The Edward S. Rogers Sr. Department of Electrical and Computer Engineering **University of Toronto**		
ECE496Y Design Project Course **Group Final Report**		
Title: Tour Guide Robot		
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Submission Date:	March 31, 2020	

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Sincerely,
Khoman Phang
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ECE496Y Course Coordinators

Consent Statement

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Team #: 140 Project Title: Tour Guide Robot
Supervisor: Willy Wang Administrator: Hamid Timorabadi

Name	ZIHAN(AARON) ZHAO	Signature	ZIHAN(AARON) ZHAO	Date:	MAR 31,2020
Name	Jingfeng (Eric) Chen	Signature	Jingfeng (Eric) Chen	Date:	MAR 31,2020
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1. Executive Summary (author: Momin Mehmood)

Museums are a hub of knowledge and history, defining the culture of a period and a people. However, it is seen that the number of museum visitors, hence the number of people learning from this hub of knowledge, has been in a steady decline since 1982 in North America[1]. This report describes and evaluates a solution to this issue aimed at making museums more attractive to the general public, especially young adults who have the biggest decline in visits[1].

Our group proposed the implementation of a tour guide robot, Touri - a robot that will provide not only additional information about the displays but also tie together the narrative to provide an overarching view of the displays - why they are in that room, why specific displays are next to each other, etc. This narrative will not only make the visit more fun but also more memorable for the visitors, encouraging them to take advantage of these hubs of knowledge.

The robot will be fully autonomous once the tour has started. This is to provide a more immersive experience for the visitor to make the entire visit more memorable.

The group decided to go with buying a robot kit rather than building everything from scratch. The main navigation will be done with line following with basic obstacle avoidance in place so Touri should not run into other people or objects in its path. There will also be distance monitoring in place via a camera so Touri can adjust its speed according to the visitors on tour. All these functionalities allow Touri to give a more interactive experience to the visitors which in turn will encourage more visitors to the museums.

2. Group Highlights and Individual Contributions

2.1 Group Highlights (Momin Mehmood):

The main highlights of the group we as follows:

1. Line following code: We created the line following algorithm to be implemented as set out by the project requirements. This means that the robot is able to detect a line and follow it, figure out when the robot is next to an exhibit and stop to convey information about that exhibit to the user.
2. Code for voice input: We used Google Speech recognition to listen for commands from the user like ‘start’, ‘stop’, etc. for the robot to follow
3. We used a bluetooth headset to connect to our robot for voice output when it stops next to an exhibit. A Python file was also created to play the appropriate audio files which describe the exhibits.
4. We have a code for facial recognition, user identification and distance measuring. This task was completed using OpenCV. We used a video stream to detect the face and also train the robot to identify the user on the tour so it can correctly keep distance from the user. The way we achieved this is by the robot asking the user to look at it. It then takes 10 photos of the user’s face over 5 seconds. These are used to train a classifier. The classifier uses a series of blank pictures for its training as this produced the best results. This, combined with the minimum image compression of 1.01 and using 5 points to build the circular local binary pattern produced a model that reliably worked to differentiate between different faces. This allowed us to then use the detected face width to estimate the distance to the user.

2.2 Individual Contribution:

Eric Chen contribution table:

Task #	Task Title	Category	Status
1	Assemble the Robot	Old	Completed
2	Install/test RISC OS software on the Raspberry pi 4	Old	Completed
3	Program/test the sensory and motor functions	Old	Completed
4	Program/test the Bluetooth wireless communication	Old	Completed
5	Program the main logic and line following functionality	Old	Completed

Table 2: Eric's contribution table

1. After our team received the purchased robot, I helped assemble the kit in a short amount of time and helped verify the integrity of our assembly.
2. I also researched the suitable OS and softwares for our Raspberry Pi, and installed them onto our robot.
3. After installing the required software and libraries, I tested and verified sensory inputs and motor outputs from the Python program the robot runs on.
4. I determined the Bluetooth output solution we will be using for our audio interaction between the user's headphone and the onboard Raspberry Pi, this will be used along with our voice recognition part of the project.
5. I worked and will continuously work on programming the main logic of the robot. Afterwards, I will also be responsible for the programming of the line following function and optimized it to work in conjunction with other aspects of the project: such as audio output, speed control, object avoidance etc.

Aaron Zhao contribution table:

Task #	Task Title	Category	Status
1	Assemble the Robot	Old	Completed
2	Camera Debugging	Old	Completed
3	Prepare client/ server program	Old	Completed
4	Debug OS	New	Complete
5	Program robot voice input	New	Completed
6	Program Bluetooth output function	New	Completed

Table 3: Aron's contribution table

1. The whole team helped assemble the robot in a short amount of time.
2. Due to a hardware error the camera was not working and I fixed it.
3. After my teammate installed some libraries on the Pi, I found out it was not sufficient to run the server/client program (which enables the robot to move and etc.) I tested for what is missing and installed what is necessary.
4. After my teammates updated the OS to a newer version the robot refused to connect, I helped make the robot work by testing and installing necessary software.
5. I implemented a voice input function using google cloud service to accept voice commands.
6. I helped implement a Bluetooth output function using python.

Momin Mehmood Contribution table

Task #	Task Title	Category	Status
1	Assemble the robot	Old	Completed
2	Assemble sensors with the Pi	New	Completed
3	Program/test the line following functionality	Old	Completed
4	Research distance measurement using camera	Old	Completed
5	Testing	Old	In progress

Table 4: Momin's contribution table

1. The entire team helped out with the assembly of the robot to reduce the time required for this task.

2. It was found that we did not have enough time to finish the entire robot assembly. So, I finished the final connections and adjustments needed for the Raspberry Pi to communicate with the sensors

3. I helped with the programming and testing of the line following functionality. This is an additional task that I took on in February due to the task being delayed. The reason for this was a faulty servo on the robot. This delayed the task as we had to first debug what the issue was and then get a replacement servo. I am currently working on and will continuously work on the line following functionality of the robot.

4. This task has been modified from the original. Initially, I was to help with research and implementation of the distance sensing. However, upon further review in February, we realised that it would be better for only one person to be in charge of the implementation for better consistency and debugging of the code. At the same time, our line following algorithm had

started to show some bugs so I helped Eric with that instead. Currently, my task to research the distance measuring via camera which has been completed.

5. This is an in-depth testing of the entire functionality of the robot. Once all the tasks are completed, a thorough testing will be carried out. Due to social distancing, this task has been delayed as we are currently putting all our work together which is taking longer than expected due to the team being spread over two continents. But we are working on completing this task to the best of our abilities with the new circumstances and aim to be done in time for our final demonstration.

John Courtney contribution table:

Task #	Task Title	Category	Status
1	Assemble the robot	Old	Completed
2	Obtain and interpret from sensors	Old	Completed
3	Control of all motor functions	Old	Completed
4	Implement basic line following capabilities	New	Completed
5	Facial Recognition	Old	Completed

Table 5: John's contribution table

1. The entire team completed this task. It was quite easy and a good way to get to know each other.

2 and 3. Before we could really get anything started, we had to ensure that we had access to the sensory and motor functions. As the Raspberry Pi was not designed specifically for this, this required installing various libraries and drivers to enable communication of the Pi and its inputs and outputs. I also set up a video feed that transmitted the information from the Pi to a laptop to better enable interaction between the two devices.

4. After getting the sensor and motor functions enabled, I set about writing a basic line-following program to follow a white line on the floor. This was successful, showing that the system had been set-up correctly. This design was subsequently improved by using a PID control module later by Momin.

5. As part of the final effort to get the robot functional, we had to implement the facial recognition option as specified in the original project guideline. This was done so that the robot could observe the people following behind, and speed up or slow down if it detected that they were approaching too close or had stopped to look at something. This required implementing three different systems to detect a human upper body, a human face and distinguish between faces. The first system was added so that the robot could recognise people from a distance and if they were not facing the camera, while the second and third were used to identify the user in a crowd of people.

3. Acknowledgements (Eric Chen)

We would like to express our deep gratitude to **Professor Willy Wong**, our supervisor, for his patient guidance and enthusiastic encouragement during the development of this project. His penetrating questions provided an insight to the project design and development and allowed us to think about issues we had overlooked in our initial design. Our immense gratitude is also extended to **Professor Timorabadi Hamid**, our administrator, for his constructive advice and useful critiques in keeping our progress on schedule. Their willingness to give their time so generously has been very much appreciated by every member in this team.

We would also give a special thanks to the **Adeept technical support** department, for their professional help, which played an irreplaceable role during this project's conception and development.

4. Table of Contents

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5. Introduction (Eric Chen)

This report summarizes the motivation, background research, design, implementation and testing of Touri - a guidance robot created as part of our final year design project course ECE496. The report concludes with a valuation of the project and future suggestions.

5.1 Background and motivation

Museums play an important role in our society when it comes to education and entertainment [2]. However, the number of museum visitors in North America has been on a downward trend since 1982 [1]. Among all age groups, children and teenagers (below the age of 24) had the sharpest decline: -17% from 2012 to 2017 [1]. In fact, a survey done as early as 2004 shows that the elderly (above the age of 55) are becoming the largest population group (at 36%) among all museum visitors in Canada [3]. One of the causes of this phenomenon is the incompatibility of the youth's energetic nature and the slow relaxing environment of a typical museum: more and more young people find non-interactive recreations like going to a museum unattractive.

A study done in 2006 found [4] that although most modern museums are equipped with audio guides - either via a traditional headphone set or a phone app, typical museum visitors are still not inclined to read signs nor listen to information about exhibits. Not only that, most museums kept audio length for each exhibit under 2 minutes in order to compensate for an average person's attention span. Yet up to 70% of all exhibits in a museum still only receive cursory glances [4]. Is there a way we can maximize the delivery of information to the visitors in an interesting and digestible way?

One solution to this problem is to improve the way people enjoy museum visits. We can fully utilize human's natural curiosity towards animate objects such as robots [5] to maximize the delivery of information. Instead of walking around aimlessly from one exhibit to another, a tour guide can be provided by the museum, creating an overarching narrative for the visitor. And instead of the typical voice-over in your digital audio guide, our autonomous robot can lead visitors around, telling the unique stories about each exhibit along the way. Compared to the traditional audio guides, our solution excels at attracting the attention of the youth and creating companionship for the elderly, and ultimately boosts the museum's ability to attract visitors.

5.2 Project goal

The goal of this project is to design and build a working model of a tour giving robot that is capable of self-navigation, object avoidance as well as providing voice-over interactions for museums.

5.3 Project requirements (Aron Zhao)

ID	**Project Requirement**	**Description**
1.0	Movement	**Primary function requirement:** Able to move around following a line on the ground
2.0	Power input: (9V max)	**Subfunction requirement:** The robot is autonomous and must be powered by its own battery (9V). Thus all electronic components on board must be able to work with said voltage.
3.1	Surrounding detection	**Requirement:** Robot must be able to detect its surroundings, such as picking up the line it's following from the ground and detect when it's near an exhibit
3.2	Line sensor	
3.3	Exhibit detection	

4.0	Decision Making	**Requirement:** Control software must be able to process logic and make decisions based on the inputs received, such as line following, object detection, exhibit detection, and voice interaction
5.0	Movement control	**Requirement:** the robot must be able to start, stop, and turn around corners without manual input
6.0	Audio output	**Requirement:** Robot must be able to output audio containing information about the exhibits
7.0	Object detection	**Objective:** It is ideal for the robot to be able to detect objects on its path and stop its movement to avoid collision.
8.0	Minimize weight	**Objective:** the lower the better. Weight will be traded off against other characteristics.
9.0	Size: 60cm x 200cm (width x height)	**Constraint:** The robot must not exceed this size to be able to path through doorways. This is the minimum width and height of a museum door
10.0	Total cost under $400	**Constraint:** The total material cost for the robot must not exceed $400 CAD, as it is the maximum our team can afford without additional aid from the department

Table 6: Project Requirements

6. Final Design - (authors: John Courtney and Momin Mehmood)

6.1 System-level overview

The block diagram gives an overview of the overall system.

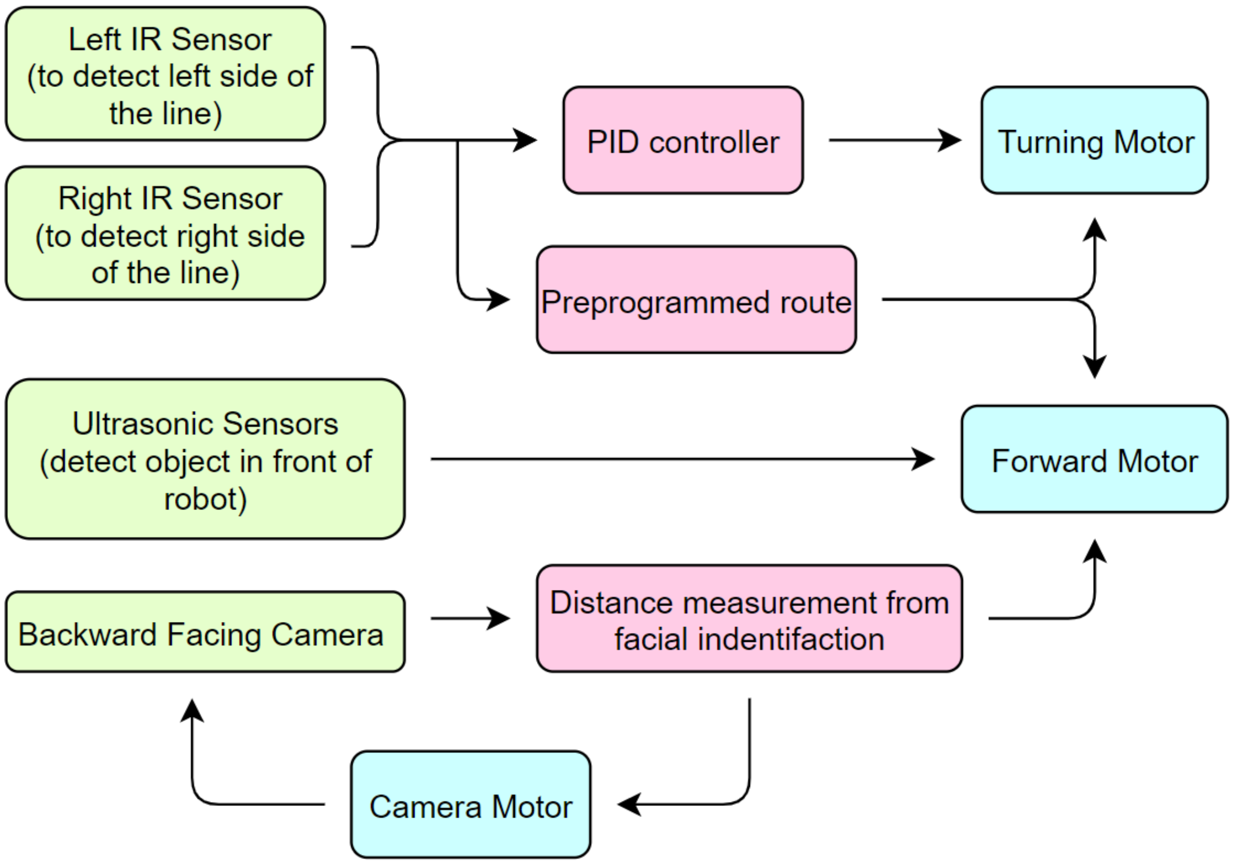

Figure 1: Block diagram for robot logice (John Courtney) (text below Momin Mehmood)

The boxes in green are the sensors or input data, red shows the algorithmic calculations and blue shows the output. As can be seen, we have our IR sensors to detect the line. The input is fed into a PID controller and the pre programmed route in parallel. The reason for the PID controller is to allow for smooth turning of the robot as we found the motion to be jerky otherwise. The pre-programmed route only selects which route to follow - the in depth one or the quick one. The output of these calculations are fed into the motors to allow for movement.

We also have the Ultrasonic sensors to detect distance from an object for the robot. This allows us to stop if there is some obstacle in the robot's path.

Finally, we have a backward facing camera. This is there to allow for facial identification as well as distance measurement so that we can keep a constant distance from the person on tour allowing for a more immersive and interactive experience.

Overview of our main algorithms

Line Following

The line following works by using the sensor input from the IR sensors. It detects the line and sends a 0 when a white line is detected and 1 otherwise. When a 0 is detected on the left side, it means the robot needs to turn left as the line is turning left. Same with the right side. If a 0 is detected on both the left and right sides, this means that the robot is near an exhibition and should stop and play the appropriate audio file.

Bluetooth Audio input/output

We used pulse audio, which is a sound system for the Raspberry Pi, to output the audio from the pi to a wireless headset/speaker.
Google audio detection is used to detect when the user is speaking and we can parse certain phrases from the audio like ‘stop’, ‘start’, ‘wait’, etc. which are then translated for the robot to follow.

Method of User Detection

For our robot, we used a system whereby the robot would establish visual contact with the user by using its “Raspberry Pi Camera v2”. This image feed would then be processed by the Raspberry Pi running the OpenCV library in Python. This system had two purposes.

1. Identify the distance to users behind the robot. This was used in case people were approaching too close to the robot and speed up to avoid becoming a trip-hazard, or slow down if it detected they had stopped to look at something.
2. Be able to identify the user from other people at the museum. This would be used in case the user and robot became separated from each other so that the robot could find the user easily.

Three separate identification systems would be running in this code.

1. A system to identify a human upper body

2. A system to identify a human face
3. A system to identify a particular face from others.

The purposes of these three methods were as follows. The first was found to work very well over long distances, still performing reliably at 7 meters distance, whereas the other two had difficulty in working at 3m and beyond.

The second system was included as it was found to work reliably at short distances, whereas torso detection could become unreliable at distances of less than 2m.

The third system was included as it was needed for distinguishing between people at the museum.

The first and second systems used a pretrained model from OpenCV. The first model used the 'haarcascade_upperbody' classifier while the second used the 'haarcascade_frontalface_alt2' classifier. A video stream was captured from the Pi camera and fed to these models to generate boxes around where in the image the face was detected. The size of these boxes was then used to estimate the distance from the camera to the user.

The third system was the most complicated, as instead of differentiating a face from another object which most likely would not be similar, it had to distinguish two faces. Additionally, it would be expected that the model should be trained in several seconds at the start of the tour. To achieve this, the training setup of the model had to be streamlined so that it could reach high accuracies quickly.

The first set in training is that the robot asks the user to look at it. It then takes 10 photos of the user's face over 5 seconds. These are used to train a classifier. For this classifier, after experimenting, it was found that the model performanced best when run against a series of plain black pictures. This combined with the minimum image compression of 1.01 and using 5 points to build the circular local binary pattern produced a model that reliably worked.

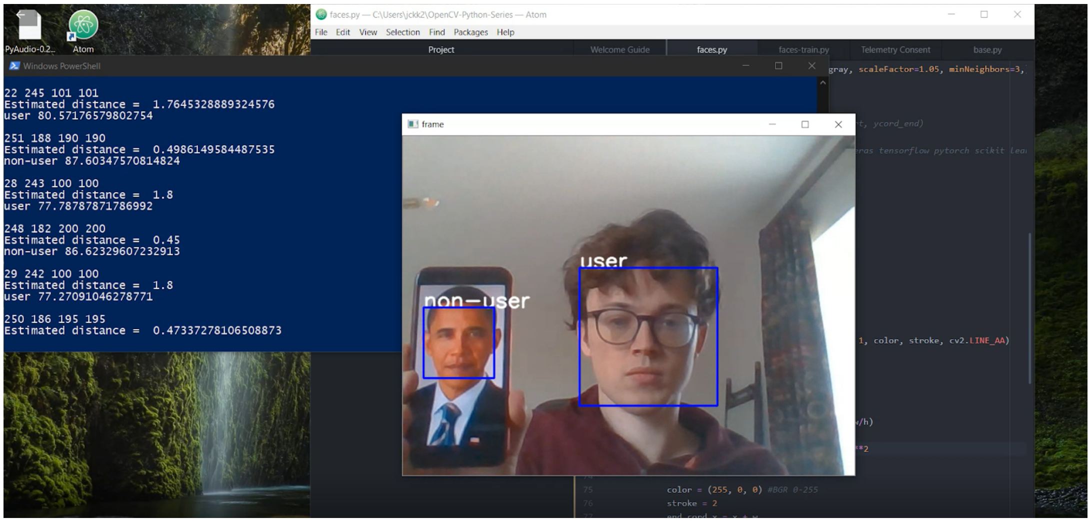

Figure 2: the running of the face identification program. The terminal on the left shows how far away it believes each face is. It believes the computer operator is about 0.47m away, while the image on the phone is 1.8m away. It estimates distance based on face size, which is why it believes the phone is much further.

6.2 Module-level overview

Bluetooth Receiver/Transmitter
Input: Shortwave 2.4-2.485 GHz wireless communication signal. Maximum speed: 2Mbps
Output: Shortwave 2.4-2.485 GHz wireless communication signal. Maximum speed: 2Mbps.
Function: The receiver enables users to pair their devices with the robot, allowing them to interact with Touri. The transmitter then can transmit the robot's output back to the user.

Camera Input
Input: The camera examines the area behind the robot.
Output: 3280x2464 static images, or 1080p30 or 720p60 video.
Function: The camera looks behind at the user to ensure they are following and they do not fall too far behind the robot. If they do fall behind, the robot slows down or stops to allow for them to catch up.

Ultrasonic Sensors
Input: The sensor examines the area in front of the robot, approximately 1m ahead, to detect the presence of any obstacle in its path. It sends out an ultrasonic signal by sending a voltage high (5V) to its input.
Output: The sensor outputs high voltage (5V) from the moment it sends out its signal until it receives the signal back, stopping after 15ms if no signal is detected. As the speed of sound is 340m/s, this gives the sensor an effective range of 2.55m.
Function: To stop the robot if an obstacle is detected ahead.

Infrared Sensor
Input: The colour of the ground just underneath where the sensor lies
Output: A voltage output from 0-5V, with precision of 10 bits. Darker colours produce higher voltages.
Function: The line the robot follows is made of a different colour to the rest of the floor. This enables the robot to follow along the line with the use of the IR sensors, detecting when it has left the line by the change of colour from the sensors. We use a PID controller for this to give a smooth line following.

Drive Logic
Input: Data from ● The ultrasonic, which is used for stopping ● The infrared-sensor, which is used for line-following ● The camera module, which is used to keep an appropriate distance ahead of the users.
Output: Instructions to the motor
Function: To stop the robot if needed, and to control the speed and navigate the robot. This module runs on the Raspberry Pi

Communication Control
Input: Bluetooth signal, with maximum information rate of 2Mbps.
Output: Bluetooth signal, with maximum information rate of 2Mbps.
Function: To transmit the audio content of the tour to the users' headsets. The robot is also able to respond to certain commands like 'start', 'wait', etc.

Motor
Input: 7.4V power input. Control from control module
Output: The speed and direction of the robot
Function: To move the car reliably and accurately as described by the drive logic module.

Table 7: Module Level description for different modules

6.3. Assessment of final design

	Adeept rover with pi4 - Touri
Strengths	It allows us to achieve more advance features including distance control, sound recognition, video input and processing Raspberry Pi is easy to communicate wirelessly and can connect to the internet Raspberry Pi is customizable since it can be easily programmed via python, and it gives full stack control to motors and sensors
Weaknesses	The rover comes with a pre designed structure so it is hard to modify the place of the sensors. This was an issue when we had to modify our camera position as the camera came facing forward but we needed it to face backward #VERIFY
Trade-offs	Buying the kit instead of building everything from scratch allowed us to save time. It also allowed us to forego the connectivity and compatibility issues we would have ran into had we created everything from scratch.
Reasons	Our team decided to use Adeept rover instead of Lego or building from scratch because of its compatibility, customizability, huge online community and more advanced processing power. We believed and still believe that having little flexibility in the design is a viable trade-off for the benefits Adeept kit provides

Table 8: Assessment of design

7. Testing and verification (John Courtney and Aron Zhao)

Change?	ID	Project Requirement	Verification Result and Proof	Requirement Verification Method			
				Similarity	Review of Design	Analysis	Testing
	1	Movement	Pass				x
	2	Power input: (9V max)	Pass		x		
	3.1	Surrounding detection	Pass				x
	3.2	Line sensor	Pass				x
	3.3	Exhibit detection	Pass				x
	4	Decision Making	Pass			x	
	5	Movement control	Pass				x
	6	Audio output	Pass				x
	7	Detect the distance to the user and other people from behind the robot	Pass				x
	8	Minimize weight	Pass	x			
	9	Size: 60cm x 200cm (width x height)	Pass		x		
	10	Total cost under $400	Pass		x		

Table 9: Testing and Verification table

Testing Criteria

Below are the following criteria used to detect if the robot met the required specification:
Test 1: Check robot can follow a line for 10 cm
Test 2: Test power supply against our circuit board (raspberry pie)
Test 3.1: Direct measurement
Test 3.2: Test we can detect the line on the ground and detect when its next to an exhibit
Test 3.3: test the robot can follow the line for navigation
Test 4: Test the robot changes speed based on the person following it - Direct measurement
Test 5: Direct measurement
Test 6: Check the robot can send and receive signals from its peripherals - direct measurement
Test 7*: This was more complicated to test, so it has been moved to its own section below.
Test 8: Test the robot can output audio when needed
Test 9: verify that the robot stops at the exhibits for the correct time. It must be able to stop while it is conveying information and start again once it is done
Test 10: Calculation. Total cost of the project was $234

Testing and Verification of User Detection

User detection was the hardest to test and verify. This is because unlike the other requirements, which were a simple pass/fail criteria, image recognition can only work to a certain standard and not in all situations.

Three criteria were examined for testing. These were:

1. Ability to accurately measure the distance between the user and the robot
2. Frequency which a user can be detected in a video feed
3. Ability to frequently detect the user in an image, while minimizing false positives.

Ability to accurately measure the distance between the user and the robot: For the first of these criteria, the following test was performed. While a human stood at certain fixed distances from the robot, while adjusting their facial expression and body position, 50 images were taken. From each image, the distance to the human was estimated, and plotted on the y-axis. Error bars representing two standard deviations of the estimates were added. This is shown below.

The accuracy was sufficient, with a maximum error occuring when the user was in fact 1m away, when the computer believed the user was 1.17 ± 0.13m away. This would be sufficiently accurate for detecting when a user was approaching too close and becoming too far away.

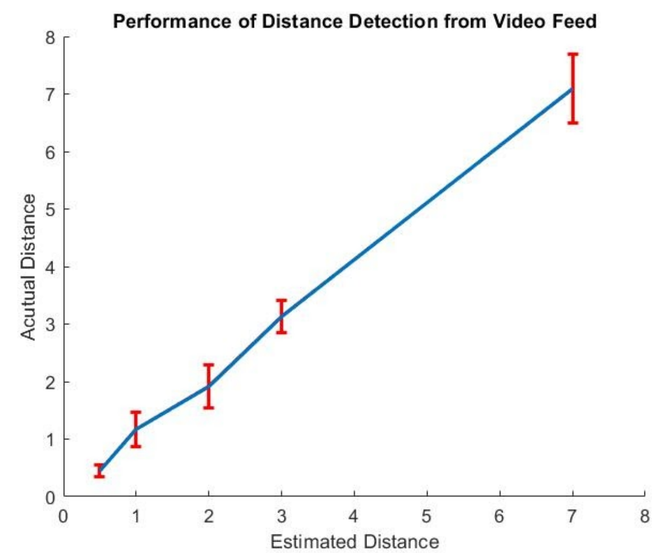

Figure 3: Distance detection and accuracy graph

50 measurements were taken each at 0.5, 1, 2, 3 and 7 meters away. The value on the y-axis is how far the computer believed the person was at these points, while the error bars show 2 standard deviations of its estimate. The maximum error occurs at 1 meter, when the computer believes the user is 1.17 ± 0.13m away, when the user was in fact 1m away.

<u>Frequency which a user can be detected in a video feed:</u> Additionally, it is important that the robot should be able to detect people in its field of view on a regular basis. This means that the robot should be able to detect a human in the video feed with frequency. A test was performed to measure how frequently the robot could detect a human standing behind it at certain distances. This is shown below.

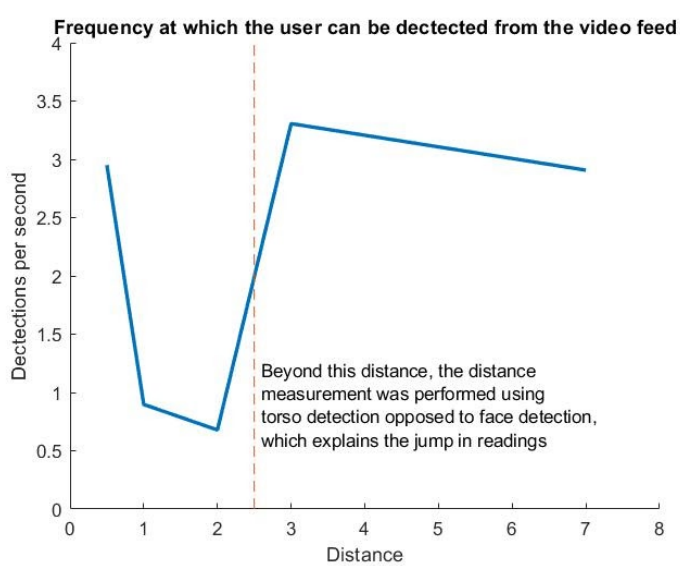

Figure 4: User detection vs distance performance graph

Figure 4 shows how many identifications per second the computer was able to make when the user was standing at 0.5, 1, 2, 3 and 7 meters away. If the user is closer, identifications are higher. The exception is when the computer switches to using upper body identification at 3m, which increases detections per second.

The robot can reliably detect a human in its frame from a distance of 7m away. It is likely that the user would remain within this distance.

Ability to frequently detect the user in an image, while minimizing false positives: This ability is used to detect the user in a crowded museum, in case other people should walk by the user. Thus it is important that there be very few false positive readings, although false negatives are of lesser importance. To test this a facial image set was downloaded, and a trained algorithm was run on the 400 images randomly selected from the data. The user was not present in any of these photos. In these 400 images, the computer thought the user was present 10 times, meaning a false negative rate of 2.5%.

Another set of 400 images of the user was fed to the computer. In these, the computer detected the user 278 times, or a 69.5% detection rate.

Of the three tests performed, this test is likely to be the result that is the least promising result. While the 2.5% false negative rate is low, it still means that if the 40 people pass close to the user, while also walking along the line direction, the robot could start to follow them. This, however, can be counteracted by waiting for multiple readings of detection. Additionally, after a few seconds, the robot should cease recognising the other person as the user and correct itself. In the unlikely case where the other person looks very similar to the user and continues walking down the line in the direction of the robot, this behaviour would have to be fixed by a verbal command from the user.

8. Summary and Conclusion (author: Momin Mehmood)

Our project came about from a basic idea: we wanted to make museums - a hub of knowledge - more accessible and enjoyable for the general public. Our research showed a continuous decline in museum visitors over the past decade. This is where our robot - Touri - came to be. The robot would provide an overarching view of the different museum displays, making the visit more fun and memorable for the visitors.

We laid out the goals and requirements for the project in our proposal. Now, having a look at the progress we have made, considering the circumstances, I would say that we have met the majority of our goals and requirements. The only thing that is currently still underway is bringing everything together for the final demonstration. The reason for the delay is due to unforeseen circumstances (mainly the virus), due to which we were unable to meet in person. However, the work is currently underway and we are aiming to have everything working as well by the time we have to demonstrate our project. As can be seen from our testing, all of our requirements have passed the tests we had laid out in our project design.

Over the course of the project, we were happy to see that our design idea was proven time and time again. Initially, when building the robot, it was great to see that we had a test code which could verify whether the sensors worked or not. Had we built everything from scratch, verifying successful communication with the sensors would have taken a lot longer than it did. Furthermore, one of our motors broke while testing. This led to a delay in the completion of some of our modules. However, we were able to get a new replacement motor and managed to get the robot back on track. The quick replacement occurred as we had bought the kit from a reputable company which was quick to respond to our enquiry. This was the main point which verified our design idea.

Overall, all of us have enjoyed the experience of working on the project. We have learned many new skills - both technical and non-technical. There were hiccups along the way, but we did our best to work around them and still try to meet the requirements. From the feedback we received from our target audience, it was found that they would be more likely to visit museums if they had Touri there to give a tour. This validated our initial hypothesis and design idea, leading us to believe that the project is a success.

However, work is not finished yet. Touri, with its current functionality, can be used as a proof of concept. In the future, Touri could have better navigation functionality. Rather than following a line, it could navigate based on immediate sensor input. Alternatively, we could use a SLAM algorithm to allow for better navigation and localisation. We would also like to improve Touri's speech functionality. Rather than having basic speech input functionality, we would like to implement a NLP functionality where it is able to extract the meaning from user input and give appropriate answers. With these new features, we believe that Touri would be an even more attractive feature for a museum.

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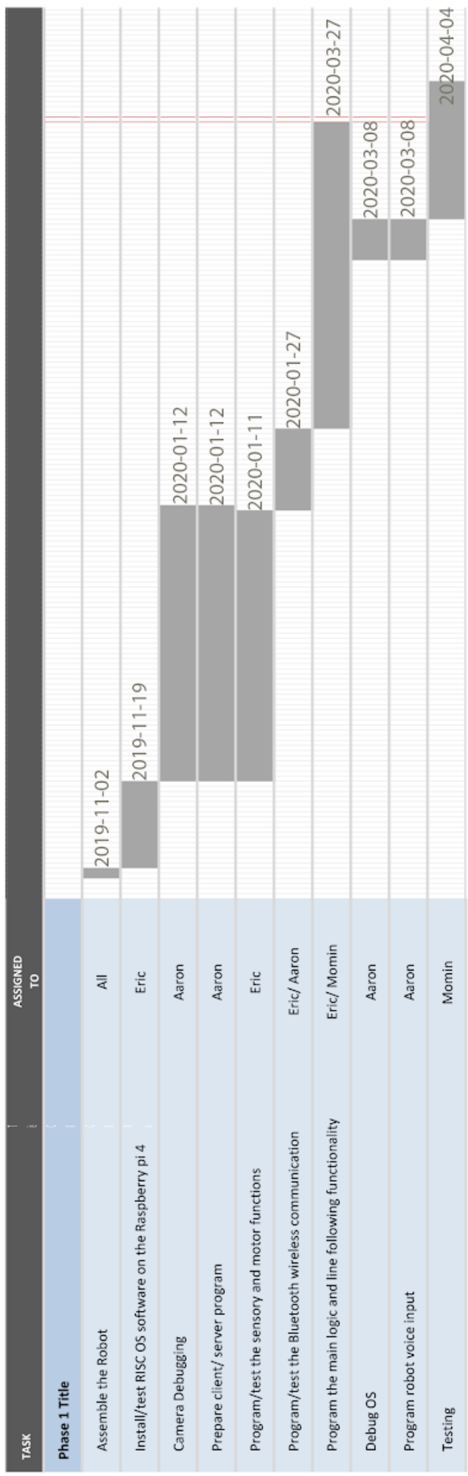
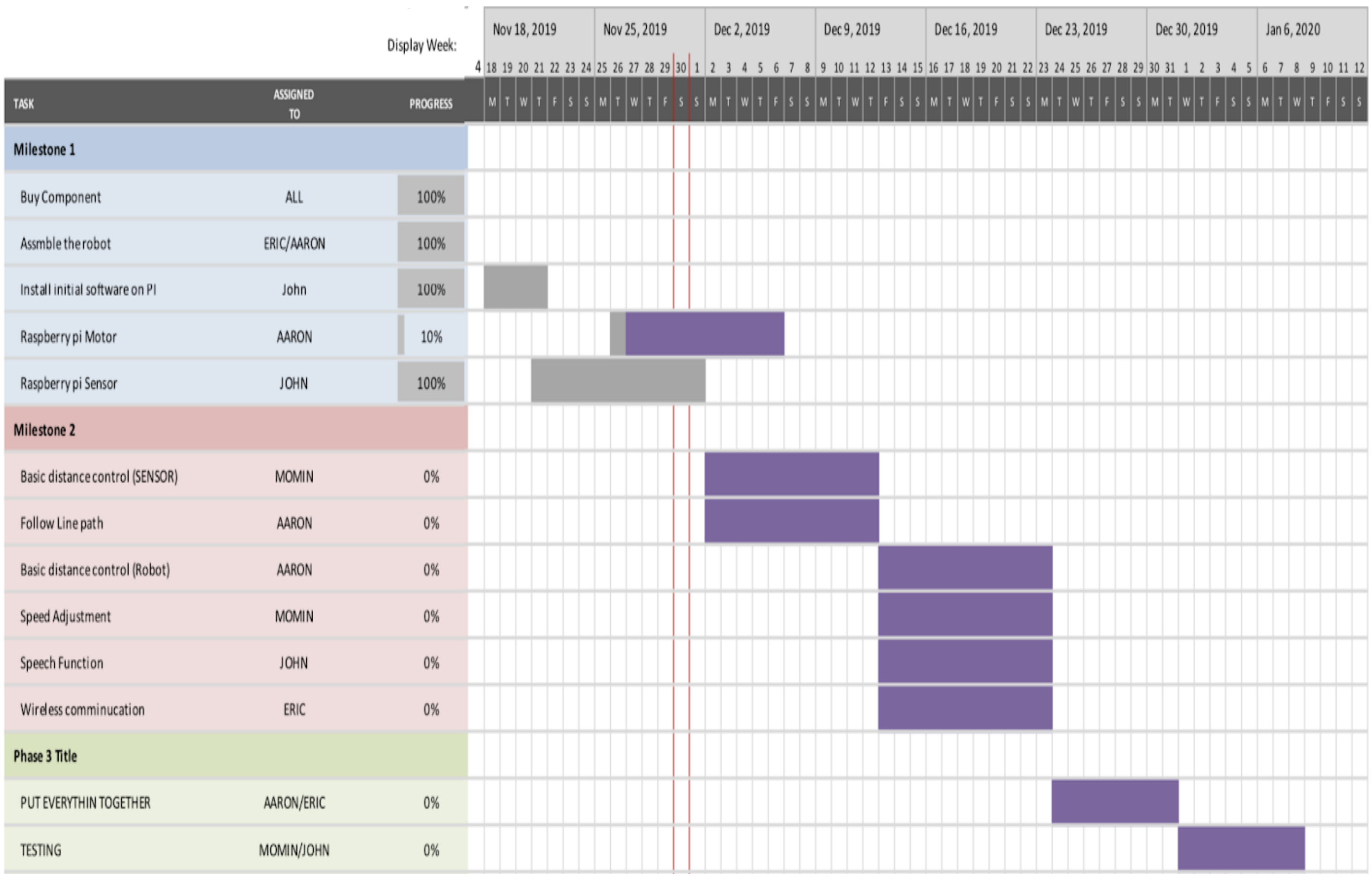
10. Appendix

Appendix A: Gantt Chart History #VERIFY




Display Week:
4
Nov 18, 2019
Nov 25, 2019
Dec 2, 2019
Dec 9, 2019
Dec 16, 2019
Dec 23, 2019
Dec 30, 2019
Jan 6, 2020
TASK
ASSIGNED TO
PROGRESS
Milestone 1
Buy Component
ALL
100%
Assmble the robot
ERIC/AARON
100%
Install initial software on PI
John
100%
Raspberry pi Motor
AARON
10%
Raspberry pi Sensor
JOHN
100%
Milestone 2
Basic distance control (SENSOR)
MOMIN
0%
Follow Line path
AARON
0%
Basic distance control (Robot)
AARON
0%
Speed Adjustment
MOMIN
0%
Speech Function
JOHN
0%
Wireless comminucation
ERIC
0%
Phase 3 Title
PUT EVERYTHIN TOGETHER
AARON/ERIC
0%
TESTING
MOMIN/JOHN
0%

Appendix B: Financial Plan

7.2 Financial plan

	Value ($)
Funding	
Student ($100)	400
Total	**400**

	Priority	Cost per Unit ($)	Quantity	Total Cost ($)	Requires Funding
Consumable & Services					
Work Venue	1	0	1	0	n
Computer Access for Group	1	0	1	0	n
Software Package Subscription	2	60	1	60	n
Total				**60**	
Capital Equipment					
Microcontroller	1	100.57	1	100.57	n
Camera	2	23	1	23	n
UltraSonic Sensor	1	3	1	3	n
Motors and Chassis	1	60.14	1	60.14	n
Sound Recorder	1	55	1	55	n
Total				**241.71**	

[7], [8], [9]

Total Funds Available (without grant): $400

Total Required Funding: $301.71

As total funds available are greater than total required funding, it does not look like we will require grant funding. Our contingency funds are $98.31. Currently, forecasted expenses amount to 75.4% of available funds.

Appendix C: Validation and Acceptance Tests

ID	Project Requirement	Verification Method
1.0	Movement	**Test:** Check robot can follow a line for 10 cm
2.0	Input: 5V for powering the controller	**Test:** test power supply against our circuit board (raspberry pie)
3.0	Size: 50cm x 60cm x 200cm (length x width x height)	**Test:** Direct measurement
3.0	Sense surroundings	**Test:** Test we can detect the line on the ground and detect when its next to an exhibit
4.0	Decision making	**Test:** test the robot can follow the line for navigation
5.0	Ability to turn	**Test:** Direct measurement
6.0	Control of peripherals	**Test:** Check the robot can send and receive signals from its peripherals - direct measurement
7.0	Audio output	**Test:** Test the robot can output audio when needed
8.0	Ability to stop	**Test:** verify that the robot stops at the exhibits for the correct time. It must be able to stop while it is conveying information and start again once it is done
9.0	Size: 50cm x 60cm x 200cm (length x width x height)	**Test:** Direct measurement

Appendix D: Code Snippets

```
elif status_left == color_select:
    #if not status_right == color_select:
        check_true_out = 0
        backing = 0
        print('right')
        turn_status = 1
        last_turn = 1
        #led.colorWipe(0,0,255)
        servo.turnRight(angle_rate)
        move.move(speed, 'forward')
```

Shows a snippet of our line following algortihm. This snippet is for turning right when needed

```
def move(speed, direction):   # 0 < radius <= 1
        if direction == 'forward':
                motor_A(0, speed)
                motor_B(1, speed)
        elif direction == 'backward':
                motor_A(1, speed)
                motor_B(0, speed)
        elif direction == 'no':
                motorStop()
        else:
                pass
```

Code snippet from the function we will be using for motor control