10/11/2017

Convoy Project

Proposal Report

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Submitted to: Emre Ozkan

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Project Initialization Date: 11/10/2017

Project Duration: 200 Days

Expected Completion: MAY 2018

Project Cost: 150 USD

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Executive Summary

In the project “Platoon (convoy)”, we are required to design a self-contained robot. The robot is a part of the convoy. The convoy is led by a leader and the robots in the convoy should move in a single file according to the movement of the leader. Upon command, to any robot between the last robot of the convoy and the leader of the convoy, the respective robot should leave the convoy and join as the last member of the convoy. The robot should indicate the convoy when it leaves and when it is in the last position. The restriction to be noted is that there is no direct communication involved between the robots in the convoy.

The self-contained robot should be able to identify the following robot, which could either be the leader or another robot in the convoy. The robot should also be able to process the leaving signal and act accordingly to the signal. When robot leaves the convoy, it should follow a leaving mechanism and it should be able to identify the last robot and get behind it. If a robot in front of the self-contained robot leaves, the self-contained robot should be able to process the leaving signal of the leaving robot and follow the next robot or the leader.

For the robot to follow the next one, it must determine its relative position from the one in front of it. Visible markers will be attached behind all of the robots and a sensor in front of the robot will use these markings to determine the relative position. A feedback control algorithm will be used to provide inputs to the motors, so they can follow the robot in front. The leaving signal will be identified by filtering the receiver’s output. Distance sensors will be used to prevent any collisions. To communicate to the other robots about their status flags, LEDs and speakers can be used.

Given the combined experience and skills of the OJO members, the company possesses sufficient knowledge and understanding to accomplish this project triumphantly. The OJO group has appointed its members to the project according to their specialties and skills. The specialists on computer area (Anar Abdullayev, Bulut Ulukapi and Umut Can Serçe) are responsible for the programming related problems, electronic part and image processing in the project. The control system specialist (Syed Saad Saif) is responsible for the control system (interfacing with microcontroller), feedback analysis of the project. The power system specialist (Abdullah Aslam) is responsible for the power related aspects such as power consumption and efficiency in the project.

The total duration of the project is estimated as 200 days from the current date (11^{th} November 2017). Apart from the end product, the company plans to provide with necessary documents such as circuit design schematic, power consumption analysis report and a user manual, which will provide more understanding to the user to make the best use of the product. The total cost of the end product is estimated to be around $141 which, indeed, is within the range of the provided budget which is $200.

Introduction

OJO is a group of highly motivated and excited engineers which are ready to take on different challenges and complexities in electrical world. In accordance with the moto of the company, the company chose the project "Platoon (convoy)", the criteria for choosing this project can be found in the appendix A1. The project requires an end product, which is a self-contained robot. The self-contained robot is a part of the convoy and it should move according to the movement of convoy's leader. When the robot receives a signal to leave the convoy and be the last one in the convoy, it should indicate it is leaving and get to the last position and again indicate that it is the last robot.

This document is a proposal report in which the problem related to the project is defined and solutions are proposed. Also, the organizational structure of the company and the division of the project tasks according to the specialties of members is provided. Furthermore, the project timeline, cost-budget analysis and information about expected deliverables are also included.

Problem statement

A self-contained robot will be designed which follows similar robots in a single line. It will also be capable of leaving the line upon the external leave command and re-join the convoy as a last one. Robots will not communicate each-others directly, they will broadcast the information which indicates that they are leaving, or they are the last one in the line. Any signal will be provided by two different actuators and be sensed by according sensors. The vehicles will keep appropriate following distance and move in the reasonable speed. When followed robot will turn on the leaving signals and start to leave the line, the following one will stop following it and look for and follow the vehicle in front of the leaving robot. All robots will have distance sensor to prevent crash. Vehicles will be able to follow leading robot when it is not following a straight line and changes its direction, also turning to the sides will not cause a problem if this process happens in the same time as a leaving process. Vehicles will be able to change their speeds as well. A vehicle should follow only the robot right in front of it and that's why it will be able to differentiate that vehicle and the one in front of it.

Specifications and requirements

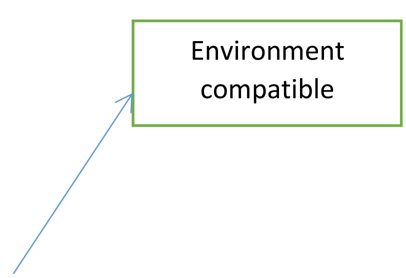
- The robots should be able to follow the leading robot with a certain accuracy. The exact requirements will be determined in the standards committee.
- On being given a signal the robot should leave the convoy and rejoin it at the last position.
- The robot should be able to determine if it is the last robot in the convoy.
- The robot should indicate to the other robot if it is the last robot or not using two independent methods.
- The robot should indicate to other robots when it is leaving the convoy using two independent method.

Objectives

The robot should be: -

- Power efficient.
- Cost Effective.
- Environment compatible (e.g. it should work in all lightening conditions).
- Light and easily maneuverable.
- Robust (minimal number of moving components).
- Have good response time (should rejoin the convoy in 10 seconds).
- Easy to use for the customer

The objective tree is shown below by figure 1.



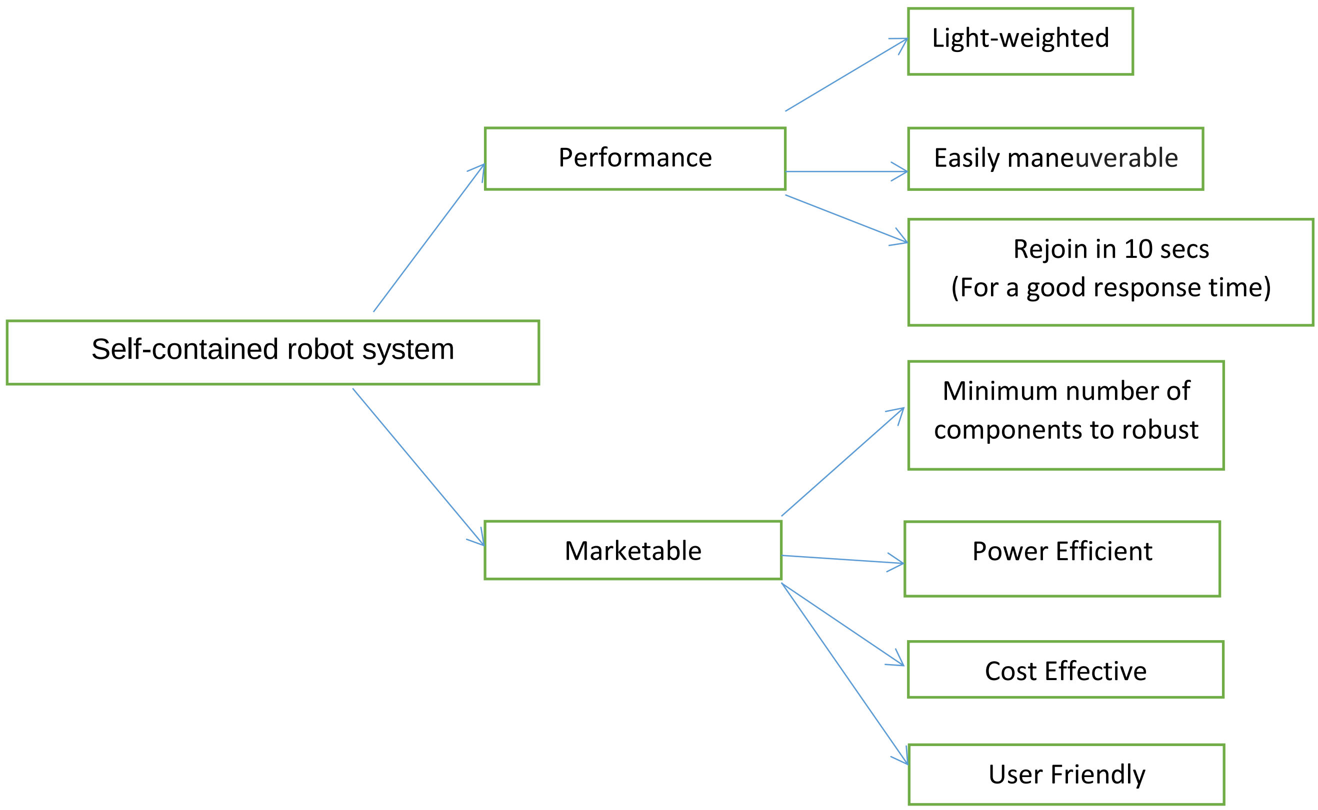


Figure 1: Objective Tree

Societal impact

Autonomous cars are getting popular nowadays due to their obvious advantages. This project will act like an initial step toward this industry. Preventing crashes, moving in reasonable speed and being able to get out of the traffic and re-joining are the similar tasks that autonomous cars should be capable of. On the other hand, experiences gained from this project can be used also in truck convoy projects similar to the one "Tesla" company is working on. Only the leading truck should have a driver and the ones follows it. This approach will decrease the drag force because vehicles will move in a line and have smaller following distance. Less drag force means less fuel consumption, less driver means less payment. Overall autonomous trucks will decrease transportation fees and contribute to the economy.

Human Resources

For the selection of the company members, individuals were chosen so that can they complement each other's skills. The company wanted to implement the project in a hi-tech manner therefore three members from the computers option were selected. These members have a deep underlying knowledge of computer systems and this will allow the company to utilize microcontrollers to its full potential. The computer members can design basic hardware circuitry to offload the CPU as much as possible. The project requires accurate and precise control of actuators, motors and/or servos for physical movement of the designed devices. OJO has a control option member who will help the company greatly with any problems that might be encounter during implementation and design. Power management is a crucial consideration in any project. OJO’s projects will be no exception to this. Given that devices the company plans to build will be mobile and will not have any direct connection with mains power. Keeping sure that the power system can provide plentiful power is essential.

Brief explanation about the team members and organizational chart (shown by figure 2) of the project are listed below:

Abdullah Aslam:

Option: Power Systems

Experience with UAV control and familiarity with programming languages.

Anar Abdullayev:

Option: Computers

Experience with microcontrollers(Arduino, PIC and ARM based ones), motion   sensors and communication interface.

Bulut Ulukapi:

Option: Computers

Experience with data structures, microcontrollers and various programming languages

Syed Saad Saif:

Option: Control

Experience in microcontroller based discrete time feedback controllers and has deep understanding of C programming language as well as object oriented programming

Umut Can Serçe:

Option: Computers

Experience with various programming languages and HDLs.

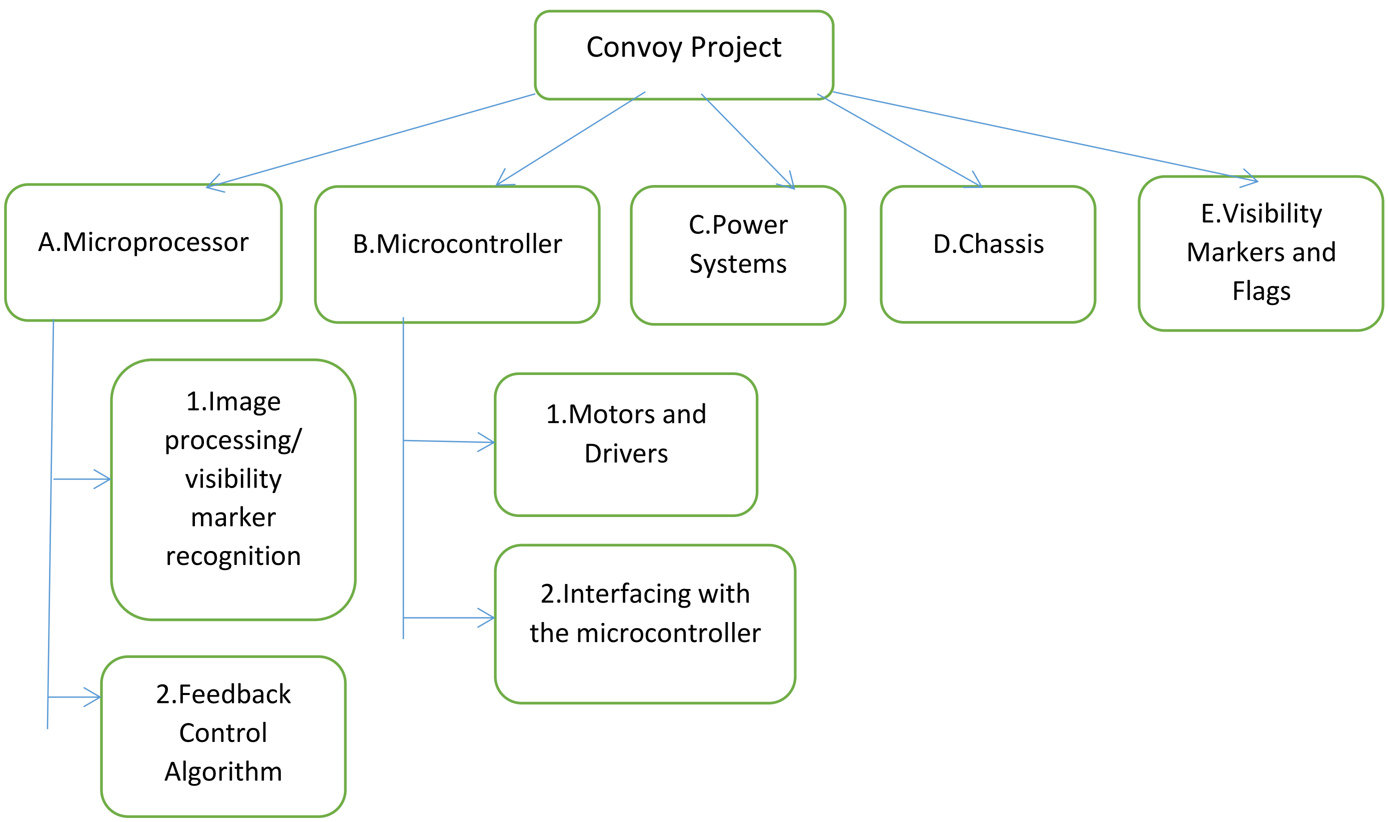


Figure 2: Organizational Chart for subsystems of the project

Projects subsystems are assigned to the project members according to their final year options and experience. The assignment is as follows:

Abdullah Aslam: Subsystems C and D

Anar Abdullayev: Subsystems B1 and B2

Bulut Ulukapi: Subsystems A1 and B1

Syed Saad Saif: Subsystems A2 and B2

Umut Can Serçe: Subsystems A1 and E

Standards

Besides from the standards are given in the description of the project, there are also other requirement to be met because this project requires collaboration with other groups. In order to prevent some problems such as blocking other robots or colliding with each other, setting the standards is highly important and directly affects the solution.

After the meetings held between the group members, it is decided that there were three main categories related with standards. These standards are about sensor types, physical properties of the robot and its path and the types, shapes or color properties of the markers.

Sensor Types

There will be certain standards about the markers and the signals that are going to be used in the projects in order to be in collaboration with other groups. For this reason, sensors should be arranged in a way that they should detect the predefined flags.

Physical Standards

A minimum and a maximum value should be set for the speed of the robots. This will make them avoid collision or losing the track. If a robot exceeds a certain speed, its follower may not be able to reach it and lose its track. In addition to the speed on the queue, the speed of leaving or joining the convoy should also have standards because of similar reasons. Furthermore, an interval for the distance between the robots needs to be determined because of reasons that were mentioned previously.

There should also be certain standards about the path that the robots are going to follow. As indicated in the description, the path might be non-linear. Therefore, a minimum radius for the curvature, which is going to be followed by the robots, needs to be set in order to prevent sharp turns. This will also help on detection of the convoy and rejoining it.

For some solutions which the group members came up with, the body of the robot itself blocks the signal which is coming from the front robot and does not let robots behind it to receive the signal.

In other words, this provides the leaving signal of a robot to reach its follower only. This blocking mechanism can be applied if all the groups agree upon certain standards about width and height.

Marker Standards

There are three different flag types in the task. The first one is the visibility marker. This will keep the follower robot on the right path. The second one is the leaving signal. This signal needs to be received by the robot that is following the one that is leaving the convoy. This will tell the follower to increase its speed and fill the gap that is left behind. The third one is the signal that will be transmitted by the last robot. This signal make the leaving robot understand where to rejoin. Since there are lots of signals and markers, there should be certain standards in order to prevent signals interfering with each other.

Some sensors which are planned to be used, requires visual inputs. For this reason, there needs to be standards for the size, the shape, the colors and the location of the marker. If these standards are not set, the indirect communication between the robots may not be proper as it is planned.

Solution Approach

The solution begins with identifying the problem clearly. All the issues will be delineated beforehand so that all the involved parties have a pellucid understanding about every single detail. OJO believes that spending an appropriate amount of time on outlining the issues produces great results and alleviates many of the issues projects experience during their development lifecycle. After this stage of the project the most efficient solution should be devised. In this conceptual design phase of the project OJO always appreciates innovative solutions to the problems. A simple solution to a complicated problem is always the goal. OJO strives to achieve this and there are many actions that the company has taken to move toward this goal. By creating a positive and creative environment at OJO, our members come up with groundbreaking ideas and can present their ideas to others without any hesitation. After the solution has been proposed and a basic conceptual design agreed upon, the overall design shall be broken down into subsystems so that work can be done in parallel. All the dependencies must be identified so that the timeline can be prepared. All the tasks that are independent of each other can be done by different team members while the tasks on which other tasks depends on can be identified and assigned critical status. Human resources can be assigned accordingly, and any some time buffers can be assigned around critical tasks so that and unfortunate circumstances do not affect the timeline.

For our project, the platoon, we have identified all the tasks that need to be accomplished and created a timeline as can be seen in figure 3. The detailed explanation of each of the task is provided in appendix A3.

Milestones

To understand the progress of the project, milestones can be defined. The milestones not only serve to evaluate progress but also serve as motivation of team members to strive to achieve them.

Milestones

The milestones for our project are as follows.

1) Complete the detailed conceptual design of the overall project.
2) Components evaluated and shortlisted.
3) Submodules implemented. All submodules perform their respective tasks.
4) All the submodules comply with the evaluation rubric.

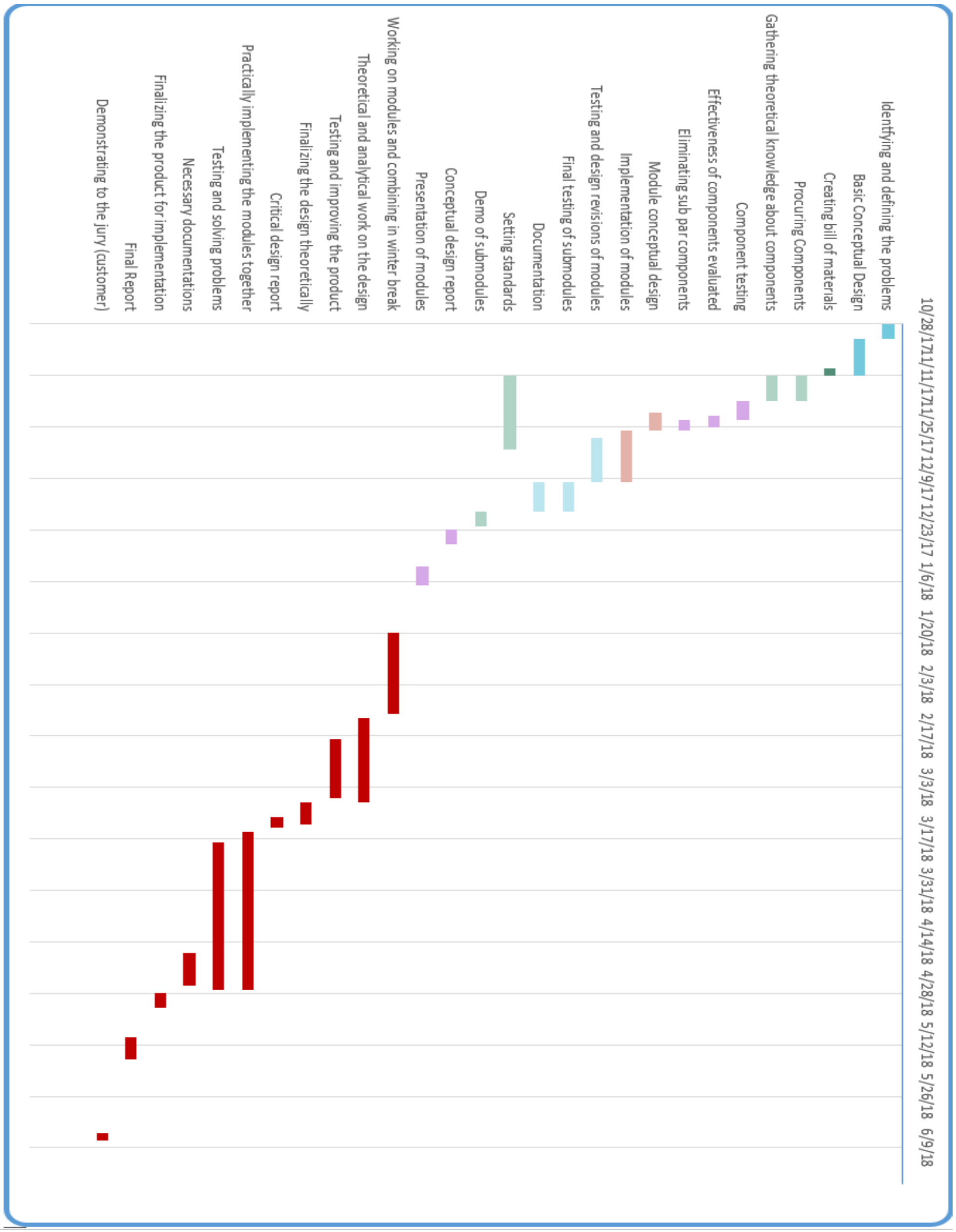


Figure 3. Project Gantt chart

Meeting the deadline always makes the customer happy. To keep up with the deadlines defining a timeline is important. The defined timeline should be possible to keep up to, so the time required for each step is thought of individually and then combined instead of trying to manipulate the timeline to fit the deadline.

To accurately evaluate the project through the various stages of its development life cycle, be an evaluation rubric must be designed so that the health of the project can be measured in an objective manner. A preliminary rubric as shown in figure 4, has been created for this purpose. This rubric shall also grow with the project as more information is gathered from experience.

	Identity Markers and Flags	**Power Supply**	**Motors and Drivers**
10 Excelllent	Identify and response all markers/flags under all types of lighting	Sufficient power and low cost	Great mobility
8 Good	Identify all markers/flags in dark and in laboratory lighting	Sufficient power but high cost	Adequate torque for completion the task
6 Satisfactory	Identify all markers/flags in laboratory lighting and sunlight	Nearly sufficient power and low cost	Oscillatory power delivery
4 Average	Identify all markers/flags in laboratory lighting	Nearly sufficient but high cost	Irregular power delivery
2 Unacceptable	Identify some markers/flags in laboratory lighting	Not sufficient but low cost	Sometimes moves sometime do not
0 Failure	Sometimes identify markers/flags and sometimes do not	Not sufficient and high cost	No movement

Figure 4. Requirement Evaluation Rubric

Deliverables

1) User manual. This contains all the information that will be useful for using the product. This includes basic tutorials and some tips to ensure long life of the device.
2) Technical Specification sheet. This includes all the technical information about our product such as dimensions and power consumption.
3) A fully functional robot that meets the design requirements.
4) Customer support. Even after the completion of the project the customer will be provided with any reasonable support that they might require for the use of the product.

Expected outcomes

The product is a great source to practice on autonomous vehicles model. Since the project is open source, one can easily make changes on the robot to use it in different conditions.

Tentative cost-budget analysis

Our company aims to provide a cost-effective end product. A product that can complete the objectives exactly and efficiently and is also within the required budget range which is $200. Our company plans to use microcontrollers, sensors, geared motors and other necessary equipment for the project. The tentative total cost mentioned, is the minimum cost for the project and is also subject to change, if a different component is used.

The total cost of the project is estimated to be 141 USD. The detailed breakdown of the component prices can be found in appendix A2.

Conclusion

In this proposal report, the problem about the project such as identification and following robot in the convoy, leaving and rejoining the convoy and indication of states (leaving or last robot) are discussed. Also the solution to the problem is devised such as using markers and sensors for identification of robot and for checking relative distance between two robots. The subsystems of this project can be a useful contribution to society. If a cost effective collision avoidance system can be designed, it can be introduced in lower end cars. This can save numerous lives.

For the project, all members of the group will be actively involved in both design and prototyping processes. As a final product, OJO Company will offer a self-contained convoy robot which satisfies the customer requirements in a smart, user-friendly and effective way.

Appendices

Appendix A1

A comparison table is prepared for choosing the right project that fits our criteria. The table can be seen on Table A.1.

	Electronics (0.25)	Image Processing (0.20)	Fun (0.35)	Robotics (0.20)	Total
Convoy	10*0.25	8*0.20	10*0.35	6*0.20	8.8
See-saw	8*0.25	2*0.20	6*0.35	8*0.20	6.1
Basketball	6*0.25	10*0.20	6*0.35	10*0.20	7.6
Maze	6*0.25	10*0.20	2*0.35	6*0.20	5.4
Obstacle	4*0.25	8*0.20	2*0.35	10*0.20	5.3

Table A.1. Comparison Table for Projects

Point	Meaning
10	Excellent
8	Good
6	Satisfactory
4	Average
2	Unacceptable
0	Failure

Table A.2. Points and their meanings for Table A.1

Appendix A2

The main equipment that will be used along with their prices are as follows:

1. 12-40V 10A Motor Driver Board (25 TL)
2. 12V 16mm 1500Rpm Gearbox Motor (31 TL *2 =62 TL)
3. Raspberry Pi Adjustable Focusing Camera Module (70 TL)
4. Arduino UNO R3 Clone - With USB Cable - (USB Chip CH340) (16 TL)
5. Raspberry Pi 3 (138 TL)
6. Ultrasonic Distance Sensor (5 TL)
7. Speaker (6 TL)
8. Sound sensor (11 TL)
9. Battery (60 TL)
10. Chassis (60 TL)
11. Other stuff like resistors, transistors, LEDs, capacitors, wires etc. (80 TL)

Appendix A3
Tasks

- Conceptual Design of overall system

  Solution to the complete system is proposed at a higher level. This is a critical task and needs to precede all the task. All the human resource shall be assigned to this task.

- Creating bill of material

  A complete list of materials to be bought is created and updated according to the project budget.

- Procuring components

  Components orders. Other theoretical things can be done during this phase.

- Gather theoretical knowledge about components

  While waiting for the components the datasheets can be read and a testing environment can be created.

- Component testing

  Once the components arrive testing of the components can begin immediately since the testing environment was already created. It is important to establish that all components are working as expected before they are combined and used together. Trouble shooting will be easier if all components are tested.

- Effectiveness of components evaluated

  Data is collected for the components to evaluate their performance.

- Eliminating subpar components

  For a task the best possible solution is selected. Any component that does not satisfy the requirements is eliminated. This phase can begin soon after the testing of the components.

- Conceptual design of modules

  During the same time where the components are being evaluated, the conceptual design of the modules of the project can begin so that they can be implemented.

- Creating microprocessor Image processing algorithm

  If image processing is used to follow the robot, an algorithm must be written and tested. This task can be done in parallel with all the other module implementation.

- Implement motors and drivers

  Motors and their drivers must be implemented and interface with the microcontroller.

- Interfacing microprocessor and microcontroller

  The main microprocessor will run all the computationally intensive algorithms while the microcontroller will be used to drive the moving components of the robot. There must be a protocol for both devices to communicate seamlessly.

- Implement Power System

  For this mobile device a battery powered power delivery system must be created. Since each part of the project relies on this module higher priority can be given to this task during the initial phase of implementation of submodules.

- Create a robot chassis

  This task is independent of all the other tasks during the implementation phase.

- Testing and design revision of submodules

  According to the evaluation rubric the performance of the subsystems can be evaluated, and the design can be improved to score better on the rubric. All of the modules will be improved as required and resigned and revised.

- Final Testing of modules

This task will be initiated after the implementation of all the modules. At this stage after the performance of all the modules is up to the desired specifications the module will be put through a stress test to elaborate any problems that were not observed during the initial testing. Any major design flaws can then be dealt with at this stage.

- Documentation

  Formal documentation for our products will be created at this stage.

- Setting standards

  As the product is supposed to work with devices created by other companies, standard specifications with precise tolerances must be clearly defined for product compatibility. This task starts from the very start of the project up to the implementations of the modules.

- Demo and presentation of modules

The ready modules shall be demonstrated. This will satisfy the client about the progress and increase confidence in the company's abilities.

- Theoretical and analytical work on the design

  Work must be done on the details of overall project. Theoretical work must be done.

- Finalizing the theoretical design

  The design has to be thoroughly evaluate, and potential issued should be identified, the theoretical design can then be iteratively designed and finalized.

- Practical implementation of the project

  After finalizing the design, the modules can be combined according to the theoretical design.

- Testing and improving the product

After the components are combined the overall design can be improved and tested for problems.

- Demonstration of the complete product

  Finally, the final version of the project can be demonstrated to the customer their reactions can be recorded. This can be useful for evaluating the overall project.

A Gantt chart that included all these tasks in provided in figure 3. The chart includes all the dates for each of the tasks.