MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

TROY TECH
FINAL REPORT

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Table of Contents

1. Introduction

Members of our company, Troy Tech are interested in creating new approaches in robotic systems and especially tele-operated robots. Our aim is to pioneer the change in robotics industry. In the project called "*Devices trying to score in each other's goals*", we aimed to design and construct a robot that is able to score in opponent robots' goal. Simplifying the players role and making the game enjoyable is crucial features of our robot. The robot does not have any self-operated or autonomous motion, an operator will control all the movements on the floor including the shooting of the ball. By producing the robot easily and accurately controllable by an operator (player) at a certain distance wirelessly, we aimed at accomplishing both performance criteria and entertainment purposes of the game.

This project had several challenging ways such as the transfer of the video data and commands wirelessly at least 30 meters in closed area. This indoor range limit was our key concern during the design procedure. Another problem was to build a robust controlled device in a small playfield, and it was expected that it moves smoothly and invariant of time. For the purpose of meeting these requirements and challenges, we also had enhanced many design solutions that are feasible and reliable. These solution approaches were also planned efficient in terms of both budget and time. Because we have always been aware of the fact that the most important cost is 'time' in all engineering applications.

In this 'Final Report', we explain all the details of our overall system including every technical information. In the previous design steps, there were alternative solutions and plan-B's. We took the advantage of following these operation principles, research and development steps, but here we include only the current parts of our end-product.

2.Executive Summary

Nowadays, robotic solutions for innovative technological products include both teleoperation and autonomous actions. As Troy Tech, we are mainly focusing on the teleoperation side and developing new solutions for wireless operations. Moreover, not only does Troy tech develop electronic systems, but also, we integrate them and test the whole system. Integration of different systems sometimes become problematic, but we are trying to predict possible difficulties and gather all the parts together in a compatible way. We especially aim both “financial efficiency” and “reliable operation” in our project and these two are essential concepts for us.

Our ongoing project requires a robot playing hockey in a hexagonal playfield. It is supposed to be controlled from at least 30-meters for indoor usage. Tele-operation will be done by just looking at a screen showing the live broadcast. The video recorded by the camera that is located on the robot will instantly transferred to the controller room.

Our teleoperated robot, Helen-V consists of five main subsystems which are video transmission, command transmission, motor control, shooting mechanism and power supply. We gave priority to solve the problem of transferring the live video data with minimum latency from the robot to the controlling side. After doing some research on this problem, we ordered a 600mw 5.8 GHz transmitter and ROTG02 as a 5.8Ghz FPV receiver with an FPV camera for this part and did some tests and quality controls. At the beginning, our camera unit was integrated with the video-transmitting antenna. Then we replaced it by a transmitter with higher power and externally connected camera. This replacement enhanced the distance that video signal reaches both indoor and outdoor areas. The second sub-system is the command transfer where we used digital data transfer from the controlling side to the robot. This sub-system includes an Arduino Uno and an Arduino mega connected to NRF24L01 transceivers. We replaced their antennas with larger basic dipole antennas with higher gain in order to increase the communication range. We use a PlayStation 1 joystick and NRF24L01 transmitter connected to Arduino Uno to give command to motors and shooting solenoid which is on the HELEN-V. The other part consists of three DC motors and two motor drivers. These motors connected to three omni-wheels takes controlling data from the Arduino Uno connected to the receiver NRF24L01. The last operational sub-system includes the mechanism to shoot the ball into the opponent’s goal. For this purpose, we prefer using a push and pull solenoid with 34 mm stroke length. We increase the 12V source voltage to 35V by the help of the DC-DC up converter and we give energy to the solenoid through the capacitors. This part is also controlled by the digital signal coming from the command transfer system. Finally, we have a power supply system which consists of a 12V accumulator and two power banks. By the help of the power banks, we get 5V DC to energize the Arduino mega and camera and the accumulator is for motors and the solenoids. Additionally, we have one more power bank at the controller room.

Although this project has many challenging aspects like the wireless data transfer to 30- meters and shooting mechanism, our group members-built consensus on this project involves much fun and the final product will satisfy our engineering enthusiasm. Actually, as Troy Tech Co. our main concern is to develop and produce a properly operating and cost-efficient robot in a short period. Eventually, it is great pleasure for us to see HELEN-V in the playfields at the end of the April 2019.

3. Design Description

3.1 Top-Down System Descriptions

Our project consists of four main subsystems; analog video transfer, command transfer, motor drive and shooting mechanism. The analog transfer subsystem is separated while other parts are jointed.

We used an FPV video camera for monitoring the game field and we preferred TS5828 transmitter in order to transmit the signal coming from the video camera. Then, we received the signal by the Rotg02 receiver module and transferred the video to a screen (android smartphone or pc) for monitoring the video of the game field. The whole process forms our analog video transfer subsystem.

Moreover, we have a command transfer subsystem which consist of a controller, an Arduino microcontroller and two NRF24 transceiver (one for receiver, another one for transmitter) successively. Also, we have one more Arduino microcontroller connected to the receiver NRF24. Finally, we have a L298N dual motor drive and motors connected successively, which forms motor drive subsystem, and we have shooting mechanism connected to the Arduino. The overall block diagram can be seen in Fig 1.

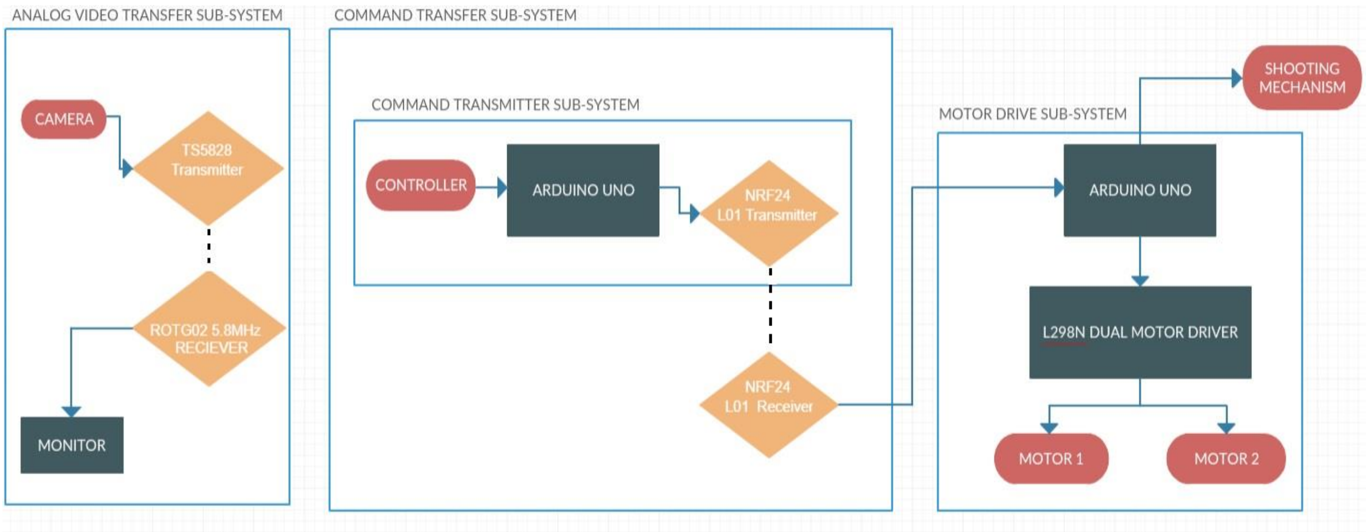


***Figure 1**: Overall block diagram of the project.*

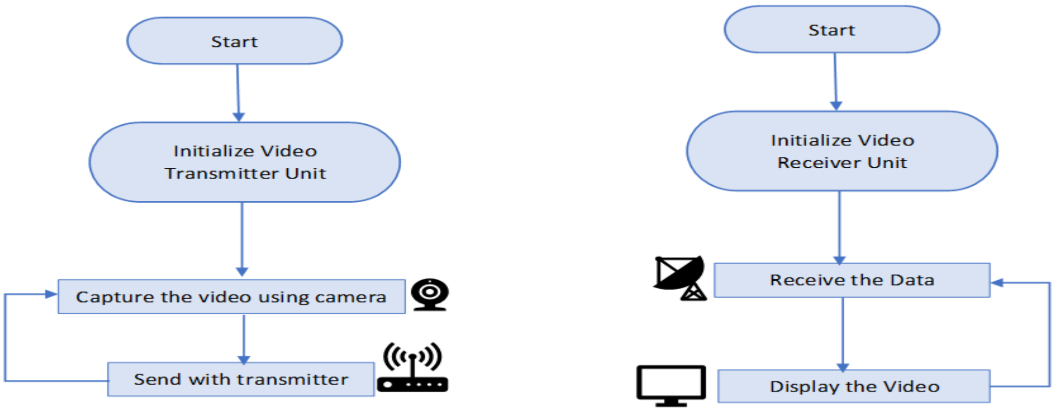


***Figure 2**: Flowchart of video transmission system*

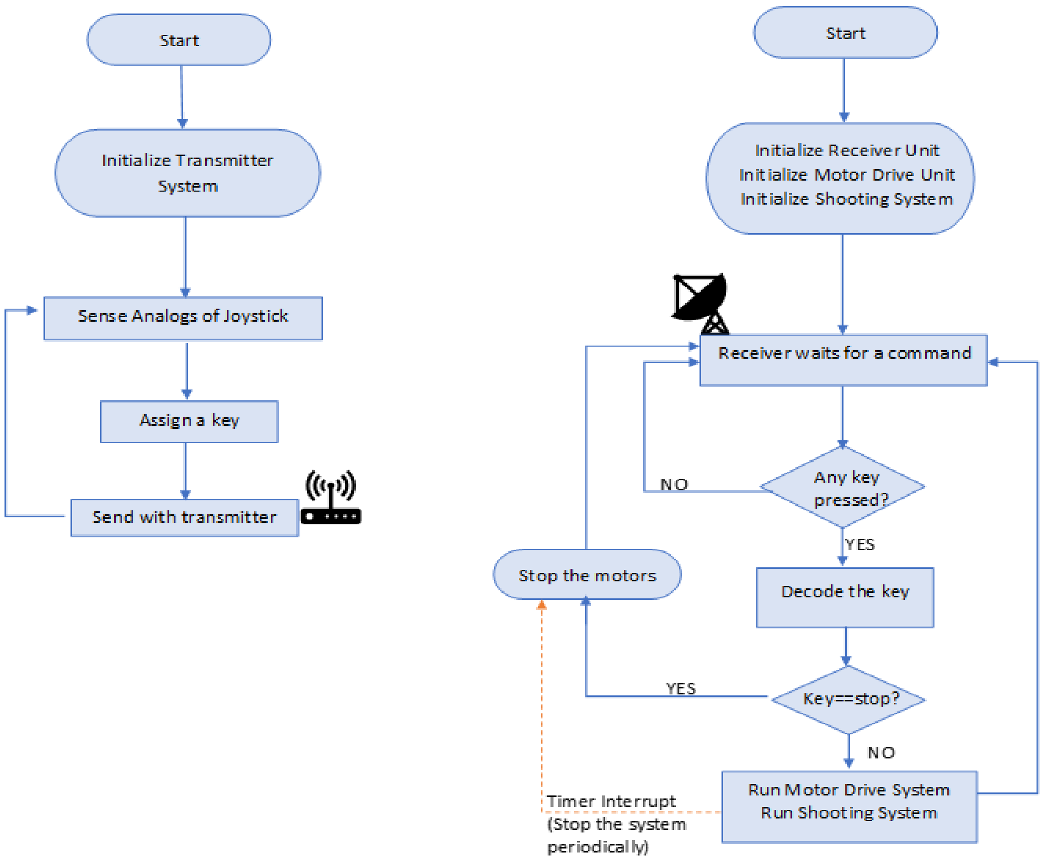


***Figure 3**: Flowchart of command transmission and motor drive systems*

3.2 Technical Specifications of Video Transfer Subsystem

We were asked for providing wireless video transfer for at least 30m distance indoor. We used a FPV video camera and transmitter-receiver pair in order to transfer the video which is recorded by the video camera. The frequency of the transmitted signal is 5.8GHz (we are able to select the channel between 5.6GHz and 5.9GHz.) while its power is 600mW.

We transfer the video as analog. It is the simplest and fastest way. Latency in analog transmission is less than other video transmission techniques (i.e. using image process technique, using 3G internet). We chose 5.8 GHz for video transmission due to its high transfer rate. It provides a better video stream than 2.4Ghz, 900 MHz and 433 Mhz. This subsystem consists of transmitter and receiver systems.

i. Transmitter:

We used a 600mw 5.8 GHz transmitter to transmit the video coming from a mini camera (Eachine TS5828S 40CH 5.8G 600MW) as shown in Fig. 4. It provides a high maximum range using its stock antenna.

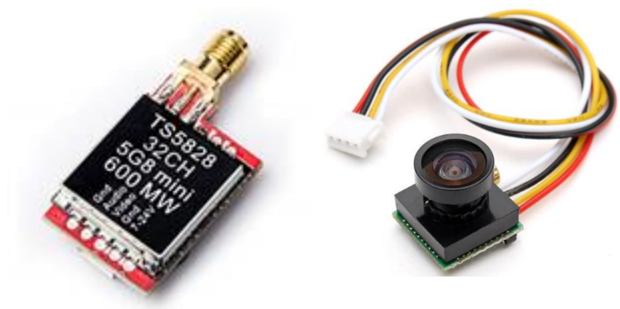


Figure 4: *TS5828S and 600TVL mini camera*

ii. Receiver:

We used ROTG02 as a 5.8Ghz FPV receiver. Advantages:

→ Good signal reception
→ Dual antenna system
→ 150 reception channels (5645~5945 MHz frequency range)
→ Low latency (around 100 ms)
→ It can be connected to a smartphone (OTG)

Figure 5: *Eachine ROTG02.*

3.3 Technical Specifications of Command Transmission Subsystem

Like in video transfer, we are asked to transfer command information for at least 30m distance indoor. We use a ps1 joystick in order to give appropriate command information. Then, we used a NRF24L01 transceiver module in order to transmit the information coming from the joystick. In order to receive the incident signal, we used one more NRF24 transceiver as receiver on the robot. The operating frequency of the NRF24 transceiver is 2.4 GHz.

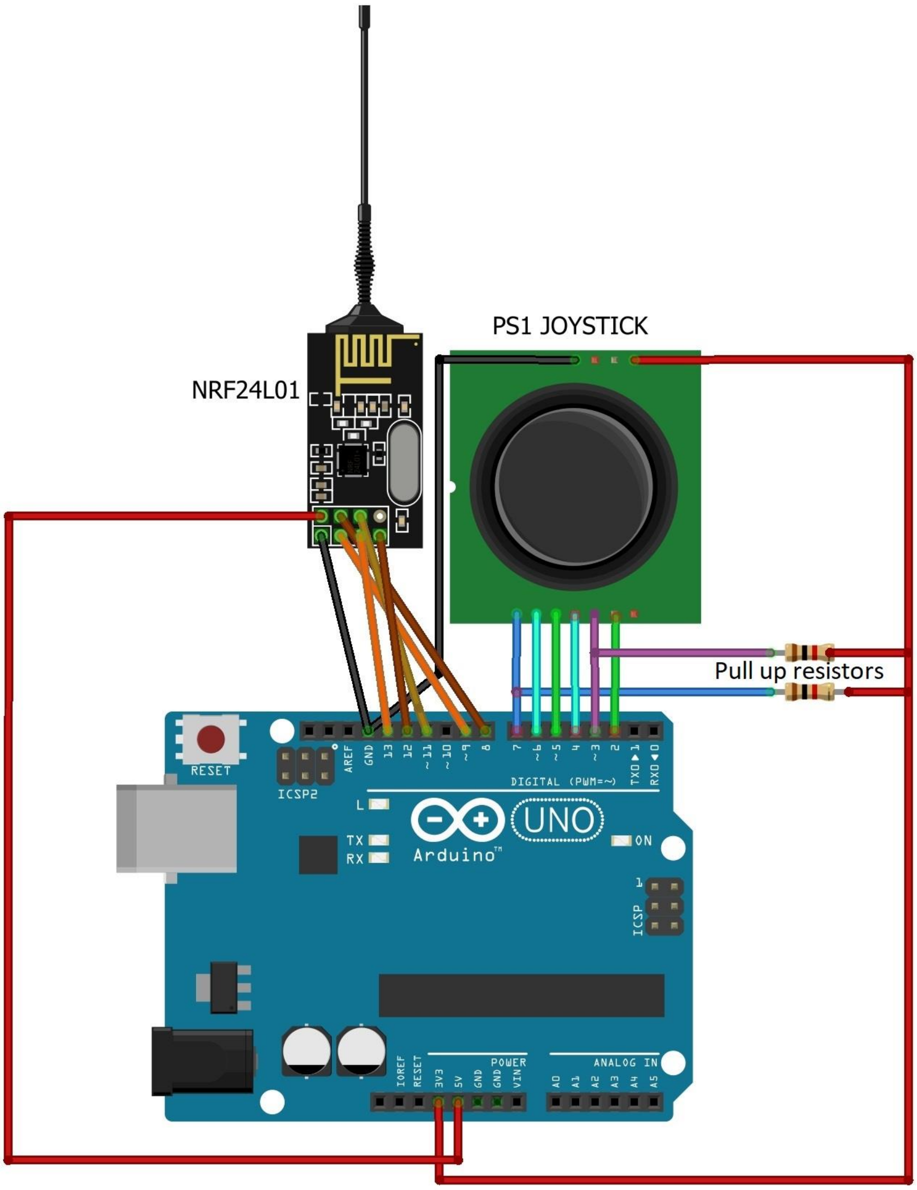


Figure 6: *Command Transmitter system*

i. Command Transmitter

We built a command transmitter unit using PS1 joystick and NRF24L01 2.4Ghz transmitter as shown in Fig. 7. and Fig. 8.

Figure 7: *Command Transmitter unit*

Figure 8: *Command Transmitter unit with antenna*

We chose NRF24L01 because of some reasons.

- It is very cheap.
- Compatible with high gain antennas and 2.4GHz antennas are also very cheap.
- Transmitter output power is 20dBm.
- It has easy to use libraries and adjustable settings by many MCU and compatible with them.
- It has safety communication. It can use upon 5-byte configurable network address to communicate just in a specific network branch.
- It is easy to power-up. There is no need for additional power supply, we connected NRF modules directly to the Arduino to be energized.

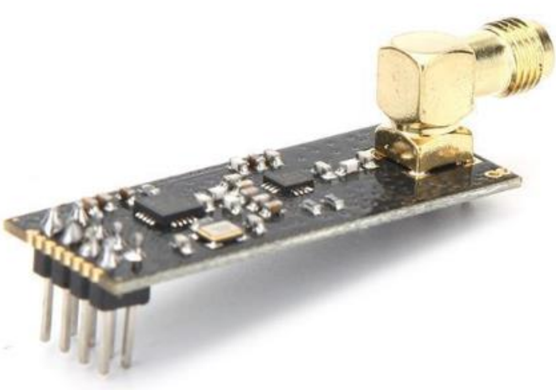


Figure 9: *NRF24L01*

In our system, we use 15dBi 2.4GHz linear antenna at the transmitter side as shown below.

***Figure 10**: 2.4GHz linear antenna*

These NRF transceiver modules can be communicated between them as reciprocal but in our system, we set one NRF module as transmitter and other as receiver. The transmitter sends data continuously regardless of acknowledge from receiver. We can use upon 32-bytes payload, but in our system, we set it 1-byte because it’s enough for us. The power of NRF24L01 is around 100 mW and 20dBm and moreover, there is an antenna improvement that has been done which adds gain as 15 dBi. The communication protocol of NRF24L01 as follows.

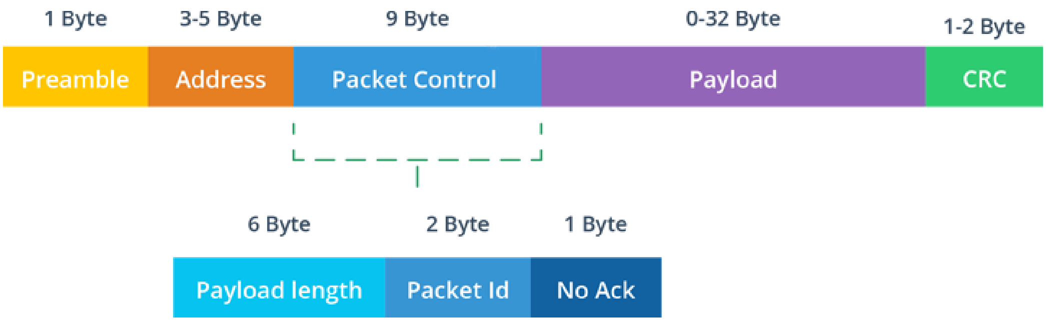


***Figure 11:** Communication protocol of NRF24L01*

Preamble: Shows beginning of a packet.

Address: Shows the network pipe address. This address is used by both transmitter and receiver to communicate just with each other.

Packet Control: Section for related settings.

Payload: Sending data is stored inside. For our case it’s 1 byte.

CRC: Cyclic redundancy check for error detection. This error detection technique is based on checking the payload value by its CRC value. CRC value is generated by some arithmetic operations with the payload so that receiver can look at the payload and CRC value in order to find out if there is an error.

We connected PS1 joystick and NRF24L01 to Arduino UNO. Arduino senses the analog buttons and normal buttons of PS1 joystick repeatedly and read these data. Then, send those data by NRF transmitter module. We have resolution-255 for analog values.

ii. Command Receiver

We used NRF24L01 module to receive command data sent by transmitter. We connected its stock antenna to it. It is not sending ACK to the transmitter back so that it is read-only. The receiver and transmitter share the same network address and share the same settings such as payload size, CRC size and data rate. After receiving the data, this module transfers the data to the microcontroller to process.

3.4 Technical Specifications of Motor Drive Subsystem

3.4.1 Motors

We chose "Namiki 22CL-3501PG" for our motor drive subsystem as shown in Fig.12. Its specifications are given in Table 1.

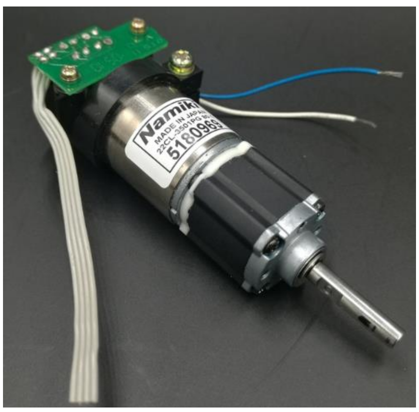


Figure 12*: Namiki 22CL-3501PG*

***Table 1**: specifications of Namiki 22CL-3501PG*

Brand	Namiki Coreless Motor (Japan)
Type	Gear Motor
Voltage	12V
Rated power	15W
Stall Torque	1.6Nm (16Kg · cm)
Continuous torque	0.5Nm
Output speed	120 r / min @ 12VDC
Diameter	22 mm
Length	65 mm
Weight	140 g

3.4.2 Holonomic Control

We chose holonomic control since its movement is better than the other options. Especially when defending, it is necessary to move left and right parallel to the goal line in order to be able to hold the ball. However, in differential drive method, the robot must turn in that direction in order to go to the right or left. Therefore, he can't see the ball while defending. However, in holonomic control method, the robot can easily go in all directions and defend his goal. The difference between two methods is shown in Fig. 13.

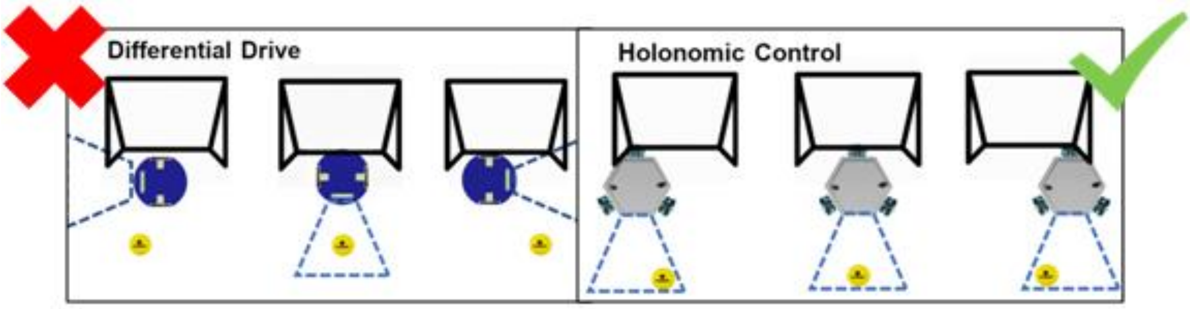


***Figure 13**: The difference between holonomic control and differential drive*

As shown in Fig. x the robot can move multiple directions (i.e. moving forward, backward, left, right and spinning around it). It is based on three separately driven wheels placed on the robot body. The direction of the robot can be changed by varying the relative rate of rotation of its wheels. Therefore, it does not require an additional steering motion. Some example motions with varying speed of wheels are shown in Fig. 14.

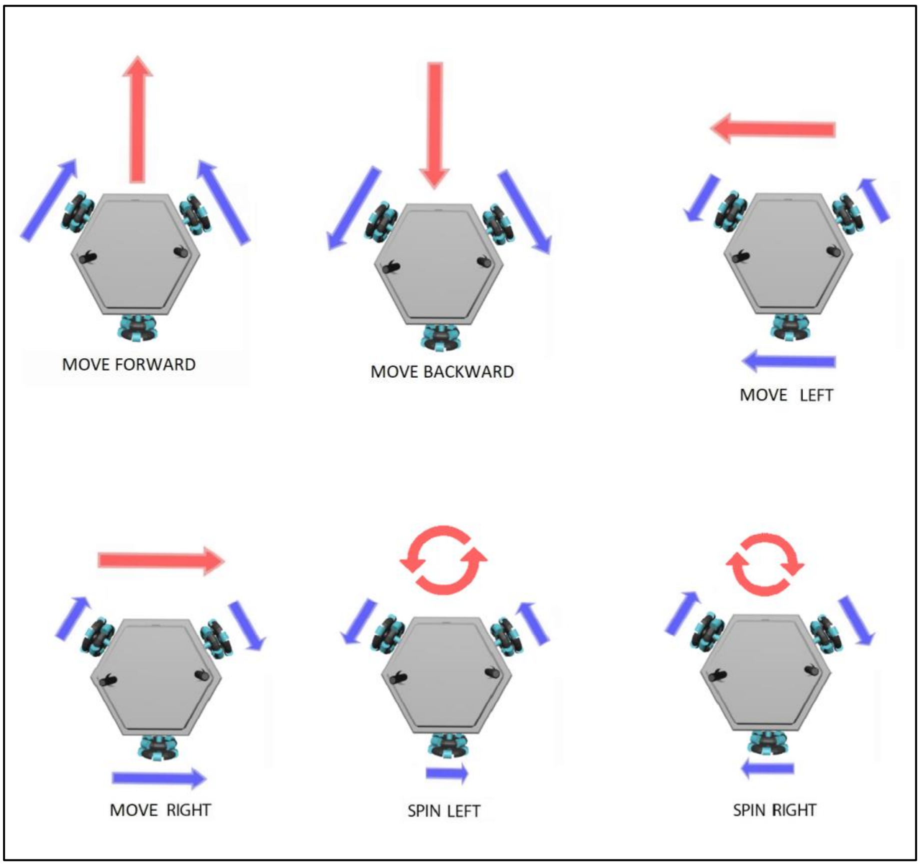
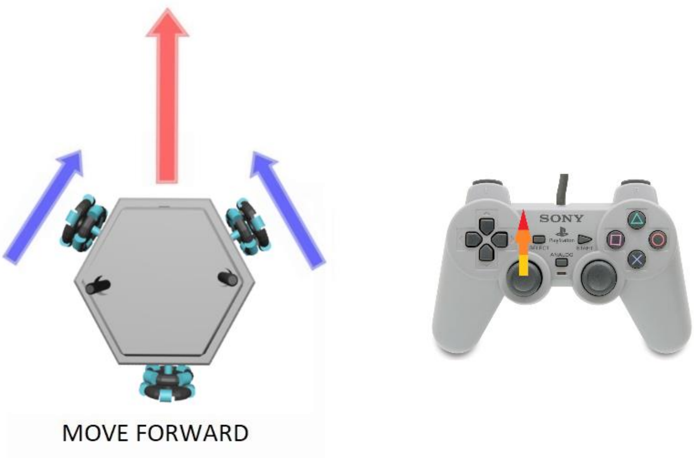


Figure 14: *Holonomic drive*

3.4.3 DC Motor Drive Movements

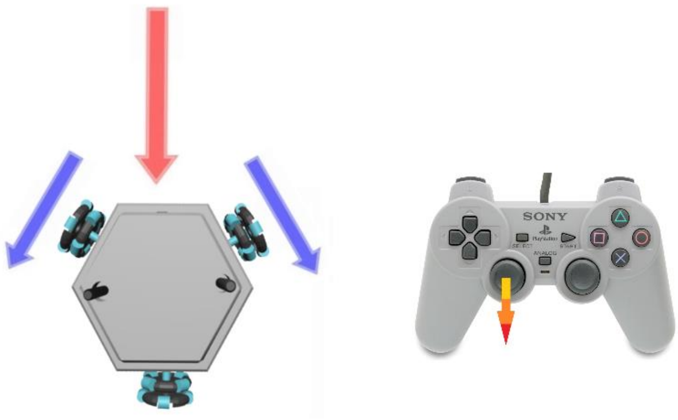
i) Move Forward

When user moves up the left analog of joystick, robot moves forward. For this operation, the two front DC motors should turn same speed and same rotation. This can be achieved with Arduino by setting the same PWM value to the both front motor pins. Note that different speeds can be obtained by changing the left analog position.



ii) Move Backward

When user moves down the left analog of joystick, robot moves backward. For this operation, the two front DC motors should turn same speed and same rotation. This can be achieved with Arduino by setting the same PWM value to the both front motor pins. Note that different speeds can be obtained by changing the left analog position.



MOVE BACKWARD

iii) Spin Right

When user moves right the right analog of joystick, robot spins right. For this operation, all three DC motors should turn at the same rotation and same speed. Note that different speeds can be obtained by changing the right analog position. This can be achieved by changing the PWM values for the motor pins.

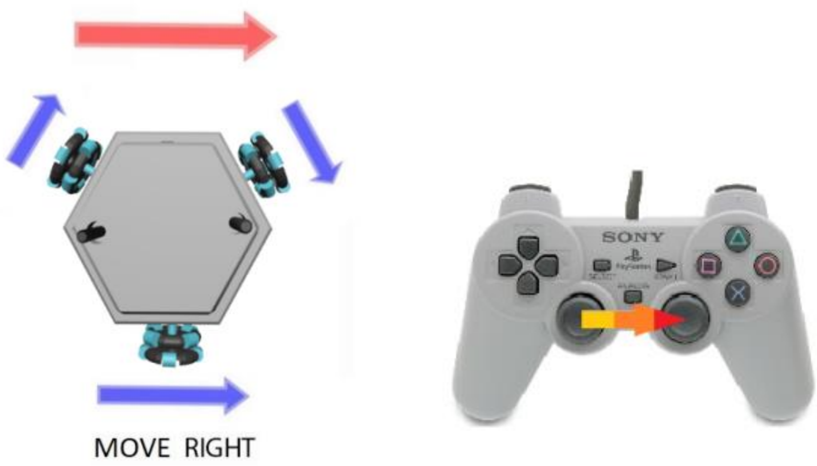
SPIN RIGHT

iv. Spin Left

When user moves left the right analog of joystick, robot spins left. For this operation, all three DC motors should turn at the same rotation and same speed. Note that different speeds can be obtained by changing the right analog position. This can be achieved by changing the PWM values for the motor pins.

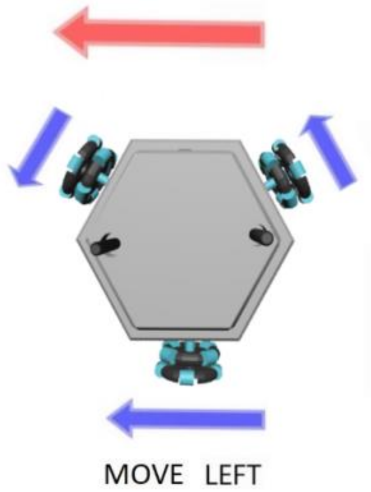
iv. Move Right

When user moves right the left analog of joystick, robot move right. For this operation, both front DC motors should rotate CCW direction and bottom DC motor should turn CW direction.



iv. Move Left

When user moves left the left analog of joystick, robot move left. For this operation, both front DC motors should rotate CW direction and bottom DC motor should turn CCW direction.



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3.5 Technical Specifications of Shooting Subsystem

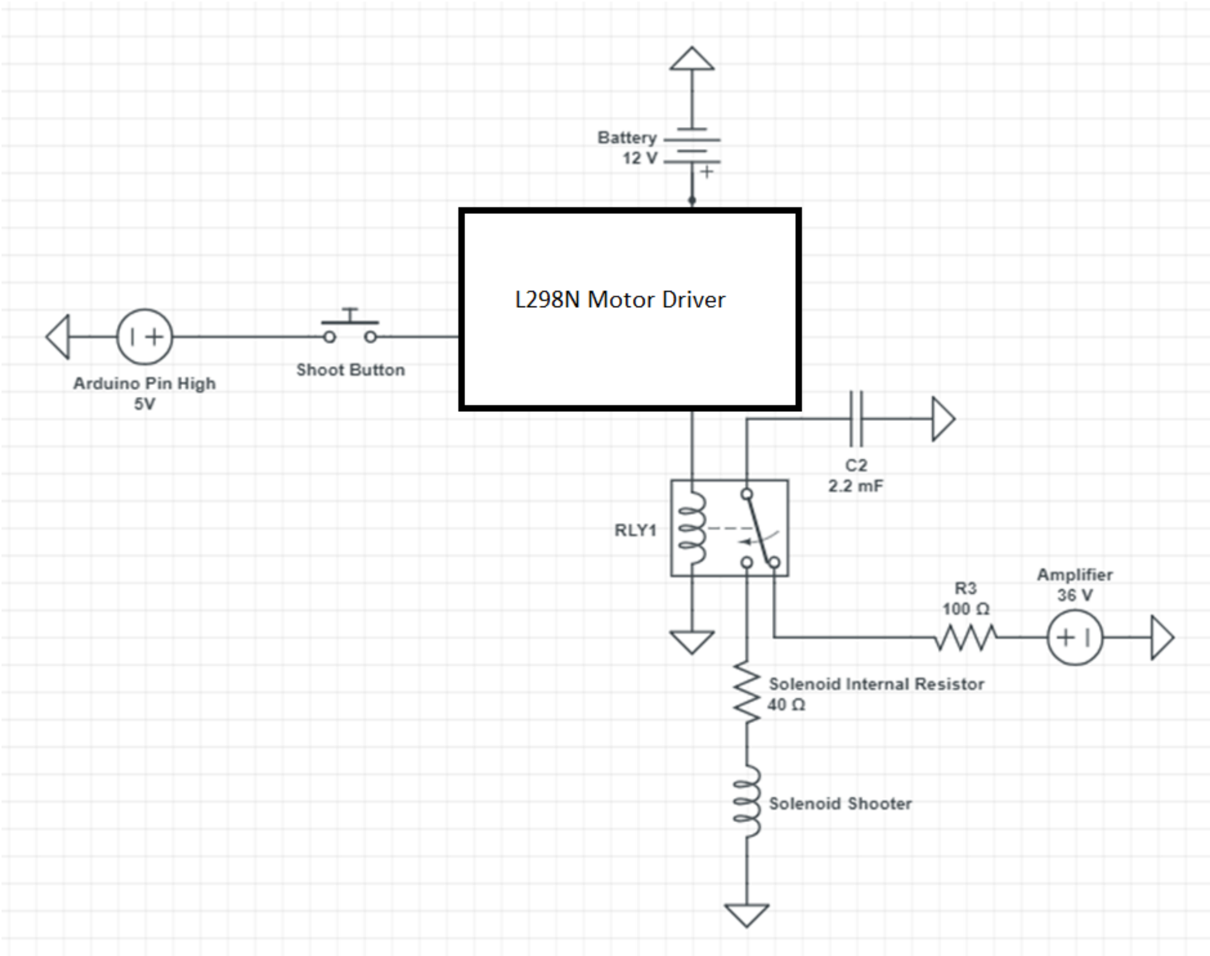


Figure 15: The circuit schematic of the shooting system.

After the researches, we decided to use solenoid push and pull actuator as our shooting system. It is much simpler than a mechanical spring system and it's mainly related with our area. Also, the size of the solenoid is much smaller than the spring system. As a company consisting of electrical engineering, we prefer using current or voltage-controlled shooting system.

We have a 24V solenoid actuator but it is allowed to use with voltage values since our shooting operation is impulsive (at the level of ms). The excitation voltage should be above the 35 V in order to have desired stroke of the shooting system. According to the tests we made, operation with 12V (it is our source voltage coming from accumulator) is not powerful enough. Therefore, we prefer using DC-DC up converter to 36V to excite the solenoid. It up converts our supply voltage 12V to 36V.

Figure 16: The push and pull solenoid actuator

We use a L298N motor drive (it is connected to the digital output of the Arduino mega) as the switching element for SPDT relay. Also, we use a SPDT 5A relay which can switch between two different circuits. Actually, we excite the solenoid through the charged capacitor. We have two different circuit: one for charging the capacitor with the DC-DC up-converter connected to the source and one for the solenoid excitation through the capacitor. By switching the relay, we are decharging capacitor onto the solenoid and after that the relay switch to the first circuit which charges the capacitor. We controlled the relay with the Arduino digital output. When the output is 1, the relay establishes a connection between the capacitor and the solenoid. When the output is 0, the relay establishes a connection between capacitor and DC-DC up-converter in order to charge the capacitor. If we push the X button of the PlayStation 1 joystick, we get 1 at the output of the Arduino Mega otherwise we get 0 output.

We used two parallel capacitor whose capacitances are 10000 uF and 5A relay.

3.6 Technical Specifications of Power Supply Subsystem

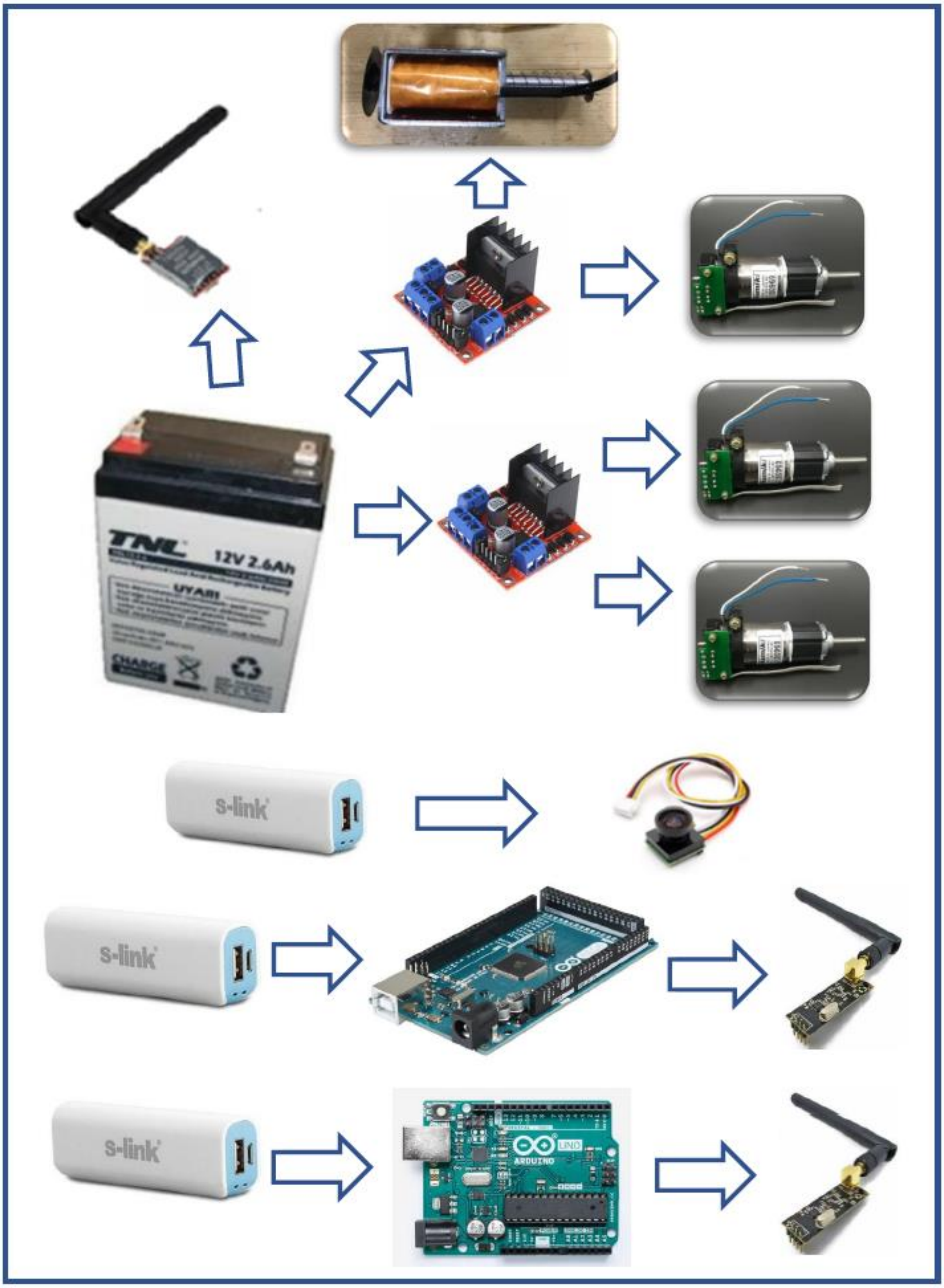


Figure 17: Overall power supply subsystem schematic.

For the power supply subsystem, we use one 12V (2.8Ah) accumulator battery with 200 Watts of output power and three power-banks. The reason why we employed accumulator battery instead of a lithium polymer battery is accumulator battery is cheap and easy to charge. Since we did not have any problem with the extra weight coming with this type of battery, it became compatible with the rest of our design.

At the robot side, an accumulator battery supplies power for three DC motors, solenoid shooting subsystem and video transmitter. Two power-banks are used for Arduino Mega and camera. Because DC motor drivers, push-pull solenoid and video transmitter work with 12V DC whereas the camera and Arduino Mega are energized by 5V DC.

At the remote-control side (player/operator), one more power-bank is used to supply power for Arduino Uno and command transmitter at the controller. Here, we made use of NRF24L01 modules as wireless command transfer devices. One NRF24L01 at the robot side and one NRF24L01 at the remote-control side. They do not need external power supply; they are connected directly to Arduinos. The overall power supply schematic is shown in Figure ...

4. Result and Analyses of Performance Tests

4.1 Range performance

Our robot has successfully passed the design specification tests. We are required to communicate at least 30 meters indoor. We did our indoor tests at two different locations. We used Google Earth Pro to measure the distances. The first test location is between D-E buildings and results are shown in figure18 and 19.

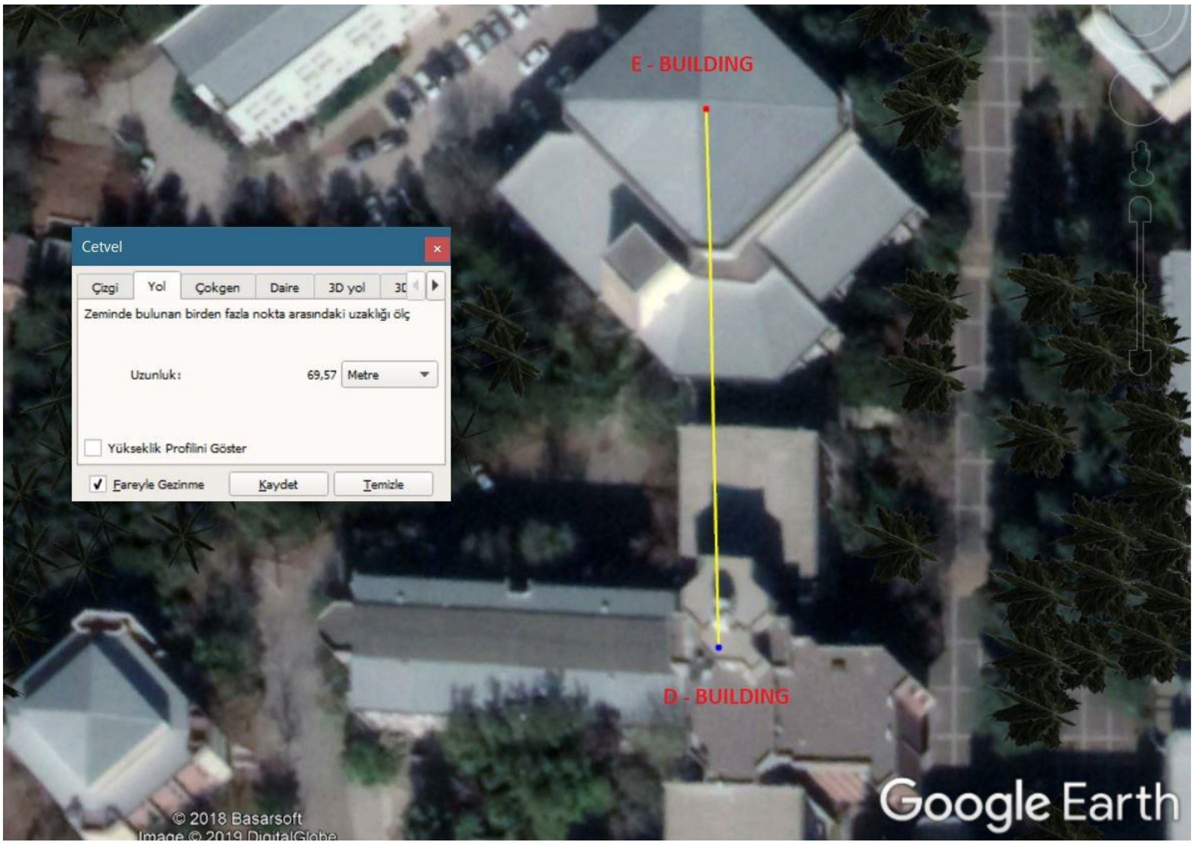


Figure 18: Command Transmission Range

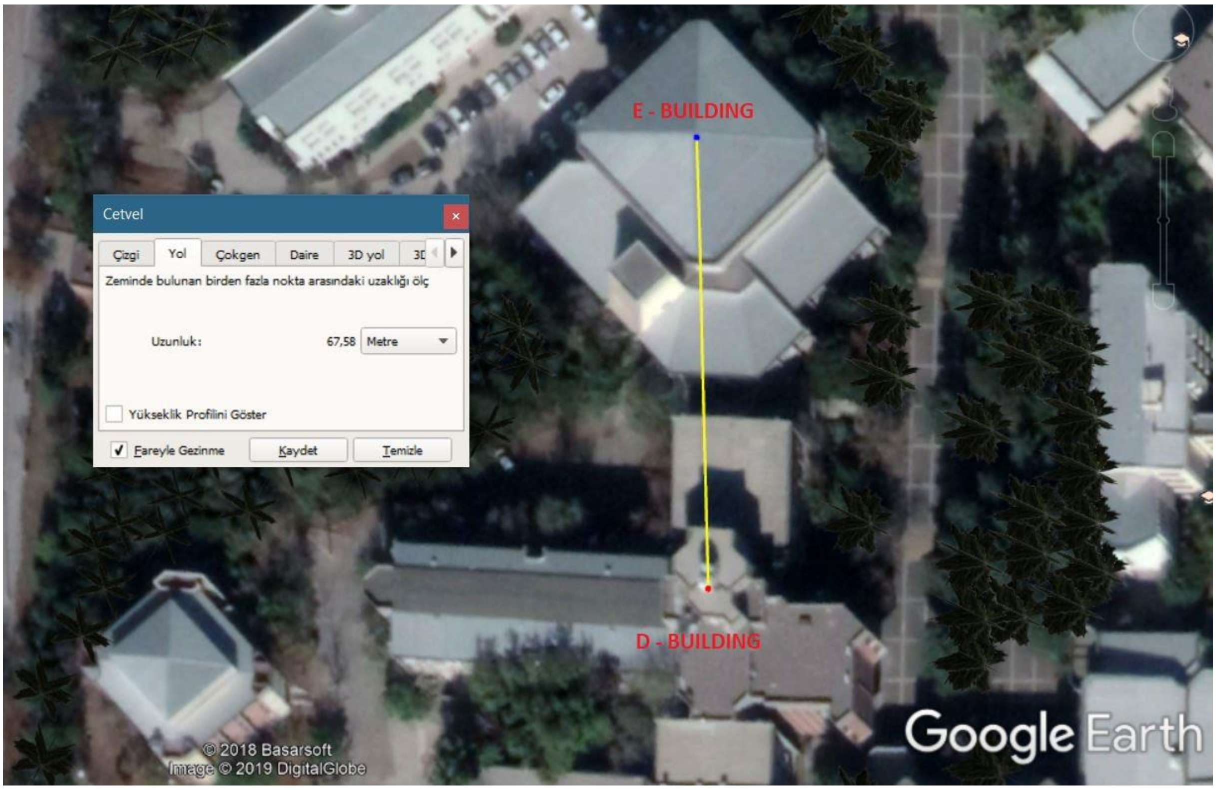


Figure 19: Video Transmission Range

The second test location is between C and D buildings and results are shown in figure 20 and 21.

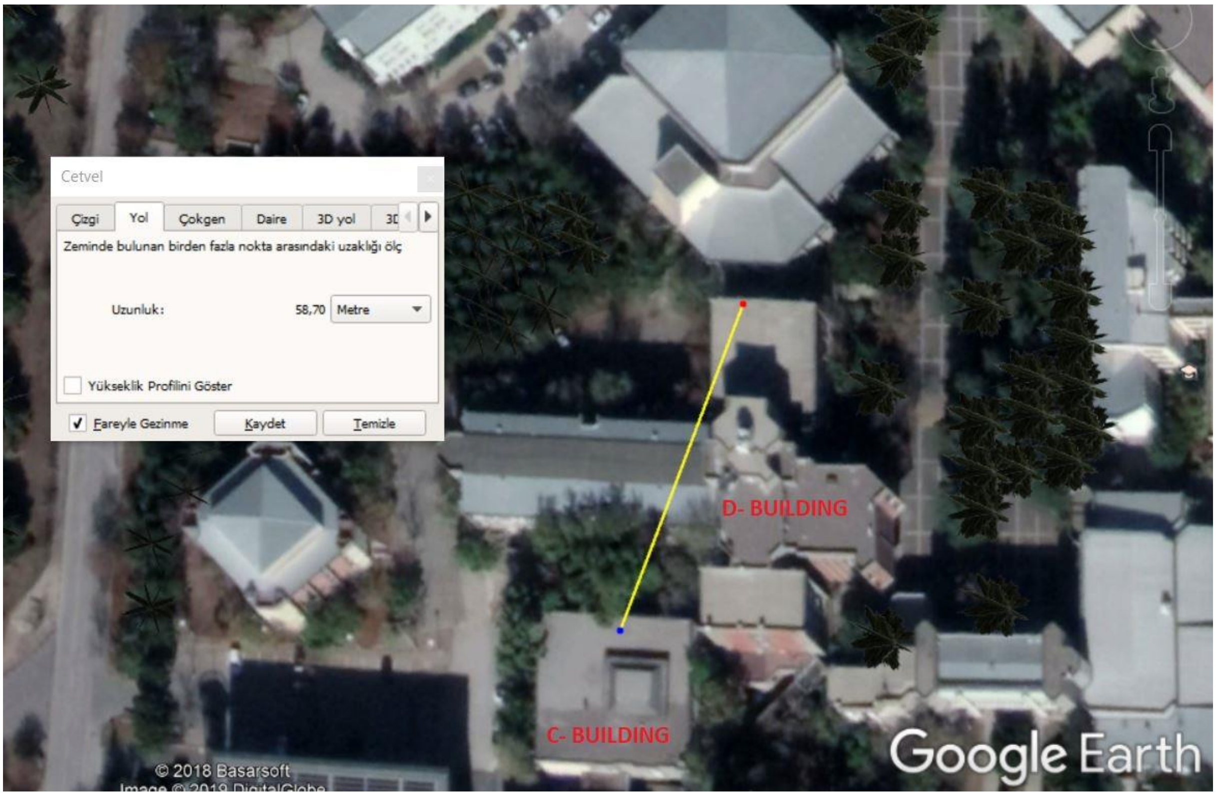


Figure 20: Command Transmission Range

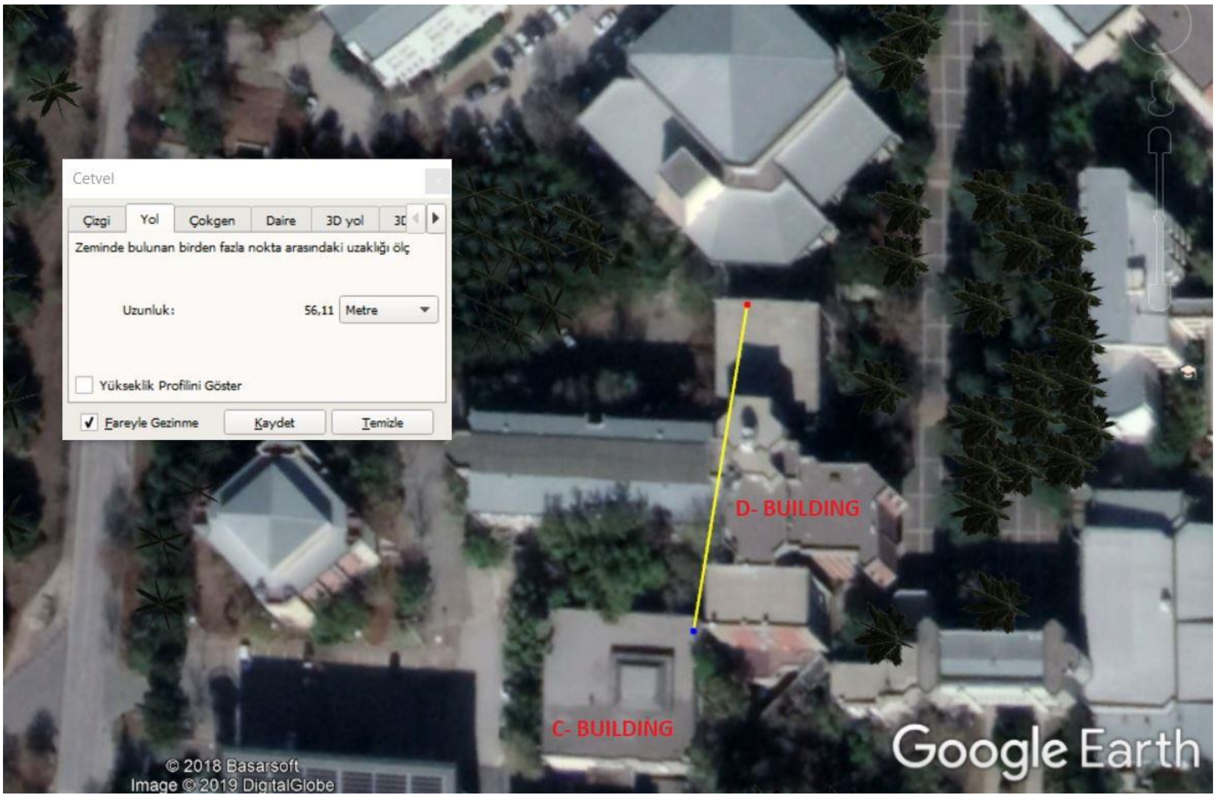


Figure 21: Video Transmission Range

We also did an outdoor test starting from A building and result in shown figure 22.

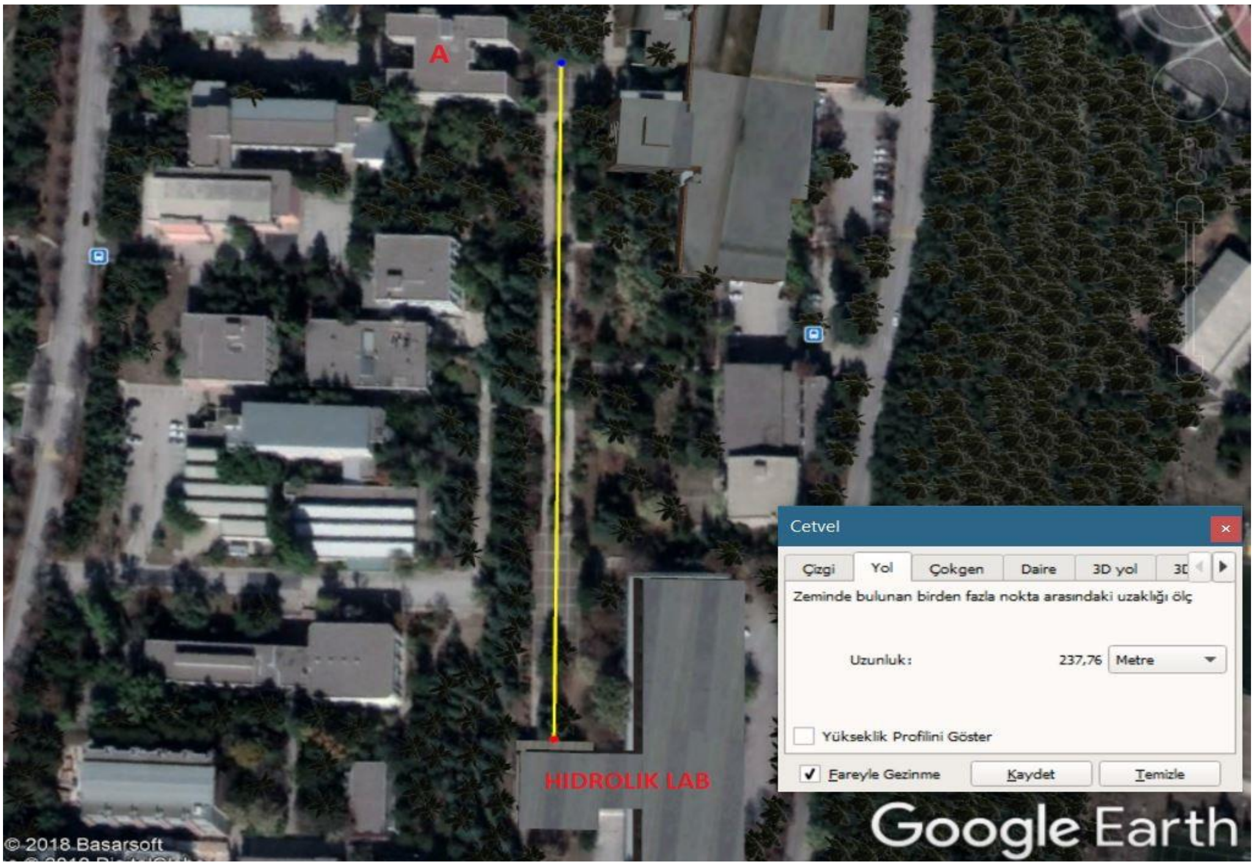


Figure 22: Outdoor Command and Video Transmission Range

4.2 Speed/Stability of Robot Movements

After complete implementation of every sub-system, we followed a test procedure to show movement performance of our robot.

The first test was done when battery was charged to 11.73 V. This voltage level represents a level after some time of gameplay. Our results are shown in the following table.

NORMAL MODE					SLOW MODE				
Forward	Backward	Right	Left	Rotation (360°)	Forward	Backward	Right	Left	Rotation (360°)
26.8 cm/s	25 cm/s	21.4 cm/s	21.5 cm/s	112.5°/s	N/A	N/A	N/A	N/A	N/A

At this voltage level, we observed unstable movement at slow mode. That's why frictional losses were considerable for this voltage level.

The second test was done when battery was charged to 12.4 V. This voltage level represents a full capacity level. Our results are shown in the following table.

NORMAL MODE					SLOW MODE				
Forward	Backward	Right	Left	Rotation (360°)	Forward	Backward	Right	Left	Rotation (360°)
30 cm/s	25 cm/s	22.2 cm/s	22.2 cm/s	124.1°/s	10.35 cm/s	5.61 cm/s	N/A	N/A	75°/s

In the following table, comparison of 12.4 V and 11.73 V can be seen.

NORMAL MODE					SLOW MODE				
Forward	Backwar d	Right	Left	Rotation (360°)	Forward	Backward	Right	Left	Rotation (360°)
30 cm/s	25 cm/s	22.2 cm/s	22.2 cm/s	124.1°/s	10.35 cm/s	5.61 cm/s	N/A	N/A	75°/s

NORMAL MODE					SLOW MODE				
Forward	Backward	Right	Left	Rotation (360°)	Forward	Backward	Right	Left	Rotation (360°)
26.8 cm/s	25 cm/s	21.4 cm/s	21.5 cm/s	112.5°/s	N/A	N/A	N/A	N/A	N/A

- It can be seen that full capacity battery results in better speed and stability.

4.3 Shooting Performance

The best mechanism of our robot can be considered as shooting system. We really paid attention to choose and build a powerful and stable shooting system. In order to get a powerful shoot, we chose a push-pull solenoid actuator with 3.4 cm stroke length. Our test results are can be seen:

- Average speed of the ball: 204.54 cm/s
- Shooting Range: More than 600 cm
- Charging Duration of Capacitor: 3.4 seconds

4.4 Power Consumption

Here you can see our test results and datasheet research for power usage of every subsystem element we have in the robot. Since some of the components need 12 V DC supply and some others need 5V supply from USB connection, their power sources are different. It was indicated in the Section 3.6 of this report.

Device	**Consumed Power**
Arduino Mega	63.5 mW
Arduino Uno	60 mW
Namiki 22CL-3501PG	15 W
Eachine TS5828S transmitter	600 mW
600 TVL camera	600 mW
Eachine ROTG02 FPV receiver	1.5 W
NRF24L01 transmitter	565 mW
NRF24L01 receiver	225 mW
Push-Pull Solenoid	24.5 W

In addition to these separate results, we needed to provide a complete result of battery usage. This performance feature needed to include real life and be similar to real gameplay conditions. To meet these requirements, we tested our robot starting from 12.04V battery level. We pressed the shooting button ten times and 75cm forward and 75cm backward movement (again for ten times). Then we measured the battery voltage level as 11.99 V. We know that the voltage and battery level of the accumulator characteristics is not linear. But this gives us an idea related to the power usage of our robot during the game.

5. Deliverables

Your shipping box contains Helen-V (Fig. 23), Eachine ROTG02 FPV Receiver (Fig. 24), a command transmitter module with PS1 joystick (Fig. 25), Artengo beach volley ball (Fig. 26) and charging cables.

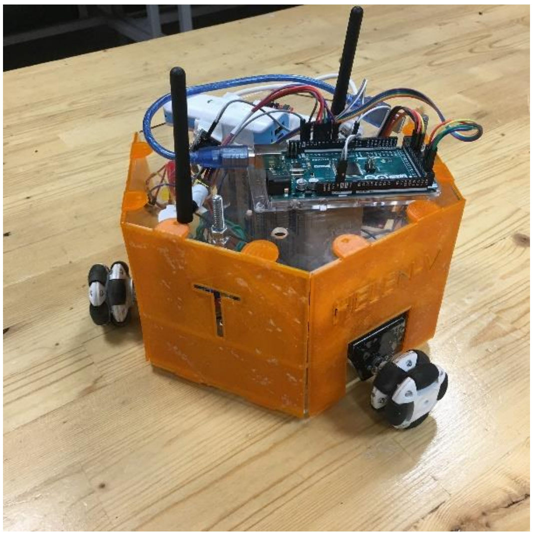


Figure 23: HELEN-V

Figure 24: Eachine ROTG02 FPV Receiver

Figure 25: Command Transmitter Module

Figure 26: Artengo beach volley ball

6. Budget

6.1 Actual Expenditures

Actual expenditures are presented in the cost breakdown table, Table 2, and the additional cost table is provided including the engineering and manufacturing costs in Table 3. The total cost is the summation of the two and calculated below tables.

Table 2: *Costs of parts in Helen-V.*

Product	Pieces	Unit Price($)	Total Price($)
nrf24l01+	2	1.78	3.56
TS5828s	1	7.70	7.70
Camera	1	6.27	6.27
Video Receiver	1	21.99	21.99
Arduino Uno	1	3.21	3.21
Arduino Mega	1	5.95	5.95
Joystick	1	2.84	2.84
15dBi antenna	1	2.24	2.24
12V Battery	1	9.55	9.55
Powerbank	2	4.75	9.50
DC motor	3	8	24
L298n	2	1.43	2.86
Omni wheel	3	5.42	16.27
Solenoid	1	13.5	13.5
Connection Equipment and body	1	15	15
Walls	3	3	9
TOTAL	**24 pcs**		**154**

6.2 Total Cost

Table 3: Additional Costs

Product	Pieces	Unit Price($)	Total Price($)
Multimeter	1	5	5
Extra Mounting Equipment and Stationery	1	10	10
Unused antenna	1	2.25	2.25
Extra Powerbank	1	4.75	4.75
Soldering Iron and Utilities	1	7	7
TOTAL	**5 pcs**		**29**

Actual Expenditures to Rebuild Robot = 154 $

Total expenses with Additional Costs = 176 $

Links for Products
nrf24l01 = https://bit.ly/2Sl34Xk
TS5828s = https://bit.ly/2QOGyJS
Camera = https://bit.ly/2QNpZhs
Video receiver = https://bit.ly/2ENhqwl
Arduino Uno = https://bit.ly/2Sl35eb
Arduino Mega = https://bit.ly/2NNXAD5
Joystick = https://bit.ly/2Sl3eyf
Antenna = https://bit.ly/2EPMls2
Signal Amplifier = https://bit.ly/2IYHOXj
Battery = https://bit.ly/2Cxq9kr
Solenoid = https://bit.ly/2SKavXG
Powerbank = https://bit.ly/2BCGgez
DC Motor = Gözeler Elektronik, Konya Sokak, Ulus, Ankara
Motor driver = https://bit.ly/2EOb1Rf
Omni Wheel = https://bit.ly/2UpvwIO

7. Conclusion

Troy Tech delivers a properly designed product which is compatible with the requirements, within a limited timeframe and economic budget constraints. Our main desire as a company is to provide unique and affordable products with significant functions, durability and performance. In this project, we present a perfectly working robot including unique design marks and precious engineering labor.

The product of our company “Helen V” is designed for a specific project which is briefly described as “designing and constructing one of the two teleoperated robots trying to shoot and score in opponent’s goal”. In this ‘Final Report’, we have explained the final steps of our design journey.

As we mentioned in previous reports, we know our responsibilities and requirements for the design procedure. We made enough progress in the first semester. In the second semester we finalized our product by choosing proper components and required improvements. We built our shooting system and modified movement system after lots of researches and comparisons between different alternatives. We tried to implement the most efficient components to our products. Also, we improved our already-working video transmission system and aimed to obtain one beyond the requirements. In addition, we focused on appearance of our “Helen V”. We did our best while designing our product and locating the components to create an eye-pleasing appearance. Neatness was important in terms of both compact sizes and robust character of the robot.

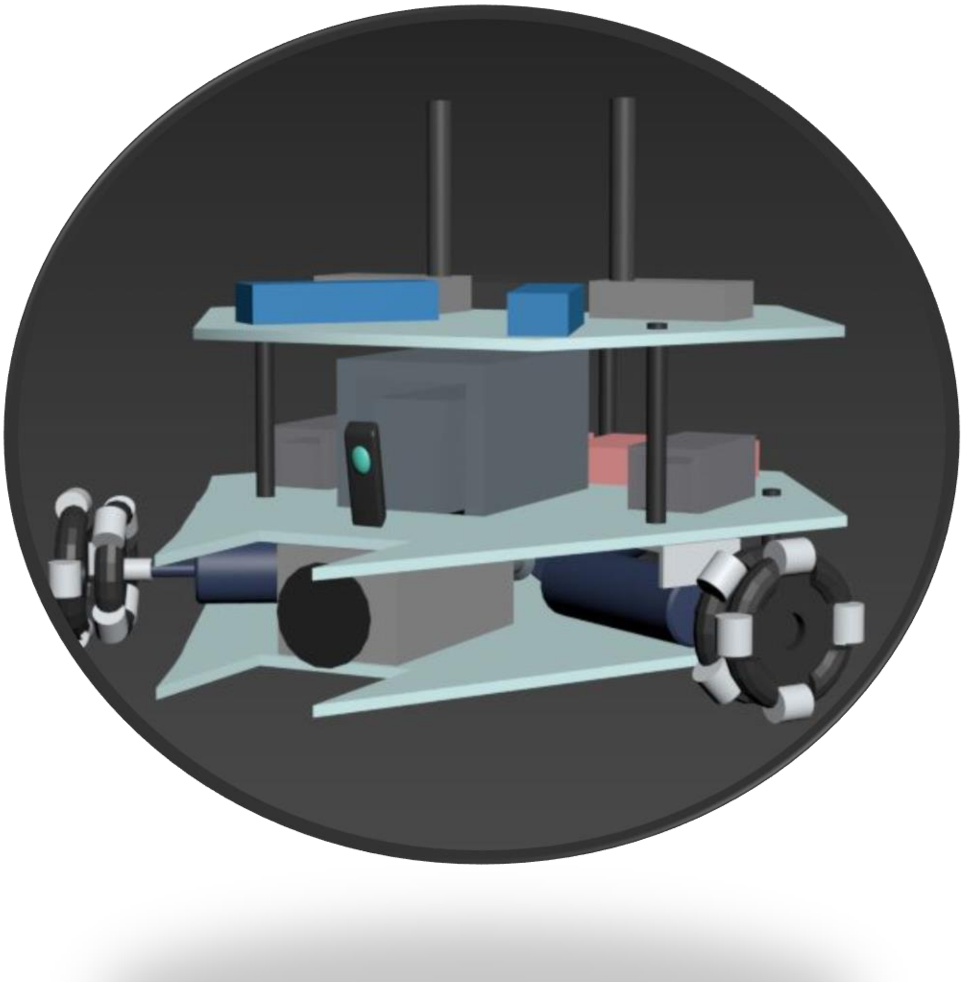
At the end of this eight-month adventure, we feel gratified after proceeding carefully on track of the project to fit the time schedule of the project as planned and launching a successful product. We really believe that the experience of this capstone project is of great value in our engineering careers.

Our team, Troy Tech are grateful for valuable help and support of our advisor Mustafa Mert ANKARALI.

APPENDICES

Appendix A-User Manual

USER MANUAL



HELEN-V

May 10, 2019

Table of Contents

1. What’s inside the box

Your shipping box contains Helen-V (Fig. 1), Eachine ROTG02 FPV Receiver (Fig. 2), a command transmitter module with PS1 joystick (Fig. 3), Artengo beach volley ball (Fig. 4) and charging cables. Remove all items carefully and do not discard your shipping box.

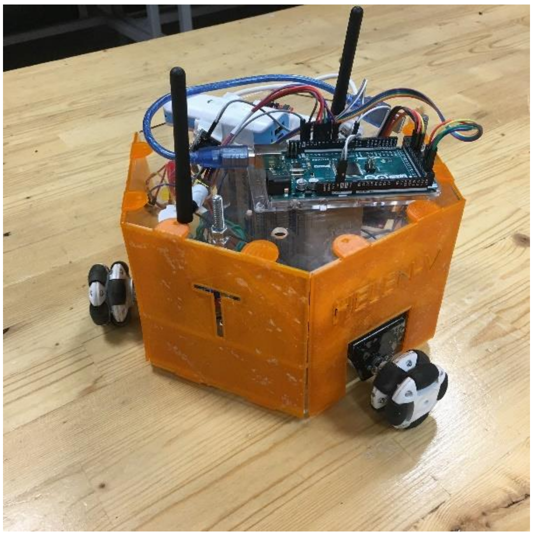


Figure 1. HELEN-V

Figure 2. Eachine ROTG02 FPV Receiver

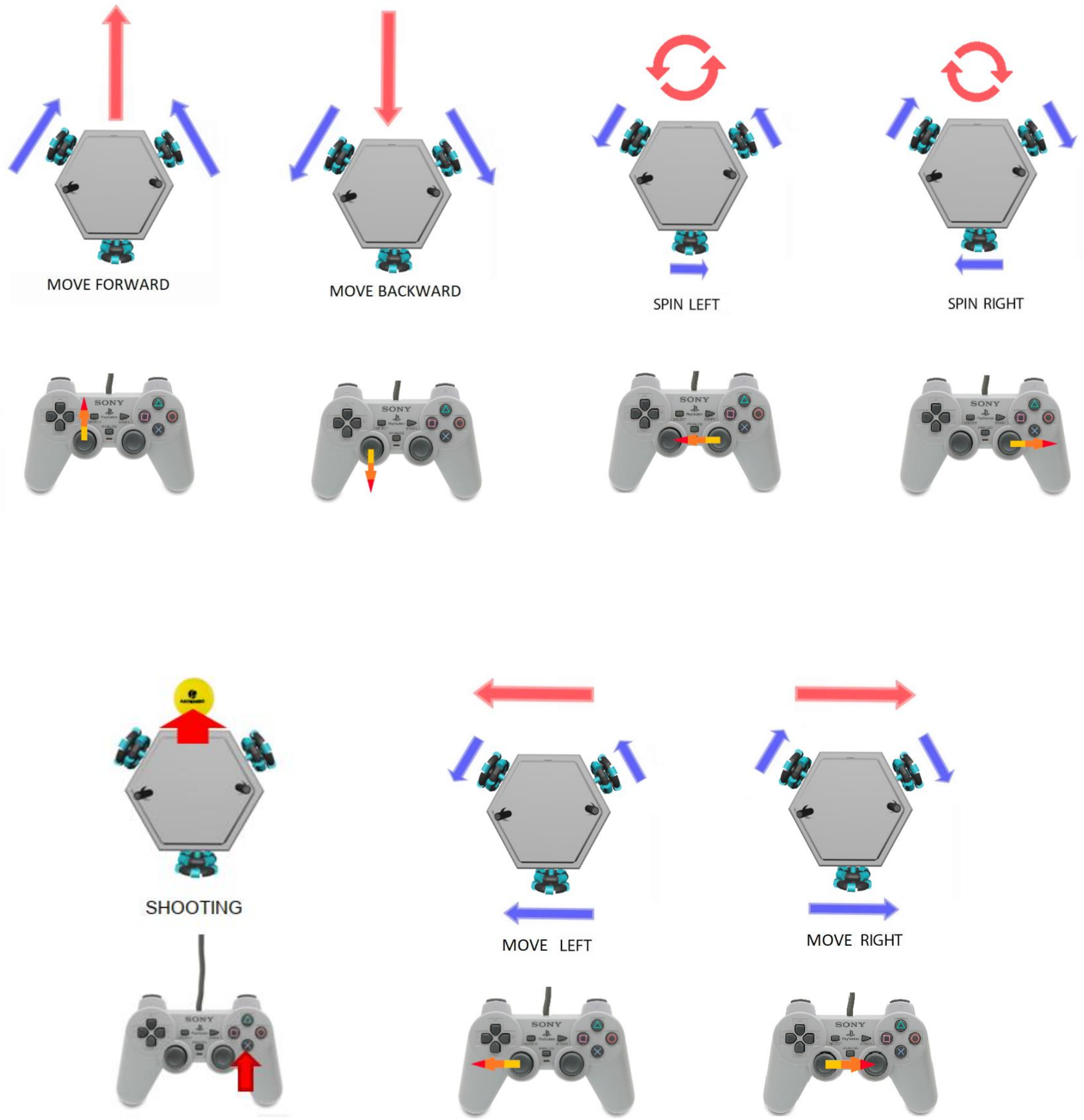
Figure 3. Command Transmitter Module

Figure 4 . Artengo beach volley ball

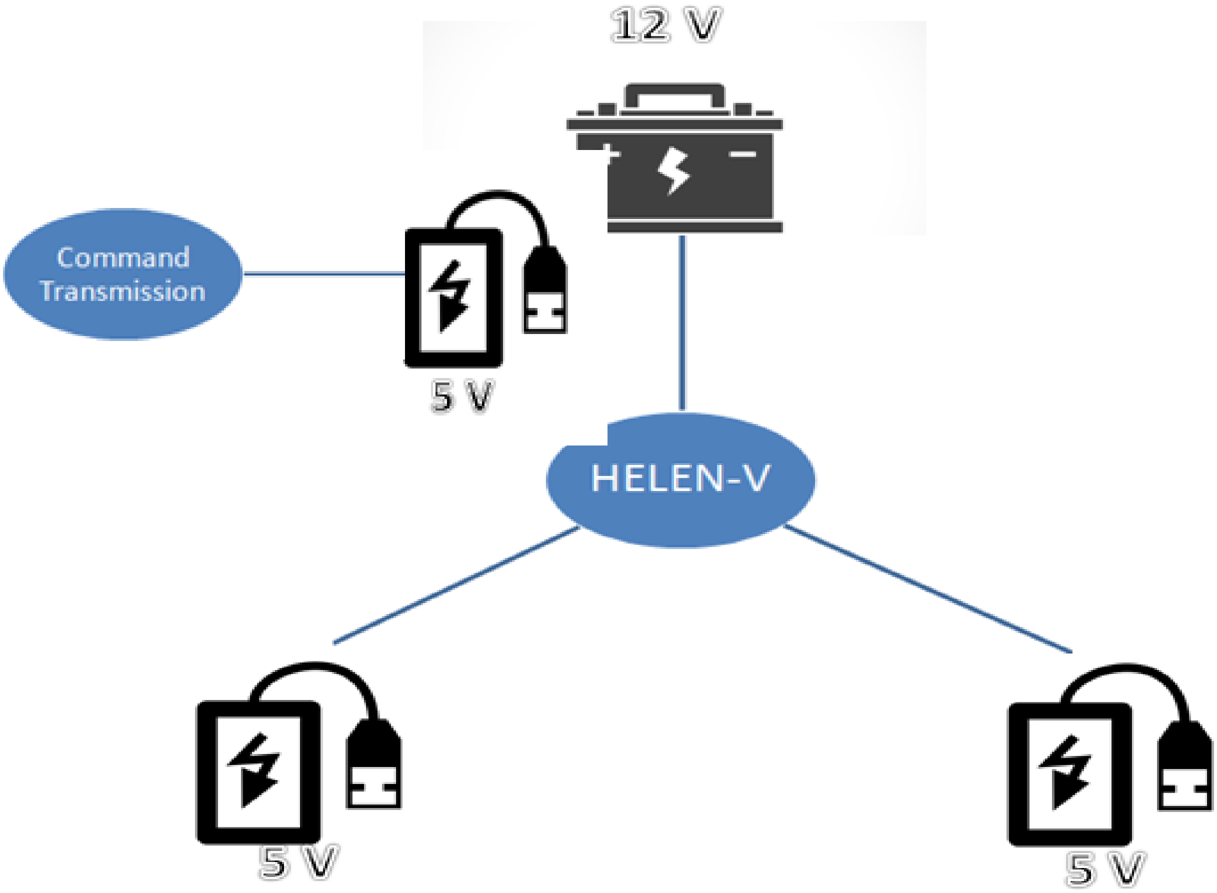
2. Quick Start Guide

1) Install any FPV receiver app to your smartphone /tablet/PC (“GoFPV” is recommended.).
2) Connect “ROTG02 FPV Receiver” to your smartphone /tablet/PC.
3) Turn on HELEN-V and command transmission unit
4) Adjust the channel of “ROTG02 FPV Receiver” by pressing the adjust buttons. If you press any of these buttons 2 seconds, it will automatically set the channel.
5) You can start playing the game!

3. Controls


MOVE FORWARD
MOVE BACKWARD
SPIN LEFT
SPIN RIGHT
SHOOTING
MOVE LEFT
MOVE RIGHT

4. Charging



Helen-V includes 2 power-banks and a 12V (2.8Ah) accumulator battery. Moreover, command transmission system has a power bank. You can charge the power-banks with a simple micro-USB cable. You can charge 12V battery using DC supply or a 12 V battery charging adaptor.

WARNING:

- While charging the 12 V accumulator battery, make sure that other power-banks are switched off.

- Reverse charging is prohibited! Do not reverse the positive (+) and negative (-) terminals when charging the 12V accumulator battery.

5. Care and Maintenance

→Recharge the batteries after each use. Only an adult can handle the battery. Recharge the battery at least once a month when the robot is not being used.

→Store the robot where the temperature is between -20º and 45º C (-4º to 113º F). Don’t leave it in your car, because temperatures in parked cars can exceed this range.

→It does not have a waterproof function, so keep the robot out of water.

→Do not use the robot in loose dirt, sand or fine gravel which could damage moving parts, motors or the electric system.

→ When not using, all the electrical source should be turn off.

→In case of a technical problem, please contact Troy Tech, please do not try to fix the problem by yourself

Appendix B

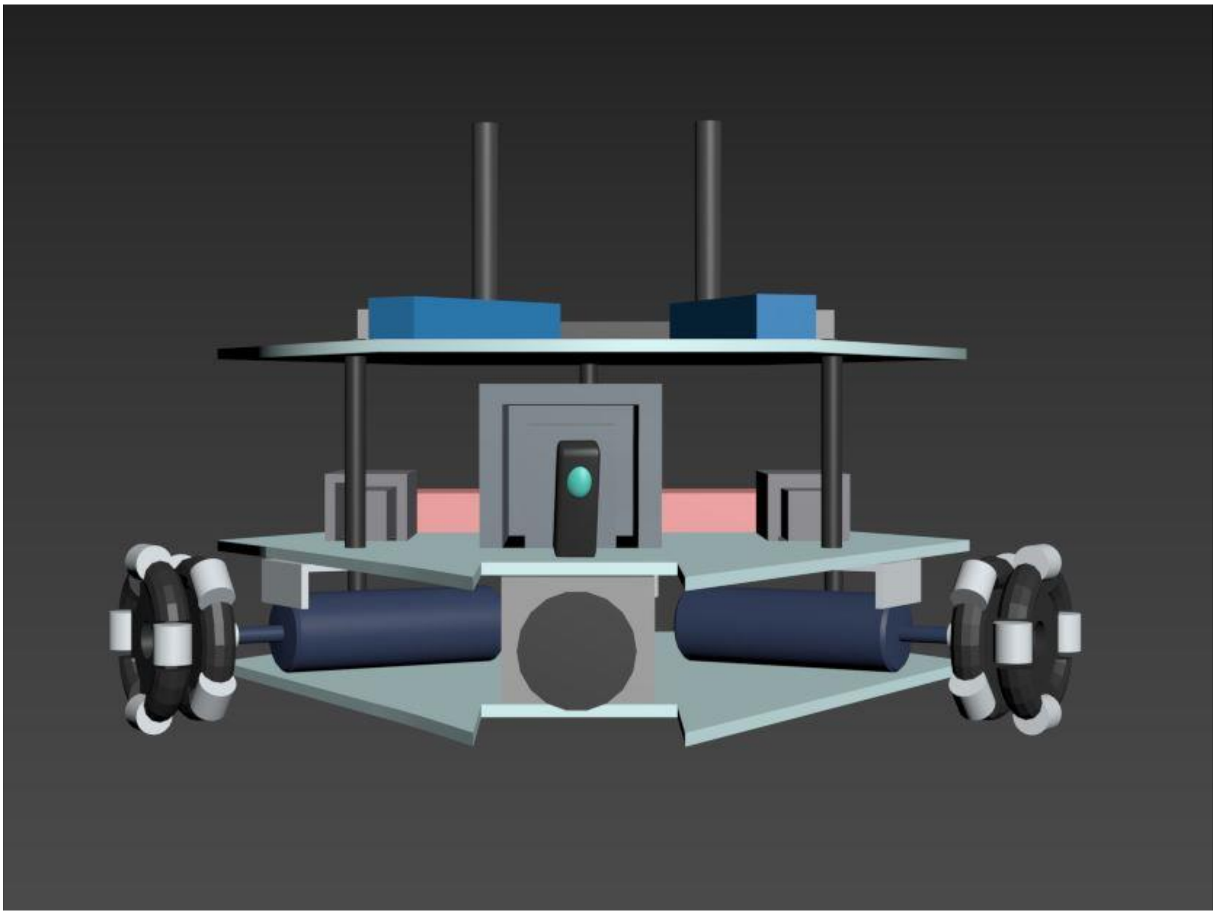


Figure 1: The front view of the robot

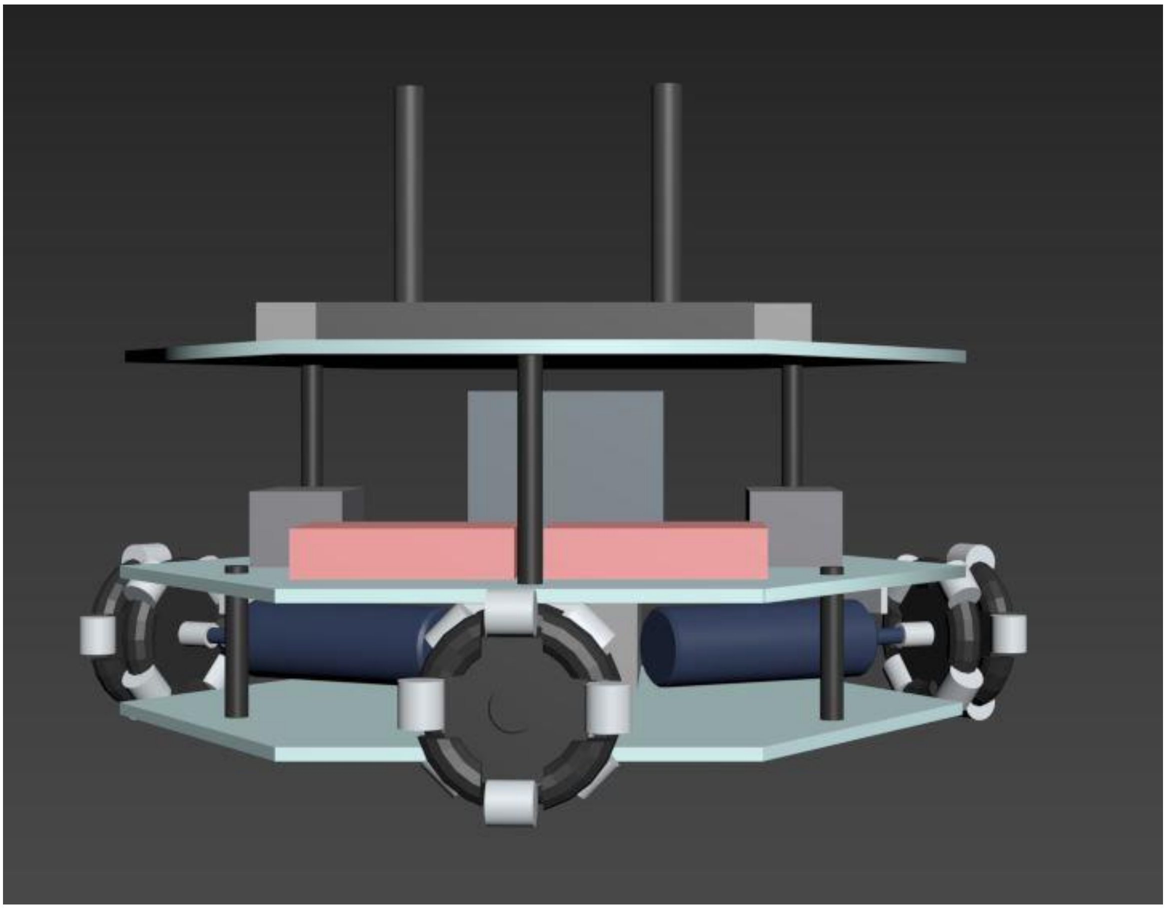


Figure 2: The back view of the robot

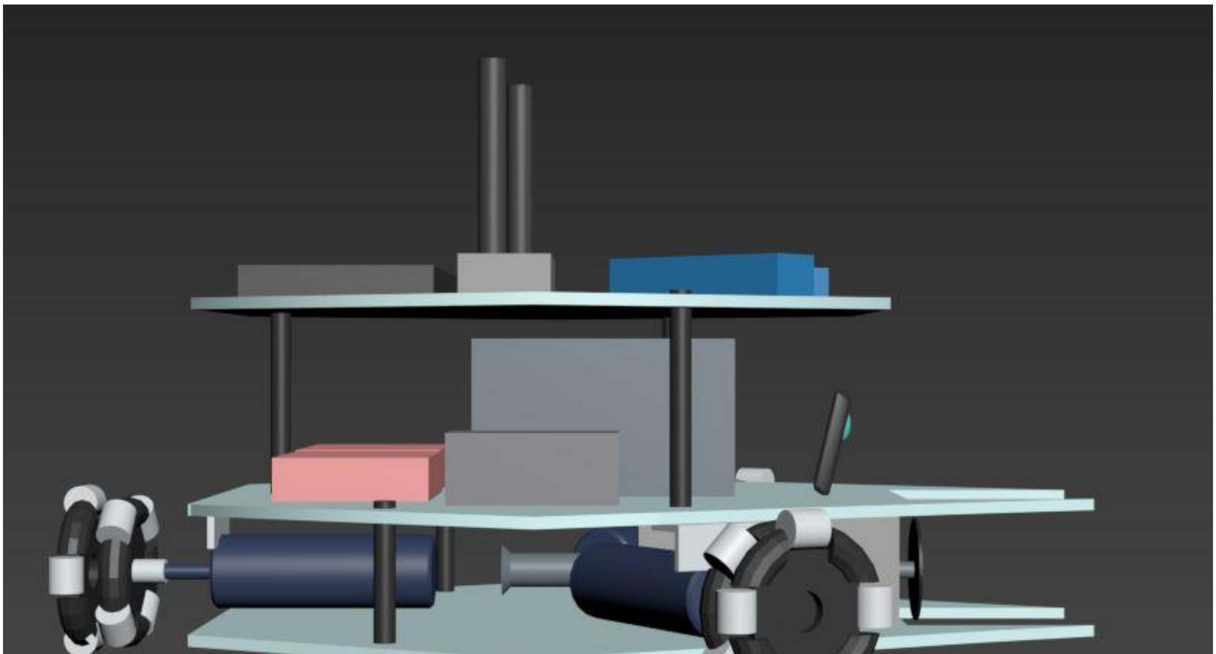


Figure 3: The left view of the robot

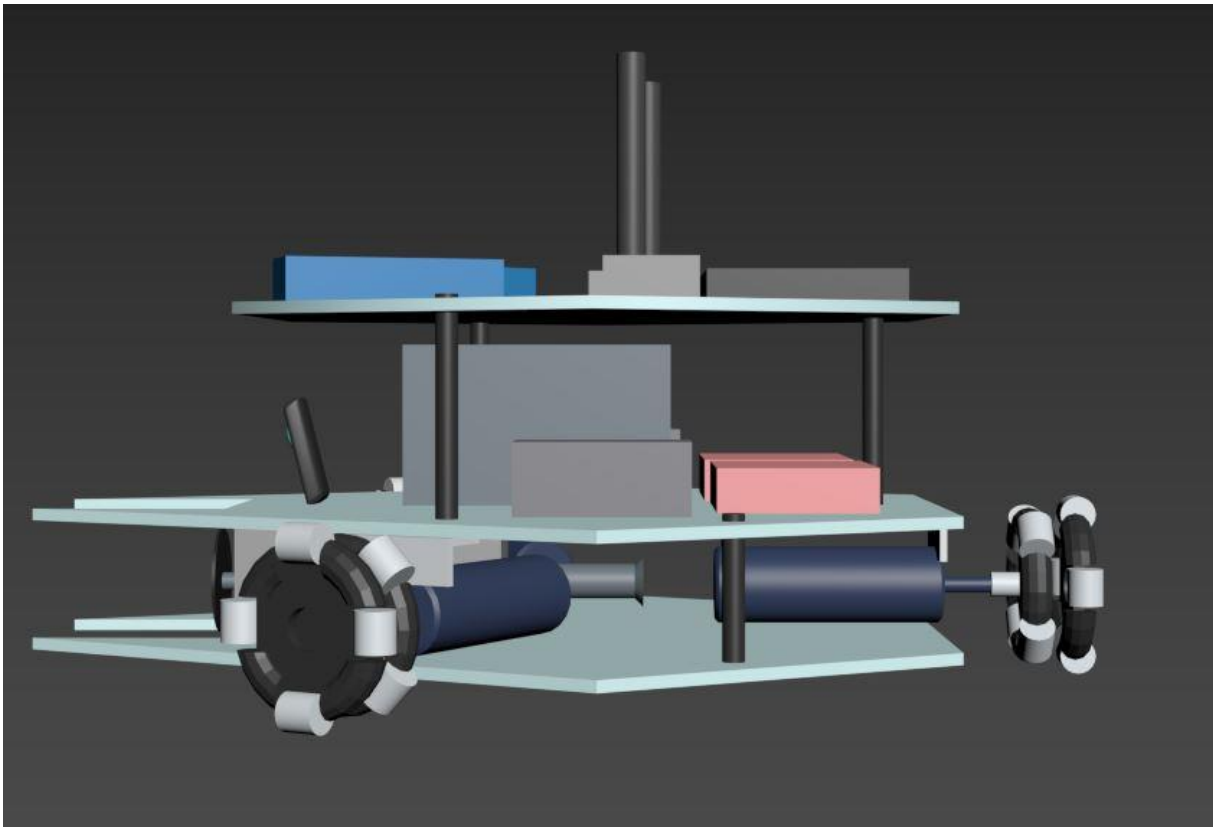


Figure 4: Right view of the robot

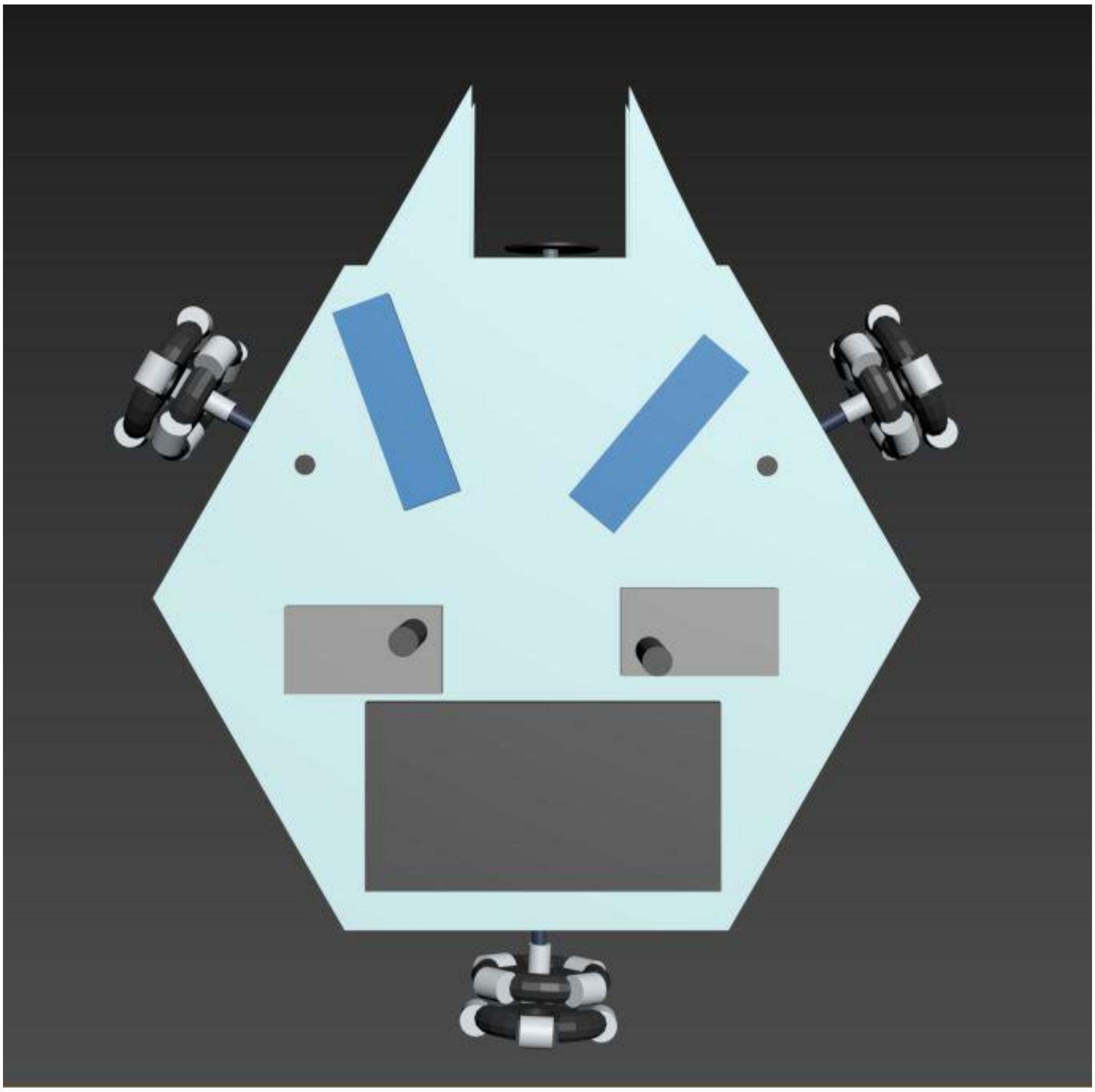


Figure 5: The top view of the robot

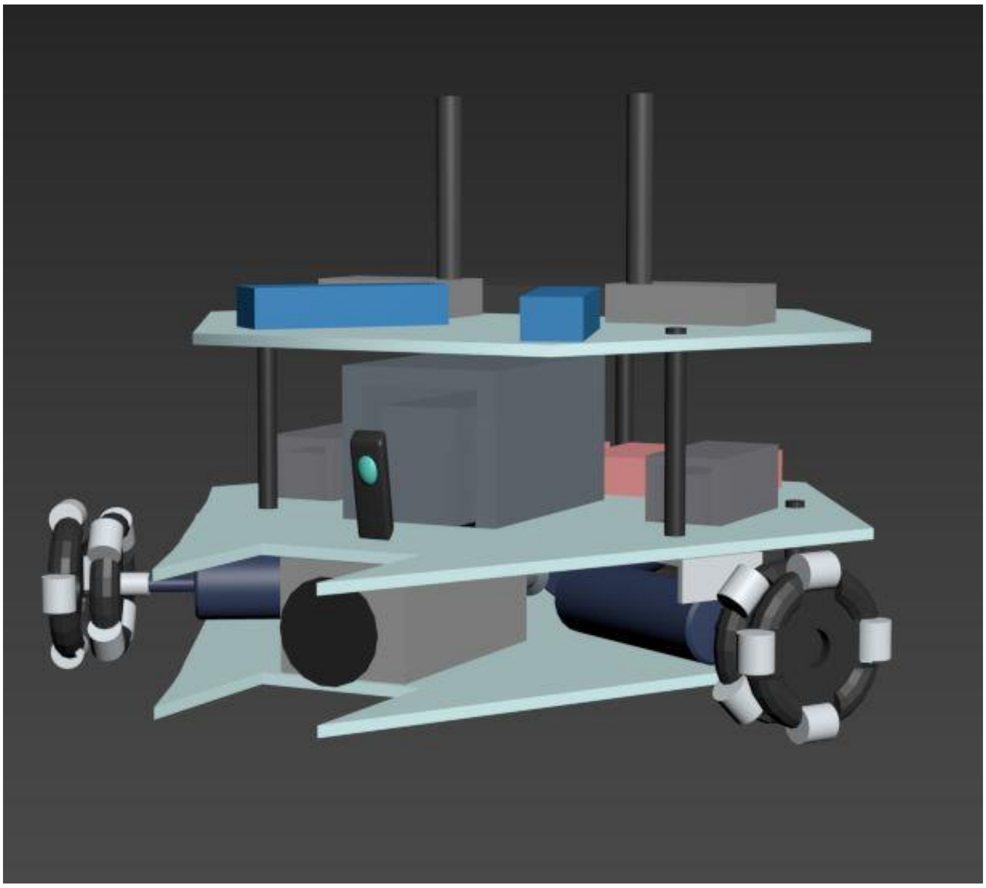


Figure 6: The perspective view of the robot

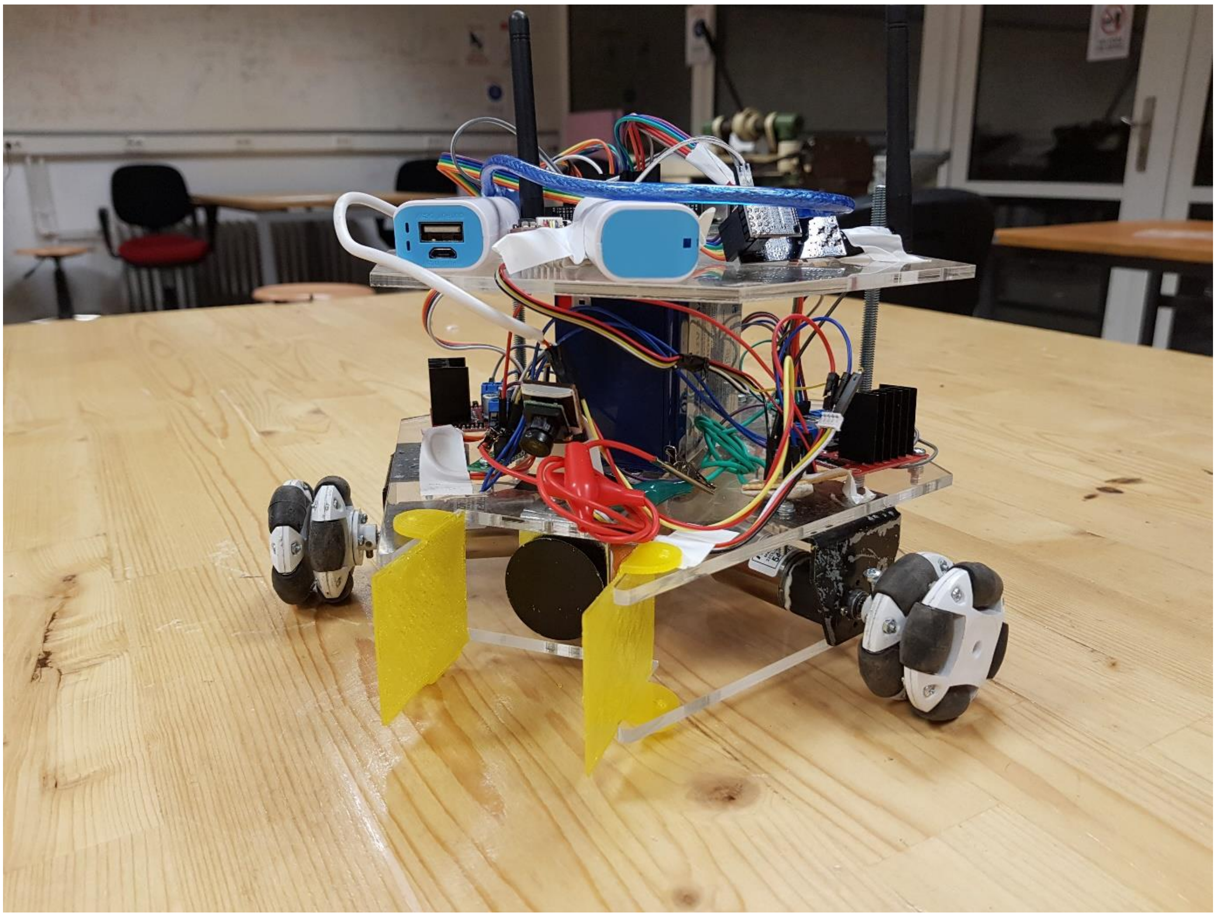


Figure 7: The picture of the robot

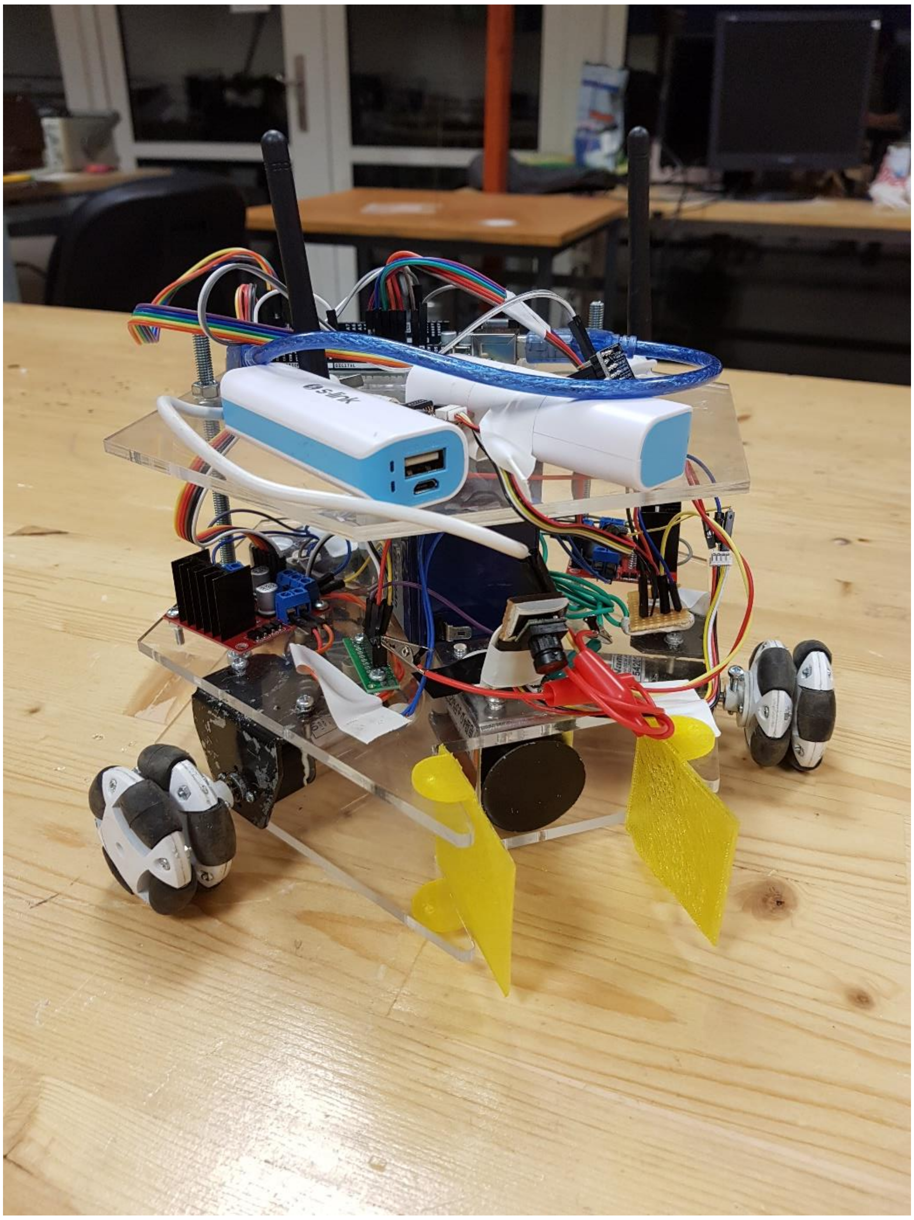


Figure 8: The picture of the robot