



MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF
ELECTRICAL AND ELECTRONICS ENGINEERING

EE493 ENGINEERING DESIGN I

Car Chasing Robot Proposal Report

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ADDRESS

Project Start: 4/10/2018

Project End: 26/5/2019

Project Budget: \$450

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1 notes

1.1 specific requirements and objectives of the project

1.2 approach to the solution of the problem

1.3 outline of the requirements for any standards that the product would need to comply with,

1.4 deliverables and expected outcomes of the project,

1.5 tentative cost-budget analysis,

2 Executive Summary

3 Introduction

Driving is a common event that many people experience in their daily life. As time passes, human reflexes started to become insufficient for driving compared to fast pace of daily life in modern world. Together with the developments in the technology, new solutions are proposed to assist the driver such as lane tracking and emergency breaking systems. The ultimate version of such solutions are considered to be fully autonomous self-driving cars.

Self-driving vehicles are presented to the society as a solution that can facilitate people's life in many ways. Fast operation of the electronics system allows faster response than humans can. A fast and reliable operation of self-driving action can prevent many accidents and increase the safety of the roads in heavy traffics since the system is immune to human defects such as distraction and panic. As a result, autonomous vehicles can open doors to a safer and more conventional future.

DUAYENLER Ltd. Şti. is launched with the aim of innovating automation technologies. In that context, a device that can detect the road and other vehicles on them will be built. It autonomously track the lane and stay on the road while trying to as fast as possible.

This report includes;

- organization of the company by explaining of the qualifications of the members.
- Requirements for physically realizing the intended vehicle
- Possible solutions in system and subsystem levels by explaining their operations
- Timeline and cost of the project
- Expected deliverables from the project

4 The Team

DUAYENLER Ltd. Şti. (DUAYENLER) was founded in September 2018 by five electrical and electronics engineering students from Middle East Technical University. The company structure is shown in *Figure 1*. The team is composed of variously skilled visionary members. The leader of the team is Halil Temurtaş, a control engineer. Being the team leader, Halil manages the organization of the members as well as drawing an outline for the future calendar. He is experienced in using microcontrollers, device testing and project scheduling. He will be working on the development of the subsystems computation, motion and driving in parallel with his experiences. Sarper Sertel, electronics engineer, has a wide understanding of microelectronics circuits and their design as well as analog lumped circuits. He is also interested in mechanical systems. He will be working on structure, driving and sensing subsystems. Enes Taştan, hardware design engineer, is interested in several topics such as electronics and mechanics. He can also design PCBs. He will be participating to development of driving, motion and structure subsystems. Erdem Tuna, embedded systems engineer, is experienced in use of microcontrollers with sensors and likes programming. He will be contributing in computation and sensing subsystems. Lastly İlker Sağlık, software engineer, is also interested in programming and microcontrollers. He will be working on sensing and driving subsystems.

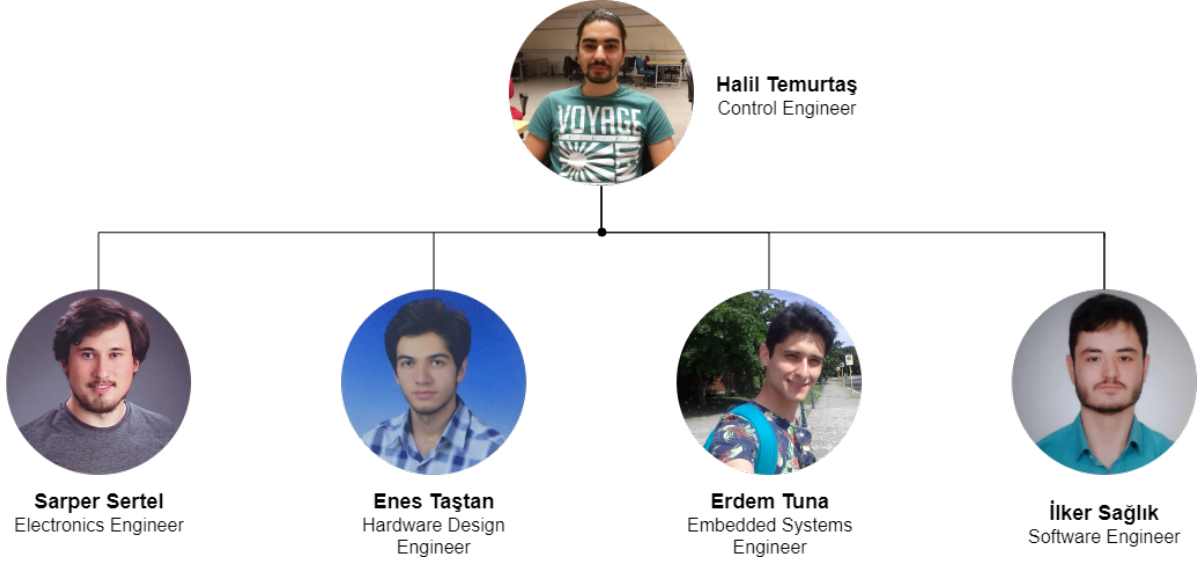


Figure 1: Company Tree of DUAYENLER.

5 Requirement Analysis

5.1 Pairwise Comparisons for Project Selection

Pairwise comparisons technique can be use to assess objectives of the project. Then, these objectives can be very useful as the desired project is selected out of all potential project. For this purpose, tables at *Figures 2,4* is created by consensus of all project-pairs. The weighted objectives are then used to construct the weighted objective tree at *Figure 3*.

	Having Fun	Competition	Original Solution	Budget	Mechanical Challenges	Complexity	Marketability	Total	Weighted Objectives
Having Fun	0	0,5	0,75	0,8	0,9	0,6	0,8	4,35	0,2
Competition	0,5	0	0,7	0,7	0,5	0,75	0,8	3,95	0,2
Original Solution	0,25	0,3	0	0,6	0,7	0,55	0,8	3,2	0,16
Budget	0,2	0,3	0,4	0	0,2	0,3	0,8	2,2	0,1
Mechanical Challenges	0,1	0,3	0,3	0,8	0	0,3	0,8	2,6	0,12
Complexity	0,4	0,25	0,45	0,7	0,7	0	0,8	3,3	0,16
Marketability	0,2	0,2	0,2	0,2	0,2	0,2	0	1,2	0,06
								20,8	1

Figure 2: Pairwise Comparison Charts

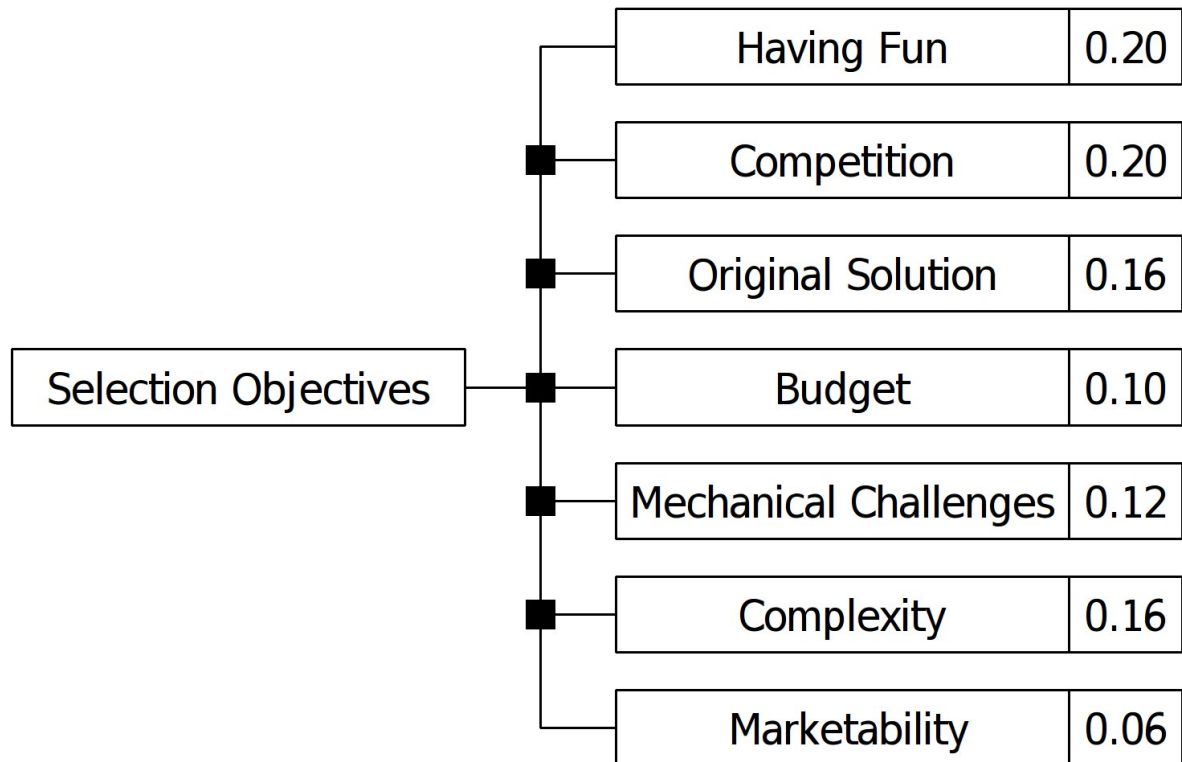


Figure 3: Weighted Objective Tree

5.2 Project Selection

	Having Fun (0.2)	Competition (0.2)	Original Solution (0.16)	Budget (0.1)	Mechanical Challenges (0.12)	Complexity (0.16)	Marketability (0.06)	Total
Balloon Catching	8 1,6	10 2	6 0,96	4 0,4	0 0	2 0,32	6 0,36	5,28
Air Hockey	8 1,6	8 1,6	4 0,64	8 0,8	2 0,24	6 0,96	8 0,48	5,84
Chasing Cars	10 2	8 1,6	8 1,28	6 0,6	6 0,72	8 1,28	10 0,6	7,48
Mapping Robot	4 0,8	4 0,8	8 1,28	2 0,2	8 0,96	0 0	6 0,36	4,04

Figure 4: Project Evaluation Chart

5.3 Pairwise Comparisons for Solution Selection

	Fast Operation	Robust	Weight Balance	Total	Weighted Objectives	Weighted Objectives
Fast Operation	0	0,55	0,4	0,95	0,32	0,144
Robust	0,45	0	0,5	0,95	0,32	0,144
Weight Balance	0,6	0,5	0	1,1	0,36	0,162
				3	1	0,45

Figure 5: Pairwise Comparison Charts for Sub-Objectives

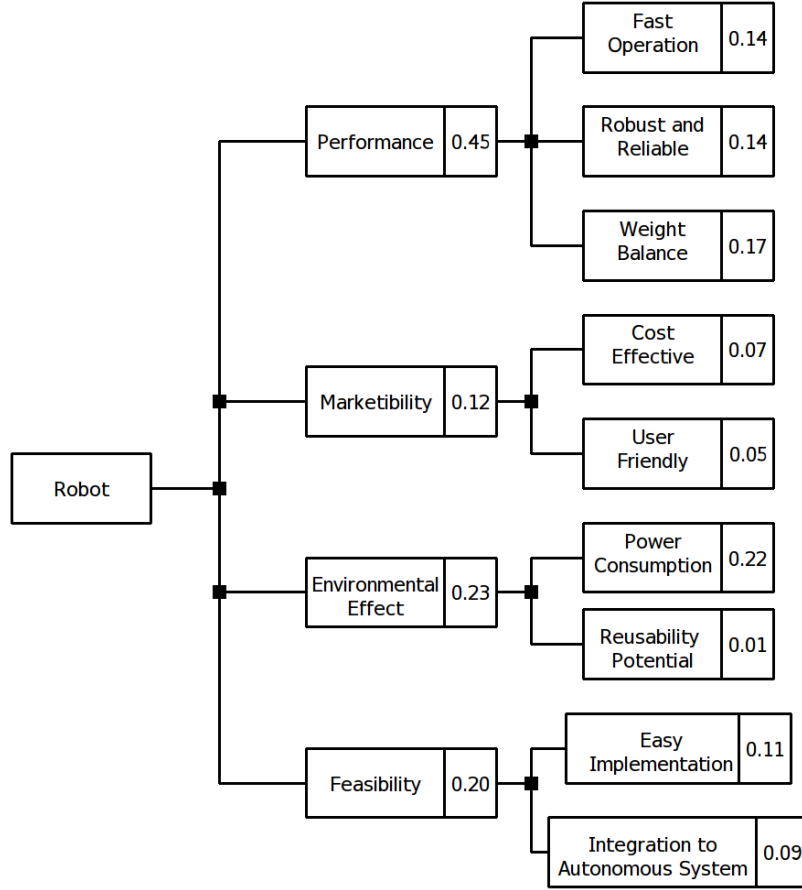


Figure 6: Weighted Objective Tree

5.4 Systems & Subsystems of Chosen Project

After choosing the project, the systems and subsystems of the project was determined by the group members. While disassembling the project to its systems, it is decided that the project will be investigated under two main parts, electrical and mechanical systems. Then, the electrical unit is then divided into three parts, that is, sensing, computation and driving subsystems. The mechanical system is also divided into two parts, that is, motion and structure subsystems. The system diagram of the chosen project can be seen at *Figure 7*. System tree of the project can be seen at *Figure 8*.



Figure 7: System Diagram for the Chosen Project

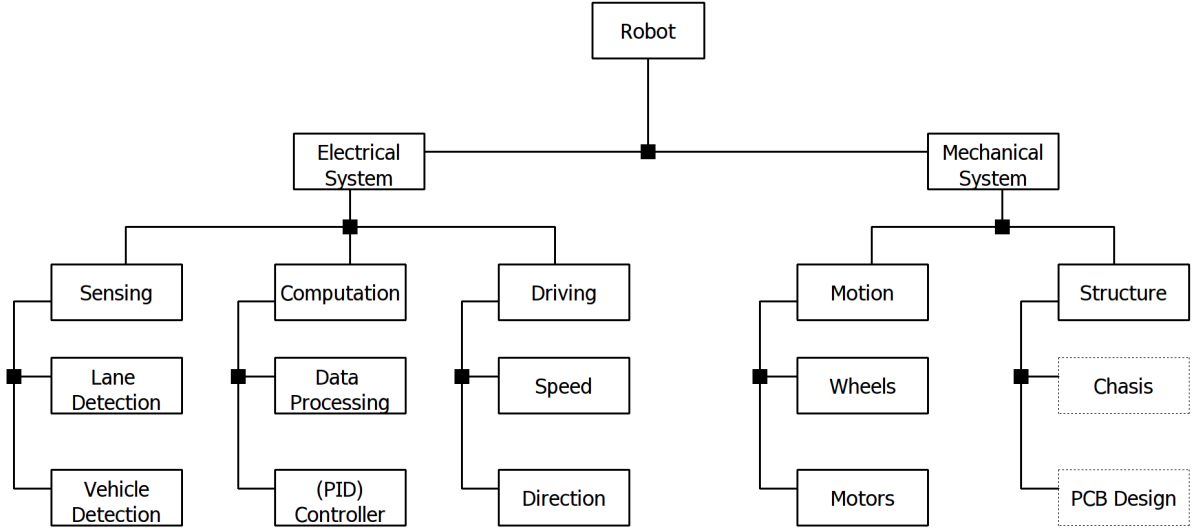


Figure 8: Systems & Subsystems of Chosen Project

5.5 Solution Alternatives for Systems & Subsystems

Following the division of the project into its sub-blocks, solution alternatives are created for these subsystems and units.

- It is decided that the line detection unit will use sensor array to detect the borders of the path. The array might be consist of color sensors of infrared sensors. A camera might also be used to back the sensor array for more reliable operation.
- Vehicle detection unit might utilize ultrasonic, laser sensor or camera in order to identify the opponent.
- Arduino, Raspberry Pi or Asus Thinkerboard can be utilized as a microcontroller by the data processing unit.
- The controller unit can adopt P,PI or PID controller.
- Motor unit might consist of brushed or brushless motors.
- The project might consist of three wheels (two of them driven by DC motors and one of the is ball caster), palette system(4+ Wheels) or four wheels (two of them driven by DC motors and two front wheels directed by servo motors)
- Speed unit might use only the output of the lane detection unit or the output data can be combined with gyroscope that can detect disturbances for speed reduction.

- Direction unit might benefit from the advantages of differential drive or can combine these benefits with the servo motors that can determine the position of the front wheels.

The solution alternatives for units in compact form can be seen at *Table 1*.

Unit	Possible Solution 1	Possible Solution 2	Possible Solution 3
Lane Detection	Color Sensor Array	Infrared Sensor Array	Infrared Sensor Array with Camera Support
Vehicle Detection	Laser sensor	Ultrasonic sensor	Camera to back of the vehicle
Data Processing	Raspberry Pi	Arduino	Asus Thinkerboard
Controller	P	PI	PID
Motors	Brushed Motors	Brushless Motors	
Wheels	3 Wheels	4 Wheels with Palette	4 Wheels with Servo Motors
Speed	Lane Detection Output	Gyroscope (Balance Detection)	
Direction	Differential Drive	Servo Motors for front wheels	

Table 1: Possible Solution Alternatives for the Units of the Project

5.6 Design Options

After determining the possible solution alternatives, it is decided that these alternatives might be combined in a design packages that can be compared with each other by using the selection objectives determined earlier. In order the combine the solution ideas, three different design option according to its complexities is considered to ease the decision process. Named as design 1, most basic design is formed considering the simpler alternatives, design 2 is formed considering the more reasonable alternatives that would satisfy the expectations and the design 3 is formed considering the best possible outcome. The design alternatives in a comparable form can be seen at *Table 2*.

Unit	Design Option 1	Design Option 2	Design Option 3
Lane Detection	Color Sensor Array	Infrared Sensor Array	Infrared Sensor Array with Camera Support
Vehicle Detection	Camera to back of the vehicle	Ultrasonic sensor	Laser sensor
Data Processing	Arduino	Arduino	Raspberry Pi+ Arduino
Controller	P	PI	PID
Motors	Brushed Motors	Brushed Motors	Brushed Motors
Wheels	3 Wheels	4 Wheels with Palette	4 Wheels with Servo Motors
Speed	Lane Detection Output	Lane Detection Output	Lane Detection Output + Gyroscope
Direction	Differential Drive	Differential Drive	Servo Motors for front wheels

Table 2: Design Options for the Chosen Project

	Fast Operation (0.14)	Robust and Reliable Operation (0.14)	Weight Balance (0.17)	Cost Effective (0.07)	User Friendly (0.05)	Power Consumption (0.22)	Reusability Potential (0.01)	Easy Implementation (0.11)	Integration to Autonomous Systems (0.09)	Total
Design 1	8 1,12	4 0,56	4 0,68	10 0,7	6 0,3	8 1,76	6 0,06	8 0,88	4 0,36	58 6,42
Design 2	10 1,4	6 0,84	6 1,02	8 0,56	8 0,4	6 1,32	6 0,06	6 0,66	6 0,54	62 6,8
Design 3	8 1,12	10 1,4	8 1,36	6 0,42	8 0,4	4 0,88	6 0,06	4 0,44	10 0,9	64 6,98

Figure 9: Pairwise Comparison Charts for Solution Selection

5.7 Pairwise Comparisons for Design Selection

6 Standards Section

Standards will be the base block that project will be built on. There are several issues should be standardized before development phase.

One of the issue is the handshake protocol. An option is use Bluetooth modules. When the distance of the two vehicle is less than 5 cm, both vehicle may send handshake signal to kill motion. Benefit of this standard is that each vehicle need to have only

one distance sensor on the back or the on the front. Another approach is having no communication protocol, but instead of this, each vehicle has 2 distance sensors which are placed back and front to detected each other, after detection, both vehicle stops individually. However, this method has a requirement that is detection platform. The reason obtain precise measurement. Otherwise, measurement may have error.

Elevation of path is another problem that should be discussed. Some of the Infrared sensors operate between 0 to 15 mm, so after discussion, it can be decided whether or not use of the sensor.

Breaking criteria should be agreed upon by teams who choose this project because deceleration difference could cause collusion between the vehicle. Therefore, it should be standardized.

7 Solution Procedure

7.1 Sensing Subsystem

This unit has two main tasks which are observing lane and another vehicle on the path.

7.1.1 Lane Detection Unit

To solve this problem, path and environmental differences, such as color difference, contrast difference could be used. In addition to these, image processing could be an alternative to detection of lane and vehicle. Infrared sensors can be used to solve lane detection problem. Line follower vehicle logic can be implemented to this problem, by placing two sensor arrays to both sides of the path to align vehicle at the center. Sensors gives current proportional to reflection of the surfaces. By using such outputs, an algorithm to be developed to track the path on the center.

Another approach to detect the lane is using camera and image processing. Camera can be placed at an angle to see the path, and by using the raspberry pi, the path can be followed. To clarify, captured frames can be analyzed by the raspberry pi, and utilizing open source image processing libraries. An example analysis can be summaries as follows: Firstly, distortions in the image can be beautified, and then color thresholding can be applied to sharply detect the elevated path. Optionally, to increase accuracy of the detection, Canny edge detection can be used. Lastly, center line can be calculated by using processed image.

Color sensor can be utilized as an alternative for image processing. Color sensors basically senses the color with the help of 8x8 array of photodiodes and generates a

PWM signal whose duty cycle is proportional to the light intensity. For example, if the elliptic path is red, we can give the s2 and s3 pins of the sensor low voltage, we activate the red photodiodes and we can use the Arduino command to measure the on or off time of the generated PWM signal. When the robots are out of the path, the output duty cycle of the sensor will significantly decrease, so this information can be used to keep the robots in the path. However, using color sensors can be problematic, because of their size and slow operation.

7.1.2 Vehicle Detection Unit

The detection of the opponent can be implemented using distance sensors. In order to stop the robot when it catches the opponent, or it is caught, a sensor must be placed at the front and the back. The most common distance sensors are ultrasonic, infrared and laser sensors.

Ultrasonic sensors have acceptable range. They send a sound wave and take back the echo, then give a PWM voltage related to the distance. However, using ultrasonic sensors can cause problems if the opponent also uses ultrasonic sensors; because of the interference. Besides, when measurement is angled, measuring is failing.

Infrared sensors can be another approach to this problem, they may provide better accuracy. Moreover, Laser distance measurement can be applied to solve this problem. They have the best accuracy, but their price is the highest among the rest.

7.2 Computation Subsystem

Functionality of computation subsystem will be presented in this section.

7.2.1 Data Processing Unit

This unit is the main algorithm application level. Data from sensor will be aggregated in this unit and will be pre-processed. Then, processed data will be output to the controller unit. Processing will mainly be done using Arduino and Raspberry Pi (if used). Suitable algorithms will be developed to realize desired operations with the controller unit

7.2.2 Controller Unit

Mathematical models will be implemented in this unit to realize controllers such as P, PI, PID. The output of the controller unit will be sent to driving subsystem. This output will be the ultimate decision to realize a desired operation according to the data sent from sensor.

7.3 Structure Subsystem

This part contains chassis and PCB sections of the robot.

7.3.1 Chassis Unit

Main purposes of this section are protection of the critical elements of the robot and holding components together. The most important part of this section is weight distribution. The chassis is supposed to be light and strong because of the competition purposes. However, it should be balanced the robot to be able to handle with turns.

7.3.2 Printed Circuit Board Unit

The main role of this part is decreasing connection mass and increase vibration strength of the robot against disturbances. Also, this section increases rigidity of the whole system.

8 Expected Deliverables

9 Conclusion

A Gantt Chart

		T0+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	Concept Development Phase (3 Weeks)																													
2	Assessment of System Requirement Phase (3 Week)																													
3	Conceptual Design and Preliminary Design Phase (4 Weeks)																													
4	Critical Design Phase (18 Weeks)																													
5	Test & Evaluation Phase (19 Weeks)																													
6	Implementation & Finalization Phase																													
7	Project Ending (T0+28 Weeks)																													
1	Concept Development Phase																													
1.1	Activities																													
1.1.1	Literature Research and Determination and Similar Platform Specifications																													
1.1.2	Feasibility Works																													
2	Assessment of System Requirement Phase																													
2.1	Activities																													
2.1.1	Determination of Team Logo and Vision & Mission																													
2.1.2	Problem Define State for All Projects																													
2.1.3	Solve Defined Problem State for All Projects																													
2.1.4	General Component Research																													
2.2	Outcomes																													
2.2.1	Business Statement Report																													
3	Conceptual Design and Preliminary Design Phase																													
3.1	Activities																													
3.1.1	Preliminary Electrical System Design																													
3.1.1.1	Preliminary Sensing Unit Design																													
3.1.1.2	Preliminary Computational Unit Design																													
3.1.1.3	Preliminary Driving Unit Design																													
3.1.2	Preliminary Mechanical System Design																													
3.1.2.1	Preliminary Motion Unit Design																													
3.1.2.2	Preliminary Structure Design																													
3.2	Outcomes																													
3.2.1	Preliminary Report																													

		T0+	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
4	Critical Design Phase																													
4.1	First Semester																													
4.1.1	Electrical System Design																													
4.1.1.1	Sensing Unit Design																													
4.1.1.2	Computational Unit Design																													
4.1.1.3	Driving Unit Design																													
4.1.2	Mechanical System Design																													
4.1.2.1	Motion Unit Design																													
4.1.2.2	Structure Design																													
4.1.3	To be detailed																													
4.2	First Semester Outcomes																													
4.2.1	Standards Report																													
4.2.2	Module Test Demo																													
4.2.3	Conceptual Design Report																													
4.2.4	Presentations																													
4.3	Second Semester																													
4.3.1	To be detailed																													
4.4	Second Semester Outcomes																													
4.4.1	Critical Design Review Report																													
5	Test & Evaluation Phase																													
5.1	First Semester Activities																													
5.1.1	To be detailed																													
5.2	First Semester Outcomes																													
5.2.1	To be detailed																													
5.3	Second Semester Activities																													
5.3.1	To be detailed																													
5.4	Second Semester Outcomes																													
5.4.1	Critical Design Review Report																													
6	Finalization Phase																													
6.1	Activities																													
6.1.1	To be detailed																													
6.2	Outcomes																													
6.2.1	Finalized Product																													
6.2.2	Final Report																													
6.2.3	Final Demo																													
7	Project Ending																													