ECE496 Project Proposal

Tour Guide Robot

Supervisor: Willy Wang

Administrator: Hamid Timorabadi

Team 140

Zihan (Aaron) Zhao

Jingfeng (Eric) Chen

John Courtney

Momin Mehmood

Submission Date

October 10th, 2019

1. Executive Summary

Most modern museums share a common problem: they lack effective methods to attract and maintain visitors. This document is aimed to present sufficient context for this problem through background research, as well as providing a sound solution bridging the gap between the problem and the museum's existing solution. Our team of four engineers aim to design and build a working tour guide robot that guides visitors around in a museum and present an attractive alternative for museums to present information and attract tourists.

The document also lists the robot's functional requirements, objectives, and constraints in order for the team to define its boundaries and evaluate its success. Moreover, validation and acceptance tests table are also provided, to help the team validate the robot's final design.

The document then utilizes a Work Breakdown Structure (WBS) to represent the major tasks the team must divide and accomplish in order to complete the design project. This is done using a Gantt chart in a hierarchical format to better manage individual tasks. A budget table is also provided in the financial plan to document the cost of the project.

Finally, this document gives an honest assessment to the feasibility of the entire proposal, listing skills and resources required for the project. This section also describes the major risks involved in the design process and the potential mitigation strategy towards them.

2. Table of Contents

3. Project Description

3.1 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 in 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 museum are equipped with audio guides either as 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 museum kept audio length for each exhibit under 2 minutes in order to compensate for an average person's attention span, and 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 museum's ability to attract visitors.

3.2 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 each exhibit.

3.3 Project requirements

ID	**Project Requirement**	**Description**
1.0	Movement	**Primary functional requirement:** Able to move around by following a line
2.0	Input: max 9V for powering the controller	**Subfunction:** The controller must be able to work with a low voltage battery (9V). The robot is mobile and will be powered by its own battery. This should be no bigger than a 9V battery as anything larger will require more powerful motors
3.0	Size: 60cm x 200cm (width x height) – average width of a door	**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
4.0	Minimize weight	**Objective:** the lower the better. Weight will be traded off against other characteristics.
5.0	Sense surroundings	**Requirement:** Robot must be able to detect its surroundings, mainly pick up the line to follow from the ground and detect when it's near an exhibit

5.1	Sense line on the ground	
5.2	Find the exhibits	
6.0	Decision Making	**Requirement:** Control software must be able to make decisions based on the inputs received. Mainly ability to follow the line and conveying information about the display i.e. the correct information is conveyed for the exhibits
7.0	Speed variation based on the person following	**Requirement:** must be able to change the speed based on the person following the robot
8.0	Ability to turn	**Requirement:** Robot must be able to turn around corners
9.0	Control of peripherals	**Requirement:** Control software must be able to control peripherals attached like motors and servos
10.0	Audio output	**Requirement:** Robot must be able to output audio containing information about the exhibits
11.0	Ability to Stop	**Requirement:** Robot must be able to stop next to exhibits for appropriate amount of time. Mainly until it is done conveying information about the exhibits
12.0	Object detection	**Objective:** We are assuming that the robot will be able to follow the line and not have any obstacles in its path. It would be good to implement basic obstacle detection so that the robot could prevent a collision in case there is an obstacle in its path

13.0	Manufactured cost under $400	**Constraint:** The budget of the team is $400. This can be increased slightly but we need to be under the $400 mark ideally

3.4 Validation and acceptance tests

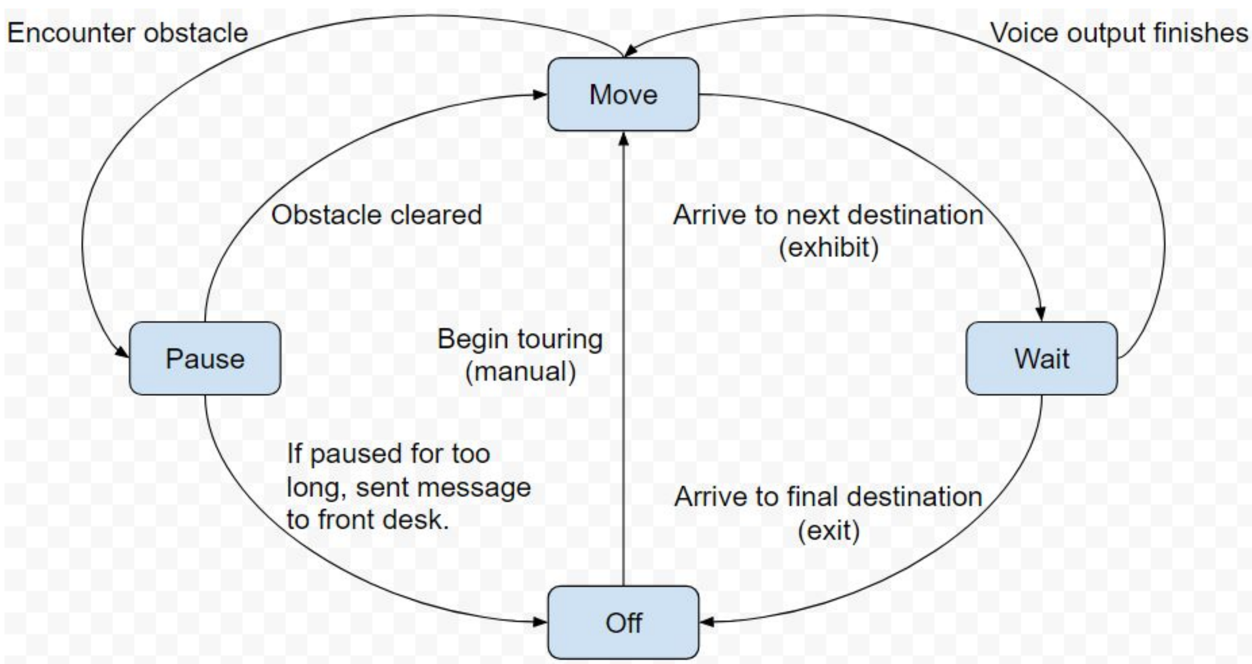
ID	Project Requirement	Verification Method
1.0	Movement	**Test:** Check robot can follow a line for 10 cm
2.0	Input: 5V for powering the controller	**Test:** test power supply against our circuit board (raspberry pie)
3.0	Size: 50cm x 50cm x 150cm (length x width x height)	**Test:** Direct measurement
5.0	Sense surroundings	**Test:** Test we can detect the line on the ground and detect when its next to an exhibit
6.0	Decision making	**Test:** test the robot can follow the line for navigation
7.0	Speed variation based on the person following	**Test:** Test the robot changes speed based on the person following it - Direct measurement
8.0	Ability to turn	**Test:** Direct measurement
9.0	Control of peripherals	**Test:** Check the robot can send and receive signals from its peripherals - direct measurement
10.0	Audio output	**Test:** Test the robot can output audio when needed
11.0	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
13.0	Cost restraint	**Calculation:** Calculation done which will verify whether we are going over-budget

4. Possible solutions and design alternatives

4.1.1 Lego robot with onboard DE1-Soc FPGA control

Since two of the team members have assembly programming experience with FPGA, and also had done similar projects in the past using DE1-Soc board, the Lego robot with onboard DE1-Soc control idea was very attractive to the team initially.

The robot will be built out of Lego blocks, with Lego sensors and motors. All inputs and outputs will be connected to a DE1-Soc board (already owned) on the robot, along with a power supply. A control program in the form of a finite state machine will calculate input data and determine the actions of the robot:



This logic will be relatively easy to implement, and because it is in assembly language, the robot will be very reliable once sensors are tested and adjusted. However, any high-level functionality (such as bluetooth, and visual processing) will be difficult to integrate with assembly.

4.1.2 Adeept rover with onboard Raspberry pi control

This robot will be assembled out of a Adeept rover kit which comes with ultrasonic sensors, line tracking sensors, cameras, motors, and a Raspberry pi motor shield. The onboard Raspberry pi will run a control program in Python which calculates the sensor input and determines the subsequent actions of the rover (similar to the control logic of the Lego robot above). It however won't be in a finite state machine form since Raspberry pi has a much more powerful cpu, all input and output will be processed simultaneously.

4.2 Evaluation:

(**Green** is better)

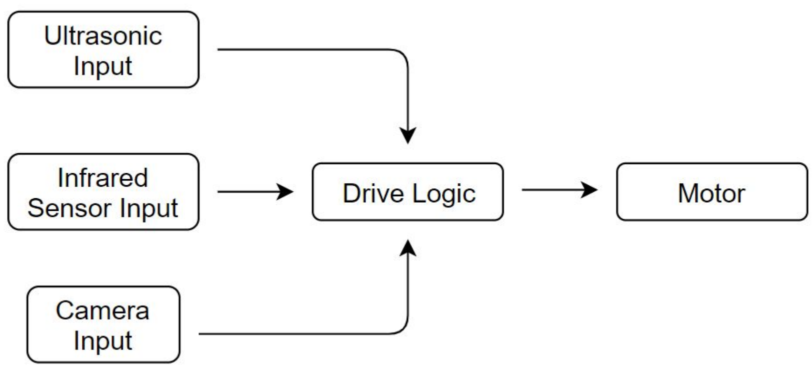
	FPGA Lego robot	Adeept rover	Reason
Control platform	DE1-Soc	**Raspberry pi 4**	Much more powerful processor
Programing language	Assembly	**Python**	High level language is much easier to parallel program and debug, hence efficiency.
Robot body	**Lego block**	Pre-built plastic chassis	The customizable nature of Lego bricks makes it easier to modify.
Sensors	Buy individually from Lego Mindstorm website.	**Comes with the rover package**	Better compatibility.
Price	**~$200 [10]**	~$270 [11][12]	The Adeept rover is more expensive, although not by much.
Third party	No, because	**Huge open source**	The popularity of

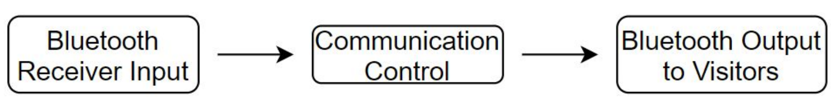
functionality	assembly	**libraries online**	Raspberry pi is undeniable.

Due to Raspberry pi being a much more well-known and widely used platform, there are large amounts of third party libraries we can potentially implement (such as voice recognition, object avoidance etc.). A commercially built kit also ensures compatibility of the majority of our components, which would save huge overhead when working with sensory inputs. Python is also much more friendly to parallel programming compared to Assembly. All of these reasons lead us to choose the Adeept rover as our final choice.

5. Technical Design

5.1 System-level overview





5.2 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 pose questions. The transmitter then can transmit the robots answers back to the user.

Camera Input
Input: The camera will examine the area behind the robot. There is also the possibility of using the swivel motor to enable it to look in front and to the sides of the robot.
Output: 3280x2464 static images, or 1080p30 or 720p60 video.
Function: The camera will look back to the users to ensure that they are following the robot. If the users fall too far behind, the robot will stop or may even reverse, and if they get too close the robot will speed up.

Ultrasonic Sensors
Input: The sensor will examine the area in front of the robot, about 1m ahead, to detect the presence of any obstacle in its path. It can be made to send 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 eventually 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 will follow will be made to be a different colour to the rest of the floor. This will enable the robot to follow along the line with the use of the IR

sensors, detecting when it was left the line by the change of colour from the sensors. We plan to use a PID controller for this to give smooth following of the line.

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, and to respond to any questions that the users may pose via the Bluetooth input. The ability to answer these simple questions will be run on the Raspberry Pi.

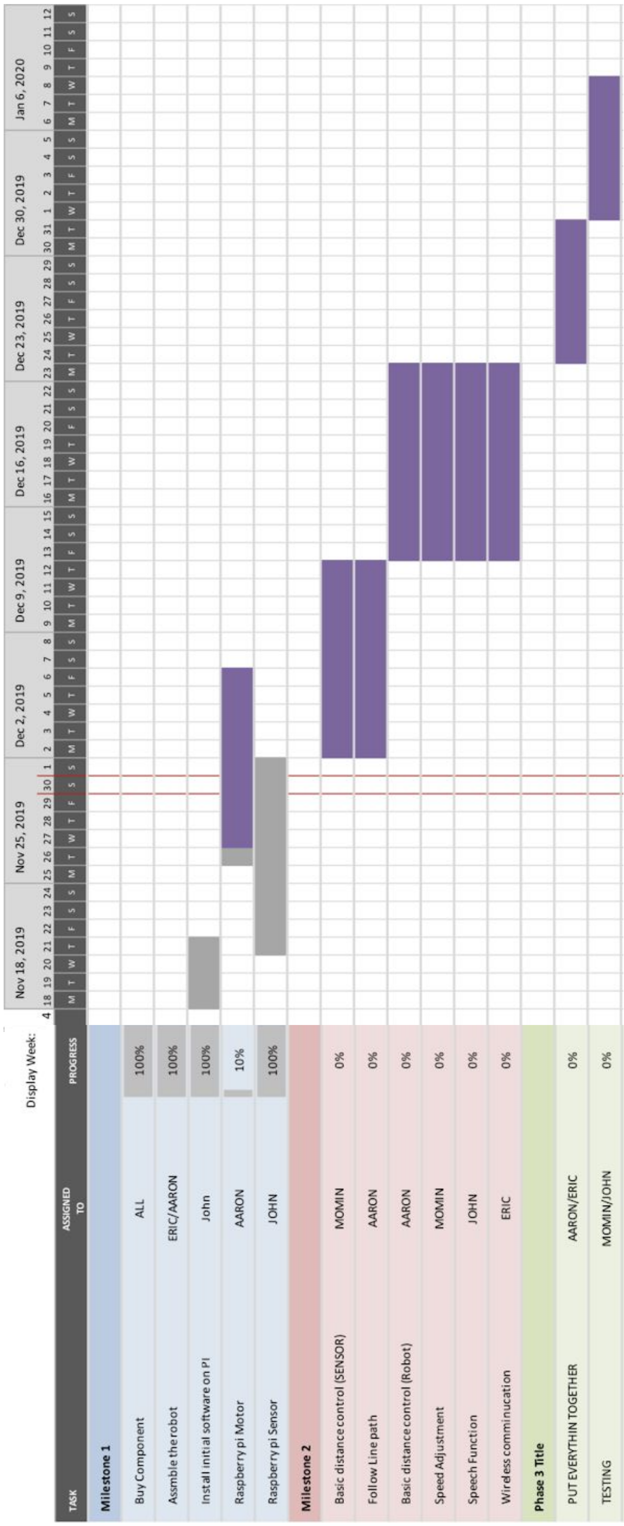
Motor
Input: 7.4V power input. Control from control module
Output: The speed and direction of the robot
Function: To move the car reliably and accurately as described by the drive logic module.

6. Assessment of proposed design

	Adeept rover with pi4
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 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 pre designed structure so it is hard to modify the place of the sensors
Trade-offs	Buy the kit directly instead of build robot from scratch saves time while costing a bit more money
Reasons	Our team decided to use Adeept rover instead of Lego because of its customizability, huge online community and more advanced processing power. We believe that having little flexibility in the design is a viable trade-off for the benefits Adeept kit provides

7. Work Plan

7.1 Work breakdown structure and Gantt chart



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.

7.3 Feasibility Assessment

7.3.1 Skills and Resources:

1. Basic knowledge of programming in both software (C, C++, python) and hardware (Lego Mindstorm, Raspberry).
2. A workspace where we can build and test hardware components.
3. Ability to work efficiently together as a team. This should include proper delegation of work, timely completion of work and good communication within the team.

7.3.2 Equipment:.

1. A gaming laptop with a GTX1660Ti GPU or above.

7.3.3 Risks and Mitigation Strategy

One essential aspect of this project is the interaction with the user. Fundamentally, this requires good sound output. Unfortunately, high quality sound devices are often very expensive, ranging into the 100’s or even 1000’s of dollars. We have tried to make the best choices for sound production and recording for our robot on a budget. Unfortunately, it is very difficult to gauge the quality of sound devices online, and it might be the case that the quality of the devices we are currently looking into might not be sufficient.

We have come up with three solutions to try and minimise this risk. The first is to wait on buying the sound equipment, using a laptop sound recorder and speaker in the meantime to develop the voice interactions with users. Having already worked on this problem through a laptop, it will give us a better understanding of the requirements of the needed sound equipment when buying.

The second solution is to avoid buying a device online, and instead buying it physically in a shop. This may be more expensive, but will give us a better idea of the quality of the device we are buying.

The final solution is in the case that we purchase a device that we later find to be insufficient for the problem. We hope that this situation does not occur, but if it does, we might fall back on the sound recording and production capabilities of one of our mobile phones. Current mobile phones have very good sound recording and production capabilities, which could be used for our robot. One downside to this method would be the compatibility issues we would have in connecting a mobile phone with the microcontroller.

Another risk is the fact that we are working with hardware. This means that if some component is defective, we will have to replace it which causes delay in our progress. To mitigate this risk, we have ordered everything we require already. The first thing we did was test that the hardware works as it is meant to. This allows us to ensure that we have all the components needed to build our project.

8. Conclusion

We have found that more and more young people are turned off by the idea of going to museums. This is causing a problem as our new generation is not learning about our history and our heritage. Research has shown that young people find museums to be a boring place meant for older people. To combat this stereotype and encourage more interest from the younger generation, we have built a robot to give tours of museums. This will ‘modernise’ the experience and bring something for everyone.

We have done a thorough investigation of the tools we will be using and done an analysis of why one option is more preferable over another. We have come up with strategies to mitigate potential risks and believe we can deliver the project within the timeframe and the budget given.

9. References

[1] “Art Museum Attendance,” Humanities Indicators - A project of the American academy of arts & science, Aug-2019. [Online]. Available: https://www.humanitiesindicators.org/content/indicatordoc.aspx?i=102. [Accessed: 18-Sep-2019].

[2] E. N. Arinze, “The Role of the Museum in Society - Public lecture at the National Museum, Georgetown, Guyana” 17-May-1999. [Online]. Available: http://www.maltwood.uvic.ca/cam/activities/past_conferences/1999conf/batch1/CAM'99-EmmanuelArinze.GuyanaFinal.pdf. [Accessed: 18-Sep-2019].

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[4] Levi T. Novey, Troy E. Hall, Science Learning in Everyday Life, “The Effect of Audio Tours on Learning and Social Interaction: An Evaluation at Carlsbad Caverns National Park” Wiley InterScience, 24-July-2006 [Online]. Available:

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[5] J. Pratt, P. V. Radulescu, R. M. Guo, and R. A. Abrams, “It’s Alive! Animate Motion Captures Visual Attention,” Association For Psychological Science, 2010. [Online]. Available: It’s Alive! Animate Motion Captures Visual Attention. [Online]. Available: http://abrams.wustl.edu/artsci/reprints/PrattRadulescuGuoAbrams2010.pdf [Accessed: 09-Oct-2019].

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[8] “Sony ICDPX370 IC Voice Recorder, black: Amazon.ca” Sony ICDPX370 IC Voice Recorder, black: Amazon.ca. [Online]. Available: https://www.amazon.ca/Sony-ICDPX370-IC-Voice-Recorder/dp/B06XFTWCBJ/ref=sr_1_2?keywords=sound+recorder+for+laptop&qid=1570716441&s=toys&sr=1-2-catcorr. [Accessed: 07-Oct-2019].

[9] “Speaker - PCB Mount,” Robotshop.com [Online]. Available: https://www.robotshop.com/ca/en/speaker-pcb-mount.html. [Accessed: 07-Oct-2019].

[10]https://www.amazon.ca/LEGO-Boost-Creative-Toolbox-Building/dp/B06Y6JCTKH/ref=s
r_1_5?crid=3F31HZ4LFOGLZ&keywords=lego+mindstorm+robotics&qid=1574330324&sprefix=lego+mindstorm+%2Caps%2C144&sr=8-5 [Accessed: 19-Nov-2019].

[11]https://www.amazon.ca/Adeept-Recognition-Transmission-Educational-Instructions/dp/B07KM3YCYP [Accessed: 19-Nov-2019].

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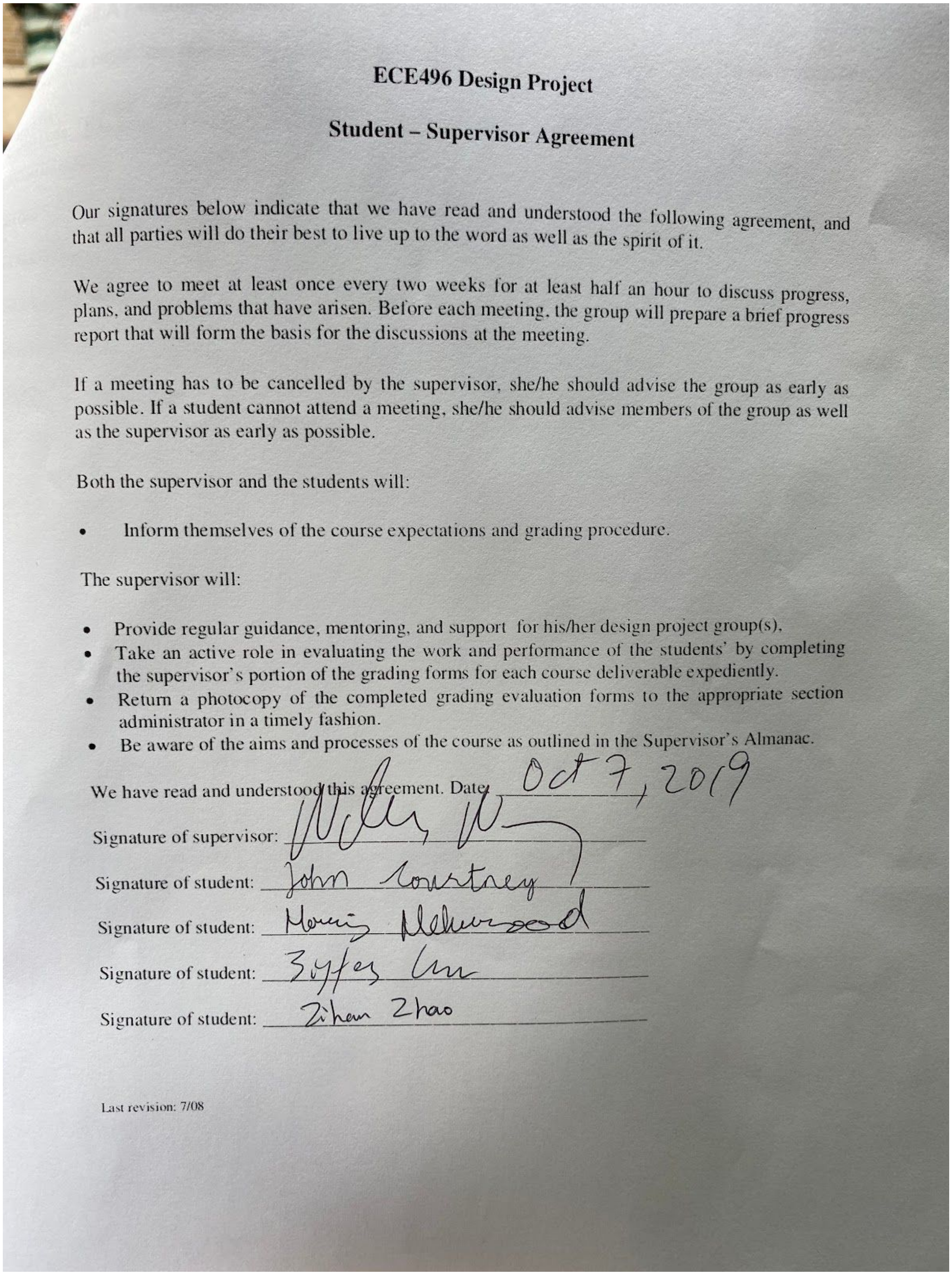
10. Appendix

10.1 Appendix A: Student-supervisor agreement form



ECE496 Design Project

Student – Supervisor Agreement

Our signatures below indicate that we have read and understood the following agreement, and that all parties will do their best to live up to the word as well as the spirit of it.

We agree to meet at least once every two weeks for at least half an hour to discuss progress, plans, and problems that have arisen. Before each meeting, the group will prepare a brief progress report that will form the basis for the discussions at the meeting.

If a meeting has to be cancelled by the supervisor, she/he should advise the group as early as possible. If a student cannot attend a meeting, she/he should advise members of the group as well as the supervisor as early as possible.

Both the supervisor and the students will:

- Inform themselves of the course expectations and grading procedure.

The supervisor will:

- Provide regular guidance, mentoring, and support for his/her design project group(s).
- Take an active role in evaluating the work and performance of the students' by completing the supervisor's portion of the grading forms for each course deliverable expediently.
- Return a photocopy of the completed grading evaluation forms to the appropriate section administrator in a timely fashion.
- Be aware of the aims and processes of the course as outlined in the Supervisor's Almanac.

We have read and understood this agreement. Date: Oct 7, 2019

Signature of supervisor: [illegible]

Signature of student: John Courtney

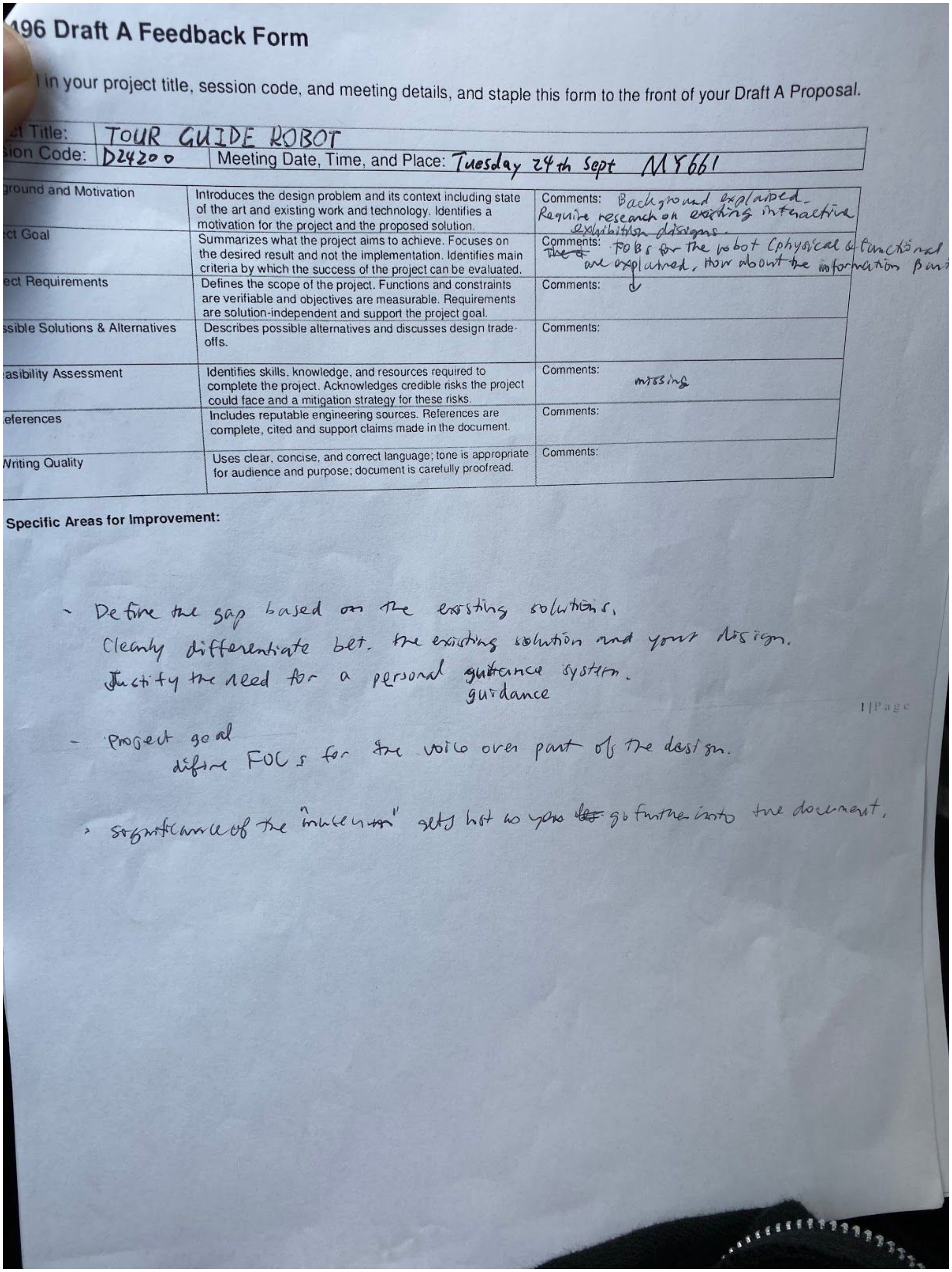
Signature of student: [illegible]

Signature of student: [illegible]

Signature of student: Zihan Zhao

Last revision: 7/08

10.2 Appendix B: Draft A feedback form (from ECP)



496 Draft A Feedback Form

…l in your project title, session code, and meeting details, and staple this form to the front of your Draft A Proposal.

…t Title:	TOUR GUIDE ROBOT	
…ion Code:	D24200	Meeting Date, Time, and Place: Tuesday 24th Sept MY661

…ground and Motivation	Introduces the design problem and its context including state of the art and existing work and technology. Identifies a motivation for the project and the proposed solution.	Comments: Background explained. Require research on existing interactive exhibition designs.
…ct Goal	Summarizes what the project aims to achieve. Focuses on the desired result and not the implementation. Identifies main criteria by which the success of the project can be evaluated.	Comments: ~~The~~ FOBs for the robot (physical & functional) are explained, how about the information part
…ect Requirements	Defines the scope of the project. Functions and constraints are verifiable and objectives are measurable. Requirements are solution-independent and support the project goal.	Comments:
…ssible Solutions & Alternatives	Describes possible alternatives and discusses design trade-offs.	Comments:
…asibility Assessment	Identifies skills, knowledge, and resources required to complete the project. Acknowledges credible risks the project could face and a mitigation strategy for these risks.	Comments: missing
…eferences	Includes reputable engineering sources. References are complete, cited and support claims made in the document.	Comments:
…Writing Quality	Uses clear, concise, and correct language; tone is appropriate for audience and purpose; document is carefully proofread.	Comments:

Specific Areas for Improvement:

- Define the gap based on the existing solutions.
  Clearly differentiate bet. the existing solution and your design.
  Justify the need for a personal ~~guidance~~ system.
  guidance
- Project goal
  define FOCs for the voice over part of the design.
- significance of the "innovation" gets lost as you ~~~~ go further into the document.

1 | Page

10.3 Appendix C: Report Attribution Table

Project Proposal Document Attribution Table

This table should be filled out to accurately reflect who contributed to each section of the report and what they contributed. Insert rows as needed. The original completed and signed form must be included in the hardcopies of the final Project Proposal draft.

Section	Student Initials			
	1.Aaron	2.Eric	3.John	4.Momin
1. Executive Summary		RS, RD, MR		
2. Table of Contents	MR	MR	MR	MR
3. Project Description		RS, RD, MR		RS, RD, MR, ET
4. Possible Solution and Design Alternatives		RS, RD, MR		ET
5. Technical Design			RS, RD, MR	ET
6. Assessment of Proposed Design	RS, RD, MR			ET
7. Work Plan	RS, RD, MR		RS, RD, MR	ET
8. Conclusion				RS, RD, MR
All	FP, CM	FP, CM	FP, CM	FP, CM

Abbreviation Codes:
Fill in abbreviations for roles for each of the required content elements. You do not have to fill in every cell. The "**All**" row refers to the complete document and should indicate who was responsible for the final compilation and final read through of the completed document.

RS – responsible for research of information
RD – wrote the first draft
MR – responsible for major revision
ET – edited for grammar, spelling, and expression
OR – other
"All" row abbreviations:
    FP – final read through of complete document for flow and consistency
    CM – responsible for compiling the elements into the complete document
    OR - other
If you put OR (other) in a cell please put it in as OR1, OR2, etc. Explain briefly below the role referred to:
OR1: enter brief description here
OR2: enter brief description here

Signatures
By signing below, you verify that you have read the attribution table and agree that it accurately reflects your contribution to this document.

Name	Zihan (Aaron) Zhao	**Signature**	Zihan Zhao	**Date:**	12/3/2019
Name	Jingfeng (Eric) Chen	**Signature**	Jingfeng Chen	**Date:**	12/3/2019
Name	John Courtney	**Signature**	John Courtney	**Date:**	12/3/2019
Name	Momin Mehmood	**Signature**	Momin Mehmood	**Date:**	12/3/2019