Middle East Technical University

Department of
Electrical and Electronics Engineering

EE493 ENGINEERING DESIGN I

Car Chasing Robot
Proposal Report

Supervisor: Assoc. Prof. Emre Özkan
ADDDRESSS

Project Start: 4/10/2018
Project End: 26/5/2019
Project Budget: $450

Company Name : Duayenler Ltd. Şti.

Members	Title	ID	Phone
Sarper Sertel	Electronics Engineer	2094449	0542 515 6039
Enes Taştan	Hardware Design Engineer	2068989	0543 683 4336
Erdem Tuna	Embedded Systems Engineer	2617419	0535 256 3320
Halil Temurtaş	Control Engineer	2094522	0531 632 2194
İlker Sağlık	Software Engineer	2094423	0541 722 9573

November 9, 2018

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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

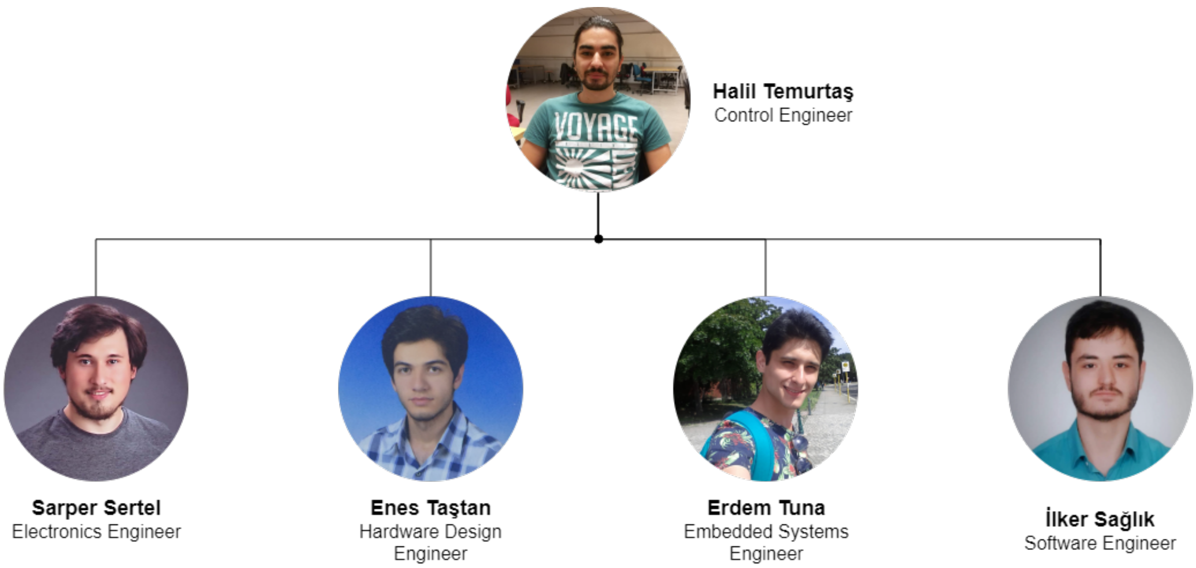


Figure 1: Company Tree of DUAYENLER.

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.

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 2,3* is created by consensus of all project-pairs. The weighted objectives are then used to construct the weighted objective tree at *Figure 4*.

	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

	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	10	6	4	0	2	6	5,28
	1,6	2	0,96	0,4	0	0,32	0,36	
Air Hockey	8	8	4	8	2	6	8	5,84
	1,6	1,6	0,64	0,8	0,24	0,96	0,48	
Chasing Cars	10	8	8	6	6	8	10	7,48
	2	1,6	1,28	0,6	0,72	1,28	0,6	
Mapping Robot	4	4	8	2	8	0	6	4,04
	0,8	0,8	1,28	0,2	0,96	0	0,36	

Figure 3: Project Evaluation Chart

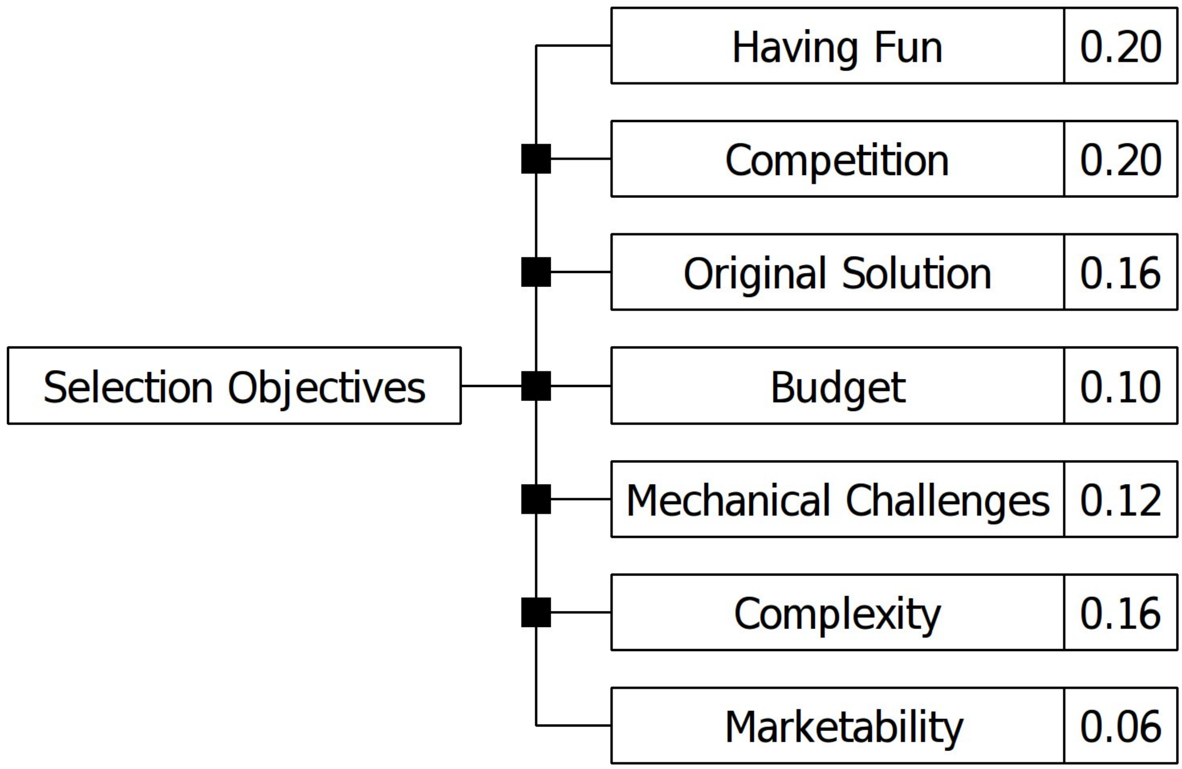


Figure 4: Weighted Objective Tree

5.2 Systems & Subsystems of Chosen Project

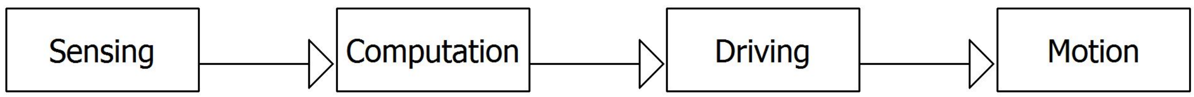


Figure 5: System Diagram for the Chosen Project

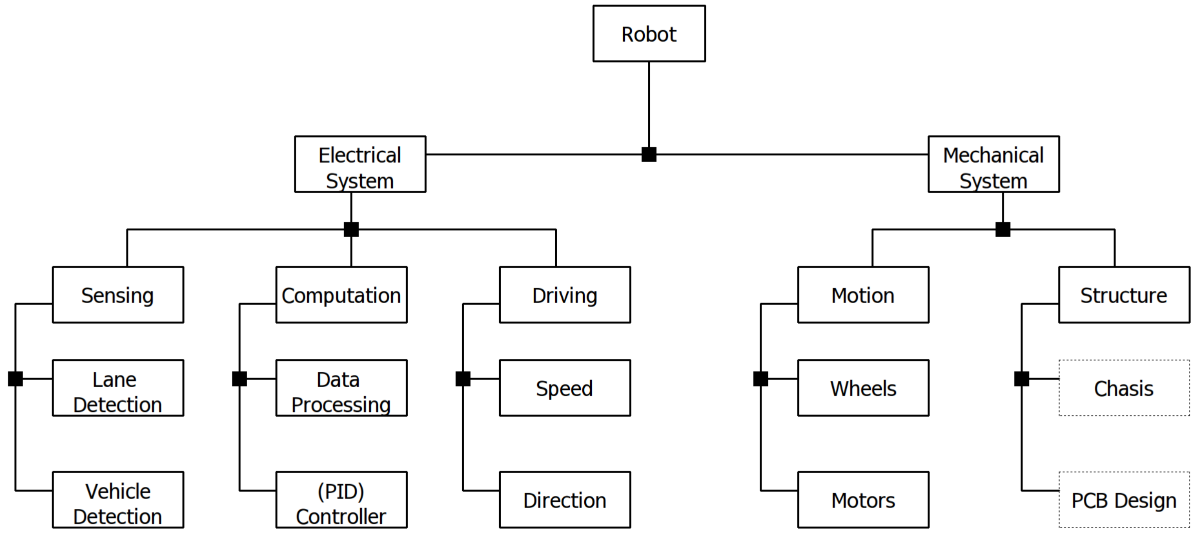


Figure 6: Systems & Subsystems of Chosen Project

5.3 Solution Alternatives for Systems & Subsystems

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: table

5.4 Design Options

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: table

5.5 Pairwise Comparisons for Design 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 7: Pairwise Comparison Charts for Sub-Objectives

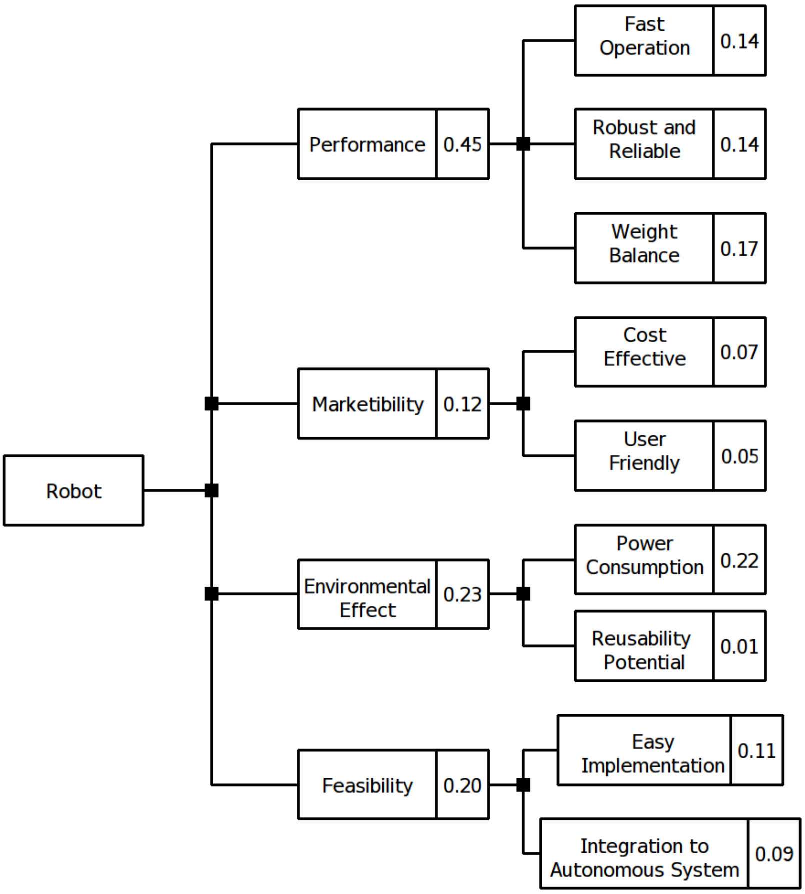


Figure 8: Weighted Objective Tree

	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

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 Driving Subsystem

This unit takes an input from the controller unit. That input involves information about what the new orientation should be. Driving subsystem, then, takes action to move vehicle according to the required direction with maximum possible speed. This subsystem consists of two units: Direction and Speed.

7.3.1 Direction Unit

Direction unit is responsible for the orientation of the vehicle. It stores the last required orientation and the new one coming from the controller. After that, it tries to make the orientation as close as new one. Both data can be represented as vectors.The angle between those two vector is tried to be minimized by the controller. Before moving on to the operation, note that the angle can be used as a measure of the error that the direction unit have. The less the angle the more correctly operates the direction unit.

Depending on the configuration of the wheels, exact control of the vehicle might vary. However, there are certain methods to accomplish orientation. The vehicle will definitely have two wheels or palettes that will be driven by two separate DC motors. That configuration allows differential drive method to orient the vehicle. PWM values of the motors can be adjusted such that the speed difference between them results in a turn as much as desired angle. The exact difference values on the PWM values depends on the specs of the used motors and voltage sources.

Two different H-bridge motor drivers are proposed to be used to drive DC motors: L298N and L293D. Both can drive two motors separately with one IC. However, maximum current rating of the former one is larger being 2A while L293D can supply 0.6A per channel.

As in the case of another configuration that involves one or two servo motors to control the directions of the front wheels. This configuration is more robust compared to ball caster utilization. However, there are more motors to control and it requires more complicated differential drive algorithms involving both DC motor differential and servo PWM to orient the front wheels.

7.3.2 Speed Unit

This unit acts as a complementary module for direction unit. It will act as a state machine. In one state, the unit will try to increase the speed of the vehicle by making overall increase in both PWM values of DC motors. The feedback of this system will be the cost function mentioned in driving unit. If that cost exceeds a specified level, unit goes to another state in which the unit will decrease the overall speed to allow direction unit to operate more correctly. In short, this unit tries to compensate the error of the direction unit by changing the overall speed of the vehicle.

7.4 Structure Subsystem

This part contains chassis and PCB sections of the robot.

7.4.1 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.

7.4.2 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.

7.5 Motion Subsystem

Motion of the system is detailed in this section.

7.5.1 Wheels Unit

There are possible solution for wheel placement on the chassis, and several wheel types. Some wheels are designed for better gripping on different surfaces. To avoids obstacles on the path, gripping of the wheel is an important concept. Some wheel types are ball caster, toy car wheel and palette. Besides, wheel placement and the wheel number should be combined with the wheel type choice.

One of the possible wheel placement is 2+1 combination. This combination can be assembled by placing 2 car wheels (with motors) to the back and the one boll caster to the front or vice versa. These configurations provide easy implementation and fairly reliable handling on the path. However, for certain obstacles may significantly disturb vehicles balance in this configuration.

Another combination is palette system. This system is used in real world where robust vehicles are needed. Similarly, this configuration can help handling obstacle in the path, but it costs for harder implementation and driving.

Last implementation is 2+2 configuration. In this configuration 2 wheels can be placed at the back and the rest at the front by placing motors to back wheels. To ease turning of the vehicle, front wheels can be controlled with a servo motor as back wheels operate in the differential drive mode. This combination may provide both enhanced grip and reliable operation.

7.5.2 Motors Unit

Motors are one of the most important physical components of the project. There are possible motor types in the market.

One of the widely used motor type is brushed DC motors. Such motors might be implemented with gears. Gears are utilized to adjust torque and RPM of the motor, which is very suitable for a racing vehicle's needs.

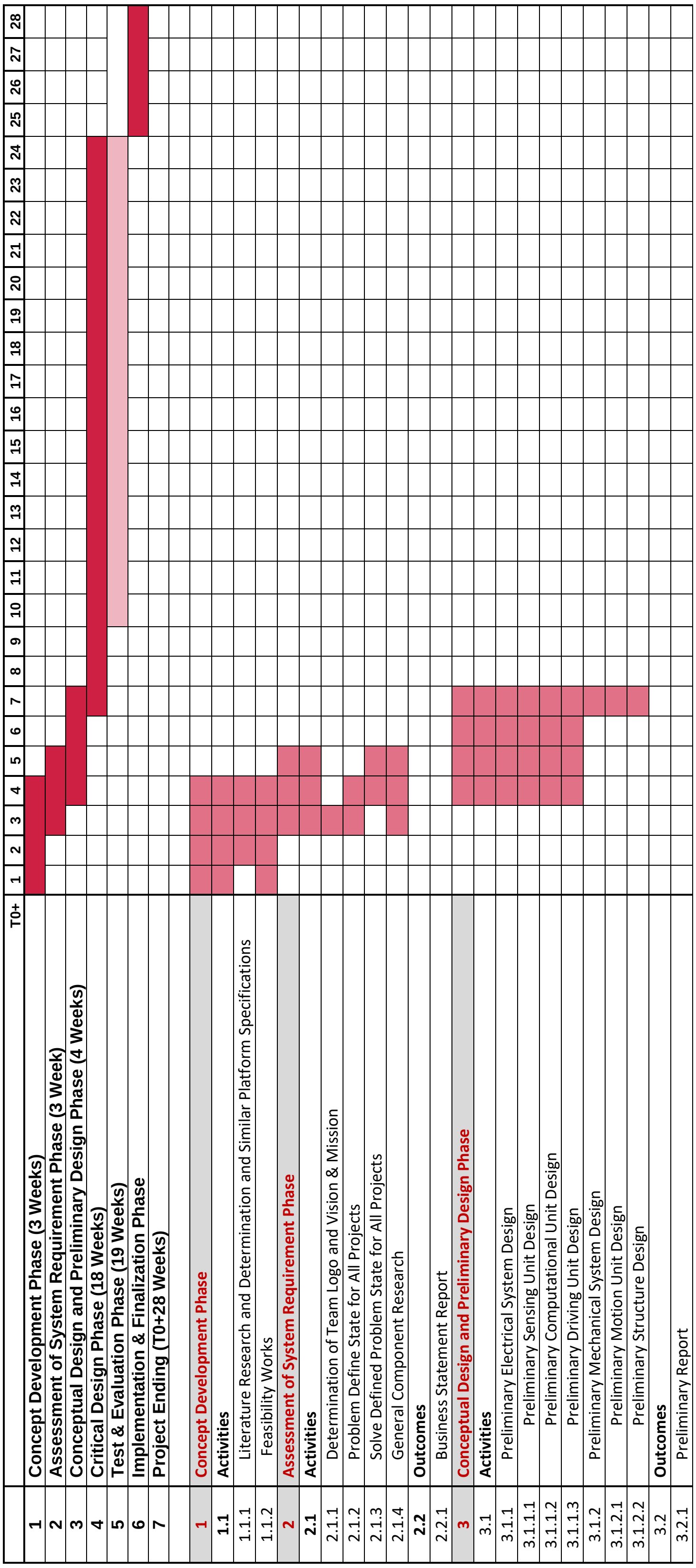
Another option is brushless DC motors. Brushless DC motors do not use brushes. This results in high torque. Brushless motors are more suitable for high RPM required areas such as CD drivers and drones.

Last option is servo motors. Servo motors are high-torque motors that can turn in an desired angle. Servos can be utilized in the direction of the vehicle on the front wheels. By using this solution, turning radius can be decrease significantly.

8 Expected Deliverables

9 Conclusion

A Gantt Chart



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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 & Evalution Phase																												
5.1	**First Semester Activities**																												
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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																												