen are used to encourage to the user.

Linda uses a map to move and navigate, this map is a grid with each cell corresponding to a coordinate. These coordinates are what you refer to when you want Linda to move to a location. On this grid map Linda needs to know where she is, this is where some form of localization takes place to determine her location on the grid map. Now that Linda knows where it is and what coordinates it needs to go to. A plan will be made to determine the best route the robot should take to get to those coordinates, this is handled by the global planner and cost map. With Linda then starts to move towards the goal by using a local planner and cost map, these are used to avoid non static obstacles (chairs for example) and people.

Linda is also able to detect and track people by using two main sensors, Red Green Blue - Depth camera (RGB-D) and a laser scanner. The RGB-D camera is used in the upper body detection, in which they classify an upper body by using a person’s shoulders and head, this is used for close up human detection. The laser scanner is used in the leg detection, which as the name suggests looks for human legs. This leg detector using various different features of a leg to determine if they are human legs. This is used in long range human detection. Using both of these detectors, Linda can reliably detect most humans. More information about both the people detector and tracking can be found in Christian Dondrup's paper "*Real-Time Multisensor People Tracking for Human-Robot Spatial Interaction*" (Dondrup et al, 2015b).

Python is the coding language used to make the different methods, this is primarily due to ROS only having full support for C++ and Python; this does not mean other languages could not be integrated into ROS, but that is outside the scope of this project as that in itself would take too much time for this project. Python is used instead of C++ because while C++ is a powerful language with lots of control over the many aspects of programming it is more complex then Python. Python is a faster language to program in as it does a lot of the more complex tasks for you such as garbage collection. Given that there was a time constraint for this project, Python was the preferred choice of the two choices for this project.

The Robot Operating System (ROS) framework is used to make the different methods. ROS is used over other robot frameworks as both the robot Linda and the robot simulator are made using this framework. Choosing to use other frameworks would have made integrating the methods on Linda more difficult. ROS does has a lot of libraries and documentation which helps with the development of the different methods.

IBM's Statistical Package for the Social Sciences (SPSS) is a software application that is used to do statistical analysis. SPSS was used to find if the data that was collected from the tests that had any statistical significant to it. SPSS was used instead of other tools such as Microsoft Excel because it has a lot of built in functions to quickly do statistical analysis on large and small sets of data. The program, like Excel, is able to produce graphs and charts with a few clicks of a button. It is able to give all the statistical data in an easy to read format that can be imported into a word document.

Ubuntu is the operating system that is used for this project as ROS is very stable on Ubuntu. Since the project supervisors use Ubuntu, any issues that may come up concerning ROS and Ubuntu they are more like able to assist.

Github was the used for version control and for backing up the artefact's code. Subversion (SVN) could have been used instead but git is considered to be fast and easier to revert back to an earlier version if need be, also SVN is a harder to set up and to share compared to git.

Both testing the methods on the robot and the human participation tests were done in upper part of the robotics lab at the University of Lincoln. The robotics lab is the only place that Linda is allowed to roam around, so it is the place where testing was carried out, the lower part of the lab had a lot of people moving around; so as not to inconvenience to other users of the robotics lab, the testing was done in the upper area. The upper part of the lab is large enough to have the robot still be an effective guide while not being too large for the participants to get lost or feel uncomfortable within the environment. The testing environment is comprised of two rooms, a lab and an office. The lab is a large room with lots of open spaces from the door to the back of the room where there are a few tables and seats by the walls. The office room is an open plan office, with a row of computers splitting the room mostly in half. The robots route has 7 waypoints including a starting waypoint where the robot will greet the follower. The robot moves to the starting waypoint just outside of the lab room, then the robot will guide the participant into and around lab. It will then leave the room to come into the other office, where it will guide the participant around the row of computers to reach the other side of the room where it ends the guide.

Refer to Figure 2 for a rough outline of the testing environment. The green circle is the starting area, the blue line is roughly the route the robot would take and the red circle is where the robot will end the guide.

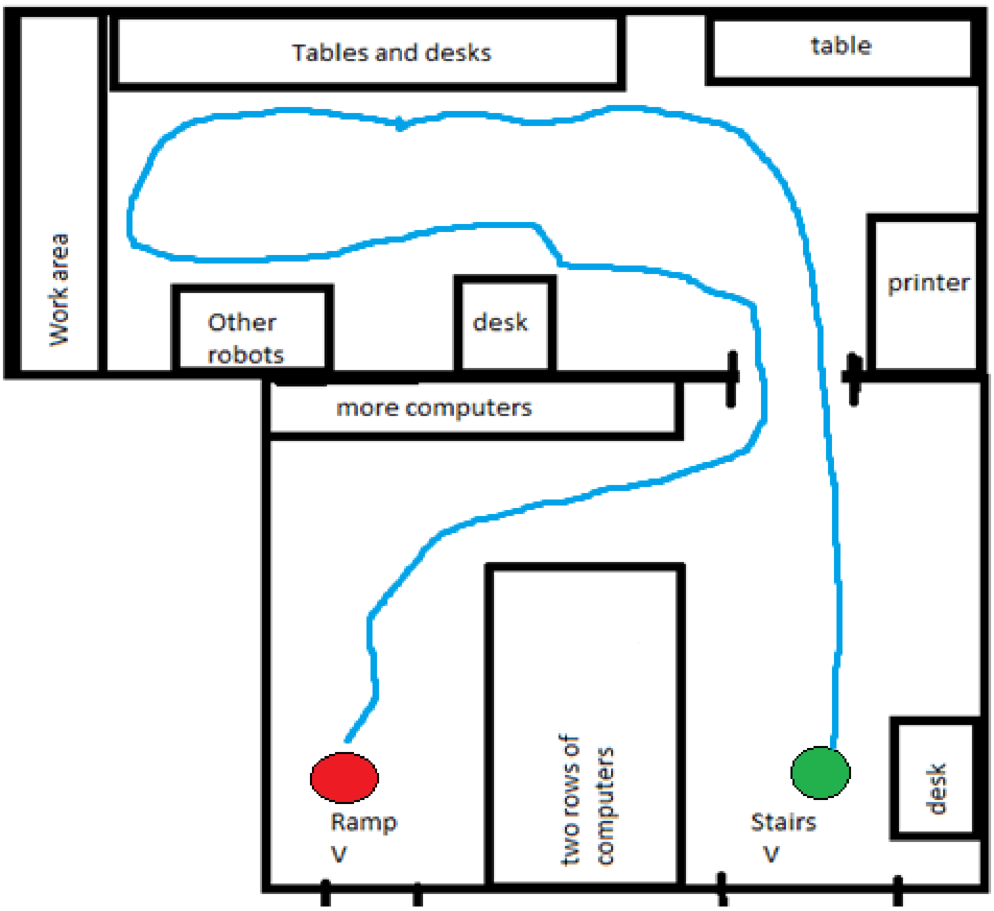

Figure 2 rough layout of testing environment

Research Methods

The projects aim is to have a robot guide that is both effective at guiding and encouraging the user to keep following. To do this two methods have be developed that use different strategies to encourage the human to follow.

A qualitative user group was the prime way of determine which method is the better method at encouraging the users to follow. The user group was used as it allowed each participant to experience the robot using the different methods. But before that we asked every person that wanted to be a participant to sign and date a consent form (see appendix Item 1). This gave a brief overview of what was expected of them and what they could expect from us, it also informed them of actions they could take in regards to the test, such as if they wanted to stop they could.

Each participant tests both methods, one at a time, by following the robot around a predefined route. The first method that was used for each participant was random. This was done to stop the results from being bias to a single method as well as to stop other participants from having to wait longer than necessary. This was to stop them from seeing and then doing the same thing in the same order, as this could have potentially affected their answers to the questionnaire. To limit potential bias to the other participants from viewing the test beforehand, the participants came in groups of 2's and 3's. Participants waiting to do the tests, waited in a different part of the lab. With first test they were told little about what the tests involves and were merely told to do as the robot asks; once they had completed the first test a questionnaire (see appendix Item 2) was given to them to find out there thoughts and opinions about that method.

The second time the participant did the test, the other method would be the one guiding them. Before they start the second test they were given more information about what the test was about and they were informed that if they didn't feel like following or didn't feel encouraged to then they could stop and the robot would then attempt encourage them to follow; they again were given the same questionnaire as before to get their thoughts and opinions on this method. Once the participant had finished with all tests, they were then asked to do another questionnaire. This was to get their overall opinion on the tests, and they were also give some open-ended questions (see appendix Item 3 and Item 4).

A different image was shown on screen for each method test, this was for two reasons, first this hide the robot output and secondly it gave the users something pleasing to look at while following the robot (see appendix Item 10 and Item 11).

The participants were given a Likert scale questionnaires. A Likert questionnaire was chosen because it is used in several different papers and books to gather participant's experiences and impression "*We obtained participants' subjective impressions with a questionnaire. Following questions were included on l-to-7 point Likert scales*"(Kanda and Ishiguro, 2012) they also mention that they using it in Kruse's paper "*Human participants experiencing the robot rate the performance of the robot on scales, such as a Likert scale*" (Kruse et al, 2013). Another good thing about Likert scale is that a numerical value to each scale. On a 1-5 scale, each number could be worth a different value, so 1 is -2, 2 is -1, 3 is 1 and so forth. With the participants filling out the Likert scale questionnaire this hoped to give a reliable qualitative data.

There are other ways qualitative data could be collected, such as observations. In human-robot interactions, questionnaires are the most common way to evaluate the users experience, "*Two main strategies are commonly used for evaluating human-robot interaction from a human subjects' perspective 1) questionnaires ... and 2) video analysis of interactions*" (Koay et al, 2006). Since questionnaires do not take as much time to make or as long to study the results compared to doing video analysis, it was the best choice for this project given, the time restraints. This qualitative data that was gather was used to determine which method was the best at encouraging a user to keep following.

To find out how effective each method is, the robot record several stats for each method: The time taken to complete a route; how often the robot loses the human follower; how far on average is the person from the robot guide. The robot recorded all this data and after each participant had finished a test the robot would write the results to a text file. This text file was then processed to become the quantitative data set. The quantitative data was then used to determine which of the methods is the most efficient in terms of speed, keeping the user in sight and which gave the most encouragement.

Both sets of data are displayed using graphs and charts to make the data more presentable and readable. The whole data set will have some statistical analysis performed to see it how reliable the data is overall.

Design

The design for both of the methods was mostly inspired by what has been done before. Parts and ideas for the methods were taken from the background research. The guiding for both methods is based on the more common simple type of guiding, in which the robot moves from one waypoint to another until there are no more waypoints to go to.

Both methods will read from a text file that will store the coordinates for the tour that the robot will take the users on. The robot will read in the first waypoint and move to it, this will be the starting point of the guide where the robot will greet the follower; like how the Rackham robot would greet its followers. Once the robot has greeted the follower it will then give them some basic instructions, once done the robot will load and move to the next waypoint.

To avoid problems with the follower not following the robot, like with the Cice robot, both methods will keep track of the followers distance from the robot. If the followers distance is within an acceptable range, then the robot will continue to guide them to the waypoint. Once the robot has made it to the waypoint and the follower is still within acceptable distance, the robot will give some information about the waypoint they are at. Once done the robot will then load the next waypoint and move to it; this process will repeat until the robot has no more waypoints to go to. At which point the robot will inform the follower of such, then go back to the starting area where it will end the program.

If at any point during the guide the follower’s distance from the robot is not within an acceptable range, then the robot will decide what action it will take to get them following again. If the follower is only a little off the acceptable range then the robot will try using verbal encouragement, such as the ones suggest in Guyatt’s paper from the background, to see if that will encourage them keep up but the robot will not stop moving toward the waypoint. If however, they are out of the acceptable distance, then the robot will say they need to move closer and the robot will then start to stop its moving towards the waypoint. If the follower gets within acceptable distance before the robot fully stops then the robot will carry on the guide as normal.

If the robot does have to stop then the robot will start a countdown and wait for the follower to come closer. If the follower does not come closer by the time the countdown ends then the robot will inform the area that the guide has ended. The robot will then move back to the starting area thus ending the guide. While the countdown is still counting, the robot will check the state of the follower. At this point there are multiple possible state that the human can be in, these are: the human is moving closer, the human is standing still or the human is moving further away, depending on this state the robot will behave differently. If the follower is just standing there then the robot will try some verbal encouragement to encourage them to come closer, so that the guide can continue. If the follower responds to this and does start moving closer the robot resets the countdown and checks there state again; this will repeat until the human is within the correct distance and then the guide will continue as before. If though the follower's state shows that they are actively moving away from the robot then the robot will end its attempts and act as if the countdown has ended thus ending the guide.

If the robot has not been able to see the follower for longer than the allowed amount of time, then the robot will stop as if the person's distance is too far and will act in the same way as describe above. This means if the follower does not show up again after the countdown has ended the robot will end the guide but if the follower does show up before the countdown ends then robot will act as described above.

Below is an activity diagram of method 1 (Figure 3) showing the steps in this method.

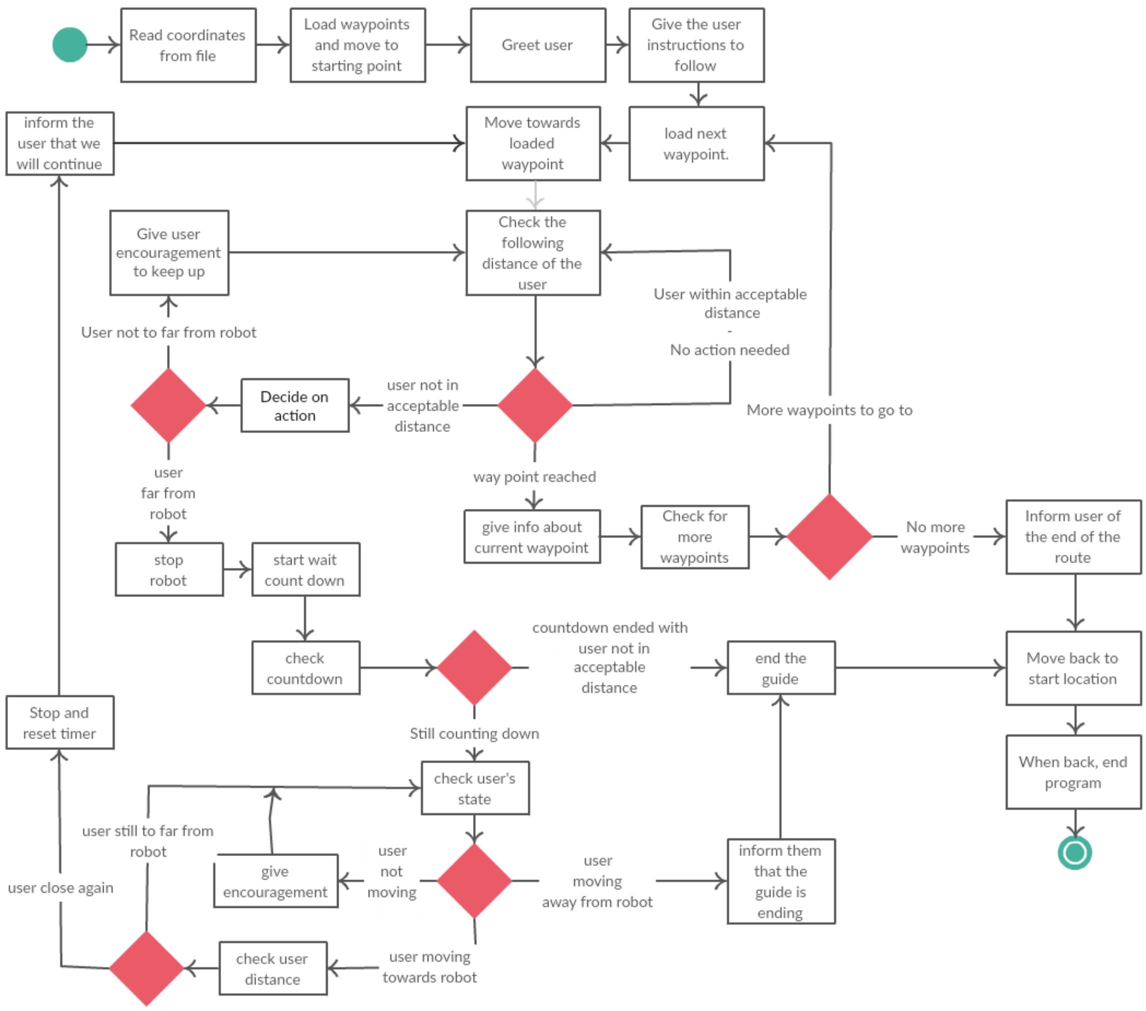

Figure 3 Activity diagram for method 1

Method 1 is designed to guide a follower around the tour and only give encouragement when it's needed otherwise the follower could find the constant "encouragement" off putting thus having the opposing effect. Method 1 makes use of only verbal encouragement and this will be the base method for any other methods that will be made.

Method 2

Method 2 builds and improves upon method 1 by adding another form of encouragement, encouragement by movement. Like it was discussed in the background research movement can be used as a way of encouraging someone, from turning one's head, imitating movement or eye contact.

For this method eye movement, contact and head rotations was used as forms of encouragement. The other nonverbal encouragements such as turning the robot body was discounted because there is the small chance that the base of Linda may rotate into something, also this may make the participant uncomfortable. Another form that was discounted was the slowing down of the robot, as Linda's currently does not move that fast and since all the participants will be able-bodied this slow down would cause annoyance.

Then the robot first greets the user it will rotate its head to face the follower and will then randomly decide if it should blink, wink with left eye, wink with right eye or just look at them; after doing one of the actions the robot will reset its head and eyes to defaults state and the guide will carry on as normal.

The other change this methods adds is when the followers is not within the acceptable distance, the robot will rotate its head to face the follower. If the user comes back into the accepted distance then the robot will randomly choose if it should blink or wink like when the robot first greets the follower. If the follower has not been seen within the allowed amount of time then the robot will stop like in method 1 but the robot will rotate the head and camera to the followers last know location. So if the follower was last seen on the right of the robot, then the robot would turn both the camera and head in that direction to see if the person is still there.

Below is an activity diagram of method 2 (Figure 4) showing the steps in this method.

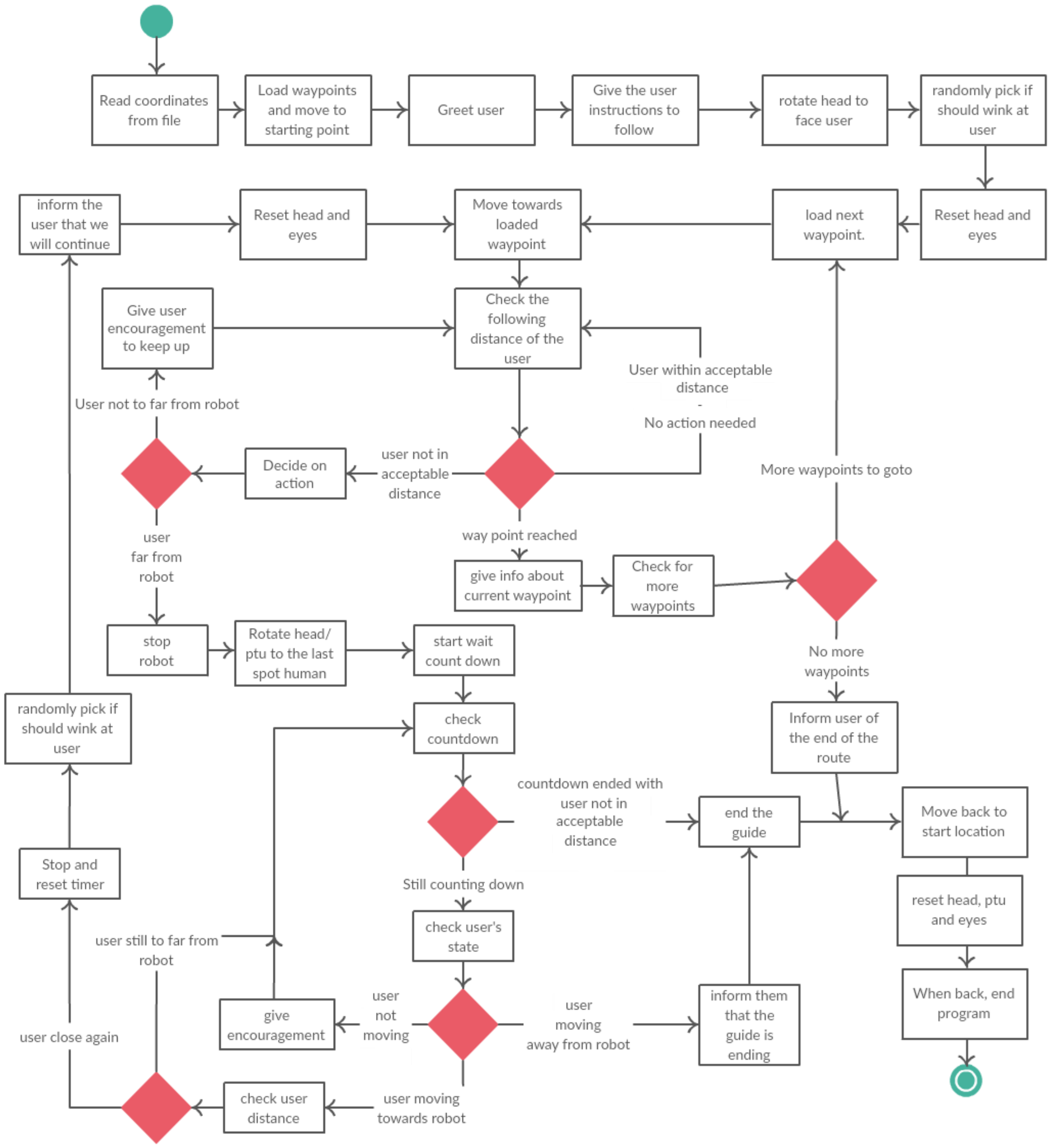

Figure 4 Activity diagram of method 2

Development

This section of the report discusses the different components that make the guiding and encouragement possible.

Moving the robot

All guide robots need to move, without it how would the user get anywhere. Both methods use a waypoints system, a waypoint is a just one set of coordinates for a location on the map. This was used as it an easy to change and manage, were you can added more waypoint providing you know the coordinates that you want the robot to go to. Both methods used the same ways points, all each one has to do is pass the waypoint to the robot. The robot then moves to that location and reports that it is there, then both methods check if that is there are any more waypoints they want the robot to go it, if not the can end the guide otherwise they just pass the next waypoint.

Seeing the human

Both methods make use of the already made human detection functions that Linda already has. When a human has been spotted the human detector publishes a set of 2d coordinates of where the human was detected in relation to the robot. The methods read these 2d coordinates and use it to work out the Euclidean distance to tell how far the human is away from the robot. With knowing how far the human is, the robot can be made to act and do thing when the human is too far or not seen. The methods uses this to know when to encourage the user follow, the human gets a bit too far the then the robot will encourage them to keep up; the human get further again then the robot will stop and wait for them.

Speaking

The speaking capabilities of Linda were used as one of the forms of encouragement and to inform the user of different things. Both methods uses the speaking over the touch screen as then the user does not have to be too close for them to know what the robot wants from them. This also means the robot does not need to take into account the different heights and reading ability of the participants.

Determining human state

Both methods try and find out the state of the human, is the human moving towards the robot or away from the robot. Normally this would require a lot of work looking at different timestamps and comparing against prior ones to see the different state of the human but thankfully this has been done and is handled by Qualitative Trajectory Calculus (QTC).

Qualitative Trajectory Calculus Basic (QTC_B) is the simpler version of QTC. The basic version only reports if the human is moving towards the robot, away from the robot or if the human is standing still. The QTC_B was used in the first method to determine if the user was moving closer to the robot when the robot had stop. If the human has moved closer, then the robot would reset the waiting time but if the human was moving away from the robot while the robot is waiting then the robot will end the guide.

Qualitative Trajectory Calculus Cross (QTC_C) is the more complex version of QTC. This version will also determine if the human is moving closer or not but can also work out if the person is on the right or the left relative to the robot. Method 2 uses QTC_C to do the same as method 1 but to also determine the last know position of the human relative to the robot, this is then used to turn the camera in the direction to see human can be found again.

More information about QTC can found in Dondrup's paper "*A computational model of human-robot spatial interactions based on a qualitative trajectory calculus.*"(Dondrup et al, 2015a)

<u>PTU turning</u>

The pan tilt unit (PTU) is a unit that allows the camera that sits on top of it to tilt and rotate. Each method uses the rotating of the PTU at least once. At the start of the guide the robot will rotate the PTU so that the camera on it will now face behind the robot, so that the robot can see the human while the robot is guiding them. When the guide has finished the methods will reset the PTU to be back in its default position. Method 2 takes this further by using rotating the PTU to find the user again if the robot cannot see them.

<u>Head and eye</u>

Both the rotating of the head and the eye movement were used as a form of non-verbal encouragement. This was chosen over other forms of non-verbal encouragement such as rotating Linda's body to see them, this was discounted for two reason; firstly have the robot rotate on a point there is a small chance that she could snag against something as she rotates and secondly having this large robot suddenly turning about to face the user could be off putting for most of them. Only method 2 uses this function and most of the participant will only see this at the beginning of the guide were the robot will rotate the head to look at them and then greet them. While greeting the robot will randomly choose if it should blink or wink at the user.

<u>The use of images</u>

Two images were mention to be used in the Research Methods section, these images serve as a passive form of encouragement and to hide the rest of the screen from the uses so that they do not gets distracted. For this same reason videos were discounted as a form of encouragement as the user would more likely watch what was on screen then listen to what the robot is asking of them. Also with the image the user can view the image once and won't need to stay very close to the screen, were as a movies clip the user would need to stay quite close to see the clip in its entirety.

Testing

The testing of the artifact was done in three parts. Part one and two were to test that both methods would function and act as they have been described in the design section, the only different between these parts is there testing environment.

Part one tested both methods in the simulator, not only did this have the benefit of not harming the robot or others from any mistakes but it is quicker to test individual components of each method. There are problems with the simulator, one of them being is that all the measurements are perfect as the robot know perfectly were the human is and there is no noise and lighting will not affect the robot in the simulation. Another problems is not all the components work in the simulation, such as the speaking or the PTU rotating, this is why testing on a real robot is needed.

Part two all the same test that were in part one are carried out on the actual robot. This is so that all the issues that come with integrating the methods with the robot can be removed so that they do not affect the user study; and just because the functions worked correctly in the simulation does not guaranty they will work similarly or at all on the robot. Also tweaks and small changes are made here to fix problems that would not appear in the simulator.

Part three is the testing of the artifact with live participants, the results from this will be shown and discussed in the evaluation section of the report.

Both part one and twos results are shown in the table below, the table shows what tests, how many times, the expected outcome, the actual outcome, what the error were found and how they were fixed.

Part one – Tests in simulator

Method 1 functions

What was being tested	Expected outcome	The outcome	What was the error	The fix
Load from text file	Load both .txt file into separate arrays	Both .txt file ever loaded correctly	n/a	n/a
Robot speaks	The speaking client doesn't work in the simulator, so had it	The robot outputs the expected text	n/a	n/a

	output the things it would have said.	with the corresponding action		
Program stops upon termination request(ctrl+c)	The program will stop whatever it is doing and exit	Upon clicking ctrl+c, the program ends	n/a	n/a
Gets the distance of the human	Robot get the Euclidean distance the humans is away from robot	The robot does get the Euclidean distance	n/a	n/a
Get the QTC_B state	Works out the QTC_B state of the human, i.e. the human is moving away from robot	The robot can tell state of the human using QTC_B	n/a	n/a
Robot moves to waypoints	The robot is expected to move each waypoint in order of list	The robot moves to each waypoint	n/a	n/a
Gets the state of the move goal	Find out if the robot has finished it move goal or not	The robot knowns if it is still traveling or it has reach a goal	n/a	n/a
Robot gives encouragement to user to keep up	If the users distance is greater than 3.5m then robot gives verbal encouragement	Robot gives some verbal encouragement when human further then 3.5m	n/a	n/a
The robot does not spam encouragement	The robot should wait 5 seconds	the robot does wait 5 seconds	n/a	n/a

	before trying to encourage the user	from last encouragement		
The robot give some time of the human to get within distance before stopping	The robot waits 4 seconds before stopping so that the human can get within distance	The robot does wait 4 seconds before stopping.	n/a	n/a
The robot stops if human is too far	The robot is meant to stop moving if the humans distance is greater than 5m	The robot stops moving if the distance of the human exceeds 5m and wait time is over	n/a	n/a
Robot stops if it cannot see the user	The robot will stop after 15 of not seeing the human	The robot does stop moving after 15 second of not seeing the human	n/a	n/a
Robot carries on guide when human is back	If the human is spotted and within distance the robot carries on the guide where it had stopped	The robot does carries on the guide when the human is spotted and is within correct distance	n/a	n/a
Robot ends guide if no human appears within correct distance	The robot will end the guide after 15 if the human has not moved closer or is not spotted within that time	The robot end then guide if the human is not spotted or the human does not get within distance after 15 seconds	n/a	n/a

Gives encouragement to human not moving	The robot while waiting for the human will give encouragement to a human that has a state of not moving	Robot gives encouragement to the human if state is not moving. Like before robot will wait 5 second before encouraging again	n/a	n/a
Robot ends guide it person still moving away	If the robot is waiting for the human but the human state is moving away the robot will end the guide if this happens for 3 counts	The robot ends the guide if the robot is seen to still be moving away from the robot after 3 counts	n/a	n/a
Load new waypoint	When the robot has reach a waypoint it will try and load next waypoint	The robot load the next waypoint once the current one has been reached	n/a	n/a
End guide once out of waypoints	When the robot has gone through all of the waypoint, the robot will end the guide and go back to the start	The robot ends the guide if there are not more waypoint to move to. Robot move back to start	n/a	n/a

Ends program when everything has finished	When the robot is back at the start the program will terminate	Once the robot is back at the start the robot then end the program.	n/a	n/a

Method 2 additional functions

What was being tested	Expected outcome	The outcome	What was the error	The fix
Rotate head	This does not work in simulator	n/a	n/a	n/a
Rotate PTU	This does not work in simulator	n/a	n/a	n/a
Gets the QTC_C state	Works out the QTC_C state of the human, i.e. the human is moving to the right or left.	The robot does find the QTC_C state for the human	n/a	n/a
Determine which side human on	Determine which side the humans was last seen	The robot reports which side the human was on last	n/a	n/a
Eyes can blink and wink	This does not work in simulator	n/a	n/a	n/a
Randomly choose to blink/wink	Since blinking does not work in the simulator, it will out point	Does output if it would have blinked, winked	n/a	n/a

	which it would do	with left or right eye.		
Reset head, PTU and eyes	Reset the head, PTU and eyes back to its default state	This also cannot be tested in the simulator	n/a	n/a

Part two – Tests on robot

Method 1 functions

What was being tested	Expected outcome	The outcome	What was the error	The fix
Load from text file	Load both .txt file into separate arrays	Both file are loaded and stored correctly	n/a	n/a
1.Robot speaks	Speak a selected line from array when certain actions are done	Robot didn't speak	Failed to pass the correct information to the function	Changed what was getting passed to function
2.Robot speaks	Speak a selected line from array when certain actions are done	Robot does speak from selected line.	n/a	n/a
Speak one line at a time	When speaking, the robot will only speak one line and then wait till done before speaking again	Robot speaks one at a time	n/a	n/a
Program stops upon	The program will stop whatever it is doing and exit	Programs stops upon c+ctrl	n/a	n/a

termination request(ctrl+c)				
PTU rotates	Rotate the PTU -180° and back to 0	During certain action the ptu does rotate	n/a	n/a
1.Gets the distance of the human	Robot get the Euclidean distance the humans is away from robot	Robot was not responding to the human changing distances	Robot was not using the correct map, so range calculation where incorrect	The map was change to the one I was basing ranges off.
2.Gets the distance of the human	Robot get the Euclidean distance the humans is away from robot	Robot works out the distance the human is from the robot	n/a	n/a
Get the QTC_B state	Works out the QTC_B state of the human, i.e. the human is moving away from robot	The robot can tell state of the human using QTC_B	n/a	n/a
1.Robot moves to waypoints	The robot is expected to move each waypoint in order of list	Robot did not move	Forgot to change the if from simulator mode	Change a Boolean to say the program is running on robot
2.Robot moves to waypoints	The robot is expected to move each waypoint in order of list	robot moving to wrong places	The incorrect coordinates were getting passed to the robot	Change to file location of the file that was need
3.Robot moves to waypoints	The robot is expected to move each waypoint in order of list	Robot moves to the next waypoint once	n/a	n/a

		the current one is reached		
Gets the state of the move goal	Find out if the robot has finished it move goal or not	The robot knowns if it is still traveling or it has reach a goal	n/a	n/a
Robot gives encouragement to user to keep up	If the users distance is greater than 3.5m then robot gives verbal encouragement	Robot gives some verbal encouragement when human further then 3.5m	n/a	n/a
The robot does not spam encouragement	The robot should wait 5 seconds before trying to encourage the user	the robot does wait 5 seconds from last encouragement	n/a	n/a
The robot stops if human is too far	The robot waits 4 seconds before stopping so that the human can get within distance	The robot does wait 4 seconds before stopping.	n/a	n/a
Robot stops if it cannot see the user	The robot is meant to stop moving if the humans distance is greater than 5m	The robot stops moving if the distance of the human exceeds 5m and wait time is over	n/a	n/a
Robot carries on guide when human is back	The robot will stop after 15 of not seeing the human	The robot does stop moving after 15 second of not seeing the human	n/a	n/a

Robot ends guide if no human appears within correct distance	If the human is spotted and within distance the robot carries on the guide where it had stopped	The robot does carries on the guide when the human is spotted and is within correct distance	n/a	n/a
Gives encouragement to human not moving	The robot will end the guide after 15 if the human has not moved closer or is not spotted within that time	The robot end then guide if the human is not spotted or the human does not get within distance after 15 seconds	n/a	n/a
Robot ends guide it person still moving away	If the robot is waiting for the human but the human state is moving away the robot will end the guide if this happens for 3 counts	The robot ends the guide if the robot is seen to still be moving away from the robot after 3 counts	n/a	n/a
Load new waypoint	When the robot has reach a waypoint it will try and load next waypoint	The robot load the next waypoint once the current one has been reached	n/a	n/a
End guide once out of waypoints	When the robot has gone through all of the waypoint,	The robot ends the guide if there are not	n/a	n/a

	the robot will end the guide and go back to the start	more waypoint to move to. Robot move back to start		
Ends program when everything has finished	When the robot is back at the start the program will terminate	Once the robot is back at the start the robot then end the program.	n/a	n/a

Method 2 additional functions

What was being tested	Expected outcome	The outcome	What was the error	The fix
Rotate head	Rotate the head to the same position the PTU is at	The head rotates the head to the PTU angle	n/a	n/a
Rotate PTU	Rotate the ptu to face the follower	The ptu rotates to face the user		
Gets the QTC_C state	Works out the QTC_C state of the human, i.e. the human is moving to the right or left.	The robot does find the QTC_C state for the human	n/a	n/a
Determine which side human on	Determine which side the humans was last seen	The robot reports which side the human was on last	n/a	n/a
Eyes can blink and wink	Eyes can blink or wink then at certain actions	The eye does blink or wink	n/a	n/a

Randomly choose to blink/wink	Choose to randomly pick if robot should wink with right/ left eye or blink	The robot does randomly pick which action it takes at the correct points.	n/a	n/a
Reset head, PTU and eyes	Reset the head, PTU and eyes back to its default state	The head, eyes and the PTU all go back to their default state.	n/a	n/a

Evaluation

This section of the report shows and discusses the results from the live testing with the human participants. The results from different questionnaires and the data that the robot itself collected. The discussion will be about that the results meaning.

Results

Quantitative data

Below are charts showing the information the robot collected during the different tests.

Figure 5 Average distance

Figure 5 shows the average distances the human is away from the robot while it's standing still and while it's moving.

Figure 6 Shows the average time it took for the robot to complete a tour. Method 1 was the quicker method, with an average time of 3.24 whereas method 2's time was on average 3.43.

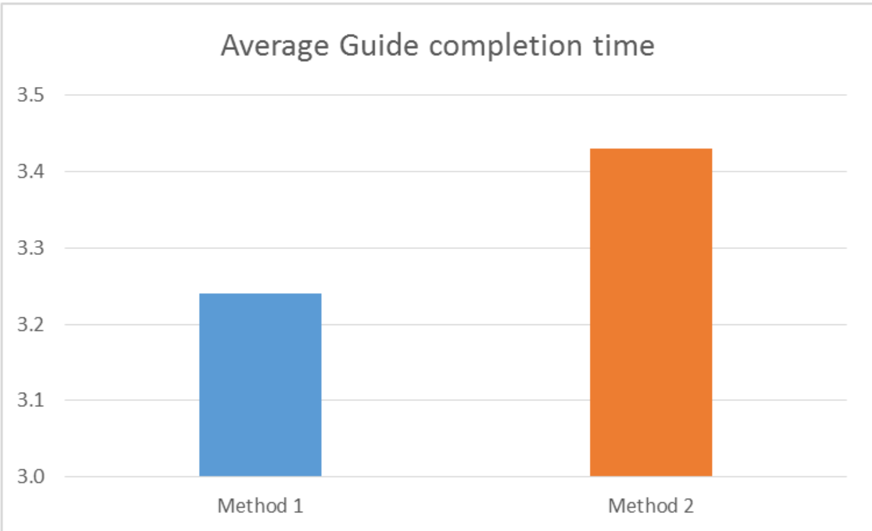

Figure 6 Average guide completion time

Figure 7 shows the number of times the robot had to stop, the number of times it encourage the follower and the number of times the robot lost sight of the follower for both methods.

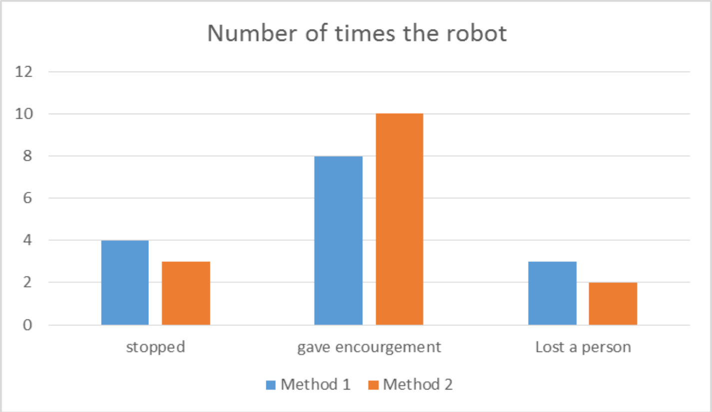

Figure 7 Number of times the robot

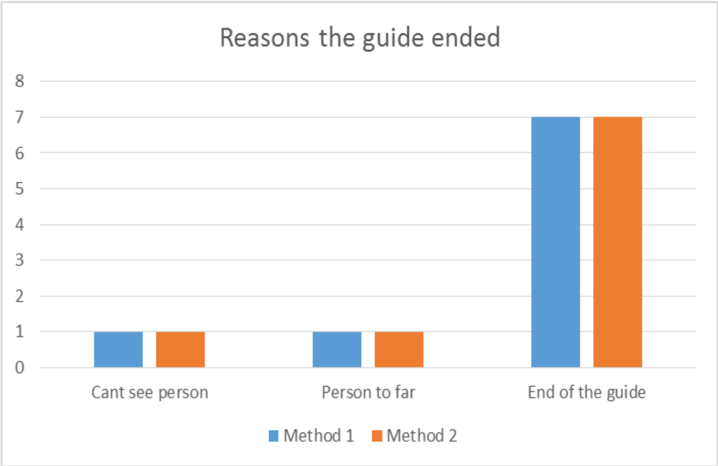

Figure 8, Reasons the guide ended

Figure 8 shows the number of times the robot ended the guide. Either due to the robot not seeing the follower, the follower was too far from the robot or the guiding ended normally. Both methods are shown.

Categorical quantitative data.

The qualitative data from the questionnaires was counted sorted into categories.

After each method test, the participants were asked to do a questionnaire about their experience during the test, below are the results for both methods.

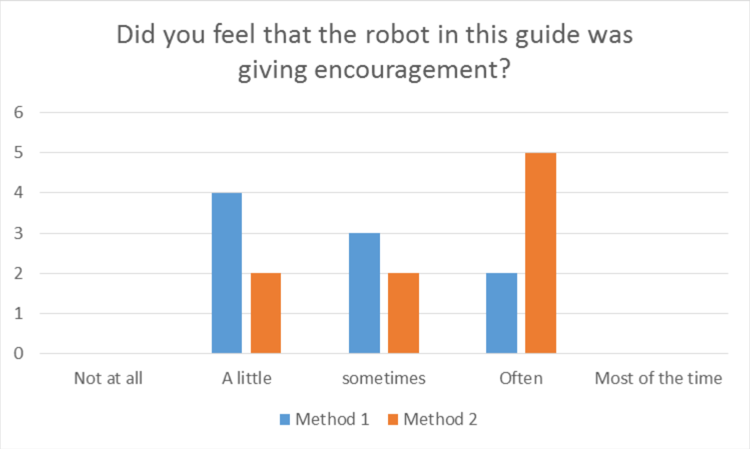

Figure 9 Robot giving encouragement

Figure 9 shows the results from the first question "Did you feel that the robot in this guide was giving encouragement?". The graph clearly shows that for method 1 the majority at 44% believe that the robot gave little encouragement, whereas for method 2 the majority at 56% believe the robot often gave encouragement.

Figure 10 shows the results of the second question, "Did you feel that the robot was reacting to your presence?". Method 1 with a small majority of 33% believe that the robot reacts often to the presence of the follower. The rest are evenly split between "not at all", "a little" and "sometimes". Method 2's majority at 44%, felt that the robot reacted often to their presence.

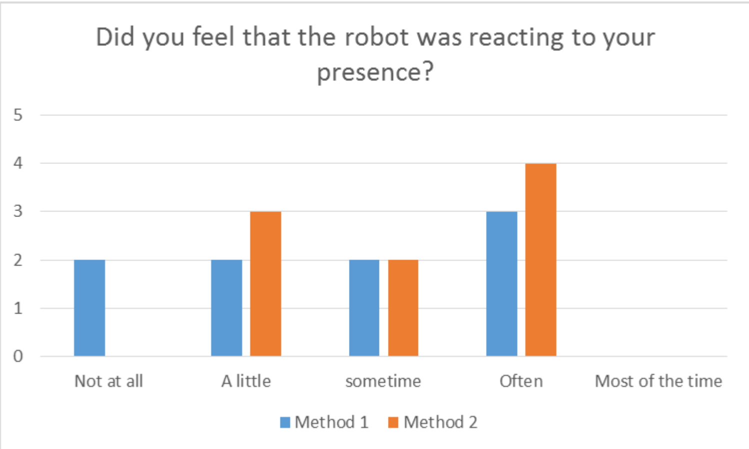

Figure 10 Robot reacting to your presence

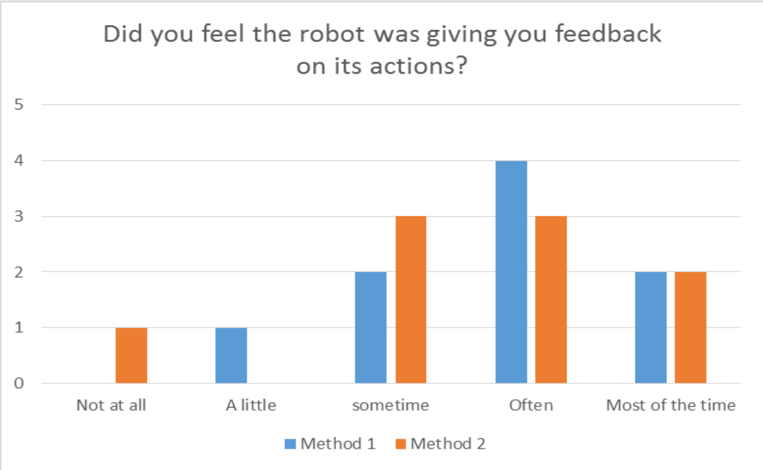

Figure 11 Robot giving feedback

Figure 11 shows the results from the third question, "Did you feel the robot was giving feedback on its actions?". The majority at 44% said that the robot was often giving feedback. Whereas method 2 has a split majority at 33%, stating that there is often, and sometimes feedback.

Figure 12 shows the results from the fifth question, "How did you feel about the robot using this method?". Method 1's majority at 67% show that they slightly comfortable with the robot. Method 2 has a small majority at 44%, show them to be fine with the robot.

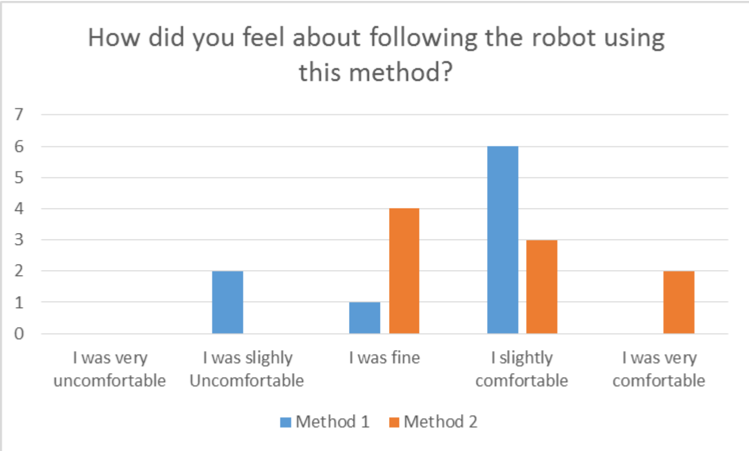

Figure 12 Feel about following

Figure 13 shows the results of the sixth and final question on this questionnaire, "Did you feel encouraged to follow the robot?". Method 1 and method 2 both have a majority at 67% saying that the often felt encouraged to follow the robot.

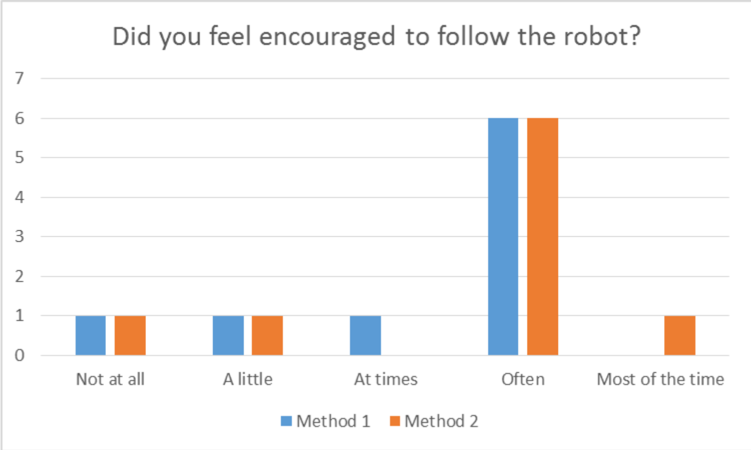

Figure 13 Encourage to follow

Once both methods of testing were completed along with there questionnaires they will given another short questionnaire and asked some open ended questions. Below are the results from the last questionnaire:

Figure 14 shows the questions and the results for the end questionnaire, which was given to the user once everything else was done. This chart shows that the majority of participants were comfortable during the tests.

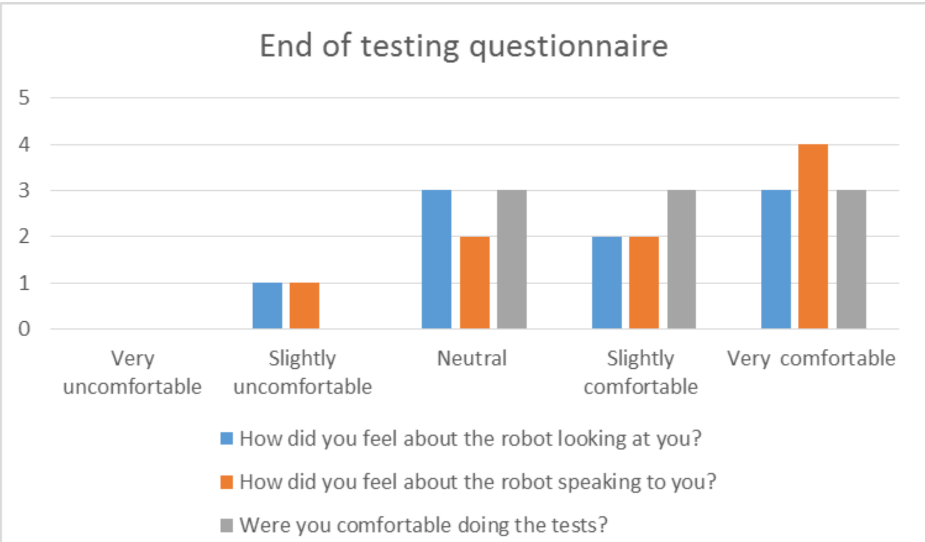

Figure 14 End questionnaire

Encouragement questions score

This part of the results shows the answers of the encouragement questions asked in the questionnaire, see Figure 9 & Figure 13 for how participant answered.

Each Likert chart question answer has a score associated to it. (“Not at all” -2, “A little”-1, “At times” +1, “Often” +2, “Most of the time” +3), each graph shows the result from these scores worked out and the average for each method.

Figure 15 show the score applied Figure 9s chart but with the average included. The chart shows that method 2 has a greater average score of 1.1 whereas method 1’s score is significantly lower with a score of 0.3.

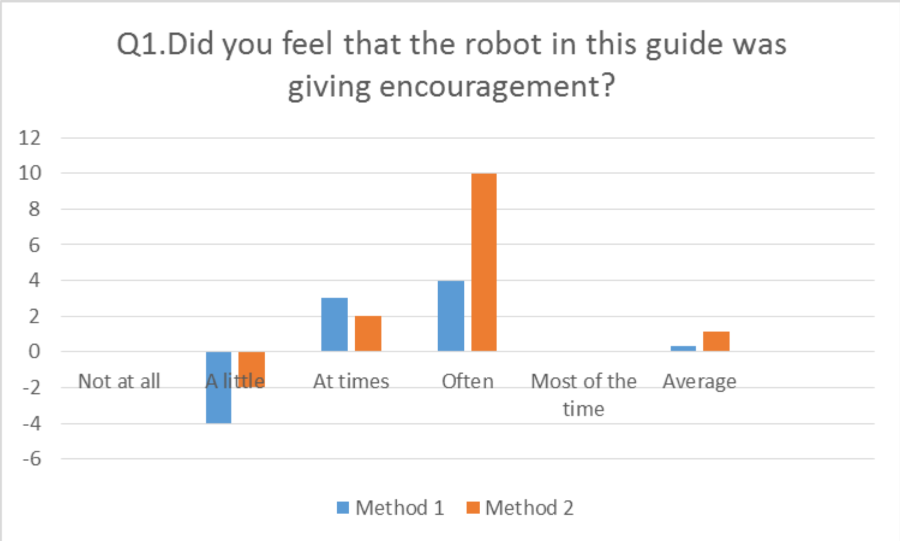

Figure 15 Robot was giving encouragement score

Figure 16 shows the scores applied to Figure 13. The chart show that method 2 have a slightly better score at 1.3 compared to method 1’s score of 1.1.

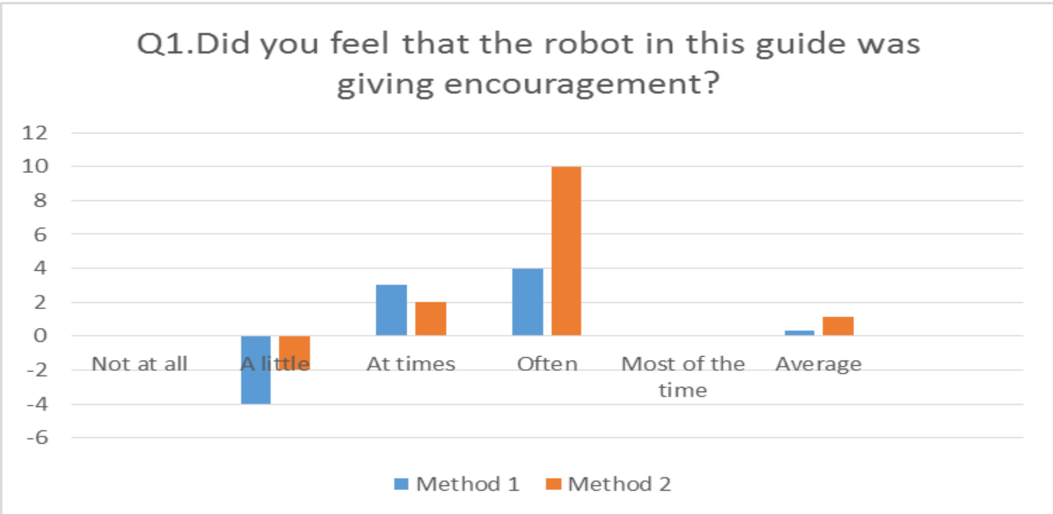

Figure 16 Encouraged to follow score

Discussion

Quantitative data

Figure 5 shows that while the robot was standing still; the human on average was at a distance of 1.7m for method 1, meaning there is a different of 0.2m when compared with method 2. What is interesting is that method 2's average distance of 1.5 is within the "close" social space according to E.T halls (Hall et al, 1968 p.93), this does mean with method 2 at least that the participants where happy enough with the robot using this method for them to be in the same closeness that you would to talk another human friend.

Figure 5 also shows the average distance of the human for when the robot is moving. The average distance between the two methods is less than 0.1 so the there is no significant distance between the two. These low distances are not really surprising as when observing the participants, for the most part they stayed very close to the robot and in some cases even flatting themselves against a wall so that they would still be considered behind the robot.

Figure 6 shows the average times it took the robot to complete their guides. There is not much of a difference between the two, differences of 0.19, so while method 2 is slower than one, it is not significantly slower.

Figure 7 shows the number of times the robot perform a certain event. The first part shows how often the robot had to stop the guide, because either the humans distance from the robot was too great or the robot could not see the human within the allotted time. Method 1 had to stop one more time then method 2, this difference is not that great so not conclusion can be drawn from this small difference. The second part of this chart show the number of times the robot had to give encouragement to the human. This happened when the human started to get further away from the robot. Method 2 did have to give 2 more encouragements to the participants than method 1 and while the difference is not great there is enough of one to say this could have affected one or two participant's answers. The last part of this chart shows the number of times the robot lost sight of the human. This would then prompt the robot to stop moving towards the next waypoint, so these numbers tie in with part 1 of this chart. Again there is a difference of 1 so there is not enough data to say this is significant.
Figure 8 shows why the guide ended, this stat was record to show if there was any significant difference in how the robot ended the guide. But as you can see there is no difference, so no information can be gathered from this that would help with comparing the two.

Categorical quantitative data

<u>After each method test questionnaire</u>

The results of the questionnaire that was given to the participants after each method will be disused here.

Figure 9 shows the results of the question “Did you feel that the robot in this guide was giving encouragement?” shows that the participants believed that method 2 gives more encouragement. Figure 7 does show there is a difference, but this difference is not significant enough for method 2 to have a high majority of the participants saying they were encouraged often. Both methods do the same function of encouraging the user with no difference in how the user gets encouraged from the robot. This vast difference in response could be due to method 2 greeting, were method 2 will greet the user by looking at the participant and ether winking or blinking at them; some of participants open ended questions response do state that the robot looking at them and winking does give the robot a “personality”, meaning that the perceived personality is more encouraging then methods 1 lack of personality; more about the open ended response will be discussed later in this report.

Figure 10 “Did you feel that the robot was reacting to your presence?” results show that majority of the participants for both methods say the robot was reacting to them. With method 1 the differences between often and there other lower scale responses is 1 point. This means method 1 needs to be clearer when it is responding. Method 2 scoring better could be contributed to the fact that method 2 would face the participant when greeting the user and if the user was too far from the robot, this head tuning showed a physical response to the human.

Figure 11 “Did you feel the robot was giving feedback on its actions?” Results show the majority of participants for both methods felt that the robot was giving feedback. Method 1 scored better with more participants saying often then in method 2. This is odd as both methods share the same feedback functions, in fact method 2 have more of them with head rotations and eye movements, but the difference is only 1 points so it is not significant enough to be to concerned with it.

Figure 12 “How did you feel about the robot using this method?” Results show all but 2 of the participants were at least “fine” with both methods. This question was asked as their comfort with the method and the robot could affect how willing they are to be encouraged. If they were uncomfortable, then it would be harder for the robot to encourage them to keep following. What was surprising is that method 1 was the most comfortable out of the two methods.

Figure 13 “Did you feel encouraged to follow the robot?” Results show no real difference between method 1 and 2, barring the one person saying method 2 made them feel encouraged most of the time. But majority for both methods do show that the participants were encouraged often by the methods.

End of test questionnaire

Figure 14 shows the results all 3 questions asked in the end questionnaire. The results show the majority of the participants were very comfortable with the robot speaking to them. This means the robot using verbal encouragement would not be hindered by them feeling uncomfortable. There is an even split for the majority on how the participants felt about the robot looking at them and it shows that only one person was slightly uncomfortable with it. But the majority felt at least neutral about the robot looking at them.

The last part of Figure 14 shows the participants were evenly split in whether they were comfortable or not. No one said they were uncomfortable so this should not negatively impact the results. 33% said they were very comfortable which might mean they would be more willing to be encourage by the robot.

Open questions responses

Discussion in this part will be about the response to the open ended questions that were asked once the participant had done finished doing everything else. For a full list of the participant’s response to the open ended questions refer to appendix Item 9. One thing to take note of is since the participants each got assigned which method they would do first randomly. When a participant say the second time around they could be refereeing to method 1 if the first method they test was method 2. Please refer to Table 1 for what each participant started with.

Participant	Method they done first
1	Method 2
2	Method 1
3	Method 1
4	Method 1
5	Method 1
6	Method 1
7	Method 2
8	Method 2

Table 1 Method tested first.

Did you notice any difference between the guide behaviours?

A lot of people notice the robot winking or blinking when the robot greeted them during the second method, with one participant calling it "seductive" "*There was a seductive wink before moving*" (participant 3) and others believed that the robot was looking at them more "*The second behaviour winked at me and seems to look at me more.*"(Participant 2), "*yes- turned to look at me more*" (participant 9).

Other another participant calling method 1 "optimistic" and "friendly" "*The second time around, the robot seemed more optimistic and friendly*" (participant 1).

Though not all the participants notices a difference with one of them commenting "*not really, the both performed around the same*" (participant 5).
This shows that for the most part the participants did notices the small differences.

Was there anything you liked/dislike about the different guide behaviours?

One participants didn't like the winking but did like the voice "*I disliked being winked at by the robot and felt it was artificial. The robot's voice was calming and informative*" (participant 2) where as two other participants liked the winking/blinking "*The wink is amazing*" (participant 3) & "*the cheeky wink, turning to talk to you then saying about the wink*" (participant 9)

A few liked the images used "*the image on the screen made the second one feel more inviting, especially as the first one was mainly code*"(participant 6) ~ the conductor of the test had accidently hide the images with the terminal, show off the code instead.

One mention they would like more encouragement from the robot "*I preferred it when there was more encouragement*" (participant 6)

One of the participants mention they didn't like their second test as the robot didn't look at them "*I preferred the second version. The head movement made me feel more involved in the tour*" (participant 4), as the second test they did was with the first method, were there is no head turning but this does show that the nonverbal encouragement is preferred to just verbal.

For the most part the participants like the images, the voice and the winking and head turning, with one of them wanting more encouragement and head turning from the robot.

In your opinion which guide was better at encouraging you to follow?

Only two of the participants said that the preferred the first method, both tested the second method first, "*The second one due to it speaking to me during waypoints*" (participant 1) & "*second*" (participant 9). This is at odds with all the other participants preferring the second method over the first, some even gave reasons for their choice "*The second one due to it speaking to me during waypoints*"(participant 1), "*the second because of the eye and head movement*"(participant 4) and "*first – seemed to acknowledge me more at the start just by turning eyes towards me*"(participant 7).

Do you have any further comment on any of the guides?

Most of the comments were of what they think could be done to improve both methods, with some wanting the guide to be more human like "*yes- needs to feel more like a human guide would, mostly by showing some attempt to acknowledge me*" (participant 7) "*perhaps have the guide turn to look at the person -unreadable word-, when it stops. I moved away a couple of times and it looked where I was not where I moved to*" (participant 5).

Some wanted a different image on the screen (though the image gets changed after every test) "*There should have been a puppy* -unreadable word- *instead of the kittens*" (participant 6)

Only really one of the participant mentioned that both of the guide methods were similar but he still found it encouraging "*They felt very similar, but the second was also more encouraging, however I do not know why*" (participant 2).

Do you have any further comments on the tests as a whole?

The participants again gave their thoughts on what needs to be changed, with two of the participants wanting the route changed "*being repeated on the same areas with the same dialog, meant I was less engaged in the second I than could have been because I knew what was going to happen*" (participant 4), "I don't know why it felt compelled to take me out of the lab and into the middle of a room to say this is the end, maybe something about what the space is or finished earlier"(participant 9), unfortunately the route could not be changed much due to limited area the robot is allowed to rom in.

One of the participants did fine that the robot had a personality "*Despite the open shell of the robot it is hard to see it as a robot due to the introduction of a personality, it's optimistic and welcoming attitude helps to personify it*" (participant 1), this was probably due to the robot greeting the user and with it variety of what it will say; such as the favoured "Hey ho, lets go"

Encouragement questions

Both Figure 15 & Figure 16 show that method 2 on average had a better score in both questionnaires, though with Figure 16 the different between the two scores is not that great and will more likely not be significant to really be able to determine that method 2 is the better method. Method 2 being the favoured methods does fit with participants answered the open-ended questions with most of them stating that they preferred method 2.

Statistical tests

A paired T test was done on both Figure 15 and Figure 16 results (without the average of course) to find if the score between the two methods was significant enough to be valid. To see the full break down of the results for the T-test refer to appendix Item 12 for Figure 15s results and appendix Item 13 for figure 16s results.

The results of the paired t-test for figure 15 give a p value of 0.0232, this is a statistically significant. This means that the score and its average is valid. It can be used to determine which method is the best for the aims of the project. However the results from the paired t-test for figure 16 gave a P-value of 0.1690, this values is not statistically significant enough so will not be used.

Conclusion

The aim of the project was to find which method was better at encouraging a user to keep following a robot guide, and which was more efficient. In terms of encouragement, method 2 meets this aim. This is primarily due to the high number of participants who said that they felt more encouraged with method 2. Figure 15 also shows the participants scoring method 2 higher when it came to giving encouragement. The participant's comments from the open ended questions show that they also preferred method 2.

With regards to the aim for the most efficient method, method 2 archives this aim because there was no significant different between the times for the completing a guide. However there is a fair difference in the number of times method 2 gave encouragement compared to method 1.

Method 2 achieved the aims of the project. So for the participants the most encouraging robot guide, is a robot that speaks and looks at you; Gives feedback on its actions and responds to your actions.

Future work

For this artifact there are a few areas that could have been improved and expanded on. Such as having the robot know which person is following it. Currently the closest person to the camera is the only person guided. If the original follower leaves the robot will carry on as long as there is someone within the correct distance. So one of the major improvements to the guide would be to have the robot able to perform human re-identification. With this improvement you could have the robot be able to guide more than one person. The idea for this would be that the robot would meet and greet several people and then guide them to a variety of points.

Changing the testing area to a larger place would be another improvement that could be apply to this project. With a larger area, it could have multiple different routes that the participants could go on. This would fix some of the issues with the participants getting bored with the same route being taken. This could be expanded to have the participant choose the route.

More methods could also be used in future iterations of this project, currently this project only had 2 but this could be expanded upon to have several more. With each one having a different form of encouragement and even different pairs of encouragement. Or just have the robot do more reacting to the participant, for example instead of the robot just stopping when the participant is out of range, the robot instead could slow down.

Some participants did mention they had problems with the voice, with one saying that they could not hear the robot clearly even with the volume was at its maximum; so for participants that are hard of hearing, or another issue, the robot could ask the participants at the start of the guide if they need any more assistance then normal.

Reflective Analysis

The project as a whole did get completed and does work but there were several issues that did hinder parts of the project. The main issues was time management, while the Gantt chart did help in some regard and the biweekly meeting helped kept the project within scope, I vastly underestimated the amount of time certain actions would need. Developing the first method took twice as long as it was thought to have taken, this of course meant everything else had to get pushed back to accommodate the loss of time. Due to the loss of time the planned 3rd method was never made but apart from that, the rest of the project went mostly as planned though now later than expected. More time for human participation testing and with more participants would have given a great set of results to compare against but again the loss of time stop this from happening.

For the most part none of the risks from the risk assessment happened and the only one that did was mitigated by the contingence plans. One of the main risks that was could have cause a lot of problems for the project, was Linda becoming inoperable/ unavailable”. This in the end never affect my project mainly due to booking time with Linda in advance and my supervisors were quick to inform me of when the robot was inoperable/unavailable and when it would be operable/available again. The only risk that happen that did slow my project was me losing some work due to failing to back up some work but thankfully it was not much and was redone quickly enough.

If this project was to be done again, then there are several thing that I would change. First one would be how I managed the time available for the project. A Gantt chart and biweekly meetings with the supervisors would still happen but I would make use of time sheets that would show how many hours I needed to work on parts and how long I have actually worked on said parts. More testing would be done, after a method proved to work both on the simulator and on the robot it would be tested with participants to get some initial feedback on what they believe would improve that method, then the next method would take some of the feedback and incorporate that into the design. The only issue with this approach is that you would need the same participants again and that would be difficult to guarantee. The last thing that would be done differently is the testing area, while it is large enough to do the testing it not large enough to have multiple routes.

Parts of the project I liked were the user participants testing, while getting it all set up, getting the time with the robot and then getting people there was time consuming and hard. The actual testing and interacting with the participants and seeing the methods work with that many more people was enjoyable. The participants that did do the tests gave for the most part good feedback on what they liked and did not like. Another part I thought that went well is the background research. With the research it made the design of the methods a lot simpler then if I had just tried to make them up without some reference to what has been. Having the simulator to test and develop methods made the whole process quicker than if testing could have only be done on the robots.

Another part that I believe went well was the design of the methods, while the participants did mention some issues with them, there was no great consensus that something needed changing with either method.

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Appendix

Item 1 Consent form

Consent form.

Date: ___________

Participants Name: ______________

This test has two parts. Part one you will be asked to stand in an area and do as the robot ask. Once you have completed the tasks for the robot you will be asked to fill a small questionnaire about your thoughts on the robot.

Part two you will be given more information on what the robot is trying to do and what the purpose of the test is, you will then be ask to interact with the robot again. Like before a questionnaire will be given to get your thoughts after the interaction. Open ended questions will be ask once all other task have been done.
You may be selected to be part of a control group, were you will be asked to walk in and out of frame of a camera a few times. I consent to participating in Christopher Buckingham and Sinjun Strydom's respected projects and I acknowledge the following:

- I understand that if I feel uncomfortable during the tests I can stop at any time
- I understand that I can leave at any time during any of the tests and the data that was collected up to that point will be deleted and not used.
- I understand that I can withdraw from the test even after my completion of the test as long as I inform the conductor of the test of my withdrawal within 2 weeks of my participation.
- I've been verbally told about the tests, their purpose and what I am expected to do in them.
- I am happy for Christopher and Sinjun to use the data that is collected from my participation in the tests to be used in there project evaluation.
- I understand that personal data collected from my participation will be anonymized
- I understand that if I wish, I can ask about the data collected from my participation after the tests and that if I want to then see that data I would be allowed to.
- I understand that I can ask questions before and after each test but not during
- I understand that I will be recorded while I do the tests but I understand that the recordings will only be used for the project evaluation and will be destroyed once the project has been completed.

With me signing this consent form I agree that I have read, understood and agree to the above points.

Participant Signature: ………………………………………………

Christopher Buckingham signature: …………………………………………..

Sinjun Strydom signature: …………………………………………..

Item 2 Repeated questionnaire

Below is the Likert scale questionnaire that each user filled out after each test.

Participant's name_______

Did you feel that the robot in this guide was giving encouragement?				
Not at all	A little	sometimes	Often	Most of the time
Did you feel that the robot was reacting to your presence?				
Not at all	A little	sometime	Often	Most of the time
Did you feel the robot was giving you feedback on its actions				
Not at all	A little	sometime	Often	Most of the time
How did you feel about following the robot using this method?				
I was very uncomfortable	I was slightly Uncomfortable	I was fine	I slightly comfortable	I was very comfortable
Did you feel encouraged to follow the robot?				
Not at all	A little	At times	Often	Most of the time

Robot behaviour ______

Item 3 End questionnaire

Below is the questionnaire that the participants were given once they had finished all the tests

Participant's name_____

How did you feel about the robot looking at you?				
Very uncomfortable	Slightly uncomfortable	Neutral	Slightly comfortable	Very comfortable
How did you feel about the robot speaking to you?				
Very uncomfortable	Slightly uncomfortable	Neutral	Slightly comfortable	Very comfortable
Were you comfortable doing the tests?				
Very uncomfortable	Slightly uncomfortable	Neutral	Slightly comfortable	Very comfortable

Item 4 Open-ended questions

Below is the open-ended questions. These questions were also asked at the end of the tests.

Did you notice any difference between the guide behaviours?

Was there anything you liked/dislike about the different guide behaviours?

In your opinion which guide was better at encouraging you to follow?

Do you have any further comment on any of the guides?

Do you have any further comments on the tests as a whole?

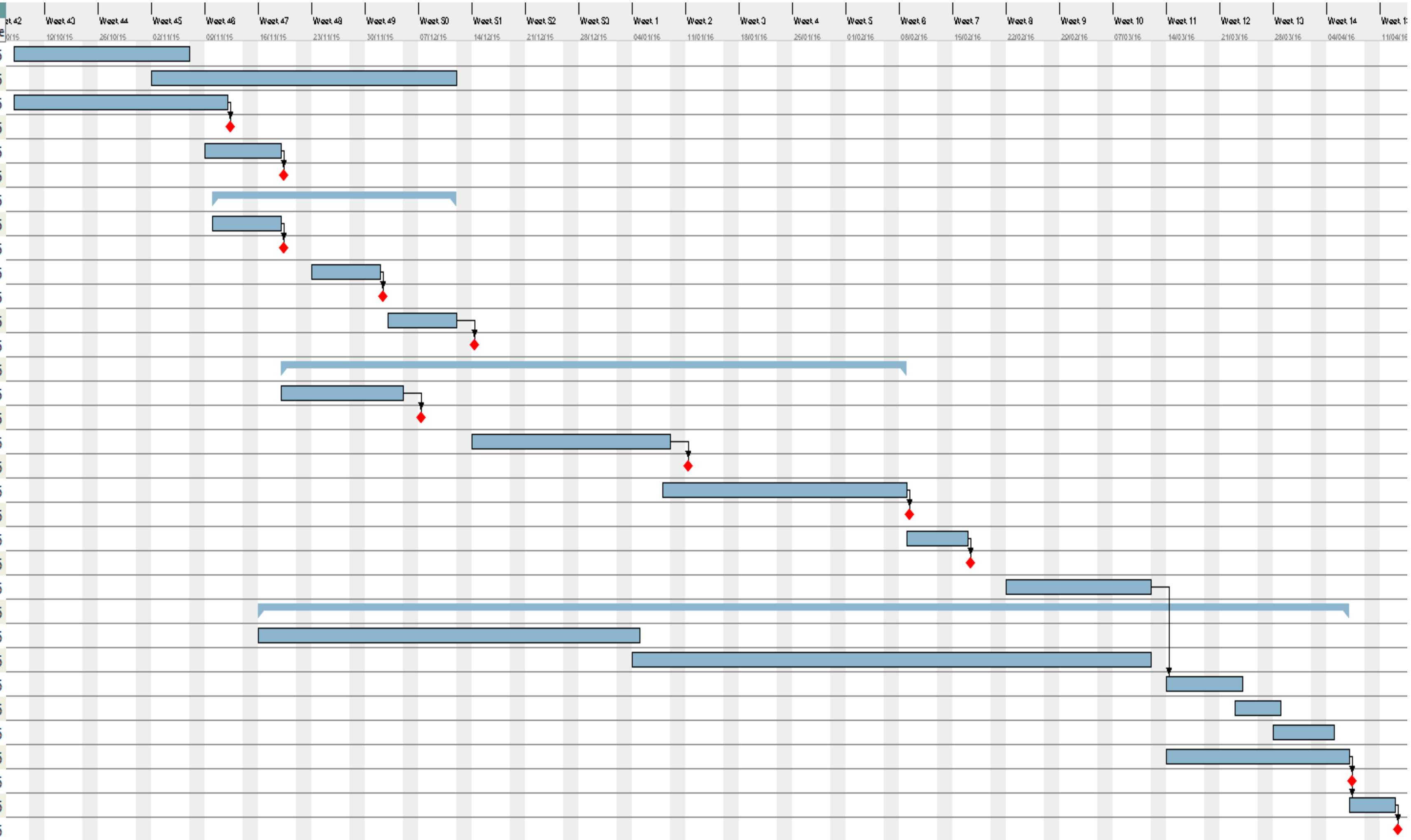
Item 5 Risk assessment and contingency plans

Risk	Severity	Probability	Contingency
Linda becomes inoperable	Medium	Medium	There a few other robots at the labs that could be used in place of Linda or if they know Linda will be useable for our time of testing they could borrow one of the other Strands robots.
ROS Simulation cannot run on my laptop/desktop	Low	Low	If my computers cannot, then I will use the ones in the university computer labs that currently can run the simulator.
Ubuntu problems or cannot run on own computers	Low	Low	If Ubuntu cannot run or is having problems running in ether of my computers then I will again use the university's computer labs.
Robot Linda is unavailable for my use.	Low	Low	This is a low risk as all uses of Linda will be booked well in advance of actual use but if for some reason Linda is need else were then there are other robots that could be instead.
Unable to get a range of different demographic people to test my methods	High	Medium	I will ask people in advance and arrange testing times with people but if they choose not to show up at the tests then there is only a few thing that can do, such as I will walk around the university and see who wants to do some robot testing but this does not alleviate the risk of not getting a good demographic.
Run out of time to finish the project	High	Low	This is low risk as I will be using various tools to keep to a schedule but if I start to have problems keeping to my plan then I will arrange a meeting with my project supervisor and discus what can be change to get me back on target.

Lose access to Dropbox/ Github/OneDrive	Medium	Low	Losing access to any of one of these would be a problem but they all have a local storage on my computers so while it would be an inconvenience, as version control would be harder, it would not slow the project down too much.
Changes to simulator break software	High	medium	A backup of the working Ubuntu OS with the working simulator will be kept- so can restore backup
Changes to ROS break program	High	medium	A backup of the working Ubuntu OS with the working simulator will be kept- so can restore backup
Computer labs change ROS version	Low	medium	I would continue to use my laptop or I would have to update my work to work on the new version

Item 6 Gantt chart

Name	Begin date	End date
Research background	15/10/15	06/11/15
Learn Python & ROS	02/11/15	11/12/15
Write the project proposal	15/10/15	11/11/15
Hand in project proposal	12/11/15	12/11/15
Research about more forms of encourag...	09/11/15	18/11/15
List of more forms that will be used	19/11/15	19/11/15
Design Methods	10/11/15	11/12/15
Design method 1	10/11/15	18/11/15
Design for method 1	19/11/15	19/11/15
Design method 2	23/11/15	01/12/15
Design for method 2	02/12/15	02/12/15
Design method 3	03/12/15	11/12/15
Design for metho 3	14/12/15	14/12/15
Developing and testing Methods in simu...	19/11/15	08/02/16
Develop & test First method	19/11/15	04/12/15
First method working in simulator	07/12/15	07/12/15
Develop & test Second method	14/12/15	08/01/16
Second method working in simulator	11/01/16	11/01/16
Develop & test Third method	08/01/16	08/02/16
Third method working in simulator	09/02/16	09/02/16
Integrate methods onto Linda	09/02/16	16/02/16
All methods integrated onto linda	17/02/16	17/02/16
Live testing with methods	22/02/16	11/03/16
Write Project report	16/11/15	06/04/16
Lit review	16/11/15	04/01/16
Write other parts of Report	04/01/16	11/03/16
Evaluation	14/03/16	23/03/16
Write conclusion	23/03/16	28/03/16
Reflective analysis	28/03/16	04/04/16
Proof read	14/03/16	06/04/16
Document complete	07/04/16	07/04/16
Print & bind project report	07/04/16	12/04/16
Project hand in	13/04/16	13/04/16



Item 7 Code for method 1

https://github.com/Sinj/Year-4-project/blob/master/scripts/robot_simple_working.py

Item 8 Code for method 2

https://github.com/Sinj/Year-4-project/blob/master/scripts/robot_meth2.py

Item 9 Open questionnaire

Participant number = pnumber e.g. participant 1 = p1

Participant	Method they done first
1	Method 2
2	Method 1
3	Method 1
4	Method 1
5	Method 1
6	Method 1
7	Method 2
8	Method 2
9	Method 2

<u>Did you notice any difference between the guide behaviours?</u>

P1: "The second time around, the robot seemed more optimistic and friendly"

P2: "The second behaviour winked at me and seems to look at me more."

P3: "There was a seductive wink before moving"

P4: "The "head" turned and acted more often, the guide seemed to acknowledge me by making "eye contact""

P5: "not really, the both performed around the same"

P6: "yes, iwas being encouraged more the second time with the robot saying I was doing a good job keep it up"

P7: “yes – she was not looking at me on the second one, there for it did linda seemed less ‘human’ in the way she interacted with me, almost like she was disinterested”

P8: “the second tests had a nice image on the screen. Did not seem to wait as long at each stop”

P9: “yes- turned to look at me more”

<u>Was there anything you liked/dislike about the different guide behaviours?</u>

P1: n/a

P2: “I disliked being winked at by the robot and felt it was artificial. The robot’s voice was calming and informative”

P3: “The wink is amazing”

P4: “I preferred the second version. The head movement made me feel more involved in the tour”

P5: “for me, both test were practically the same, except the start where the second behaviour was more friendly”

P6: “I preferred it when there was more encouragement”

P7: “dis - that fact she didn’t recognise me as human at the first waypoint
dis – not looking at me in the second tests
lik – winking, her catchphrase(hey ho, lets go)”

P8: “the image on the screen made the second one feel more inviting, especially as the first one was mainly code”(accidently flip the screen to code without noticing till half way though their test)

P9: “the cheeky wink, turning to talk to you then saying about the wink ”

<u>In your opinion which guide was better at encouraging you to follow?</u>

P1: “The second one due to it speaking to me during waypoints”

P2: “The second”

P3: “2nd”

P4: “the second because of the eye and head movement”

P5: “the second guide was slightly better, but only the stare but otherwise the same throughout the test”

P6: “the second”

P7: “first – seemed to acknowledge me more at the start just by turning eyes towards me”

P8: “the second one had a nice display but the first one was more encouraging”

P9: “second”

Do you have any further comment on any of the guides?

P1: “The speech pattern that the robot uses seems very alien – its disjointed and rather difficult to list too”

P2: “They felt very similar, but the second was also more encouraging, however I do not know why”

P3: n/a

P4: n/a

P5: “perhaps have the guide turn to look at the person -unreadable word-, when it stops. I moved away a couple of times and it looked where I was not where I moved to”

P6: “There should have been a puppy -unreadable word- instead of the kittens”

P7: “yes- needs to feel more like a human guide would, mostly by showing some attempt to acknowledge me”

P8: “the robot did not seem to notice when I lagged behind and so just carried on with the tour without me”

P9: “”this is where work on baxter takes place” could have turned to me but didnt”

Do you have any further comments on the tests as a whole?

P1: “Despite the open shell of the robot it is hard to see it as a robot due to the introduction of a personality, it’s optimistic and welcoming attitude helps to personify it”

P2: n/a

P3: “it might have worked better if I could have heard it”-(the volume on the robot was at its max)

P4: “I also feel that the nature of the test, being repeated on the same areas with the same dialog, meant I was less engaged in the second I than could have been because I knew what was going to happen”

P5: n/a

P6: n/a

P7: “would help if she actually physically recognised me – both tests failed, possibility because the sensors didn’t recognise me, I am shorter than her, top sensor”

P8: “the different between the two tests were not that great, not much motivation to keep following”

P9: “I don’t know why it felt compelled to take me out of the lab and into the middle of a room to say this is the end, maybe something about what the space is or finished earlier”

Item 10 Puppy

Image taken from google, source of the image: (perfectlytimedimages, 2016)

Item 11 Kittens

Image taken from google, source of the image:

(bordervets, 2016)

Item 12 Paired T test Q1 results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Method 1: robot was giving encouragement?	.333	9	1.3229	.4410
	Method 2: robot was giving encouragement?	1.111	9	1.2693	.4231

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
-.7778	.8333	.2778	-1.4183	-.1372	-2.800	8	.023

Item 13 Paired T test Q2 results

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Method 1: you feel encouraged to follow the robot	1.111	9	1.5366	.5122
	Method 2: you feel encouraged to follow the robot	1.333	9	1.6583	.5528

Paired Differences					t	df	Sig. (2-tailed)
Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
-.2222	.4410	.1470	-.5612	.1167	-1.512	8	.169