Design and Manufacture of the Mopping Floor Robot

ENGD3000 – Individual Project

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Abstract

Nowadays, the demands for cleaning robots are growing rapidly. However, robots that are mopping the floor with water are less frequently in use. In that study, the main aim is to design and manufacture the robot that cleans the floor with water. The robot is controlled via the android application. The android application is connected with the cleaning robot by using a Bluetooth module. The crucial features implemented into the system are a water pump and the rotating mopping system responsible for cleaning the floor and absorbing the water left on the floor. The literature review gives an overview of various approaches implemented in mopping robots to find out how the cleaning robots might be made or what features could be potentially valuable. According to current literature, it is believed that the four-wheel system is more effective in terms of manoeuvrability. With the use of the system Modelling diagrams, the robot's specifications are presented to set the limits and show the potential behaviour of the system. Moreover, some of the electronic component's choices are presented in order to justify the choices. According to executed tests, it has been proved that the designed and built mopping floor robot is working as assumed. The android application controls the robot. Features such as water pump or rotating mopping system can be turned on or off in the android application. Furthermore, the robot is capable of cleaning the student accommodation. Overall, the work of the robot is satisfactory. The possible future improvements such as autonomous mode are described in the future work chapter.

Acknowledgements

Firstly, I am thankful to my supervisor Dr Seng Chong. The guidance and advice of Dr Seng Chong help me get through the whole project. I could meet him whenever I had any doubts about the project. Moreover, he was always eager to provide resources that could help me with the project.

I am also grateful to my parents for being supportive whenever needed. Finally, I would like to thank my girlfriend for her love and support throughout the project. Without all the support I received, I would never be able to complete the project.

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1. Introduction

The demand for cleaning robots grows rapidly. The cleaning robots fulfil our life by replacing humans in repetitive tasks. Understanding the past and previous building approaches expands the perspective, whereby some ideas can be implemented in the project.

1.1 Aim and objectives

To accomplish the project, it is crucial to designate the project's main aim and set the objectives that will help to achieve the outcome. The main aim of the project is to build the mopping floor robot controlled via the android application. Moreover, the robot must be driven in a four-wheel system, i.e. each wheel is programmed and driven separately. The water pump and the rotating mopping system are the features that should have been implemented to clean the floor properly. The objectives are kind of milestones that help to achieve the primary goal. The objectives of the project are as follow:

- Research about past and present of the cleaning robot and implemented approaches (literature review).
- Make a successful connection between Bluetooth module, microcontroller, and smartphone application, in order to control the robot and its features.
- To design and assemble a suitable robot for the student accommodation, i.e. design and build based on an electrical schematic, software design in Arduino IDE environment.
- Robot test to resolve emerging problems and achieve the best efficiency.

1.2 Scope of the project

The project's scope is all the work that needs to be done to achieve the main aim of the project. The work breakdown structure is a part of the scope. The work breakdown structure in appendix B presents tasks and milestones that had to be done to complete the project. Constraints are also a part of the scope. Limitations of the project are mainly described in the requirement diagram in figure 4.1.2.

1.3 Structure

This structure explains what each section is about. The structure of the report is as follows:

- Introduction – Present the main aim of the project and objectives.
- Literature Review – Review the academic research and technical approaches of past and present cleaning robots.
- Methodology – Justification of how the project had been carried out.
- Specification & Design – Explanation of design choices. Explanation of how the system is designed in terms of its specification, limitations, dynamic behaviour and electrical schematic.
- Implementation – Describe the most critical operation of the system. Also, it specifies problems that occurred during operations and how they have been overcome.
- Results and Evaluation – Comprehensible and critical evaluation of executed tests and the robot work.
- Future Work – Present the ideas that have grown during the project. Provide the starting point to potential future improvements.
- Conclusions – Summary of the whole project. The section describes what has been achieved and the critical evaluation of the project.

2. Literature review

2.1 Background

The idea of replacing household duties is not a discovery. People have always been striving for an easier and more comfortable life. One of the tasks that have been not successfully replaced is mopping. The first steps in that field had been made in the late 1980s [1]. Since then, much progress has been made; however, robots are not on a daily basis yet. That means that there is still space for improvements to make robots more user-friendly and easy to access.

This chapter will discuss things such as the benefits of using mopping robots and existing mopping robots. Cleaning robots have a wide range of applications; they can be used either in households or in different areas such as warehouses or train stations. Japanese railway companies developed a cleaning robot. The cleaning robot could clean different areas, for instance, brick, wooden, and carpet floors. The robot was using ultrasonic sensors, the distance between the robot and obstacle was constantly detecting. What is more, the machine was able to reach the charging station whenever needed. Due to that, the human factor is even less because the robot works independently, and it only requires attention in case of maintenance [2].

2.2 Four wheels approach

Engineers have applied different kinds of methods while developing cleaning robots. Most of the cleaning robots use a two-wheel; however, the four-wheel system has its benefits. By controlling the cleaning robot with four wheels independently, the user can have higher control of the robot. The cleaning robot increases its possibilities in terms of changing direction as well. Furthermore, using four wheels increases manoeuvrability; hence the robot can clean hard-to-reach places [3].

2.3 Bluetooth module

The Bluetooth module is a powerful component, and in combination with a microcontroller such as Arduino Uno, it can control a system or components remotely. An excellent resource to manage a Bluetooth module is an android application. Using the existing applications or by programming in C++ (e.g.in the MIT app inventor), the Arduino can control any connected device [4]. The range of possibilities is enormous. Most of the robots are autonomous and navigate on their own. However, using Bluetooth capabilities, the robot can be controlled either via voice or by the user.

2.4 Flexible application

The benefits coming from using the cleaning robot are crucial, especially nowadays. It is a massive advantage of robots in that they can quickly adapt to different environments and situations. The robot, which the app can control, reduces the number of people required to clean specific areas. In that situation, the remote cleaning robot is an excellent solution. Robots can be modified to user needs. It means that the cleaning robot can be equipped with specialized cleaning agents. Furthermore, it is challenging to maintain hygiene in a high-risk area; however, the cleaning robots could minimize human interaction in desired areas [5]. Radioactive areas were always a concern for humanity. One of those places is a fuel development facility in South Korea. A highly radioactive zone exists in such a place, where people cannot enter without a hazmat suit. However, radioactive places have to be cleaned and decontaminated. The cleaning robot is a perfect solution because the robot can remotely decontaminate a contaminated floor [7]. Therefore, the cleaning robot is eliminating human interaction with radioactive contaminants.

2.5 Different approach

Most of the cleaning robots are autonomous, and it is working correctly. Nevertheless, some places are potentially dangerous for the robot. Hence the robot needs to be under human control. Some of the common areas, especially stairs, are dangerous for the robot because some of the machines might not detect the gap between the surface and stairs. Moreover, in outdoor areas or warehouses, we can find places where the wires might not be adequately isolated. If the mopping robot faces such a difficulty, it could damage the robot, or a short circuit may happen. Those situations present that not an autonomous robot but controlled by the user can find its application. A good approach includes both modes: autonomous and controlled manually via android application [6].

2.6 Similar existing robots

2.6.1 HOTBOT

Mopping robots are not supposed to be always an expensive purchase. In Malaysia, the mopping robot called “HOTBOT” was first designed and then developed and tested [8]. The main aim of that robot was to work autonomously and to be economical. Well-written code is a priority to make the economic robot. The robot is relatively small in terms of dimensions. The main body has a tubular shape with a diameter of 375mm, and the height is 250mm. It is not an ideal optimization of its size, and the appearance could be modified to attract a potential user. However, it has to be considered that the robot is not as expensive as it could be. The robot has a lead-acid 12V battery to power up other components such as the microcontroller, water pump, or dc motors. The robot has two dc motors next to each other and one on the front. Due to the height of the robot, adding an extra wheel might be a good idea. The cleaning robot with four wheels is more stable and less susceptible to unexpected difficulties faced during cleaning. Furthermore, the robot is equipped with a roller, responsible for cleaning and absorbing the water. Using only one roller might be less efficient than using two in that case. It is less likely to miss the dirt spot because two rollers have a more comprehensive range of cleaning and the absorption of the water increases. The significant improvements implemented in the robot are the features. The robot is capable of informing a user as soon as the battery charge level, water temperature, or the water level is beyond a certain level. Such features help the robot become more economical and avoid the situation when the reservoir is empty, which can potentially damage the water pump or the robot. The robot is programmed to follow a particular path. It is a good option if the user is cleaning the same area. The disadvantage of that solution is that the user cannot navigate the robot. If a sudden situation occurs, such as an uninsulated hanging wire, it might interact with the water what could cause damaging the cleaning robot.

2.6.2 Multifunctional cleaning robot

One of the main problems faced in the cleaning robot industry is associated with the fluid left out on the floor. The fluid which is not entirely pumped back or absorbed can damage the floor. The researchers from Soochow University designed, built, and tested the mopping robot prototype [9]. They applied a new approach to this problem. Adding an extra sponge on the back of the robot increases the absorption of the water; hence, the liquid does not remain on the floor. It is more effective while the mopping robot is working and using two wipes instead of one. The problem that may occur is a soaked sponge. It may happen when the sponge absorbs too much water; hence, the water will remain on the floor. To avoid such a situation, the geometric parameters of the sponge should have been calculated. The use of the most absorbing wipes might have a crucial influence on the effectiveness of the cleaning robot. The performance of the mopping module had been tested experimentally. The floor was clean and dry without fluid spots. Researchers proved that the use of a second sponge has a positive impact on the dryness of the cleaned floor.

2.7 Summary

The analysis of existing literature is vital to understand how the existing cleaning robot's work. Furthermore, it reveals the advantages and disadvantages of mopping robots. Most of the cleaning robots are using two wheels. Researchers had been successfully proved that four wheels could achieve high manoeuvrability [3]. Four wheels system is more stable; hence the robot is capable of cleaning more complex areas.

The Bluetooth module connected with the microcontroller such as Arduino is an excellent solution to control the robot [4]. Nowadays, programming is becoming more common, whereby it is less complicated either to write the code or find the existing samples of the code. The capabilities of using Bluetooth module and microcontroller are powerful. By using those components, the robot might be controlled according to the user needs, starting with the voice control and ending on autonomous control.

Robots find their application in various fields. In hospitals, it is essential to reduce human interaction in undesirable places [5]. What is more, the cleaning robots might be equipped with specific special agents. For this reason, the cleaning process is done thoroughly and without human contact. Another example that confirms the usefulness and flexibility of the cleaning robots is the radioactive areas [7]. People should always avoid radioactive places, even though it is sometimes difficult. The mopping robot is an excellent solution for radioactive areas. Without human interaction, the robot can decontaminate the highly radioactive zone.

The cleaning robots are mostly autonomous. As a consequence, they could face a problem during the cleaning process. Not every autonomous cleaning robot has a built-in sensor to detect obstacles. Hence, the robot might fall into a pit, or during the cleaning process, the water may interact with electric wires, what could damage the robot. The solution for that difficulties might include implementing the extra mode to allow the user to control the robot manually [6].

An attempt to make a cleaning robot "HOTBOT" had been made in Malaysia [8]. The robot is economical, and the manufacture is not expensive. The HOTBOT works autonomously and has a lot of valuable features. The robot indicates if the water in the reservoir is beyond a certain level. However, the robot uses three wheels, and it can cause instability during the cleaning process, especially on uneven floor.

Another attempt had been made at the Soochow University. The main research problem was that fluid is likely to be left out after the cleaning process. By adding a sponge to the back of the robot, the water could be absorbed. The experimental data illustrate that the sponge is doing its work correctly [9]. After the cleaning process, there is no water on the floor, and everything is absorbed in the wipe. The problem that may occur is associated with the volume of the sponge. The very wet sponge during the mopping process might not absorb water at all, and it can damage the floor. The capacity of the sponge should be appropriately calculated to avoid cleaning the floor with a wet sponge.

3. Methodology

The methodology section depicts how the work is carried out, i.e. what techniques had been used to reach specific goals and aims. Before building the cleaning robot, it is an excellent approach to research about similar products. By doing research, the developments can be found and applied to the design. First of all, the current literature had been reviewed to understand better the concept of cleaning robots. Moreover, the research enables us to see the whole project from different perspectives. The DMU library was the leading resource for searching various articles about cleaning robots.

The diagrams are an excellent method to present the design from various perspectives. To create the diagrams, the visual paradigm software has been used. In that program, four diagrams were created:

1. The Use Case Diagram presents the interaction between the user and the robot interface.

2. The Requirement Diagram specifies the requirements of the project.

3. The Activity Diagram presents the system's dynamic behaviour from any point and shows how some of the components interact with each other.

4. The State Machine Diagram presents the implemented algorithms and describes steps and transitions that can be made in the robot controller.

All of the diagrams presented above have a significant impact on the project. It enables to define and limit the specification of the robot. What is more, the applications of diagrams provide a complete understanding of the decision that had been made and explains the system behaviour. To summarise, the diagrams save time because they give the perspective and set the limitations of the design of the robot.

The report provides a description of certain electric components. The idea for that is to explain why a specific model or component has been used. By preparing the list of the main component earlier, it assures that the component will interact and cooperate. It is highly advised, especially in programming, where libraries, e.g. Arduino IDE software, are essential.

KiCad software (section 4.2.4) was used to create and design the electrical schematic of the robot. Before the building process, it is an excellent approach to design the electrical schematic. It might have some modifications during the building process; however, the schematic during the building process gives more assurance that the components are connected correctly; hence it will not damage the components. The programming is less demanding when all the hardware is connected correctly.

When the robot is designed and assembled, the results and evaluation of the result are essential. It is an excellent approach to describe the faced problems and how they had been overcome. Furthermore, the evaluation of the robot enables us to see what requirements and aims have been achieved and what has not. None of the projects is perfect; hence it creates the path for future improvements of the project.

4. The specification & design

4.1 Use of diagrams to explain design & specification

4.1.1 Use Case Diagram

Use Case Diagram delivers information to the reader in a more pictorial way. There are plenty of different kinds of diagrams. Different diagrams are an exceptional technique to present the product from a different perspective and provide a better understanding of the product. In the figure 4.1.1, there is shown a use case diagram. It presents the interaction between the user and robot interface. Figure 4.1.1 explains how the user can connect with the robot and what alternatives can be found in the menu. According to figure 4.1.1, features such as a water pump or rotating mopping system could be on or off simultaneously or separately. The use of the Use Case Diagram is crucial. This particular diagram helps during the building and programming process by determining the limitations implemented in the robot. Moreover, it clearly shows what options the user can access.

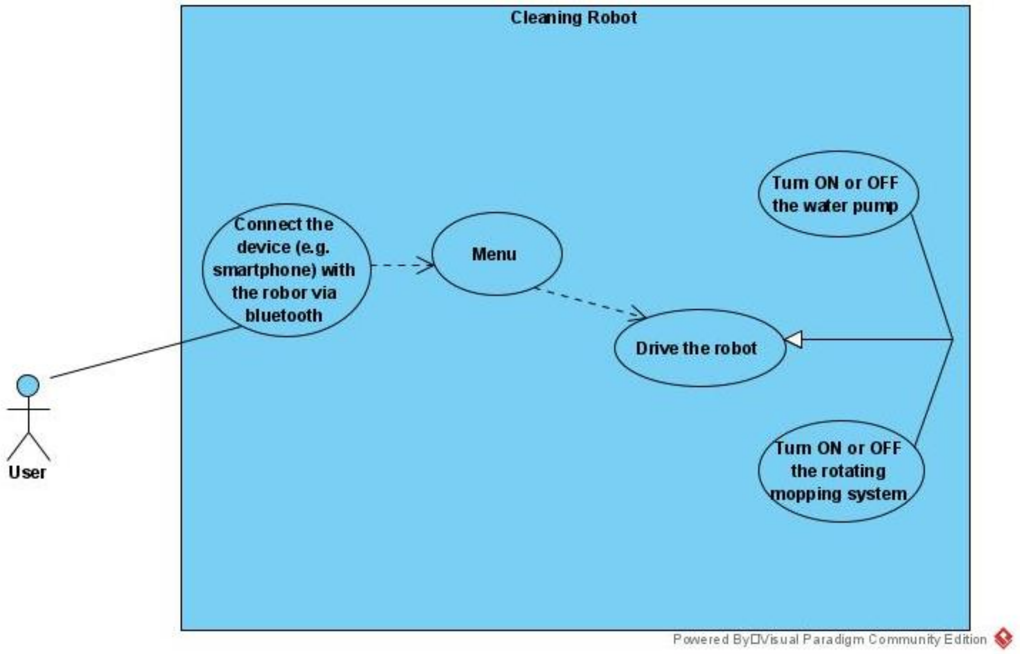

Figure 4.1.1: Use Case Diagram

4.1.2 Requirement Diagram

The requirements and specifications of the robot are one of the most significant concern before the building process. Those things present how the system behaves and determine its assumptions and limitations. The requirement diagram in figure 4.1.2 is a bit more complex diagram; also, it shows the final requirements and limits. The diagram is divided into five subsections: functional, performance, interface, constraint, and others. The functional section specifies what assignments and activities the robot should have been able to achieve. The performance section is responsible for describing how the system (i.e. cleaning robot) is likely to be operated. The interface subsection refers to the robot and the human interaction. In the constraint section, there are included robot's restrictions and project limitations, such as budget or size. The last section, the others, might include a piece of various information dependently on the needs. In this project, the other section shows the recommended safety requirements in order to avoid damaging the robot.

One of the sections in the literature review describes the four-wheel system. According to the requirement diagram, it can be spotted that a four-wheel system has been implemented into the mopping robot. This kind of driving system expands the ability to change direction and increases manoeuvrability [3]. Moreover, in the figure 4.1.2 interface section, it can be seen that the remote control of the robot has been implemented. The cleaning robot is controlled via the android application. According to the literature [6], this type of control has its benefits. When the user controls the robot, it reduces the chances when the robot faces a dangerous situation. What is more, the mopping robot could be controlled to the user wishes.

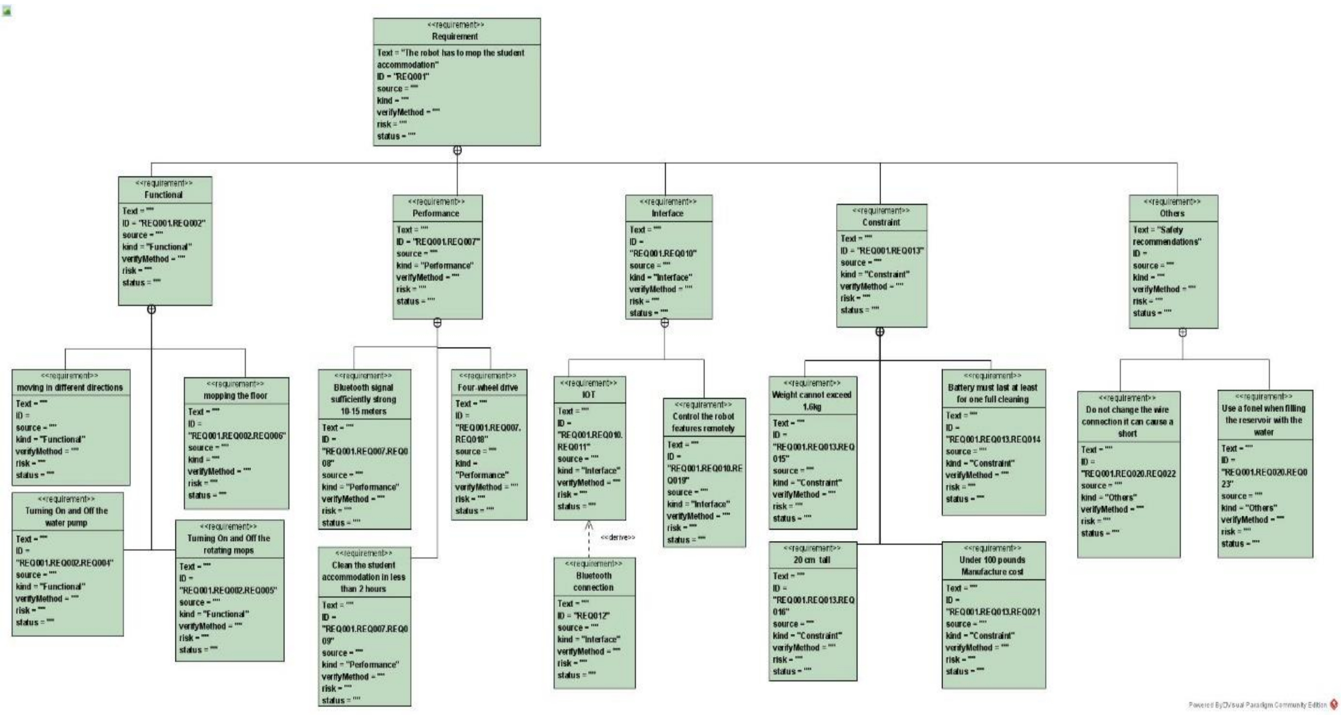

Figure 4.1.2: The Requirement Diagram

4.1.3 Activity Diagram

The activity diagram illustrates the system's behaviour and refers to the final Use Case Diagram (Figure 4.1.1). The difference between the Use Case Diagram and the Activity Diagram is that the Activity Diagram depicts what causes the particular activity. Moreover, the Activity Diagram in the figure 4.1.3 illustrates the workflow and concurrent tasks. In the figure 4.1.3, it might be seen that different actions might happen; for instance, if the robot controller is not going to connect with the robot, the action is not going further. As mentioned above, the Activity Diagram depicts the system's behaviour; an example of that can be seen below. When the user needs to turn on the water pump, the water pump is actuating, and the diagram illustrates what flows in that particular step: signal and power. To summarize, the Activity Diagram shows the system's dynamic behaviour from any point and defines what causes the flow in the system.

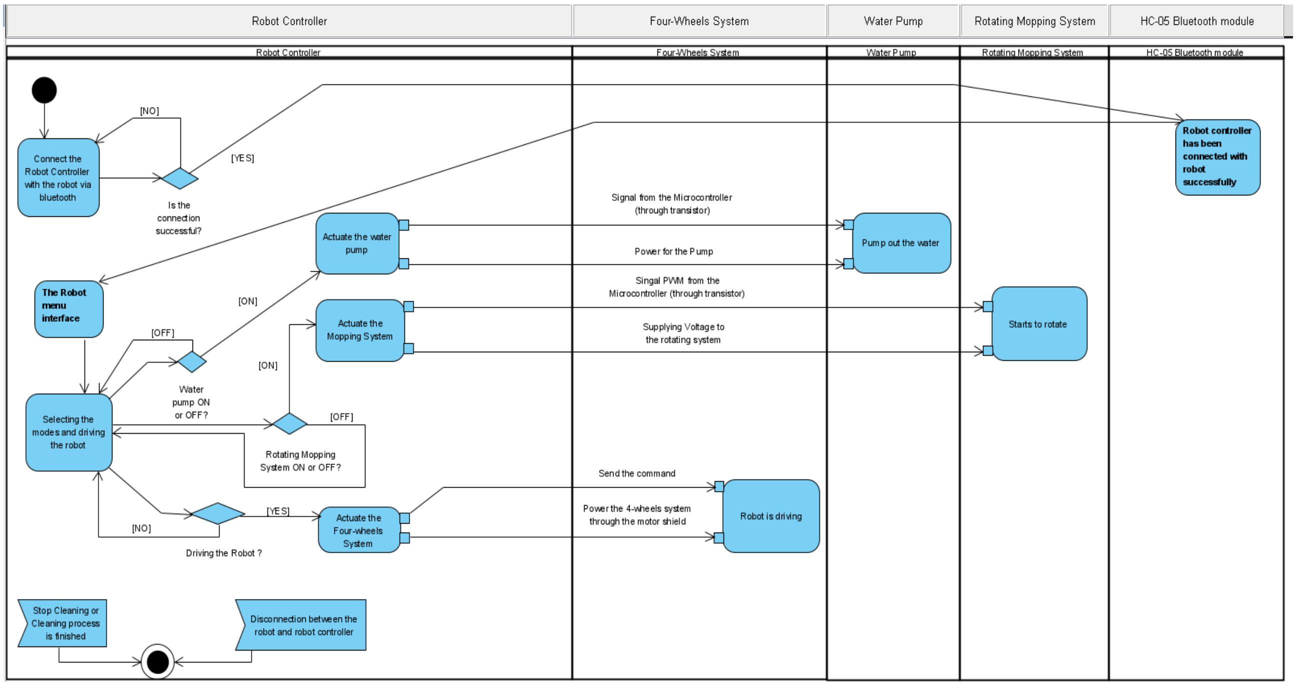

Figure 4.1.3: The Activity Diagram

4.1.4 State Machine Diagram

Understanding how the cleaning robot is programmed and how the user can control the robot is beneficial. The software of the cleaning robot was developed in the Arduino IDE environment; however, showing the whole code might be confusing and incomprehensible for the reader. The state machine diagram in Figure 4.1.4 explains all of the things above in a more transparent way. Firstly, to get control over the robot, the battery must supply the voltage to the robot, then the connection can be made via the android application. The android application sends and receives specific commands to the microcontroller. Those commands in figure 4.1.4 are replaced with simple transitions such as ‘Press the button to turn on or off the water pump’ to presents alternatives. When the robot controller menu has been opened, the user has a few options: driving the robot, turning on or off either the water pump or rotating mopping system. It is crucial that those actions can be done concurrently. Hence, when the robot is driving, the rotating mopping system can operate simultaneously. Furthermore, tasks such as turning on or off the water pump or rotating mopping system are assigned to the one button, i.e. one button is turning on and off the water pump, and the second one is turning on and off the rotating mopping system. To sum up, the State Machine Diagram in figure 4.1.4 explains algorithms implemented in the robot and presents how the robot can be operated in a more apprehensible way.

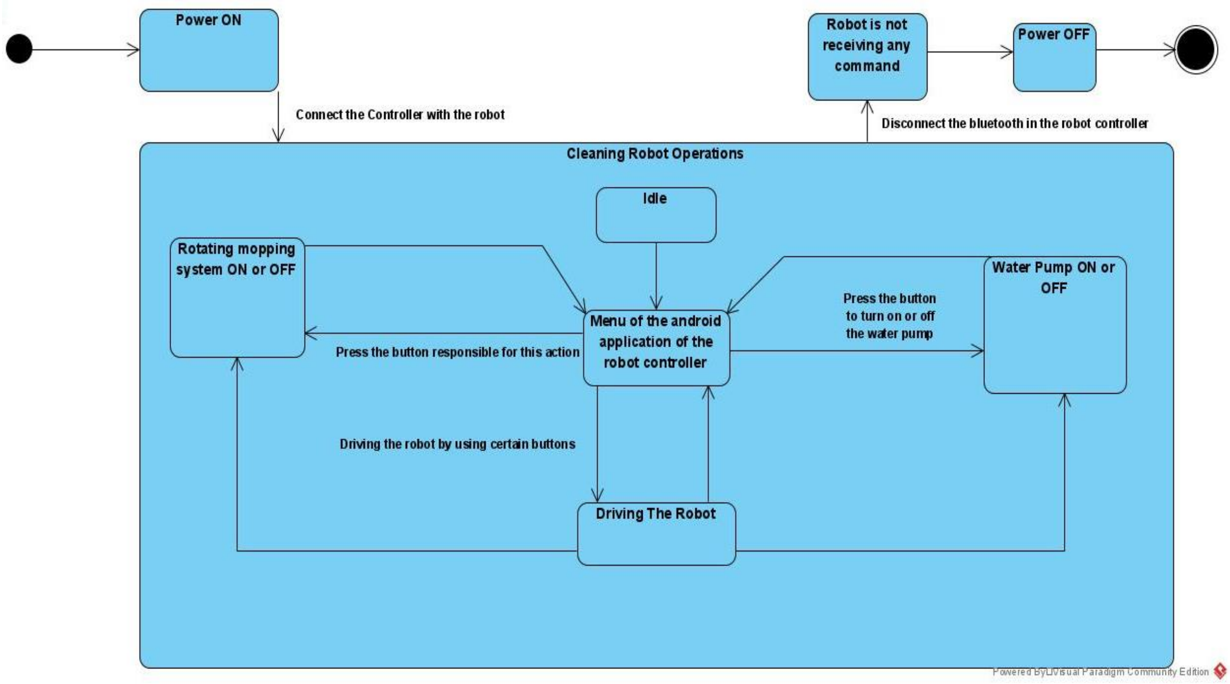

Figure 4.1.4: The State Machine Diagram

4.2 Electrical and electronics components

4.2.1 Microcontroller

The microcontroller Arduino Uno (figure 4.2.1) was selected in combination with Motor Shield L293d (section 4.2.2) to control the mobile cleaning robot. The main reason for choosing this certain board is that the microcontroller might be stuck together with the motor shield L293d; hence it saves some space and creates possibilities in the coding field. Besides, the Arduino Uno board has plenty of various input and output pins (table 4.2.1) [10]. Additional benefit coming from this board are PWM outputs. In that project, some of the components, such as rotating mops, are using PWM outputs. By using PWM output, the speed of the connected component might be controlled according to the needs. The vast libraries availability was also taken into account during the selection of the microcontroller. All of the above features convinced me to choose the Arduino Uno board.

Figure 4.2.1: The microcontroller Arduino Uno [10]

Microcontroller	Atmega328P
Operating Voltage	5 V
Recommended Input Voltage	7-12 V
Input Voltage Limits	6-20 V
Analog Input Pins	6 (A0-A5)
Digital I/O Pins	14 (6 x PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5KB Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

Table 4.2.1: Arduino Atmega328P specification [10]

4.2.2 Motor shield

The motor shield L293d in figure 4.2.2 had been selected for this project due to capabilities flowing from the connection between chosen microcontroller and motor shield. One of the shield features is that it can drive four DC motors; consequently, pins such as 3,4,5,6,7,8,11,12 are in use [12]. Nevertheless, there are still free pins that can be used for the user needs, for instance, water pump, rotating mops. The supply voltage range is from 4.5 V – to 36V DC (table 4.2.2), so the range is entirely sufficient because the external power supply used in the project is 12V. The motor shield has four H-Bridges; hence the chipset provides 0.6A (1.2A Peak) current per each bridge with thermal shutdown protection [11]. What is more, the shield is equipped with the pulldown resistors. Due to those resistors during power-up, the motors are off, otherwise short might occur. To sum up, the shield L293d was chosen over other models due to its capabilities combined with Arduino Uno; also, the features such as built-in pullup resistors and the current capacity were crucial.

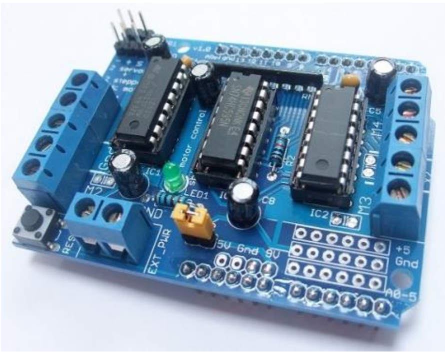

Figure 4.2.2: The Arduino motor driver shield [11]

Type	L293D
Supply Voltage	4.5 – 36 V DC
Output current per channel	600 mA
Peak Output Current	1.2 A
Input Voltage	7 V
Other Important Features	- Can drive up to 4 DC motors, 2 Servo’s motors or 2 stepper motors - Speed selection for 4 DC motors

Table 4.2.2: Arduino Atmega328P specification [11]

4.2.3 HC-05 Bluetooth module

Bluetooth module is one of the most essential components in this project. The Bluetooth module sends and receives the data from another device with built-in Bluetooth, for instance, a smartphone [13]. The HC-05 Bluetooth module (figure 4.2.3) had been selected for this project due to its functionality with the microprocessor. Moreover, the connection between the Bluetooth module and microprocessor might be a demanding task; however, the guide can be undoubtedly found due to its popularity. Hence, the wireless connection between the system and the robot becomes less complicated. The exciting feature is shown in table 4.2.3; the wireless connection range is approximately 10 – 15 metres in practice; this range is sufficient for student accommodation. The functionality of the microcontroller and other features of the Bluetooth module convinced me to choose this particular model; the availability and cost were advantageous.

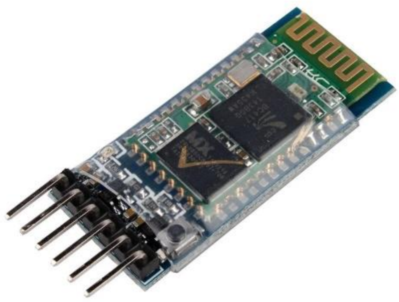

Figure 4.2.3. HC-05 Bluetooth module [13]

Type	HC-05
Operating Voltage	4 – 6 V (Usually +5V)
Operating Current	30 mA
Range	< 100 m (10 – 15 m in practice)
Other useful features:	- Can be operated as a Slave, Master or Slave and Master modes - Easily connection with Laptops, Smartphones

Table 4.2.3: The HC-05 Bluetooth module specification [13]

4.2.4 The electrical schematic

The electrical schematic in the figure 4.2.4 presents the connections of the cleaning robot. There are connections of all of the components on the schematic, such as Arduino Uno fitted into the motor shield, rotating mops, Bluetooth module, water pump, and four wheels connected to the motor shield. What must be noted is that, on the schematic, the Motor Shield A1 is not fitted to Arduino Uno; however, it is caused by software limitations and clearness of the whole schematic. In reality, the Motor Shield and Arduino Uno are stacked together. The indication external power supply 12V or just +12V means that this is connected to the lead-acid battery 12V. The power supply supplies the microcontroller and other components; hence, it drives the DC motors (wheels). The battery of 12 volts is sufficient for this project. Furthermore, due to battery voltage, the robot might include future improvements such as an additional servo motor without changing the power supply.

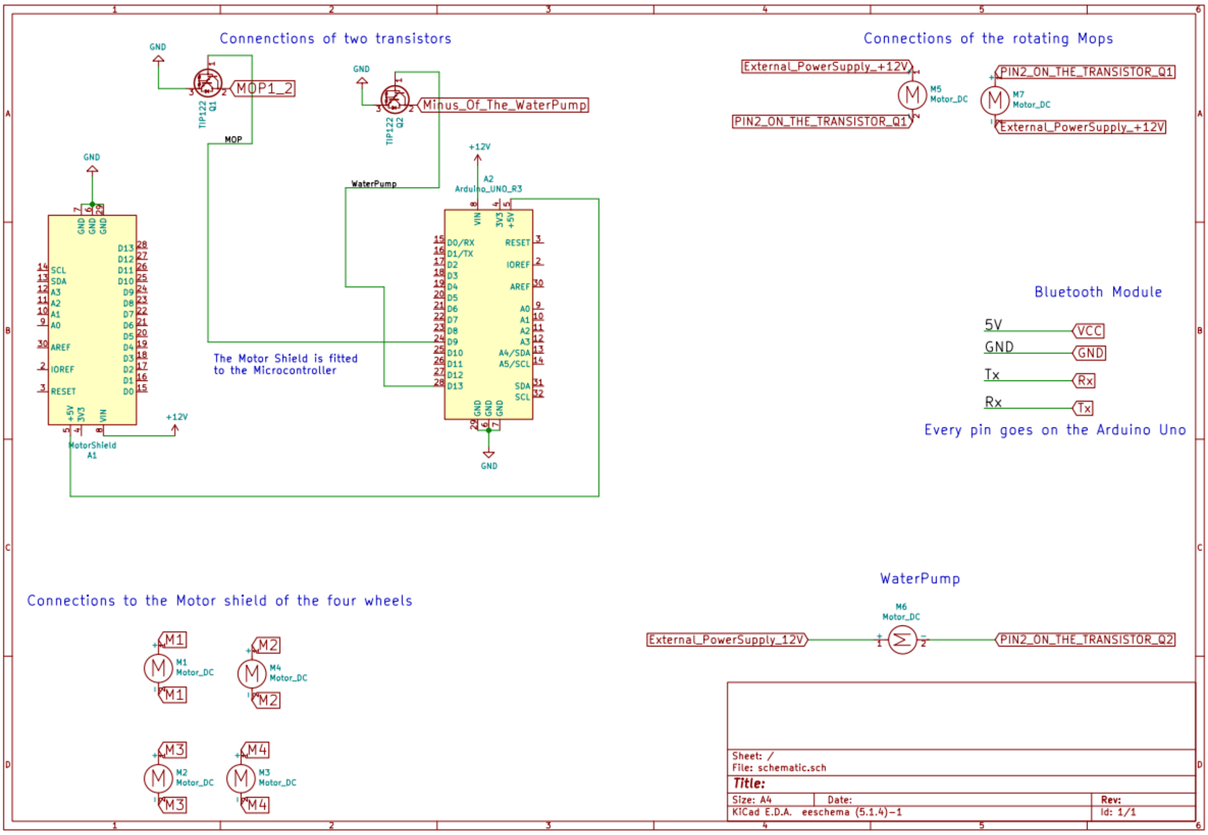

Figure 4.2.4: The electrical schematic of the connections of the cleaning robot

5. Implementation

The implementation process in terms of software and hardware is usually complex. To understand the operations implemented in the working cleaning robot, it is crucial to find out how specific solutions have been carried out. The Implementation chapter depicts the most critical operations that had been implemented during work on the project. Furthermore, it reveals the unforeseen problems of hardware and software. Also, it clarifies how the problems had been overcome.

5.1 Crucial operations – Hardware and unforeseen problems

5.1.1 Space saving

In that project, managing the space is one of the most fundamental elements. In figure 5.1.1, the base of the robot is presented. The robot's base has a limited space, whereby to avoid the lack of space, some of the components were assembled beneath the first surface. The motor shield L293d had been chosen for the project on purpose. One of its features is that it fits (figure 5.1.2) into the microcontroller; therefore, it can save some space. The motor shield mounted onto the microcontroller had been assembled on the lower base; hence, more space could be used on the higher base. Moreover, most of the wires are hidden under the main base because most cables are connected to the microcontroller.

Figure 5.1.1: Base of the cleaning robot with mounted wheels

Figure 5.1.2: Arduino Uno mounted into Motor Driver Shield L293d

According to the electric schematic Figure 4.2.4, there are few connections to ground or power supplies, e.g., 5V, 9V or 12V. It is likely that sometimes some of the components are not working because of faulty connection. To make it transparent and more accessible in case of looking for faulty connections, the small breadboard had been mounted next to the microcontroller (Figure 5.1.3). This approach enables to make an external space for ground, power supply or different needs. What is more, the breadboard gives the more space for features such as a rotating mopping system, water pump. Furthermore, a separate power supply rail might be implemented on the breadboard according to the user needs.

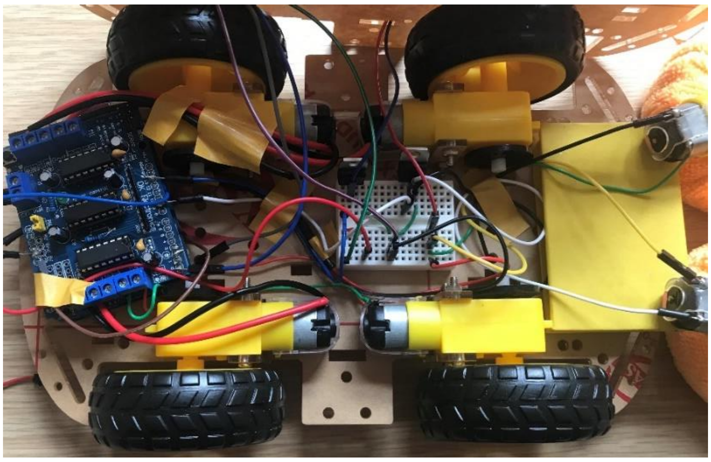

Figure 5.1.3: Connections of the robot with use of the small breadboard

One of the few critical operations that have been executed is associated with soldering. There is a disadvantage of fitting the Arduino Uno with a Motor shield. Pins such as RX, TX, GROUND, 9 and 13 are in use for external features. However, there is no space for connecting those wires straight into the microcontroller or motor shield. The problem has been resolved by using the soldering iron. In figure 5.1.4, it can be seen how the wires were soldered to the corresponding pins. Every wire was soldered to the motor shield, except TX (PIN 1), which was soldered to the microcontroller, for the reason that potentially the solder could join the RX and TX pin what could cause the errors in data transfer to the Bluetooth module.

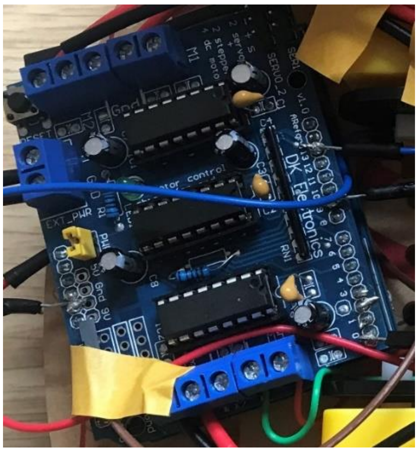

Figure 5.1.4: Presents the soldered wires

5.1.2 Hole in the reservoir

The cleaning robot that uses the water pump requires the reservoir. For the purpose of the project, a small bottle of 100ml volume had been chosen. However, the top of the bottle was plain and did not have any hole. In order to make a hole in the top of the bottle, a drill was used. Before the drilling process, the diameter of the pipe that would go through the hole had been measured. Ideally, the pipe diameter is measured by calliper; nevertheless, this tool was out of reach; hence, a ruler measured the width. In figure 5.1.5, the drilled holed is shown. The drill bit was 7mm in size; hence the hole is 7mm in width as well. The size of the hole has the same size as the pipe because the material that the pipe is made of is a bit flexible. Therefore, there is no loose, and the pipe fits ideally, as shown in the Figure 5.1.6.

Figure 5.1.5: Drilled hole in the reservoir

Figure 5.1.6: Pipe fitted into hole

5.1.3 Rotating mopping system

The rotating mopping system is one of the most crucial systems of the cleaning robot. This system has an important task which is cleaning the floor with the use of water. Before building this system, a few things were taken under consideration, such as the material of the wipe, montage of the geared motors and montage of the wipe on the wheels.

First of all, the research says that microfibre is one of the best material that mop can be made of [19]. The microfibre mop has a higher volume of absorption of the water, i.e. the mop can clean more space than a cotton mop. Furthermore, the mop made of a microfibre lasts for a longer time in comparison to cotton. All of the benefits coming from microfibre material have a positive effect on the robot's performance. Another reason why the microfibre wipe has been selected because it cooperates perfectly with the water, and water is the only liquid that the water pump is operating in this project.

Once the material was selected, the problem that was associated with attaching the wipe on the wheels occurred. The wheels are rotating; hence the wipe has to be appropriately attached to avoid slipping of the wheel. The solution for this problem was to cut the wipe in a circular shape and sewed it around and attached it to the wheel. The sewed microfibre wipe attached to the wheel might be seen in figure 5.1.7. The wipe sticks well when the wheel is rotating or in an idle state. What is more, the mop head might be taken off and washed.

When the wipe was attached to the wheels, the last task to complete the rotating mopping system was to mount the system successfully. The assembly of the mopping system was the primary concern. This system has to work appropriately, whereby there cannot be any loose during rotating, and the whole system must be stable. In figure 5.1.7, it might be seen that under the geared motors, there is a yellow pad. The pad was stuck to the lower base by using double-sided tape. On the joint between the top base and geared motors, some of the glue had been used. All of the actions above were implemented to make the whole rotating system stable and work as required. The confirmation of correctly working the rotating mopping system is presented in the results chapter.

Figure 5.1.7: The rotating mopping system

5.2 Crucial operations and unforeseen problems – Hardware and software

The subsections of section 5.2 depict the most critical operations implemented in the system. Furthermore, it reveals problems that occurred during the most critical operation and how the problems had been overcome.

5.2.1 TIP122 Transistors

The transistors are an excellent component to control something, e.g., a rotating mopping system or water pump. One of the features of the base of this transistor is that it can turn on or off the transistor [20]. In figure 4.2.4, it might be seen how the transistors are connected. Each transistor is responsible for one feature of the robot. Firstly, the connections were different; hence the water pump did not work properly because whenever the robot was turned on, so was the water pump. However, the assumption was different; the water pump or rotating system must be turned on only when the button is pressed in the application. Previously the ‘plus’ of the water pump was connected to pin two and negative to the ground. To fix it the more research about transistors and their connections was made. The dependency of the connections between the transistors and other components were discovered. The base of each transistor must be connected to the microcontroller because it sends certain commands responsible for turning on and off the water pump or rotating mopping system. Once this dependency was found, the other connections were straightforward and can be seen in the electrical schematic in the figure 4.2.4. The smartphone could control the features when the connections were changed, and the water pump or rotating mopping system were powered only when the button was pressed.

5.2.2 Motor shield and Arduino Uno

The use of the motor shield L293d and the microcontroller Arduino Uno was a key to the well-functioning system. By using the available library, the programming and control of the four-wheel system were less challenging. However, before those two components were cooperating, the communication issue appeared. Due to the limited amount of information about the motor shield and microcontroller, the control, for instance, the four-wheel system, was demanding. Nevertheless, after a certain amount of time, the library that enables controlling dc motors was found. The library is called ‘AF_DCMotor’ (Adafruit-Motor-Shield-library) and can be found in the Arduino software libraries. In the figure 5.2.2, it is presented how each wheel is determined. The number in the bracket means which channel is in use on the motor shield. The figure 5.2.3 is a part of the source code that shows how the motors are working. Using the Adafruit library, it is possible to control every wheel separately, i.e. give the speed from (0 – 255) and set the direction (forward or backward).

What is also crucial for the project is strictly associated with the communication between the motor shield and Arduino Uno. When those two components are fitted into each other, some of the pins are in use straight away. So, it is crucial to familiarize what pins are free and could be used for additives such as water pump and other features. The pins 9 and 13 for the rotating mopping system and water pump were not chosen randomly. According to found information, it was clear that pins 2,9,10,13, and 6 analogue Pins might be used for external features [21].

```

#include <AFMotor.h>

//creates two objects to control the terminal 1,2,3 and 4 of motor shield
AF_DCMotor motor1(1);
AF_DCMotor motor2(2);
AF_DCMotor motor3(3);
AF_DCMotor motor4(4);
```

Figure 5.2.2: Implemented library and determination of the terminals

```
void forward()
{
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(FORWARD); //rotate the motor clockwise
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}

void back()
{
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(BACKWARD); //rotate the motor anticlockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(BACKWARD); //rotate the motor anticlockwise
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(BACKWARD); //rotate the motor anticlockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(BACKWARD); //rotate the motor anticlockwise
}
```

Figure 5.2.3: Setting the speed and direction of each wheel

5.3 Software

5.3.1 Robot controller application

The mopping robot is controlled via the smartphone application. In the figure 5.3.1, the application is presented. The application is receiving specific commands that the microcontroller and Bluetooth module send. The commands that the application is receiving are in source code in the Appendix A. In the void loop, certain commands are defined. Each void is corresponding to a particular task such as mop off, forward, left.

By using the controller below, the robot can be controlled. The red light in the top left corner is blinking, and the light changes to green when the connection is complete. Giant four black buttons with small blue arrows inside are responsible for driving the robot. The arrows in the circular shape are indicating the current direction. The first button from the left next to the red circle turns on/off the water pump. Furthermore, the second button from the left turns on/off the rotating mopping system. The rest of the buttons are not in use; however, it is an excellent start point for future work and additional features.

During the connecting process between the robot and controller, a few problems prevented the successful connection. Firstly, before the connection can be complete, the device must be paired with the Bluetooth module; otherwise, the connection will not be complete. Another problem appeared while uploading the code to the microcontroller. It is crucial to remove the RX and TX wires while the code is uploading because those pins might interfere with the serial connection.

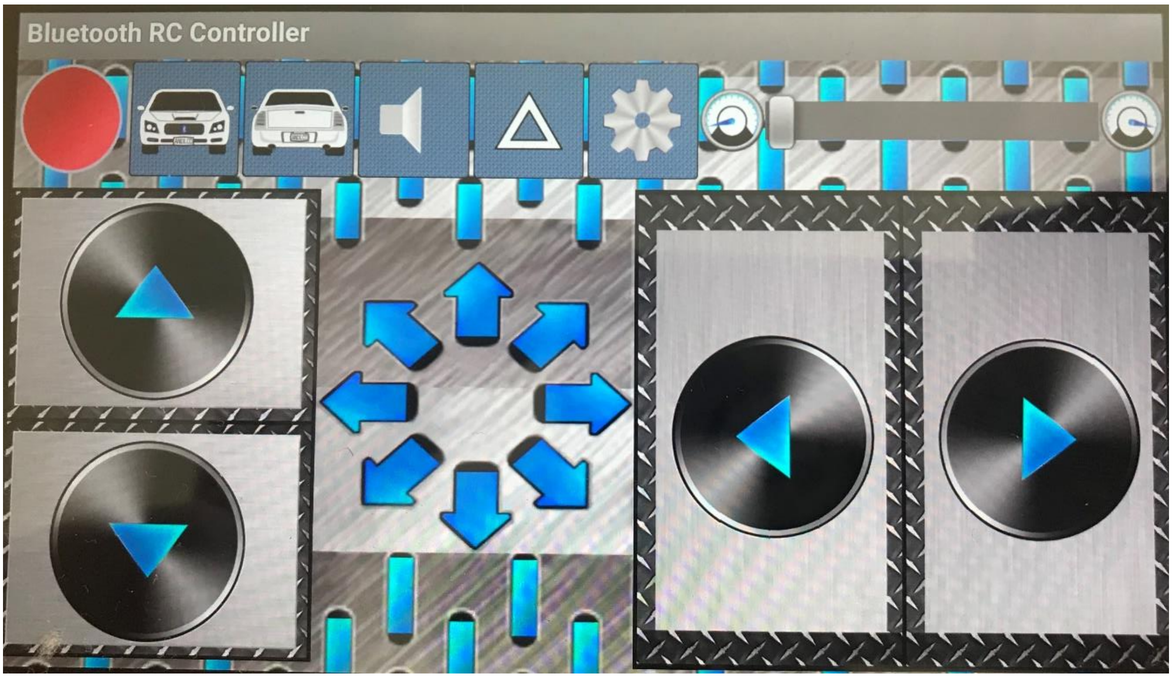

Figure 5.3.1: The robot controller application

6. The results and evaluation

Results and their critical evaluation are an important part of the report. The critical analysis explains and depicts to what extent the aims and objectives had been achieved. What is more, it points the strengths and weaknesses of the Robot. The chapter results and evaluation mention all of the above and explains how the experiments were carried out.

6.1 Tests and results

During the whole time of building the robot and programming the software in Arduino IDE with association with the smartphone application, plenty of tests were carried out to achieve the desired goals. To those tests, we might include, for instance, checking whether the wheels are driving in a correct way or does the Bluetooth module is sending the correct commands to the robot controller. However, in that section, the final tests and their results are presented.

6.1.1 Description of the tests and their procedure

The tests that had been made were strictly checking the robot behaviour and its features while the user controlled the robot. The tests that had been executed covers a comprehensive range of the capabilities of the cleaning robot. Attention was pointed on:

- four-wheel-drive system and its performance

- performance of the water pump

- effectiveness of the rotating mopping system

- quality of the Bluetooth connection between the robot and robot controller

- capabilities of the rotating mopping system in terms of water volume absorption

- general work of the mopping robot

To carry out tests and complete them without any obstacles, the procedure should have been followed. The procedure of preparing the robot for the test is as follows:

1. Check whether there are not any loose wires.

2. Top up the reservoir with the water by using a funnel.

3. Supply the voltage to the robot by connecting the microcontroller with the battery.

4. If the Bluetooth module is blinking, turn on the Bluetooth in the smartphone and pair the robot with the device. If the Bluetooth module is not blinking, check the connections.

5. Once the connection is successful, the cleaning robot can be tested.

6.1.2 Results of the tests

The testing of the robot was carried out in the student accommodation environment. The tests were executed in accordance with assumed points in the section 6.1.1. The figures 6.1.2 – 6.1.4 present the cleaning process. Firstly, the dirty part on the floor has been located; then, the robot pumped out some water in order to soak the rotating mopping system. In the figure 6.1.4, the rotating mopping system is on and clean the dirty part on the floor.

Figure 6.1.2: Dust located

Figure 6.1.3: Water pump is pumping out the water

Figure 6.1.4: Cleaning the floor using rotating mopping system

The four-wheel-drive system of the cleaning robot was tested as well. The figures 6.1.5 – 6.1.7 show how the robot drives in a different direction. The robot is able to drive forward, left, right and reverse. During driving, the robot was moving properly according to commands that the user pressed in the android application. What is more, the robot was also tested in terms of the wireless range. The robot was able to be driven into different rooms while the user remains in the same spot. The test checked all the assumptions that were made in the previous section. However, the evaluation of the results is presented in the next section.

Figure 6.1.5: Robot starts the movement

Figure 6.1.6: The robot is turning left

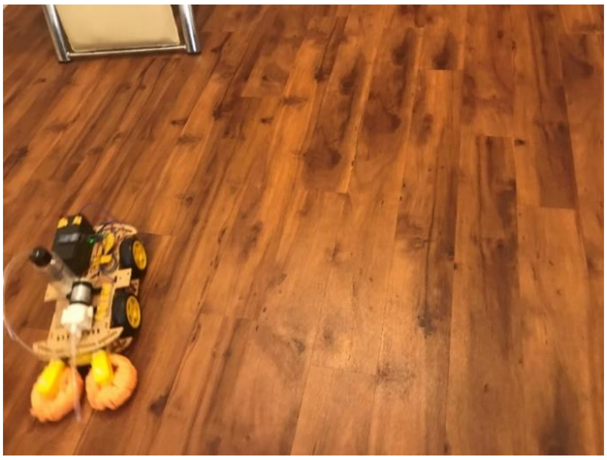

Figure 6.1.7: The robot is turning left and goes back to the initial position

The approximate run time [14] of the robot can be calculated by using the following formula.

$$\text{Run Times in hours} = \frac{\text{Battery capacitance mAh}}{\text{Measured current consumption mA}} \tag{1}$$

The battery used in the project has a 1.2Ah (1.2 * 1000 = 1200mAh) battery capacitance. The current has been measured with the multimeter (Figures 6.1.8 – 6.2.2) to determine the current consumptions and calculate the approximate run time of the cleaning robot. The multimeter was set in series with the battery and microcontroller to get the most reliable values. The range on the multimeter was set to 200mA because the measurements would not exceed 200mA. With the collected data and when the AmphHour(Ah) of the battery was known, the estimated run time of the robot has been calculated and presented in the table 6.1.2. The last activity is the most likely to happen. In the described way the robot usually works, the water pump current consumption is divided by three, due to it is working only a few times during the cleaning process.

Activity	**Calculations**	**Estimated Run Time in Hours**
Idle State	1200/19.8 = 60.6	Approximately **60 hours and 36 minutes**
Water Pump	1200/74.2 = 16.17	Approximately **16 hours and 12 minutes**
Rotating Mopping System	1200/110.5 = 10.86	Approximately **10 hours and 51.6 minutes**
Driving Robot	1200/ 137.1 = 8.75	Approximately **8 hours and 45 minutes**
Most likely use of the Robot : Robot is driving, Rotating Mopping System is ON and water pump is turned ON a few times during cleaning	1200/ 137.1 + 110.5 + 24 = 4.42	Approximately **4 hours and 25.2 minutes**

Table 6.1.2: Table presents estimated calculations of the Run time of the robot based on measurements

Figure 6.1.8: Water pump

Figure 6.1.9: Rotating mopping system

Figure 6.2.1: Idle state

Figure 6.2.2: Driving robot

6.2 Evaluation of the results

6.2.1 Results of the tests and critical evaluation

In that section, the evaluation of the results is described. Firstly, the results refer to sections 6.1.1 and 6.1.2.

The four-wheel system works appropriately. The robot can move in different directions, such as forward, back, left, right. Each wheel is programmed and driven separately; thereby, the robot has more manoeuvrability capabilities. When the robot was driven, no problems or complications occurred.

The performance of the water pump is another assumption that was tested experimentally. The primary assumption of the work of the water pump is to pump out the water whenever a certain button is pressed. During the test, the water pump was working correctly. The water was pumped out when the button was pressed. Once the button was pressed again, the water pump stopped the pumping process.

The rotating mopping system was strictly checked in the test as well. The main job of the rotating mopping systems is to absorb the water that comes out from the water pump, and with the soaked wipe, mop the floor. In the figures 6.1.2 – 6.1.4, it could be observed that the water from the floor is absorbed, and the floor is clean. Moreover, the robot did not leave out any water spots. During the test, a weakness has been discovered in the mopping system. The wipes of this system have a tendency to get dirty quickly. Hence, the wipes should have been cleaned after every cleaning session to not spread the dirt on the floor.

The quality of the connection between the robot controller and the robot itself is decent. The robot has a substantial Bluetooth signal range. The robot might be controlled from a different room, e.g., the robot could drive to a different room while the user remains in the same place. Obviously, the robot will not operate on a long-distance range; however, the range 10 – 15 meters is sufficient for student accommodation and works correctly.

The run time of the robot has been calculated. The robot is capable of being controlled for approximately 4 hours 25 minutes. However, it must be considered that temperature might reduce the run time. Furthermore, as the battery loses the charge during cleaning, the battery discharges quicker. With that being said, it is still a decent run time. The robot could clean the student accommodation a few times without the need for recharging.

6.3 Further tests in the future

To gain more confidence about created a cleaning robot, further tests should be carried out. Firstly, the robot should have been used on a daily basis, what could reveal potential problems or weaknesses that had been omitted. According to the run time, the robot should have been working until the battery will be discharged to get more realistic numbers. This kind of test reveals the actual run time; what is more, this test can determine the difference between the calculated value based on measurements and the real-time after the battery is going to discharge. A good approach would be to test the robot and check how the machine behaves on different varieties of the floor. The tests were mainly carried out on the wooden floor; thus, there is a lack of information on how the robot will work on other floors such as kitchen tiles, vinyl. This kind of test could give a closer perspective in terms of efficiency and the robot's general performance in various environments.

6.4 Summarization

6.4.1 To what extent the goals have been achieved.

The project's main goal was to create an easy in use mopping cleaning robot controlled remotely via an android application. Moreover, the robot features are a part of the main goal as well, e.g., water pump and rotating mopping system. In the lights of tests, it has been proved that the robot is working as intended. The user can control the robot via application, the water pump, or the mopping system might be turned on/off (Figures 6.1.2-6.1.4). Furthermore, the robot can be driven in different directions (Figures 6.1.5-6.1.7).

6.4.2 General evaluation

According to tests that were executed to check the robot's performance and its behaviour, it might be said that it meets the assumed requirements. Moreover, the robot is capable of mopping the floor, and for the student accommodation standards, this robot is entirely sufficient and useable. However, as in every project, the robot has its strengths and weaknesses; table 6.4.2 presents them based on conducted experiments. Nevertheless, the number of pros is surpassing the cons. The robot is usable and works as it was planned. The weaknesses of the robot might be reduced in future improvements what can potentially make the robot even more serviceable.

Strengths	Weaknesses
- Features that help to clean the floor such as water pump or rotating mopping system	- Robot is not able to clean the carpet due to its design and capabilities, whereby it limits types of floor that might be cleaned
- Strong Bluetooth signal	- The appearance might not be encouraging for everyone
- Remote access to the robot and manual control	- The volume of the reservoir could be bigger (100ml)
- Capacity of the battery up to 4 and a half hours in the run mode	
- easy-to-use the robot controller	

Table 6.4.2: Table of the strengths and weaknesses

7. Future work

During work on the project, specific ideas appeared that can improve the project in various aspects. The future work chapter depicts some of the ideas that can be implemented in the future. Those ideas are based on either discovered weaknesses during the implementation testing process or related to the articles included in the literature review that suggests certain upgrades that could increase the performance of the cleaning robot.

7.1 Autonomous mode

Nowadays, smart homes are getting more prevalent; hence the demand for the autonomous mode is increasing. The created mopping robot is capable of navigating only when the user is in control. However, an additional mode which is the autonomous mode would be a significant improvement of the machine. A good approach has been implemented in the automatic cleaning and mopping robot [6]. The machine can be controlled by the user or work autonomously. The implementation of two modes expands the applications where the robot might be used.

To make an existing robot autonomous, a good solution could be to add the ultrasonic sensor. The figure 7.1 presents an example of the ultrasonic sensor that can be used in combination with the microcontroller Arduino Uno. The described sensor is a good option for a more budget project. The HC-SR04 sensor detects the obstacles by emitting ultrasound at 40 kHz [16], the sound travels through the air, and if the obstacles appeared, it is detected, and the sound goes back to the module. The range is between 3 – 400 cm [15]. Furthermore, to calculate the distance between the sensor and obstacle, the travel time and speed of the sound are taken into account. The data is sent to the microcontroller; hence, the robot can easily avoid obstacles.

Figure 7.1: The ultrasonic sensor HC-SR04

The more costly approach might be implemented in the project as well. The Lidar (Light Detection and Ranging) is a type of sensor used to achieve the autonomous mode. There is a previous experiment where the Lidar sensor was successfully implemented [17]. In that research, the Lidar sensor was delivering and receiving the data in conjunction with the Arduino. Furthermore, based on the data from the sensor, the robot could move in the area and avoid obstacles as well. In the figure 7.2, there is an example of the Lidar sensor. This kind of sensor has a range of up to 40 metres [18] which is a massive difference compared to the HC – SR04 sensor. The previous sensor works in combination with sound; however, the Lidar works with the light. To calculate the distance, the sensor illuminates the light on the objects, then beams of the light hit the object and go back to the laser scanner. The time of this action determines the distance; therefore, time is known, and the velocity of the light (299,792,458 m/s) is known as well; hence the distance is calculated.

Figure 7.2: Lidar- Lite 3 Laser Rangefinder

7.2 Additional sponge

One of the Chinese universities [9] used a sponge to improve the water-absorption. The wipe with proper calculation of the volume is a considerable improvement that could be implemented in the system. The mopping robot clean the floor by using water; therefore, it is crucial to absorb the whole water that had been pumped out; otherwise, the left-out water is a potential threat to the floor. The mopping robot that was created is using two rotating mops. The enormous advantage could be assembling the sponge on the back of the robot; hence, the water that has not been completely absorbed into the rotating mopping system would be soaked up into the sponge. The approach for implementing a sponge is associated with the servo motor. Stick will be attached to the servo, and a sponge will be mounted at the end of this stick. It enables to move the sponge up and down. According to the specific task, the user could choose whether there is a need for an additional sponge on the back. The example of how it could look is presented in figure 7.3; however, instead of the roller, the sponge will be attached.

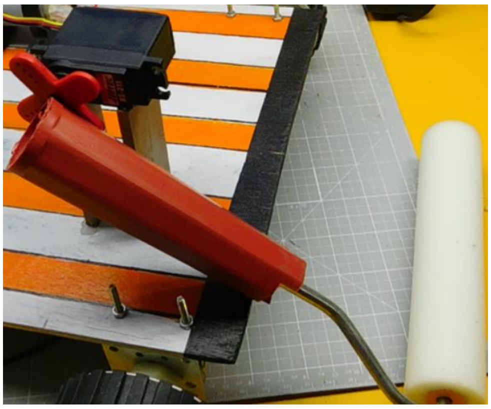

Figure 7.3: Servo motor mechanism

8.Conclusions

The report depicts how the wiping robot has been built, with descriptions of its specifications and limitations by using SysML diagrams. Moreover, in the study, the literature review is conducted to give the perspective of how the cleaning robots work and how they are made of. Furthermore, the tests and its evaluation were carried out to determine how the robot works and find its strengths and weaknesses.

The project's main aim was to build a wiping floor robot controlled remotely via the android application. According to executed tests and their evaluation, the main aim had been achieved. The robot is capable of being driven in different directions. What is more, the features work as assumed, i.e. the water pump and rotating mopping system can be turned on or off by using an android application. The performance of the features is satisfactory. The rotating mopping system cleans the floor well; also, the absorption of the wipe is sufficient because there are no water spots on the floor after the cleaning process. What is more, the water pump is pumping the water properly, and leaks of the water do not exist.

The study strengthens my conviction how the electrical schematic and SysML diagrams are helpful before the building process. The building process of the robot is based on diagrams whereby the limitations and specifications of the hardware and software were known. Therefore, it reduced the chances of failure during the building process. The electrical schematic is a key to well working project. When the problems occurred, the problem could be easily found by following the schematic. What is more, by overcoming the problems associated with the connection between Bluetooth module, microcontroller, and smartphone application, the knowledge about these components has expanded. By using gained experience, a more complex project can be created in the future.

Despite that, the aim is achieved, and the robot is working correctly; the project is never perfect. According to the executed experiments, the weaknesses of the robot were discovered. More tests on different kinds of floor should be executed to determine how the robot behaves in different environments. Moreover, the tank can be a potential problem due to its size, whereby the reservoir during a longer cleaning process has to be refilled more often. Despite some of the weaknesses, the robot proved in the executed experiments its capabilities of cleaning the student accommodation properly and can be a good cleaning floor robot.

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Appendix A – Source Code

```
//This arduino code is used to control a robot wiping robot using an app that communicates with Arduino trough a bluetooth module.

#include <AFMotor.h> // include the adafruit motor library

//creates four objects to control the terminal 1,2,3 and 4 of motor shield
AF_DCMotor motor1(1);
AF_DCMotor motor2(2);
AF_DCMotor motor3(3);
AF_DCMotor motor4(4);

int pump = 13;// Water pump
int mop = 9; //Rotating mopping system, pwm signal
char command;

void setup()
{
  pinMode(13, OUTPUT);// define the water pump as an output
  pinMode(mop, OUTPUT);// define the mopping system as an output
  digitalWrite(pump, LOW); // Set to low, to be turned off after powering
  digitalWrite(mop, LOW); // Set to low, to be turned off after powering
  Serial.begin(9600);  //Set the baud rate to your Bluetooth module.
}

void loop(){
  if(Serial.available() > 0){
    command = Serial.read();
    Stop(); //initialize with motors stoped
    //Change pin mode only if new command is different from previous.
    // each case defines one activity
    switch(command){
    case 'F':
```

```
      forward();
      break;
    case 'B':
       back();
      break;
    case 'L':
      left();
      break;
    case 'R':
      right();
      break;
    case 'W':
      pumpon();
      break;
    case 'w':
      pumpoff();
      break;
    case 'U':
      mopon();
      break;
    case 'G':
      forwardleft();
      break;
    case 'I':
      forwardright();
      break;
    case 'H':
      backleft();
      break;
    case 'J':
      backright();
      break;
```

```
    case 'u':
      mopoff();
      break;
    }
  }
}

void forward()
{
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(FORWARD); //rotate the motor clockwise
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}

void back()
{
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(BACKWARD); //rotate the motor anticlockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(BACKWARD); //rotate the motor anticlockwise
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(BACKWARD); //rotate the motor anticlockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(BACKWARD); //rotate the motor anticlockwise
}

```

```
void left()
{
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(0); // set speed to 0
  motor2.run(RELEASE); //turn motor2 off
  motor1.setSpeed(0); // set speed to 0
  motor1.run(RELEASE); //turn motor1 off
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}

void right()
{
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(0); // set speed to 0
  motor4.run(RELEASE); //turn motor4 off
  motor3.setSpeed(0); // set speed to 0
  motor3.run(RELEASE); //turn motor3 off
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(FORWARD);//rotate the motor clockwise
}
void pumpon()
{
  digitalWrite(13, HIGH); // turn ON the water pump

}
void pumpoff()
{
  digitalWrite(13, LOW); // turn OFF the water pump
}
```

```
void Stop()
{
  motor1.setSpeed(0); // set speed to 0
  motor1.run(RELEASE); //turn motor1 off
  motor2.setSpeed(0); // set speed to 0
  motor2.run(RELEASE); //turn motor2 off
  motor3.setSpeed(0); // set speed to 0
  motor3.run(RELEASE); //turn motor3 off
  motor4.setSpeed(0); // set speed to 0
  motor4.run(RELEASE); //turn motor4 off
}
void mopon()
{
  digitalWrite(mop, HIGH); // Turn ON the rottating mopping system
}
void mopoff()
{
  digitalWrite(mop, LOW); // Turn OFF the rottating mopping system
}
void forwardleft()
{
  motor3.setSpeed(200); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(110); //Define maximum velocity
  motor2.run(FORWARD); //rotate the motor clockwise
  motor1.setSpeed(110); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}
```

```
void forwardright()
{
  motor3.setSpeed(110); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(FORWARD); //rotate the motor clockwise
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(110); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}
void backleft()
{
   motor3.setSpeed(200); //Define maximum velocity
  motor3.run(BACKWARD); //rotate the motor anticlockwise
  motor2.setSpeed(110); //Define maximum velocity
  motor2.run(BACKWARD); //rotate the motor anticlockwise
  motor1.setSpeed(110); //Define maximum velocity
  motor1.run(BACKWARD); //rotate the motor anticlockwise
  motor4.setSpeed(200); //Define maximum velocity
  motor4.run(BACKWARD); //rotate the motor anticlockwise
}
void backright()
{
  motor3.setSpeed(110); //Define maximum velocity
  motor3.run(BACKWARD); //rotate the motor anticlockwise
  motor2.setSpeed(200); //Define maximum velocity
  motor2.run(BACKWARD); //rotate the motor anticlockwise
  motor1.setSpeed(200); //Define maximum velocity
  motor1.run(BACKWARD); //rotate the motor anticlockwise
  motor4.setSpeed(110); //Define maximum velocity
  motor4.run(BACKWARD); //rotate the motor anticlockwise
}
```

Appendix B – Interim Report

1. Abstract

The purpose of that paper is to show the progress and research that had been made. The reader can also find out what the plans are. The idea of this project is to build an IoT floor cleaning robot control by the smartphone app.

2. Introduction

The main goal for that study is to design, assemble, and program the floor wiping robot. The idea is to send data between the microcontroller and Bluetooth module to control the robot. By using a smartphone, the user can use features of the robot, for instance, turn ON/OFF the water pump or drive the robot in the direction he wants. Furthermore, the robot has two motors attached to the mop refills. The mop refills will enable maintaining a dry and clean floor.

3. Overall aim and Objectives

The project's primary aim is to create an IoT floor cleaner robot controlled remotely by an android APP. The robot will drive in different directions, such as forward, reverse, left, and right. The robot should be easily operated for daily use, either technical or non-technical people. In order to reach the overall aim, the below objectives will be carried out:

• To carry out a literature review and investigate different possible choices of electronic components.

• To integrate the microcontroller with an IoT WIFI module with the purpose of controlling the robot and its features.

• To design and assemble a valuable and suitable robot for student accommodation.

• To test the assembled robot and improve the hardware or software to make the robot more efficient where necessary.

4. Background review

The First cleaning robot was presented in the late 1980s. Since then, different approaches and improvements have been made. One of the assumptions for the robot was to clean somehow, not in any complex way [1]. Mobile robots have plenty of applications. They find adoption in different areas, such as shops, warehouses, airports, domestic households, and even train stations. One of the Japanese railway company invented a cleaning robot that could clean the floor station. By using ultrasonic sensors, the robot is capable of detecting obstacles. The robot is able to clean the whole station, and if the battery has a low charge level, the robot is programmed to go back to the charging station [2]. One of the main advantages is that the floor robot can replace humans in repetitive and time-wasting tasks. As can be seen in the Japanese case, Robots can work autonomously; they do not require any help from their users unless it is maintenance. However, existing robots also have downsides. Every time the robot starts its own work, it has to learn the environment. The environment can also be hazardous for the robot because when the robot faces the water, pit, or electric cable, a short circuit can happen and damage the robot [1].

There are certain robots that use only two wheels instead of 4, a robot with four wheels is more flexible, and manoeuvrability increases its effectiveness. Due to higher flexibility, the robot can clean corners which are usually hard to reach for two wheels robot [3]. Nowadays, the demand for cleaning robot is rising. Robots might be improved by implementing the Internet of things into the whole project. Moreover, four wheels are also crucial in order to get a highly effective mobile robot. Finally, the project aims to develop and build the Arduino floor cleaning robot using IoT, four wheels, and a low budget approach.

5. Progress thus far

Since my first meeting with the supervisor, I started doing research about IoT cleaning robots. After deciding, what features my robot should have, and I did more research about components. It is essential to know the difference between specific components because it significantly impacts the final outcome. Firstly, I decided to use the motor shield L293D, which enables me to control four wheels. Then, instead of using microcontroller nano, Arduino Uno is going to be used as a microcontroller. Due to higher popularity, it has more libraries to use. Another problem was to choose either Wi-Fi or Bluetooth module. Bluetooth HC-05, the transceiver, has been chosen. Bluetooth module is the main form of connectivity for IoT. Besides, Bluetooth is used in smartphones for a long time. In my project, the Arduino car is controlled by a smartphone app; that is why the Bluetooth module is more reasonable to use. Last but not least of components is the water pump, the pump has to be minor, and the operating voltage should have been 12V maximum. The chosen type is DC6-12V R385, and it fits my circuit. Everything is going to be placed on a mobile kit robot base. The initial sketch of the robot has been made, including two views upper (Fig. 1.0) and front (Fig. 1.1).

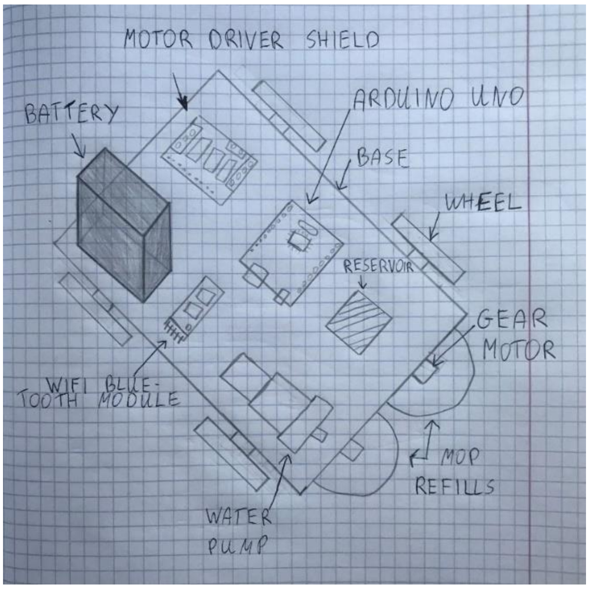


Fig. 1.0

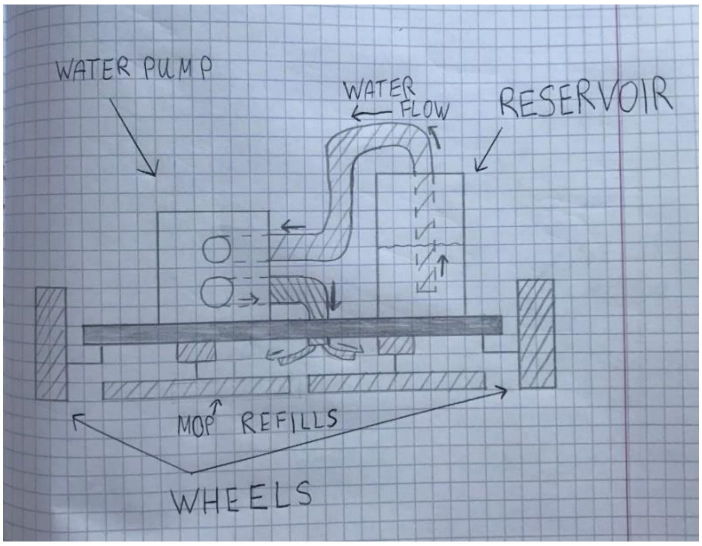
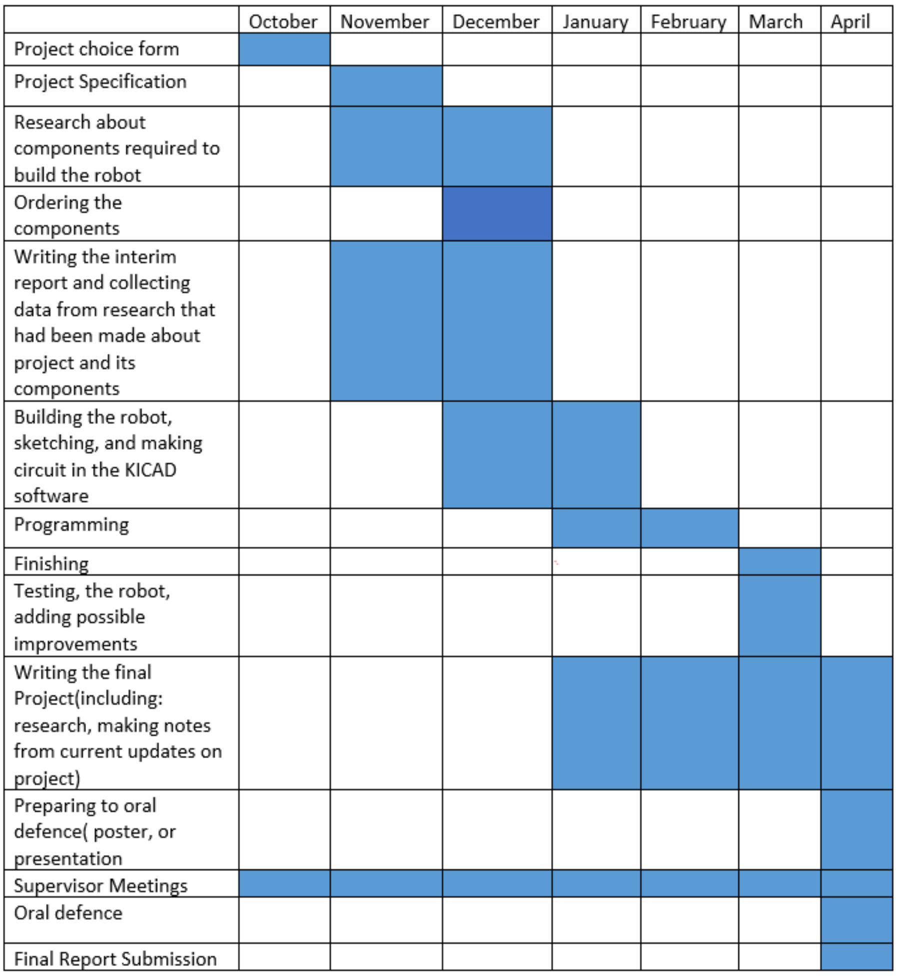


Fig. 1.1

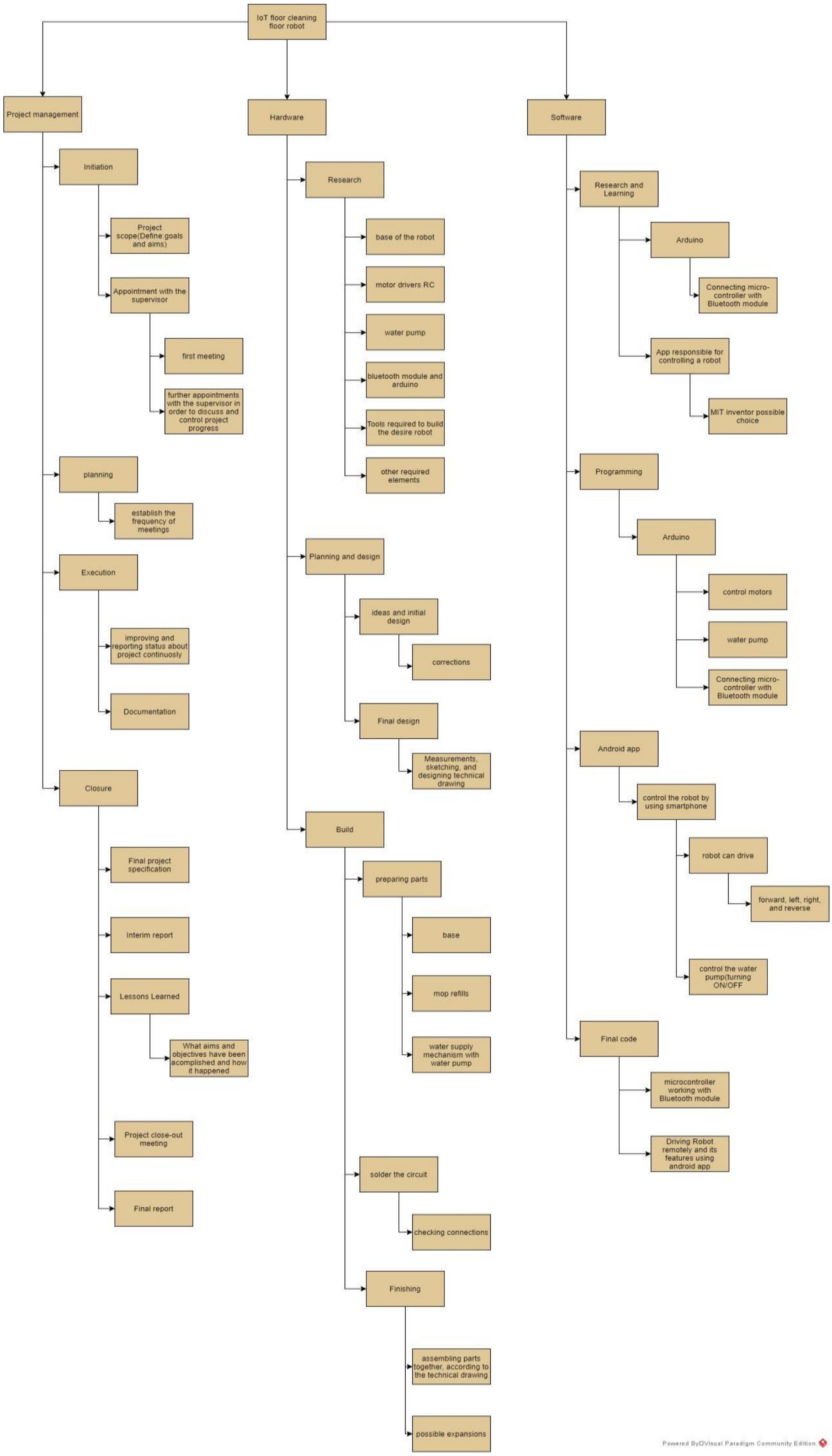
6. Plan for the next stage of the project with work breakdown and Gantt chart

The required components to build a robot has been ordered. Within a week or two, it should arrive. Meanwhile, I will use a hand-drawn sketch; hence assembling the robot should be more apparent. Additionally, creating schematics in KICAD software is key to correct assembling and connecting the circuit. It is crucial to have a clear view of the circuit and its connections to avoid short circuits or different difficulties. After the assembling is done, programming is the thing I would be focusing on. Firstly, is to make a robot drive in different directions. After that, other features will be sorting out, such as a water pump or control gear motor responsible for rotating the mop. When the main assumptions are made, there is an option to add improvements.

Gantt chart



Work breakdown structure



7. Conclusion

The objective of this project is to design and build the IoT floor cleaner robot controlled by an android APP. Moreover, the robot will be designed in a user-friendly method; even though the user is not strictly connected with technical stuff, it can be used by that kind of person. Moreover, the robot is going to be equipped with four wheels, which improves its mobility. In that project, it has been decided to make a connection between robot and smartphone by using microcontroller Arduino nano and Bluetooth module to get the best possibilities and effectiveness from that combination. Improvements can be made, which makes this project even more attractive due to prospects.

8. References

[1] A. Kleiner, "The Low Cost Evolution of AI in Domestic Floor Cleaning Robots," The AI Magazine, vol. 39, (2), pp. 89-90, 2018.

[2] X. Gao et al, "Floor-cleaning robot using omni-directional wheels," Industrial Robot, vol. 36, (2), pp. 157-164, 2009.

[3] T. T. Tun et al, "Four-wheel steering and driving mechanism for a reconfigurable floor cleaning robot," Automation in Construction, vol. 106, pp. 102796, 2019.

Appendix C – Project Specification

Project Specification

Individual Project - IoT based floor cleaner for student accommodation.

Marcin Murach

P2433714

Description of the project

The goal of the project is to build and program the cleaning floor robot, controlled by android an application. The robot is going to has four wheels, floor mop responsible for absorbing water. The water will flow from the water pump through a pipe onto the floor. The features of the robot are controlled remotely using smartphone.

Aim of the project

To build and program an IoT floor cleaner robot. The microprocessor will be connected with Wi-Fi or Bluetooth module. Furthermore, the base will be able to drive in different directions, for instance, forward, reverse, left, and right. The robot will work according to what a user requires. Features such as the water pump, the robot itself, floor mop can be controlled using an Android application.

Objectives to reach the aim

The robot will be assembled as soon as possible, to have more time for finishing him and adding possible expansions.

Programming the robot step by step and do not leave it for the last moment. It will help to make the robot more efficient and work smoothly.

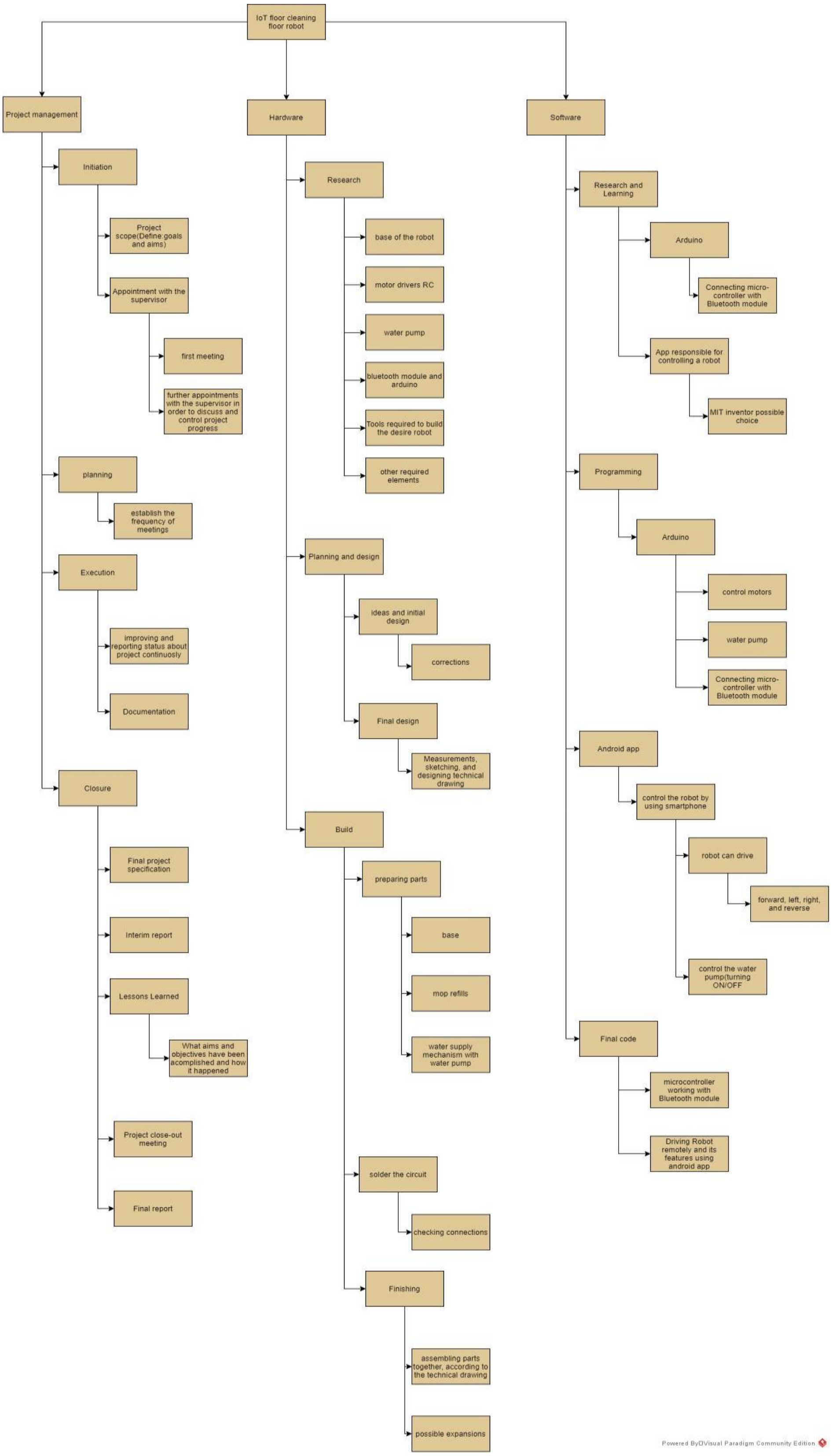
Making regular appointments with the supervisor in order to keep the progress with the project and to avoid ambiguities about the final project

Research about required components to build a robot. Find a better option in terms of efficiency and cost.

Gantt chart

	October	November	December	January	February	March	April	May
Project choice form **12.10.2020**								
Project Specification **13.11.2020**								
Interim report **14.12.2020**								
Supervisor meeting to discuss interim report feedback **15.01.2021**								
Designing the Robot								
Ordering parts required to build the Robot and Assembling								
Programming								
Finishing								
Testing								
Project write-up and documentation								
Data Collection and Research								
Supervisor Meetings								
Oral defence								
Final Report Submission								

Work package breakdown



Appendix D – Logbook

Logbook

Week 26.10.2020 – 01.11.2020

This week, the first meeting with the supervisor has been accomplished. During the meeting, the main aim of the study had been decided. From this week, I could plan my robot with more details. What is more, I set the limitations with the supervisor. From this point, I could start thinking about how am I going to build my robot, what components to use etc.

Week 02.11.2020 – 15.11.2020

During this specific period, I had to focus on my project specifications. In the project specification, I had to include some important things that will limit the boundaries of my project; also, the Gantt chart and work breakdown structure had to be done to present how I plan to do my project. To essential things can be included main aim and objectives that I had to write. After the project specification has been sent, I was waiting for a meeting to get feedback on the project specification.

Week 16.11.2020 – 22.11.2020

The appointment is scheduled for next week. Hence, I started to do more research about cleaning robots to prepare literature for my interim report.

Week 23.11.2020 – 13.12.2020

During this period, I primarily focused on the interim report. After the appointment with the supervisor, I did not have any doubts about the project. My main aim was to design and build the mopping cleaning robot controlled via the android application. After gathering all the necessary data and information, I started to write the interim report. By the end of 13.12.2020, I have finished my interim report and upload it via Turnitin.

Week 14.12.2020 – 10.01.2021

After receiving the interim report's feedback, I knew that I am on a good path. I did more research about the components that I planned to order. It is crucial to know how electronic devices work and whether there are compatible with each other. The list of all components and the base of the robot with wheels I made an order. The Christmas break was coming soon, so after Christmas is finished, I could start assembling the robot.

Week 11.01.2021-17.01.2021

All of the types of equipment have arrived. I did some research about the correlation between the motor shield and Arduino Uno. Then, I wanted to check that in a real-world case, so the motor shield had been connected with Arduino Uno. Then, I attach two geared motors with wheels. The purpose of that was to find out how it works together. To make it all work, the 12V battery was connected as well. The battery was connected to the motor shield. I wrote the simple code to run two wheels and check if everything is fine. The wheels were rotating correctly. After that, I decided to create an electronic schematic of my robot (Figure 1).

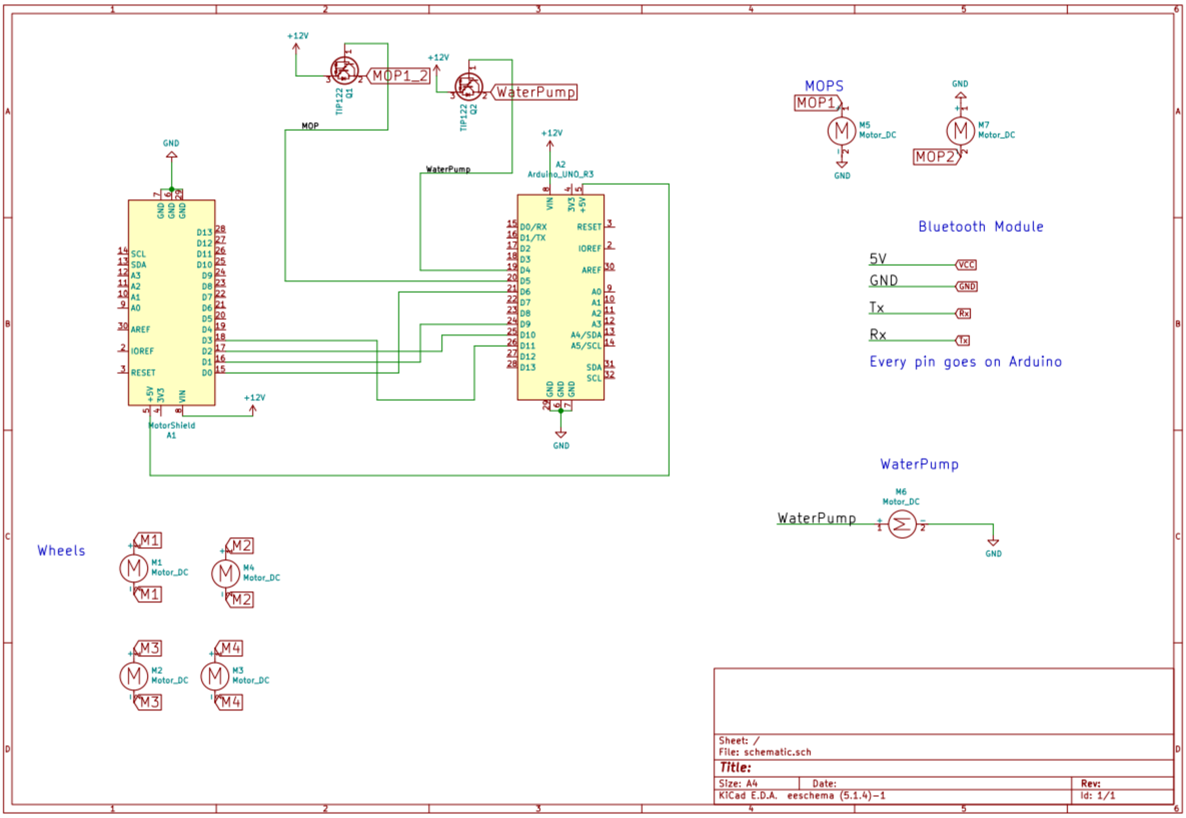


Figure 1. The screenshot from the Ki Cad software presents my initial schematic of the robot.

Week 18.01.2021-24.01.2021

The schematic of the robot was complete; hence I could start to build the robot. Firstly, I soldered the wires to the wheels, then to the water pump (Figure 2). After the soldering was done, I started to fit the components on a base. During that, one problem occurred. I realized that there are many components, so the common ground, +5V and +12V, should be allocated somewhere. Which are more the transistors should be near that. I had only quite a big breadboard; using that board would inefficient due to its size. I decided to order a small breadboard. Once it arrived, I checked how much place it takes. It worked perfectly due to the small size of the breadboard. Then I start to assemble some equipment of the base (Figure 3). What is important is that I did not montage them permanently because I want to make sure that my code works, and if not, I can always change something.

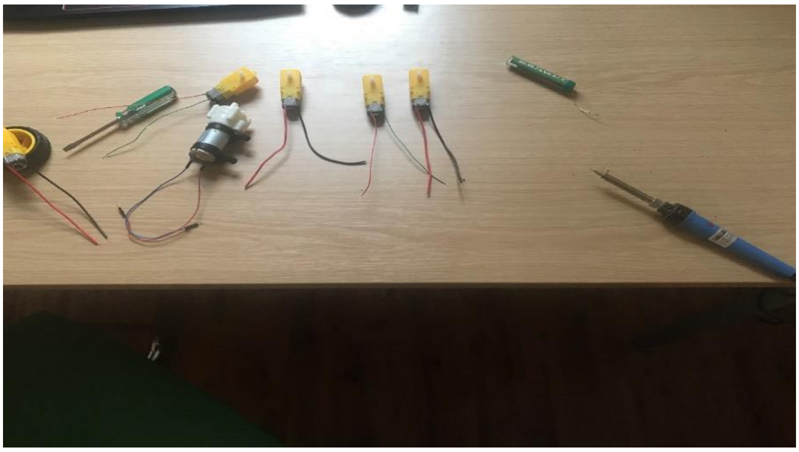


Figure 2. The photo shows the wires soldered to the geared motors and water pump.

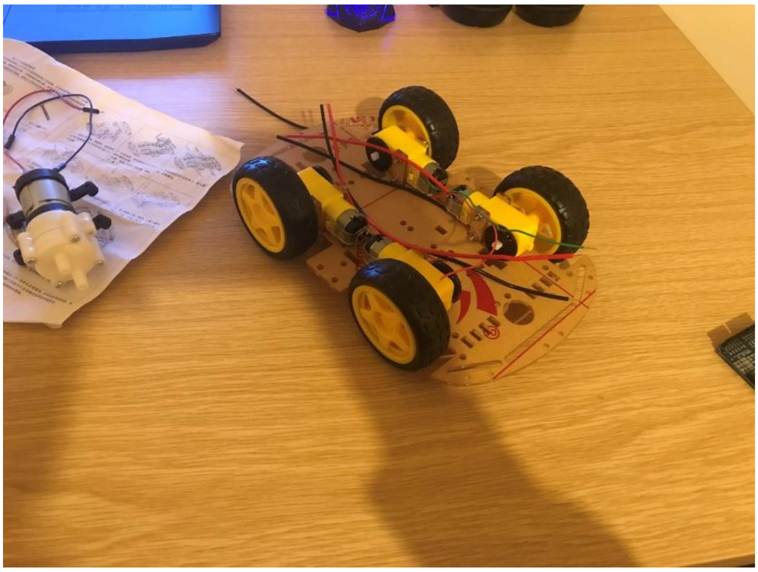


Figure 3. The photo presents the assembled base with wheels.

Week 22.01.2021-07.02.2021

By following my schematic, I connected the whole circuit (Figure 4). On the breadboard I did the separate line for +5V, +12V and ground. When the hardware was done, I started to make something work in my software. I watched some videos and went through libraries in Arduino to find something useful. I manage to move my wheels by using smartphone app, however it is random movement yet. I did not manage to control the wheels in the desired way yet. Now I am working on the code to control the robot and other features.

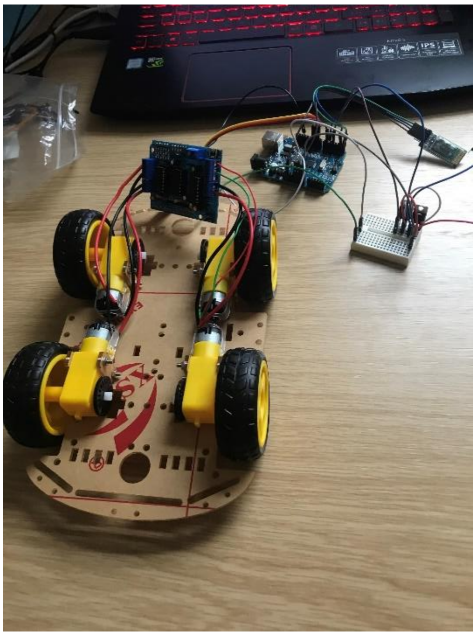


Figure 4. The photo shows connected circuit. I removed the water pump while I am working on the code, because it is more convenient.

Week 08.02.2021-14.02.2021

The wheels are starting to move forward, reverse, left and right. In the Figure 5 it is shown How did I manage to run motors and control the mobile car. On the screenshot it is only shown forward and backward, however I have the full Arduino code, but there is no point to showing my whole code, due to its size. Moreover, this piece of code shown (Figure 5) is sent to the Bluetooth module.

```
    case 'u':
      mopoff();
      break;
    }
  }
}

void forward()
{
  motor1.setSpeed(255); //Define maximum velocity
  motor1.run(FORWARD); //rotate the motor clockwise
  motor2.setSpeed(255); //Define maximum velocity
  motor2.run(FORWARD); //rotate the motor clockwise
  motor3.setSpeed(255); //Define maximum velocity
  motor3.run(FORWARD); //rotate the motor clockwise
  motor4.setSpeed(255); //Define maximum velocity
  motor4.run(FORWARD); //rotate the motor clockwise
}

void back()
{
  motor1.setSpeed(255); //Define maximum velocity
  motor1.run(BACKWARD); //rotate the motor clockwise
  motor2.setSpeed(255); //Define maximum velocity
  motor2.run(BACKWARD); //rotate the motor clockwise
  motor3.setSpeed(255); //Define maximum velocity
  motor3.run(BACKWARD); //rotate the motor clockwise
  motor4.setSpeed(255); //Define maximum velocity
  motor4.run(BACKWARD); //rotate the motor clockwise
}
```

Figure 5. This screenshot presents part of my code.

Week 15.02.2021 – 21.02.2021

In that week, I was trying to control the water pump (Figure 6). My assumption was to control the water pump by pressing the button to turn it on and turn it off. By sending a command to the android application, I have managed to control the water pump. During that, I face a problem, and the water pump was working straight after I connected the power supply instead of turning it on or off only when I press a specific button in the application. After doing research about transistors and their connections, it has been sorted out. The problem was associated with the connection to the transistors. Hence, my schematic of electronic connections is updated with correctness.

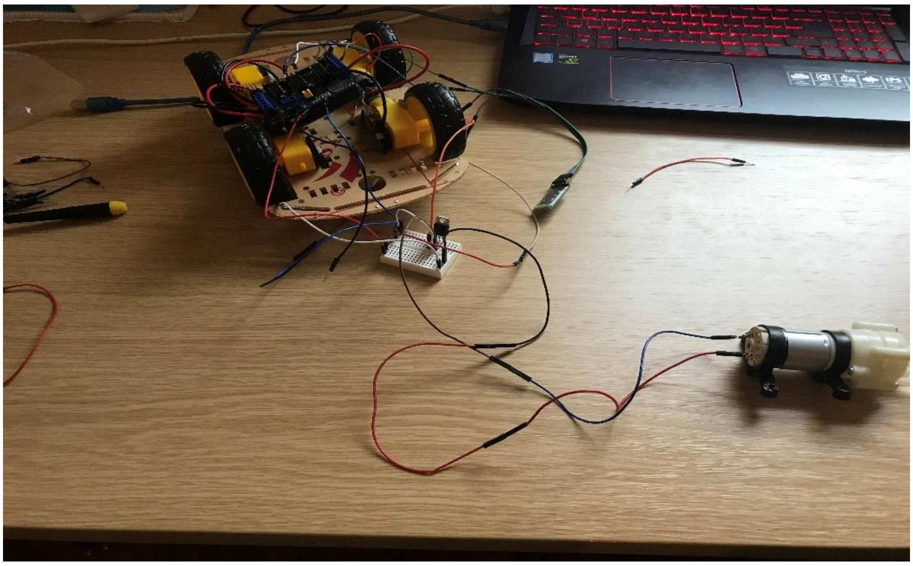


Figure 6. The photo presents connected water pump into circuit.

Week 22.02.2021-14.03.2021

The water pump is done. Now I have to deal with the mops. The mops have to rotate inwards to absorb the water properly. Firstly, I attach two wipes to the wheels, which are going to be rotating mops. I used the needle to sew the wipe across the wheel. After manual work is sorted, the mops have been connected. Then I have to attach the DC motors responsible for rotating mops. To make it stable, I used glue (Figure 7).

Figure 7. The photo presents DC motors attached to the base.

Just before using glue, The whole electric connections (Figure 8) has been made. I have tried to make it clean as possible. What is more, before assembling final parts I checked if everything is working properly.

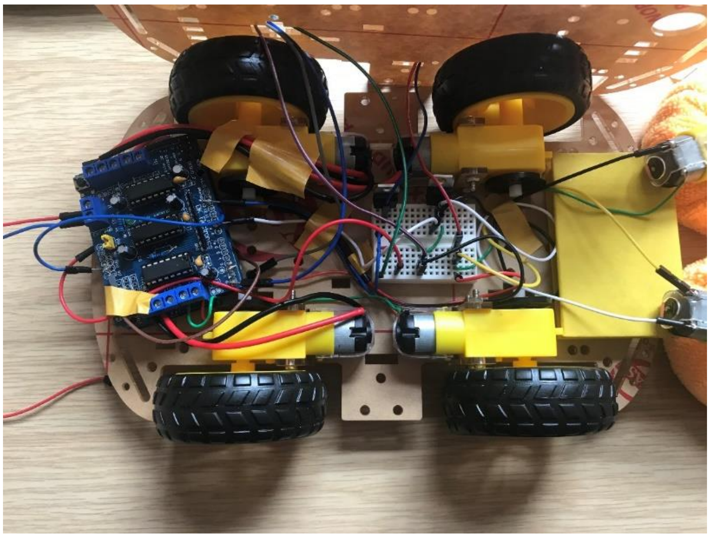


Figure 8. The electric connection of my robot.

When the connections were checked the second base had been assembled. On the figure 9 there are protruding wires. On the left there are four wires sticked together. Those wires are coming from Bluetooth module. It is important to have those certain wires easily accessible, because when the code is uploading the RX and TX have to be disconnected.

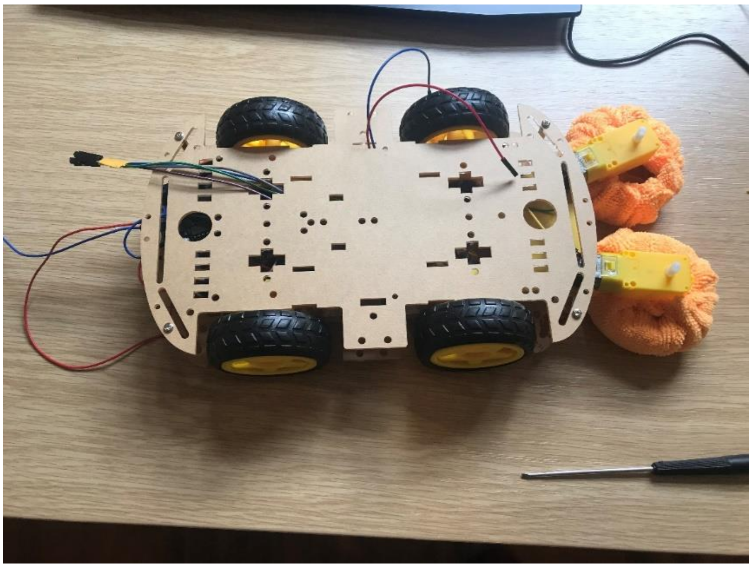


Figure 9. The photo presents assembled second part of the base.

Week 15.03.2021 – 21.03.2021

I have found out during the test that whenever I supply the robot with power, the water pump or rotating mopping system is working. The error was associated with the connection of the transistor. The problem was that the transistors were supplying the water pump and rotating mopping system after the power was ON instead of waiting until the button is pressed. I did more research about the transistors and found out that the transistors are connected wrong; hence the voltage is supplied into the features of the robot. I have changed the connections, and everything worked fine. In the figure 2.1, the final schematic of the electric schematic is presented.

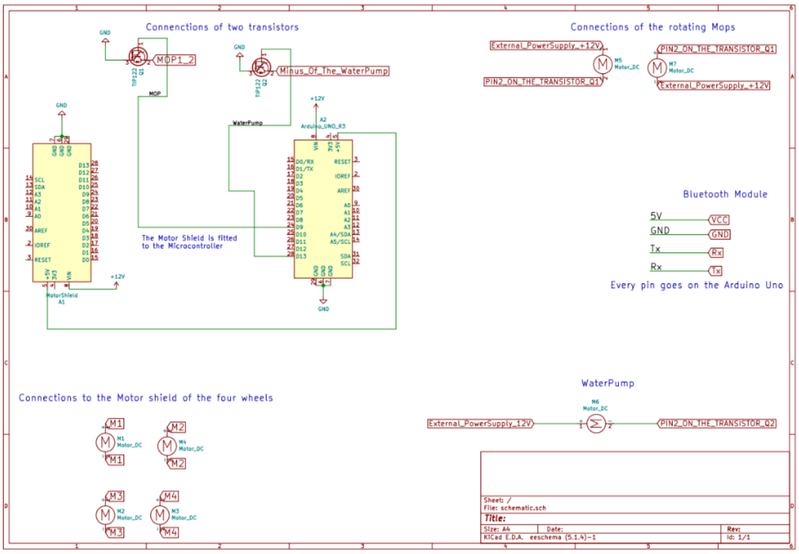


Figure 2.1 The updated and working the electric schematic of the robot

Week 21.03.2021 – 28.03.2021

Finally, I attached the rest of the items, such as the battery, water pump, reservoir. Most parts are attached by using double-sided tape. The robot is working fine. The robot is moving forward, backward, left and ride. The mops are rotating when the button in the application is pressed. The same thing is with the water pump. The robot is ready to carry out some tests for the final report purpose.

Figure 10. The photo presents mobile cleaning robot.