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DCR
Dust Cleaning Robot

Department Of Engneering
CPEG 475 : Senior Capstone
Design 1

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Abstract:

The evolution of renewable energy attracted the attention of many countries to implement the renewable energy sources as essential sources for generating electricity. Renewable energy sources such as trees, sun, and wind does not cause any pollution because they are natural sources. On the other hand, non-renewable energy sources such as coil and oil causes hazardous problems to the nature. For example, the process of manufacturing the oil needs intensive digging under the ground to get it; then it goes under several manufacturing stages to produce the oil. As an affect, this process will cause dangerous problems to the nature due to the smoke resulted from the manufacturing process. Also, when factories and many people start consuming oil as a fuel; they will cause pollution to the environment due to the numerous amounts of smoke produced from using it. Thus, non-renewable energy will affect on the global warming's dilemma negatively. As a result, we decided to do a project that is related to the renewable energy; and after many researches in the field of renewable energy, we found that there is a direct relation between the solar panels' efficiency and the cleaning process of the panel [1]. In other words, if the solar panel was not cleaned, it will cause a deteriorating in the efficiency levels of the solar panels; which means less electricity will be produced [1]. However, due to Kuwait's dusty weather, we decided to design a robot that cleans the solar panel from dust because the accumulated dust will affect negatively on the efficiency of the solar panels. After assessing all the information gathered from an extensive literature review; deciding upon the best techniques, requirements, robot's design and avoiding faults in previous designs, were developed. The most threat we faced is how to stabilize the robot on the solar panel. Therefore, we derived to a solution which is stabilize the robot on a frame that has the same dimensions of the panel whereas the robot will move up and down; then the frame will move to the next uncleaned area of the panel. At the end of this project, part of the design was developed. This project, Dust Cleaning Robot (DCR) has a common relation between environment and renewable energy because solar panels are part from the renewable energy; and the DCR provides cleaning to theses panels without any wasted water. In fact, designing DCR encourages as a team to realize the importance of renewable energy in our lives; and how many countries including Kuwait moving toward implementing solar panels in schools, co-operation markets, and well-known companies such as Kuwait oil company. Thus, DCR will benefit a lot of families who are implementing solar panels in their homes and they will not be worried about the cleaning process or any damages caused to the panels or to themselves. Also, DCR will save a lot of time and effort especially in large place where there are hundreds of solar panels.

CHAPTER 1

Introduction

Chapter 1: Introduction

1.1 Executive Summary

The evolution of renewable energy prompts the focus of many people and organizations to start adopting and implementing renewable energy in humans' live. Nowadays, our need of renewable energy is very important. The reason of this because renewable energy does not cause any pollution; in other words, renewable energy sources such as sun, trees, and wind does not cause any pollution problems contrary to the other nonrenewable energy sources such as oil. Thus, by using renewable energy in generating electricity, the global warming dilemma will be solved. Therefore, we choose to do a project which is related to renewable energy. Our project is aiming to solve one of solar panels problems that interfere with its performance which is the cleaning process. According to a study conducted by researchers who work in the field of renewable sources of energy, solar panels can lose 15-25% of their efficiency if they were not cleaned properly. In other words, they will generate 15-25% less electricity [1]. So, cleaning solar panels is strongly related with its performance which means neglecting cleaning the solar panels for long time will affect its performance rapidly [1]. Thus, we thought how we can solve the problem of solar panels' performance from deteriorating. Thus, we derived to a solution which is Dust Cleaning Robot (DCR). DCR is an automounts robot that's main aim to clean solar panels from dust in order to obtain the performance level of the panel as high as possible. DCR is equipped with high quality brush to clean the dust from the panel. Also, we are thinking of implementing additional features regarding the brush to obtain complete cleaning of the panel. Actually, the main threat we faced is how to control the movement of the robot on the panel. Thus, after researches done in that field, we decided to stabilize DCR on a mechanical frame that will moves right and left. Whereas, the robot will move up and down; and after the robot clean a specific area, the frame will move to the next uncleaned part of the panel. Additionally, some of the important features of DCR that it is does not require human interaction or manual cleaning.

1.2 Problem statement

As mentioned in the introduction sun considers as source for renewable energy, and we can generate electricity from sun through solar panels. Solar panels are used to generate electricity by absorbing the sun light and then produce electricity through a certain process. Solar panels nowadays are very widespread in many countries. But, it needs care to produce the optimum level of efficiency. This means, we need to clean our solar panels. Cleaning solar panels is a controversial issue. This is because there are many ways of cleaning solar panels. Nonetheless, we may wonder how we can stand up and clean thousands of solar panels without any effort from us. Hence, our capstone project's main aim is solving that problem with a new technological way of cleaning in order to prevent any deteriorating in the performance levels of the solar panels.

1.3 Goals

Our project, the Dust Cleaning Robot (DCR) has these goals:

- Eliminate human interaction in the process of cleaning solar panels.
- Developing easy and flexible way of cleaning solar panels especially in large arrays of panels.
- Maintaining the level of solar panels efficiency through cleaning them.
- Developing an Autonomous cleaning of dust on the surface of the solar panels especially in the dusty weather of Kuwait.
- Saving time and effort.

1.4 Objectives

Our project, the Dust Cleaning Robot (DCR) has these objectives:

- Providing a robot that moves in all the directions of the panel with the help of mechanical moveable frame.
- Protect solar panels' efficiency, and keeping them clean.
- Providing a complete process for the cleaning.
- Designing application that sends notification in case if there is dust.

1.5 Project SWOT Analysis

The Project SWOT analysis shown in *Table 1.1* represents the Strengths, Weaknesses, Opportunities, and Threats of the project. These factors will help the team members to be aware of weaknesses and try to solve them or improve the weakness to strengthens factors.

Table 1.1: Project SWOT Analysis

Strengthens	**Weaknesses**
• Save time and effort instead of manual cleaning. • No human interaction in the process of cleaning. • Sending notifications for the user when the panel is dusty.	• The mechanical design may not fit the solar panel. • The sensor may not recognize the dust.
Opportunities	**Threats**
• The mechanical design should be designed with precise measurements. • Many people can implement the cleaning system in their homes. • The cleaning system can be used in large arrays of panels.	• The panel not cleaned completely from all dust and dirt. • Software problems. • Need of mechanical assistance in the design of the mechanical frame.

1.6 Team SWOT Analysis

The Team SWOT Analysis shown in *Table 1.2* represents the four factors of the project. It shows the team's strongest and weakest tasks. The team members will take the benefits of the strengths to cover their weaknesses.

Table 1.2: Team SWOT Analysis

Strengthens	**Weaknesses**
• Having the full summer to work on the project. • The team has common meetings and study hours. • Learning new skills in different eras in engineering.	• Lack of sufficient knowledge in mechanical designing and in robotics. • Limited time in learning new programming language.
Opportunities	**Threats**
• Launching the cleaning system in many houses and companies. • Chance to work in the area of renewable energy companies in the future.	• Late shipment of the project components. • Some mechanical parts not available in the market. • Time conflict of meeting.

1.7 Report Content

The report is composed in the following manner: Chapter 1 provided a detailed overview of the capstone project's idea, goals, objectives, and SWOT analysis. Chapter 2 will include the literature review about different projects that are similar to our project, and a comparison between them and DCR project. Chapter 3 discusses hardware, software and both functional and nonfunctional requirements needed to build this project. Chapter 4 will cover the implementation of each component used to construct the project and how they are connected. Chapter 5 covers the ethical issues related to the project and its impact along with the global, economic, environmental, and social contexts. Finally, chapter 6 briefly concludes what has been discussed and states the phases of project planning and future goals of the DCR project.

1.8 Conclusion

This chapter provided a detailed overview of the idea behind the project. It stated the executive summary of the project, goals, and objectives, and provided the SWOT analysis. It also raised motivation to solve a relatively challenging industrial problem that many have attempted to develop. Through the next chapters of the report, a detailed discussion of the project will be carried out.

CHAPTER 3

Design and Analysis

Chapter 3: Design and Analysis

Chapter three is about system design and analysis. It will cover the system architecture, the nonfunctional and the functional requirements including hardware and software requirements used in our project. Also, the system's flowchart is discussed as well as the use case diagram.

3.1 System Architecture

The System Architecture of DCR represents the main components of our design, how they are connecting with each other as shown in figure 3.1. the battery will supply power for the Motor Driver, then the Motor Driver will supply power for the DC Gear Motor to work and switch on the DCR. Following that, the Arduino Mega will send pulses using PWM (Pulse Width Modulation) to the Motor Driver. In addition, the Arduino Mega contains the main commands responsible for running and activating the system. Consequently, the Arduino Mega will send signals also to the Bluetooth module which will work in hand with our application functionality.

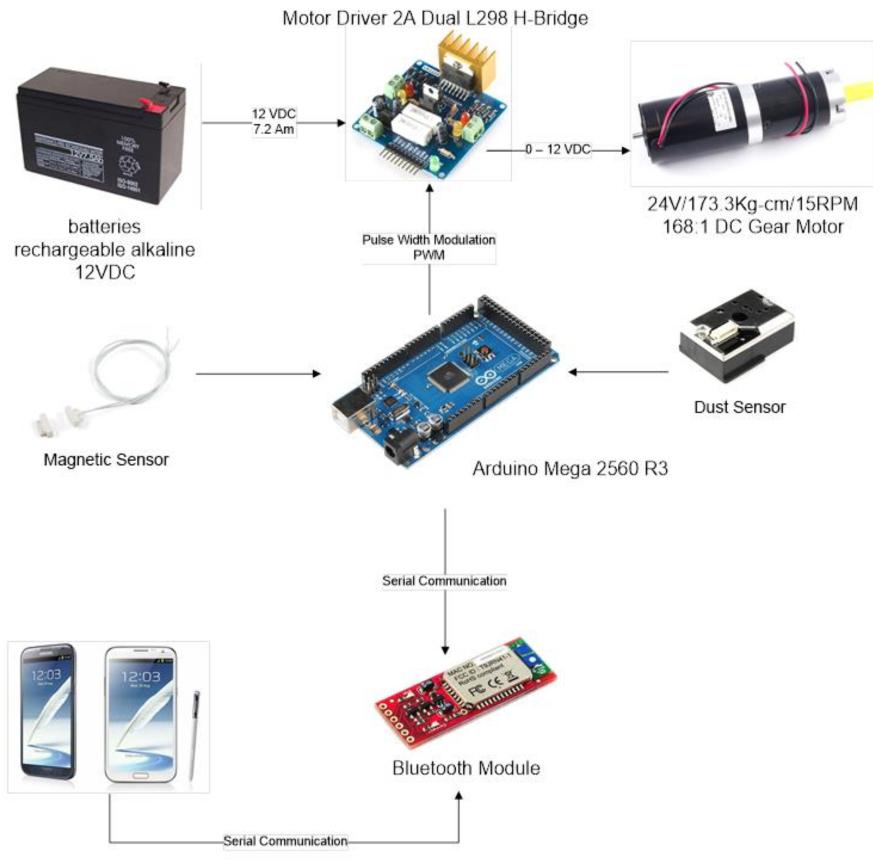

Figure 3.1: system architectures

3.2 System Requirement

The system requirement includes:

3.2.1 Functional Requirement

The functional requirement means the main functions generated through the DCR. Also, it includes all the requirements that are responsible for establishing the functionalities of our system. Functional requirement includes:

- Start cleaning the solar panel either manually using a switch, or through the application via Bluetooth. Or automatically by detecting the dust, or in a regular basis by setting a time.
- Using the Dust sensor to sense if there is dust.
- The application will send a notification if there is dust.
- DCR will clean the whole area of the solar panel using Magnetic sensor to detect the edges.

3.2.2 Non-Functional Requirement

The non-functional requirement evaluates the functions provided by the system. The evaluation factors are:

3.2.2.1 Reliability:

We thought of having additional features in the DCR such as water cleaning, but after many researches we realized that adding this feature will make the system heavier, slower and will consume large quantity of power. Thus, our system will be more reliable if we didn't provide this feature.

3.2.2.2 Response Time:

Our system will have fast response time because latency in response time between the user and the system itself considers as failure for the whole design.

3.2.2.3 User Friendliness:

The application that we will design it will provide the user with a flexible using of the DCR including switching it on/off and sending notifications in case if there is any dust detected. Also, the user has the potential to activate and deactivate the DCR through the application or a button in the DCR. In addition, the user can specify which panel wanted to be cleaned through the application.

3.2.2.4 Maintainability:

The system may face two types of failures, mechanical failure, and electrical failure. The causes of the electrical failure are the magnetic sensors, and the dust sensor, the power supply. The sensor will fail when its dirty, the solution is to clean it or replace it. The battery will be changed every two years. There will be a schedule for maintenance to maintain mechanical and electrical issues.

3.2.2.5 Performance:

The system has optimum performance in the dust cleaning process. Also, the cleaning part is achieved in short period with an accurate way of cleaning. Following that, our strategy in the dust caning process is ideal because using the mechanical frame that moves right and left ensures that every part of the solar panel is cleaned well. Also, the robot will move up and down to clean the specified area with a short time cleaning mechanism.

3.2.2.6 Availability:

The system and the application can be used at any time. But, the application is used within a limited distance which is 20 meter; and the reason of this because the Bluetooth module works within a maximum distance of 20 meter.

3.3 Hardware

3.3.1 Microcontroller

The microcontroller is the main core of DCR. It is connecting all the project components together since it has several I/O pins.

3.3.1.1 Arduino Uno:

As shown in figure 3.2, Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. In addition, it has a weight of 25 grams, length of 68.6 mm, and width of 53.4 mm, the cost of Arduino Uno is around $30, this Arduino is recommended to use for basic, simple, and light projects [11].

Figure3.2: Arduino Uno Microprocessor [11].

3.3.1.2 Arduino Micro:

As shown in figure 3.3, Arduino Micro is a microcontroller board based on the ATmega32U4. It has 20 digital input/output pins (of which 7 can be used as PWM outputs and 12 as analog inputs), a 16 MHz crystal oscillator, a micro USB connection, an ICSP header, and a reset button. In addition, it has a weight of 13 grams, length of 48 mm, and width of 18 mm, the cost of Arduino Mega2560 is around $25, this Arduino is recommended to use for everyday objects as it is easy to integrate [11].

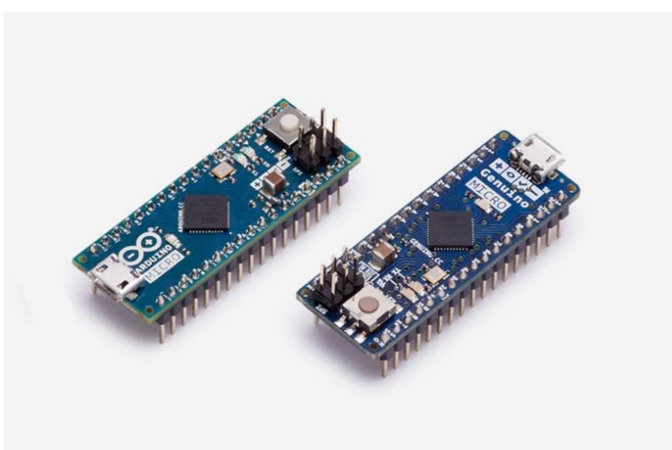

Figure 3.3: Arduino Micro Microprocessor [11]

3.3.1.3 Arduino Mega

As shown in figure 3.4, Arduino Mega2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. In addition, it has a weight of 37 grams, length of 101.52 mm, and width of 53.3 mm, the cost of Arduino Mega2560 is around $58, this Arduino is recommended to use for complex projects [11].

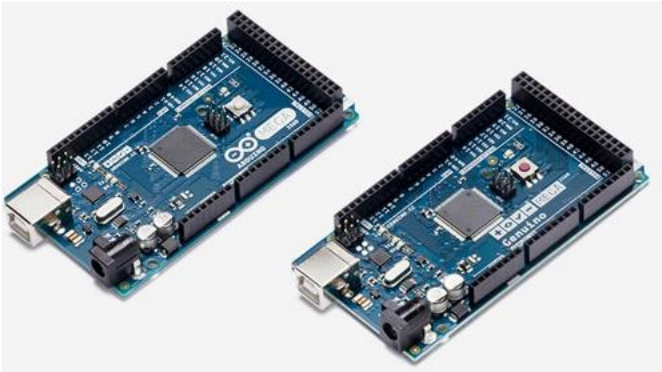

Figure 3.4: Arduino Mega2560 microprocessor [11].

Table 3.1: comparison of different microcontrollers.

Type	Processor	CPU Speed	Analog	Digital IO/(PWM)	Length and Width	Weight	Cost	Recommended for
Uno	ATmega 328P	16 MHz	6	14 (6)	68.6x53.4 mm	25g	$30	Basic, simple, light projects
Micro	ATmega 32U4	16 MHz	12	20 (7)	48x18 mm	13 g	$25	Everyday objects. Easy to integrate
Mega	ATmega 2560	16 MHz	16	54 (15)	101.52x53.3 mm	37 g	$58	Complex projects

In DCR, the microprocessor used is Mega2560 as a design choice. According to table 3.1, it has reasonable number of pins that can cover the need of 5 motors and for each motor we need 3 pins that means 15 digital ports.

3.3.2 Motor driver:

As shown in figure 3.5, the motor driver is dual bidirectional motor driver (rotating in both forward and reverse directions), is based on the L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow to connect easily and independently controlling two motors of up to 2A each in both directions [12].

It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. The motor supply is 6 to 35 VDC, the output power is up to 2A each, has control pins to enable and direction [12]. The motor driver will be connected to the controller and battery supply as inputs in the other hand it will control the DC gear motor.

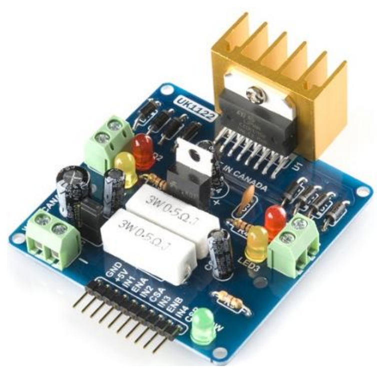

Figure 3.5: Motor Driver[12].

3.3.3 Detecting Sensors:

3.3.3.1 Miniature Magnetic Contact Switch:

As shown in figure 3.6, the 3562-magnetic contact switch is very small and is designed for surface mounted installations. The switch handles gaps of up to 12mm (1/2 inch) (the maximum distance at which the sensor can detect a standard object) between the magnet and the switch. The switch will turn the digital input "on" when the magnet is within 12mm of the switch, and will turn "off" when the contact is broken by moving the magnet more than 13 mm away [13].

Figure 3.6: Magnetic Sensor [13].

3.3.3.2 IR sensor:

An infrared sensor (figure 3.7) is an electronic device, that emits in order to sense some aspects of the surroundings. An IR sensor can measure the heat of an object as well as detects the motion. These types of sensors measure only infrared radiation, rather than emitting it that is called as a passive IR sensor. Usually in the infrared spectrum, all the objects radiate some form of thermal radiations. These types of radiations are invisible to our eyes, that can be detected by an infrared sensor. The emitter is simply an IR LED (Light Emitting Diode) and the detector is simply an IR photodiode which is sensitive to IR light of the same wavelength as that emitted by the IR LED. When IR light falls on the photodiode, The resistances and these output voltages, change in proportion to the magnitude of the IR light received [14].

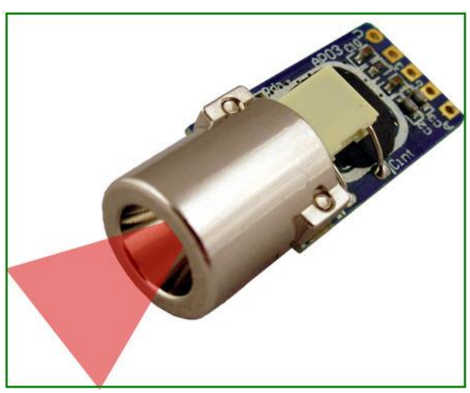

Figure 3.7: IR sensor [14].

As technology, the IR detects the obstacle in specific range, that range is bigger than the magnetic sensor's range. Magnetic sensor has to be very close to the obstacle in order to take action. in DCR the motor used is moving slow so there is no need to use the IR which needs bigger ranges. So we decided to choose the magnetic sensor.

3.3.4 Motors:

3.3.4.1 Dc motor (figure 3.8)

Fast, continuous rotation motors – Used for anything that needs to spin at a high RPM [15].

3.3.4.2 Servo motor:

Fast, high torque, accurate rotation within a limited angle – Generally a high-performance alternative to stepper motors, but more complicated setup with PWM tuning. Suited for robotic arms/legs or rudder control etc [15].

3.3.4.3 Stepper motor:

Slow, precise rotation, easy set up & control – Advantage over servo motors in positional control. Where servos require a feedback mechanism and support circuitry to drive positioning, a stepper motor has positional control via its nature of rotation by fractional increments. Suited for 3D printers and similar devices where position is fundamental [15].

We will use the dc motor as sown in figure 3.8. because of many aspects like in servo motor doesn't rotate 180 degrees, where we need a full rotation of 360 degrees.

The gear motor used is a 24 volt gear motor, generating 173 Kg-cm of torque at 15 RPM. It's a large motor that provides an amazing amount of torque. The type of the gear motor is DC motor, its output power is 30 W [16].

Figure 3.8: Gear motor [16].

3.3.5 Optical dust sensor:

As shown in figure 3.8, dust sensor is an optical air quality sensor, designed to sense dust particles. An infrared emitting diode and a phototransistor are diagonally arranged into this device, to allow it to detect the reflected light of dust in air. It is especially effective in detecting very fine particles like cigarette smoke, and is commonly used in air purifier systems [17].

The sensor has a very low current consumption (20mA max, 11mA typical), and can be powered with up to 7VDC. The output of the sensor is an analog voltage proportional to the measured dust density, with a sensitivity of 0.5V/0.1mg/m3 [17].

Figure 3.8: Optical dust sensor [17].

3.3.6 Bluetooth Module:

In figure 3.9, the Bluetooth module. used in the design of DCR works on serial communication. The Bluetooth module used in DCR has two main tasks. The first main task is: notifying the user about the dust through both the dust sensor and the Bluetooth module which will work in hand to notify the user in the application. Th second task is:

switching on/off the DCR through the application. However, Through the Arduino kit, serial data will be sent to the Bluetooth module when the DCR. The Bluetooth module receives the data from the Arduino through the TX pin of Bluetooth module (RX pin of Arduino), then send it to the application to notify the user if there is a dust.

Figure 3.9: Bluetooth module [18].

3.4 Software:

3.4.1 Arduino Software (IDE)

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards can read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online. Also, users can tell the board what to do by sending a set of instructions to the microcontroller on the board. Thus, to achieve the process of making the Arduino board do what users want, they must use the Arduino programming language (based onWiring), and the Arduino Software (IDE), based on Processing [11]. The figure 3.10 is the logo of the software.

Figure 3.10: Arduino IDE Software [11]

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3.4.2 MIT App Inventor

MIT App Inventor is a software for building mobile applications on Android operating systems. It allows beginners to code and create apps. Also, it transforms the complex language of text-based coding into visual, drag-and-drop building blocks. The simple graphical interface of MIT grants even inexperienced beginners the ability to create a basic, fully functional app within an hour or less. MIT's mission is to empower all people, especially young people, to become creators of technology instead of being consumers for it [19]. The figure 3.11 is the logo of the software.

Figure 3.11: MIT App Inventor [19].

3.5 System Flow chart:

The system flow chart in figure 3.12 represents how the system process of work from the beginning till the end. There will be three main way to establish the cleaning, the first way is by the user input, that the user has the ability to choose manually certain panel to clean. Second, if the weather is dusty, where the dust sensor measures. The DCR will start clean working. Third, by set a regular time for example once a week or once a month, then the DCR will start cleaning automatically. Also, the application will allow the user to clean the whole panel manually not only specific panel. the mechanical frame will move left side to clean the un-cleaned part of the panel along with the DCR which will moves up and down to clean.

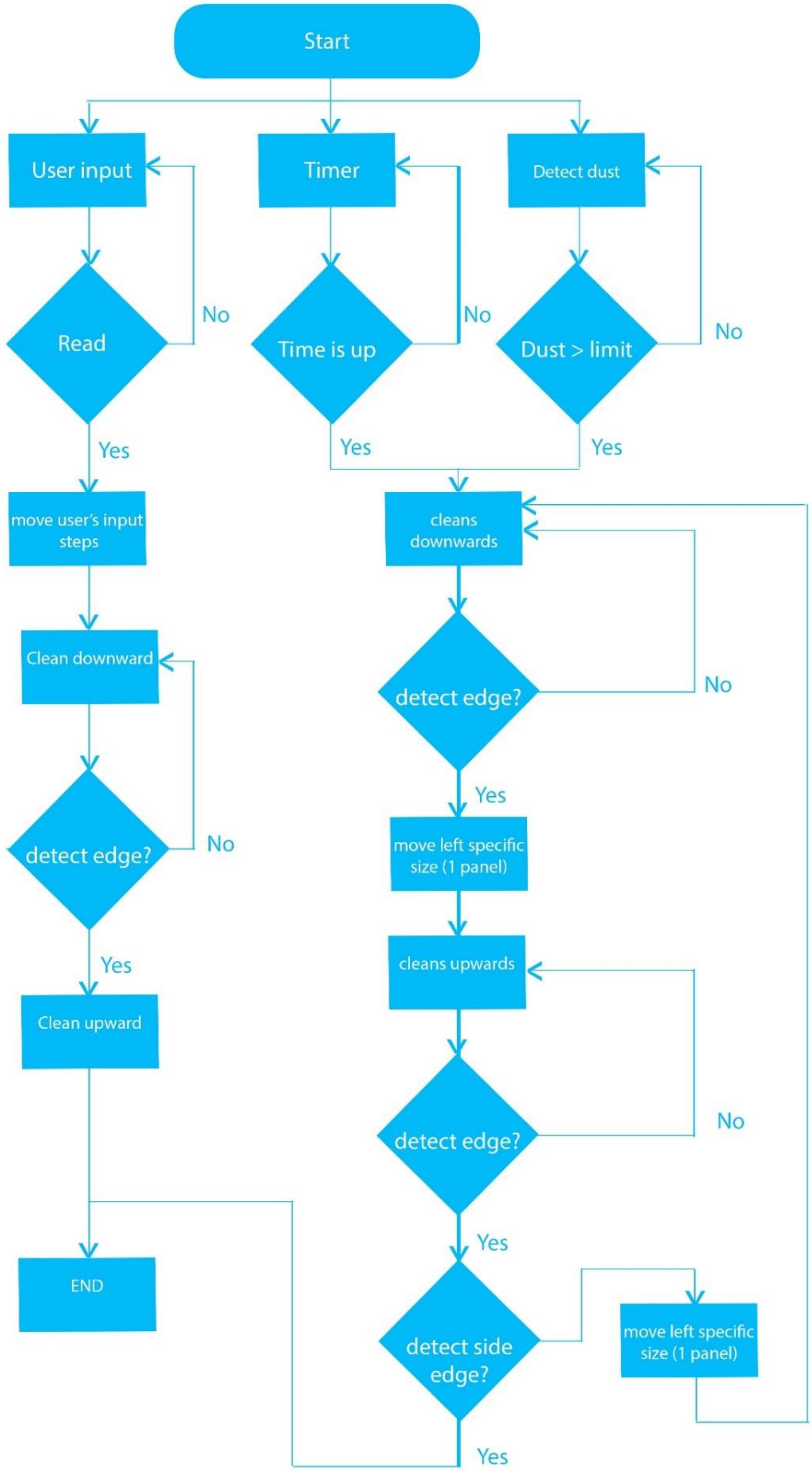

Figure 3.12: DCR flow chart.

3.6 System Use Case Diagram

Use Case Diagram is a diagram that describes the main functional requirements of the system; or in other words what the system should do. Also, it describes the interaction between the user and the system. The following figure which is figure 3.13; represents the use case diagram of DCR. It shows the services available by our system DCR to the user. These services are: receiving notifications through the application, activating and deactivating the DCR through the application, and switching on and off the DCR manually through a button in the DCR. In addition, all the services which are obtainable by the application are established through connecting the Bluetooth module and the dust sensor with the Arduino mega. Then, the Bluetooth and the dust sensor will interact with both the Arduino and the application using serial data communication.

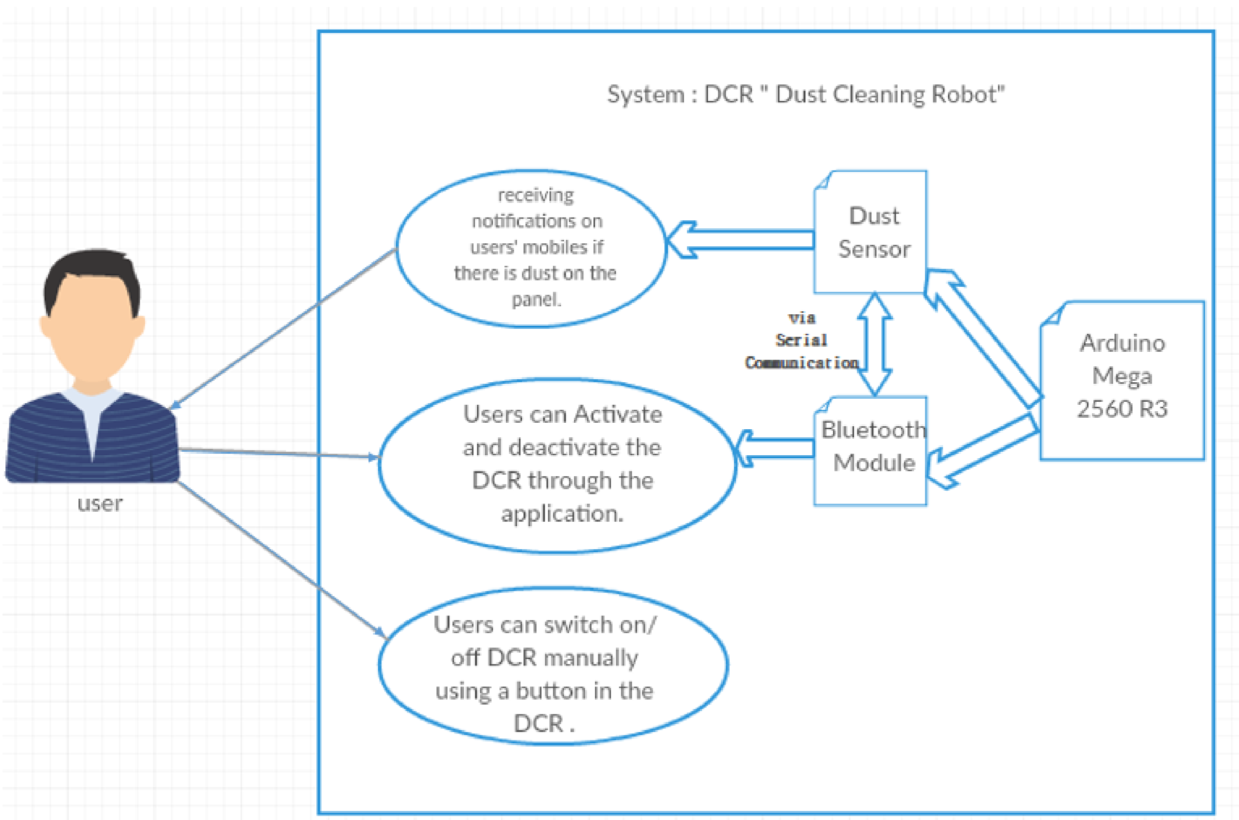

Figure 3.13: Use Case Diagram.

3.7 Budget

The following table represents the cost of all hardware components which are purchased for achieving the DCR. Also, the quantities and prices are provided in table 3.2.

Table 3.2: Budget of DCR.

Item Code	Item Name	Qty	Cost - KD
DEV-11061	Arduino Mega 2560 R3	1	KWD 18.560
ROB-09670	Motor Driver 2A Dual L298 H-Bridge	3	KWD 33.552
RTC	Bluetooth	1	KWD 4.500
---	wires and connectors	1	KWD 4.500
---	Batteries 4.5 Am 6 VDC - or 7Am 12VDC Qty:1	2	KWD 7.500
3274_1	24V/173.3Kg-cm/15RPM 168:1 DC Gear Motor	5	KWD 115.200
---	Solar Panel	1	KWD 0.000
COM-09689	Optical Dust Sensor - GP2Y1010AU0F	1	KWD 3.824
3562_0	Miniature Magnetic Contact Switch BR-2023	4	KWD 3.200
	Shipping	1	KWD 35.200
	Tax		KWD 10.000
	Total Cost		KWD 236.036

3.8 Conclusion

In this chapter, the system architecture was explained. Also, the functional requirements were discussed including the hardware and software requirements needed for achieving and designing the DCR. The nonfunctional requirements also were listed and explained. To capture more information about our DCR architecture, we added flowchart, use case diagram, and the budget of all the hardware components of DCR.

CHAPTER 4

Implementation

Chapter 4: Implementation

Chapter four will cover the implementation of DCR along with its connections to create the system. Every component of DCR was tested individually then connected them to each other to build the DCR system. In addition, software and the mobile application will be discussed in this chapter.

4.1 Implementation of components:

DCR is made up of several components that are connected to finally get a successful implementation. Figure 4.1 shows the main parts of the system.

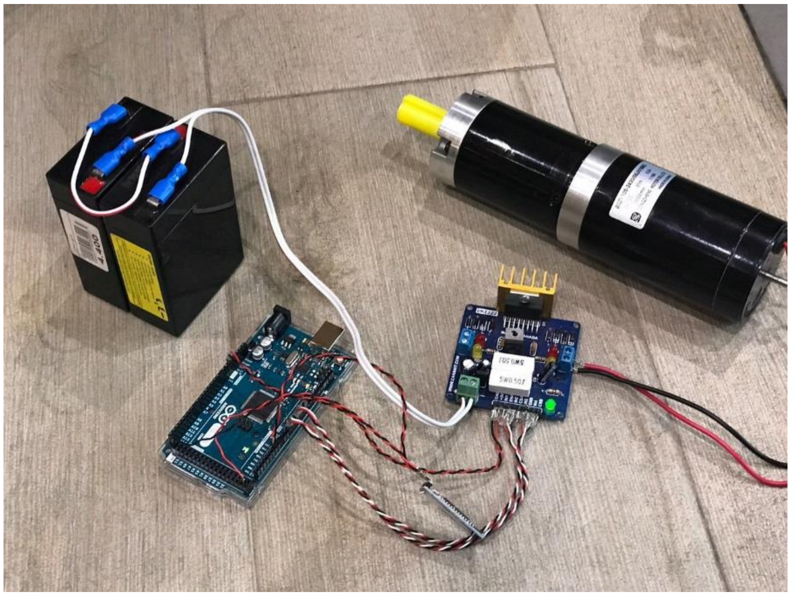

Figure 4.1: DCR components implementation

4.1.1 Software Implementation:

DCR uses a software to implement the mobile application. DCR application is easy to use, little understandable commands. It is used to manually move the frame to specific panel to clean. So, the user can use it easily.

The figure 4.2 shows MIT app inventor, where the android application implemented such that the user use to move the panel.

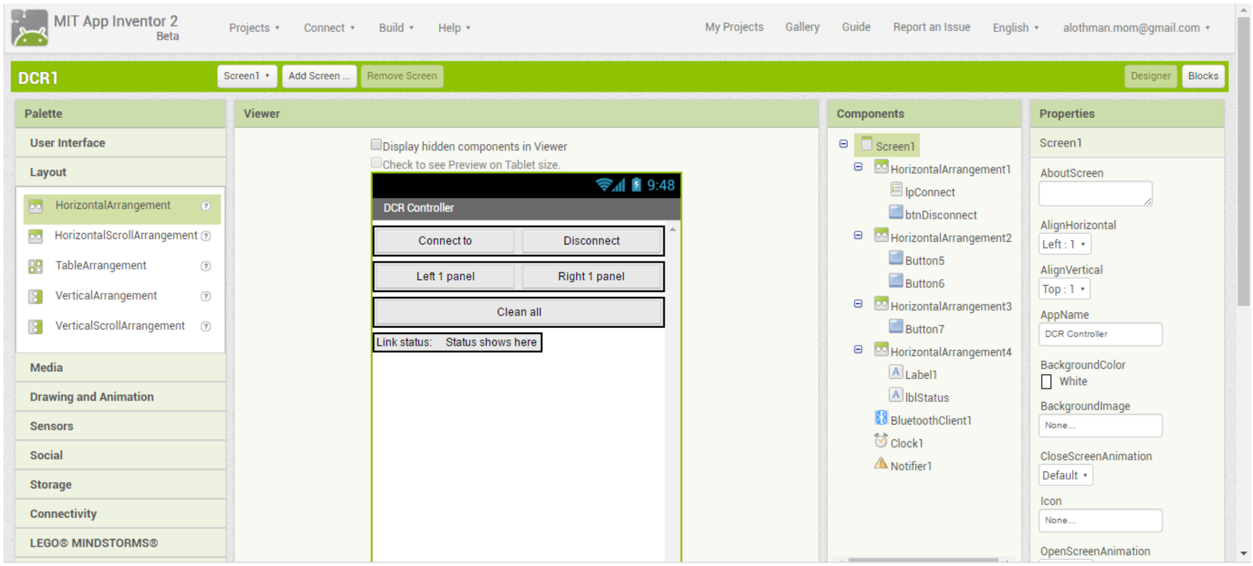

Figure 4.2: MIT app inventor

4.1.2 Hardware Implementation

An individual test of each component was needed to fulfil the project requirement and the desired functionality of each component.

4.1.2.1 Bluetooth module

The Bluetooth module is connected to the Arduino Mega 2560, and it was successfully accepting signals from the android application and send it to the motor through the microcontroller.

4.1.2.2 Gear Motor

The motor is accepting the sent signals from the Bluetooth module through the microcontroller. The motor turns forward, and backward successfully depends on the user’s input.

4.2 Conclusion

This chapter demonstrates the software and hardware components that are used to in DCR implementation along with their connections. Each component was tested individually.

CHAPTER 5

Evaluation

Chapter 5: Evaluation

Achieving any engineering project should meet its goals and objectives. But, that is not the only case to achieve a successful project. The reason of this because doing a project without satisfying the customers' requirements will lead to failure. Also, not meeting the effects of the project on global, economy, society and the environment aspects will also lead to failure. Thus, creating guidelines that explains these aspects will help the project's team to take them into consideration. In addition, in this chapter we will discuss the engineering ethics that we should consider and implement it in DCR. Engineering ethics explains the various problems that may face the user, and we will provide the solutions of these problems.

5.1 Engineering Ethics

DCR will offer to the user many choices in the cleaning strategy. First, the DCR will be activated automatically if there is dust in the weather. Second, we will provide automatic cleaning for a specific period such as every 1 week. Third, we will offer a very useful option which is choosing a specific area in the solar panel to clean it. In addition, DCR will not cause any damage to the panel or any scratches. Thus, DCR will not cause any negative effects on the solar panel because it will increase the efficiency of the panels' performance. [1]

After many researches in the field of solar panels' cleaning, we thought of a problem that may occur which is the birds' drops on the panel. Consequently, we derive to a solution for this problem which is providing an option for the user to select a certain panel through the application so that the DCR start cleaning it. Moreover, the application will notify the user through the application if the panels need cleaning. So, we will not bother the user for any passwords or sign in to activate or deactivate the DCR; and anyone can just download the DCR application and use it to control the DCR. Consequently, this option will add more flexibility to any family who will implement DCR in their homes because any member of the family can be notified on their mobiles or tablets.

5.2 Impact of Engineering Solution

DCR has several impacts on several contexts, and the following sections will represent the DCR impacts on each context.

5.2.1 Impact on Global Context

DCR is a technological way of solar panels' cleaning that will ease the process of cleaning them. In fact, DCR will be more beneficial to implement it in large arrays of solar panel which will facilitate the process of cleaning the panels instead of cleaning hundreds of panels manually. DCR can be implement in any place that uses solar panels as a source of generating electricity. For example, DCR can be in implemented in companies, hospitals, schools, and homes. Thus, DCR is global project because as mentioned it can be implemented in any place where solar panels exist.

5.2.2 Impact on the Economic Context

We think that DCR will have overwhelming results on the economic context. The reason of this because the DCR will not have any water expenses; especially in large places where they implement hundreds of panels and huge amounts of wasted water that is wasted due to solar panels' cleaning. Thus, DCR will develop the cleaning operation of solar panels without any water and any economic expenses on the users.

5.2.3 Impact in a Social Context

DCR will save time and effort because users will not need to clean the solar panels by themselves. Also, they will not be hesitant about any damage that may occur if they clean the panels by themselves. Also, we created an application to offer convenience and flexibility of use between the user and the DCR. Through the application, users will be capable of switching the DCR on/off, and cleaning certain panel. Also, users will not need to check if the solar panel is uncleaned or not because they will be notified if any dust or dirt was detected.

5.2.4 Impact in an Environmental Context

DCR is an environment-friendly project because of two reasons. The first reason is because DCR deals with the field of renewable energy, and as we mentioned in chapter one that our main aim is to do a project that is related to renewable energy. Renewable energy uses renewable sources to get energy from such as sun, trees, wind, etc. On the contrary, non-renewable energy such as coal and oil which causes huge pollution for the environment which will lead to huge hazard problem which is global warming. The second reason is DCR will help the solar panel in absorbing the maximum sun light from the sun. the reason of this is because DCR will protect the solar panels from any dust or dirty spots that will affect negatively on the absorption process of the solar panel. According to a study conducted by researchers who work in the field of renewable sources of energy [1], solar panels can lose 15-25% of their efficiency if they were not cleaned properly. In other words, they will generate 15-25% less electricity. So, cleaning solar panels in harsh conditions will need more special care in cleaning them. Additionally, DCR will not need any water consumption in the process of cleaning which will saves huge amounts of water.

5.3 Conclusion

This chapter provided an evaluation of various aspects of the DCR on global, environmental, social, economic, and ethical aspects. Furthermore, DCR have positive effects on all the aspects.

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