DESIGN AND DEVELOPMENT OF DISINFECTING ROBOT FOR ACADEMIC INSTITUIONS

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A Final Year Design Project (FYDP) submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of
BSc Eng. in Electrical and Electronic

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Declaration

It is hereby declared that

1. The Final Year Design Project (FYDP) submitted is my/our own original work while completing degree at Brac University.
2. The Final Year Design Project (FYDP) does not contain material previously published or written by a third party, except where this is appropriately cited through full and accurate referencing.
3. The Final Year Design Project (FYDP) does not contain material which has been accepted,or submitted, for any other degree or diploma at a university or other institution.
4. We have acknowledged all main sources of help.

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of Fall, 2022 has been accepted as satisfactory in partial fulfillment of the requirement for the degree of BSc Eng. in Electrical and Electronic on 15/12/22.

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Ethics Statement

The plagiarism has been checked and the similarity index is 5%.

Abstract/ Executive Summary

Cleaning up areas where people assemble is necessary due to the proliferation of several fatal infections, including the coronavirus. Nowadays, humans perform disinfection procedures in a variety of settings, which doesn't result in efficient results and may even be harmful to people. The COVID-19 pandemic has resulted in widespread school closures and an enormous crisis in education. While the past almost two and a half years have been difficult for all of us, students were especially impacted by the extended closure of their schools. In light of this, a technological solution to the issue has been developed to disinfect classrooms using an IoT-based UV-C disinfection system. Although the sterilizing properties of the C-band of ultraviolet (UV) radiation are universally acknowledged, their application has recently become more important and common due to the Covid-19 outbreak. Usually utilized in a regulated manner, UV light produces no waste and is environmentally beneficial. Six UV-C lights that cover the entire system's 360 degrees are linked to the top of the structure in this project. It is a semi-autonomous device that will be operated by a mobile application and will follow the necessary safety protocols to shield students from UV ray exposure. The system will have a limited range for objects and human detection. Moreover, the device will immediately turn off when humans are detected within a 36-meter range. The method is also capable of identifying those who exhibit early symptoms of viral assaults. According to the findings, this device requires 10-15 minutes of UV-LED exposure for any microbe to fully perform its germicidal functions.

Keywords: UV-C disinfecting system, Mobile App, ESP32-Microcontroller, Human detection, Object Detection, Temperature Detection, RFID (Radio Frequency Identification)

Dedication (Optional)

Our research is devoted to our adored family. A special thank you to each and every member of the FYDP group members and friends who have continuously supported, inspired, and paved the way for success as well as to our advisors who have guided us down this arduous path.

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List of Acronyms

UV-C	Ultra-Violet-C
PCB	Printed Circuit Board
IoT	Internet of Things
HTTP	Hyper Text Transfer Protocol
MQTT	Message Queuing Telemetry Transport
LIDAR	Light Detection and Ranging
RFID	Radio Frequency Identification
PIR	Passive Infrared Sensor
CAD	Computer-Aided Design

Chapter 1

Introduction- [CO1, CO2, CO10]

1.1 Introduction

The chapter offers information about the project's foundational elements. The major goal of the project is to create a radiation-based system that will provide a microorganism free surrounding of all kinds of educational establishments. This system needs to be affordable for both public and private institutions in order to utilize it for sterilization purpose. This chapter goes into detail about the project's goal and the reasons the system is crucial for the community. The requirements, component lists, and system setup have all been discussed. The system is not a novel concept in the global market. Although they are expensive, people utilize the system for hospital disinfection all over the world. Some of them have many features and are very resource-intensive. Some of the studies which was conducted has been detailed in the background story and literature review. This has led to a clearer description of the demonstration of the proposed system. Additionally, a 3d model of the system has been included. Some applicable standards and codes have also been followed during the system's design.

1.1.1 Problem Statement

The health and economic systems of nations around the world have been significantly impacted by epidemics brought on by virus attacks. Infectious diseases that spread from person to person, from animal to human, via the environment or through other media typically produce disease outbreaks. Similarly, outbreaks might follow chemical or radioactive substance exposure. Infectious illnesses with the potential to become pandemics have consistently developed and propagated throughout history. Humans have already been severely impacted by a number of terrible pandemics and epidemics, including the plague, cholera, flu, Middle East respiratory syndrome coronavirus (MERS-CoV), severe acute respiratory syndrome coronavirus (SARS-CoV), and swine flu. In 2019 COVID-19 coronavirus disease pandemic was affecting the entire world. [1] According to World Health Organization (WHO), coronavirus disease 2019 had progressed to 220 countries as Of May 25, 2021. [2] As a result of this pandemic, more than 166 million people were infected which caused more than 3.4 million deaths. This includes the 1.5 million students who were impacted by the coronavirus pandemic on a global scale. Global school closures and an unparalleled crisis in education have also been brought on by the COVID-19 epidemic. Despite the fact that the past almost two and a half years have been challenging for all of us, students were particularly affected due to the prolonged closure of their schools (more than 18 months).[3] During the COVID-19 school shutdown in 2020, at least 463 million children globally were unable to access remote learning. The government chose this method of action while considering safety issues. A major contributing factor to this is the absence of an effective radiation-based sterilizing mechanism. Globally, chemical-based manual sterilization, which also involves human intervention, has been a long-standing practice. However, this approach somehow doesn’t completely eliminate all microorganisms. Thorough research might lead to the conclusion that using a radiation-based sterilizing technology will help to overcome this limitation. In one study, the researchers designed an inexpensive UV-C sterilizer box that will employ ultraviolet radiation to destroy bacteria in a contained setting. Additionally, security elements are included to shield people from ultraviolet radiation exposure. [4] In another research, a UV-LED has been used as the main sterilizing device, because it doesn’t include any dangerous materials and has a longer operational life by exposing bacteria to UV-LED light for 30 minutes for E. coli and 10 minutes for Vibrio respectively, the results demonstrated complete germicidal effects. Furthermore, eliminating human involvement is this method’s additional benefit. In order to create radiation-based sterilizing systems that effectively kill around 99 percent of germs, many engineering techniques have been employed throughout the world. However, most of them are either limited to working on a single path or are unable to cover the greatest number of afflicted locations at once. Moreover, significant features in a single system have also been found missing. This has become one of the greatest matters of concern as the threat of the coronavirus is returning, and people around the nation are still ill-equipped to deal with it.

1.1.2 Background Study

Extensive research has been done on the current situation in Bangladesh to have a better understanding of the Covid-19 side effects and several types of research have been conducted regarding this issue. Measurement methodologies, disinfection equipment, disinfection periods, and room parameters are all complicated elements that influence infection.

[5] Y Zhao and his team developed a disinfection robot system, which sprays various kinds of disinfectant liquids. Therefore, to spray the liquids, their team attempted to develop image processing that would allow the robot to understand hand movements. These movements would act as commands for the bot. The hardware system is a complicated construction. They have been utilized nozzle, RGB-D camera, LIDAR, and many other high-cost components which arequite complex to operate.

[6] Moving on another research done by G. S. Sonawane and their team developed a UV Disinfection Machine, which would ensure mass disinfection of human belongings. The disinfection duration may be adjusted automatically using IoT system and based on the number of active cases in the area at any given moment. Additionally, metal was put within the container to better reflect the Radiated rays.

[6] In another research work, Rai, A. Chaturvedi, and his team developed a robot to sterilize an operating room. This robot consisted of UV-C lamps with a camera on top of the robot, which covered a complete 360 degrees of its surrounding. The radiation given off could disinfect any

bacteria. They also carried out experiments to see how long it takes to sterilize bacteria from different distances. This system is mainly for the operating rooms to minimize the growing rate of infections after any kind of surgery.

[8] Moreover, Kurniawan and his partner conducted research and developed a UV-C Health Care Surface Disinfection Robot, which uses a path planner to map out the disinfection zone and work accordingly, but this comes at a higher price.

[9] However, Argen Mary Arceño and his team focused on the different types of bacteria, which could be disinfected by UV-C light. They put it to the test by taking temperature readings and comparing them to changes in humidity in bacteria samples. They achieved it by taking the exposed sample's images through image processing and using image conversion. Their robot was also voice-controlled through a mobile app and the temperature and humidity readings of the samples were displayed in that application.

[10] Another research and development team lead by Siddhant Kamlaskar and his team made an autonomous mobile sanitizing system, which would sanitize an area in the absence of humans. Nevertheless, it was mainly designed to be a portable sanitizing unit.

[11] Lastly, in another engineering solution for water sterilization based on UV-LEDs was given by Noriyuki YAGI and her colleagues. The results showed that E. coli and Vibrio parahaemolyticus were completely eradicated by UV-LED. With an exposure time of 10 to 30 minutes, it was also effective against various bacteria and viruses.

After going through the various projects and research done before, different usage and ways of how disinfecting objects have been considered. A comparison can be done on what to use and knowledge has also been gained about how to monitor and change the time according to the needs of the project. The main focus of the project is the use of radiation to eliminate bacteria and other microbial germs including covid-19.

1.1.3 Literature Gap

A sterilizing method that doesn't involve humans is one of the most significant needs that the modern world requires. As a result, an engineering approach has been taken to address this demand. For educational institutions, this project aims to construct an IoT-based UV-C sterilization system. Microorganisms have been effectively eliminated for more than a century by using UV-C light. Numerous studies have been carried out to discover why it is so powerful against various varieties of bacteria and viruses, including the new coronavirus. [5] Yu-Lin Zhao and his team worked on a spray disinfection system. Using innovative chlorine dioxide (ClO2) sterilizing technology, this study reduced the number of germs and viruses in the air along with surfaces. Additionally, a sterilization robot system was developed in order to disinfect the operating rooms. The system was an IoT-based system with a gesture recognition function, and it was operated by a semi-automated remote module. Although the effectiveness of eradicating Escherichia coli (E. coli) bacteria was 99.8%, but this study did not demonstrate the effectiveness of eradicating other viruses. They have used nozzles, RGB-D cameras, LIDAR, and many other expensive, complicated-to-use components.[6] In addition, in another research paper, a machine will be operated automatically and without human touch. All items belonging to people inside the machine's enclosed chamber will be sterilized by powerful UV-C radiation. The COVID-19 virus will be completely destroyed once this project is physically implemented. IoT allows for the automatic adjustment of disinfection time. Although there was no alternative for surface or air sterilization, the results for human belongings showed an effective result. [12] Furthermore, P. Chanprakon and his associates created a UV robot or UV bot In order to sterilize an operating area or patient room. Three 19.3-watt UV lamps positioned on the top of the UV bot platform provide 360° coverage for the bot. Additionally, they evaluated how well Staphylococcus Aureus bacteria were destroyed on sample plates that were 35 cm from the UV light source and 8 seconds after exposure. The robot can only irradiate microorganisms that are drug-resistant and is manually controlled. In the system, they have incorporated an ultrasonic sensor for object detection and a web camera for human detection. The whole system is controlled by raspberry-pi and 3 UV lamps covering a 360-degree direction.[13] In addition, K. M. Fernandes and his team developed a powerful disinfection device that combines RFID-based technology with germicidal UV-C (ultraviolet-C) tubes to track users' body temperatures and credentials and save the data on an excel sheet. Our system enables objects placed inside it to be sanitized from all sides. After two bacteria were inactivated by the UVC equipment for 30 seconds, experiments were performed on them. However, the device won't be able to function well for surface or air sterilization.[14] In another research, Conor McGinn and his team developed a cost-effective UVC wirelesssensor that may be utilized to measure the UV radiation dose on a surface over time while performing UV disinfection. The devices were positioned at 12 different positions in a computed tomography room, the system's applicability was evaluated. Each of the sites approximately got a UVC dosage of 13mJ/cm2 over three cleaning sessions that lasted roughly 10 minutes each. This is higher than the published D90 values for SARS-Cov-2, influenza, and a number of other recognized diseases that are mostly present in hospitals. Despite the system's effectiveness, time-consuming issues cannot be disregarded.[15] Indra Adji Sulistijono and his research collaborators created a mobile robot to handle the logistic delivery task in hospitals or isolation sites in order to minimize interactions between medical personnel and COVID-19 patients, in order to provide the logistics for a mobile robot, a low-level controller is required. In this study, low-level control has been implemented utilizing a PID control with a specific parameter value. The mobile robot has also been physically controlled by teleoperation, allowing it to move and transport loads up to a specific maximum weight. The mobile robot may be manually controlled and can carry out the delivery task, reducing contact between medical personnel and COVID-19 patients, according to the results of the studies that have been done. In this project, examining all the information from the aforementioned studies, we will employUV-C radiation to effectively disinfect educational institutions. In the studies stated above, various UV-C sterilizing techniques have been used. UV-based sterilization systems were usedby G. S. and K. M. and their team for the aim of disinfection; however, the systems were unableto sterilize the air or surfaces. Similarly, Chanprakon and Indra employed UV-based disinfection systems, but both of the controls for the systems were manual. Conor and his teamdesigned a UVC sensor that has produced remarkable results for eliminating microorganisms but required a prolonged sterilization process. Taking all of these issues into account, a UV-C-based disinfection system will be designed where several UV-C lights will be used for effective air and surface sterilization. Furthermore, a feature will be incorporated that involves taking students' temperatures to identify those who are showing early signs of the coronavirus. The system will need less time for sterilization and will also be a cost-effective solution for all educational institutions.

1.1.4 Relevance to current and future Industry

The coronavirus epidemic is having an effect on countries' health and socioeconomic systems around the world. With the extremely infectious and dangerous nature of coronavirus, hospital space cleaning technologies and the prevention of human exposure to pathogenic settings are critical.

This project is mainly designed to sterilize an area where the incoming and outgoing number of people is vast. Hence, it has been built for educational institutions first, that too for a small area. Not only this, but this project would make risk assessments with the help of thermal temperature readings and compare them with previously recorded body temperature values. This is much needed as daily manual sterilization is not satisfactory throughout the day. In order to further work on getting an optimal solution, a disinfecting spray was used known as chlorine dioxide and it has an efficiency rate of above 99.8 %. [16] However, in another research, a box was used to disinfect personal belongings in a densely populated area using a UV light compartment that has a shiny interior to reflect the oncoming lights. Now, moving into the next design by an Indian team, our robot somewhat functions similarly but even better. It is important to note that before 2020 none of these disinfecting techniques were up and running, even though they are quite vital in our everyday life even without the pandemic. Now, our system can automatically check in on the surroundings and gather important information, and display on the on-screen monitor such as humidity, an individual's body temperature when they enter and leaves the room.

Although some research was conducted on the design of the suggested system for this project, none of them had the same features as this system. While most researchers used pricey cameras for the same goal, people and object detection sensors have been used to make the system cost-effective. A cheap smartphone will be sufficient to operate the system, but the majority of researchers made their system entirely autonomous by integrating auto-navigating components with the main system. The system will also include a feature for measuring human body temperature. With all these capabilities, the system may significantly contribute to hospital sterilization while taking into account the requirements of academic institutions. Bangladesh is developing a higher rate of microorganisms as time goes on; however, the country is trailing behind in the disinfection industry. It would be an understatement to suggest that this country lacks an adequate disinfection system. To kill microorganisms, academic institutions and hospitals still rely on germ-killing fluids and sanitizers. Cleaning crews spend the majority of their time utilizing these chemicals to clean floors and other surfaces. All of these issues might be solved with IoT-based technology. This technique not only saves money and time but also assures a 99 percent safe workplace. It has the potential to reduce the need for cleaning personnel. A person with sufficient expertise in robot control will be able to operate it. Without hitting the country economically, it can be stated that the built-in IoT-based robot can do tasks and even more without any hesitation.

1.2 Objectives, Requirements, Specifications, and Constrains

1.2.1. Objectives

Educational institutions face a significant threat from pathogenic bacteria since students are constantly exposed to a range of germs. It has been shown that classrooms are the optimal place for germs to contact young children. Regular classroom cleaning is therefore one of the best infection prevention strategies for lowering the number of microorganisms.

This research attempts to sterilize classrooms using a system with the least amount of human interaction possible that will help lower the number of infections among educational staff and students. The system will utilize UV-C light with a wavelength of 254nm as it has been demonstrated to be extremely radioactive and effective in eradicating 99.8% of microbiological germs. However, this robot will run for more than 130 minutes when fully charged. The system will require 8-10 minutes to thoroughly disinfect a 784-square-foot typical classroom. That means on an average scale, the robot can disinfect 12 classrooms within 120 minutes after being fully charged.

This design is well above economical than other competing models on the market today, but it will also include additions like sensors that can assess body temperature instantly and give us real-time feedback on the student's health condition.

Certain points have been listed below in order, to sum up, the entire concept-

1) Construction of a robot capable of disinfecting classroom surfaces and walls.

2) Construction of an Internet of Things-based UV disinfection system ensuring least human interaction.

3) The robot will be radiation-based ensuring human safety from a certain distance.
4) PIR and ultrasonic sensors will be utilized to detect individuals and objects.
5) Each student's personal ID card will be scanned by an RFID scanner that will be integrated into the system. After the scanning procedure, students' personal data, including their temperature detected by temperature sensor, will be saved on a database platform.
6) A smartphone app will be used to control the system. As an alternative to the smartphone app, a six-channel remote controller will be available.
7) Due to the system's inexpensive components, the disinfection robot is an affordable option.

1.2.2 Functional and Nonfunctional Requirements and Specifications

1.2.2 (a) General Requirement:

The system will be designed for academic institutions. Initially, this setup will be tested at building 5 of BRAC University. In this particular building, each floor has approximately 4 classrooms. According to the thumb rule, each student takes about 2.5 square meters, giving us a total of 62.5 square meters per classroom if there will be maximum of 30 students per room. The proposed system will maximum of 6ft*2ft*2ft. If we can set up the ultra violet-C lamp in such a way that we can provide enough UV radiation with a wavelength of 254 nm, we will be able to inactive microorganisms. To do that we need to measure the traveling speed of the robot and calculate the exposure time for microorganism inactivation. So, brightness and power need to calculate from the photodiode and power meter. Assuming we are using a 36w UV lamp and in the ideal case, we will get 36w UVC output. The evaluation has been done in this case with the ideal case in consideration. [7] In an ideal situation, ultraviolet radiation would be 100 percent effective against any microorganisms. If the robot visits objects from 36cm away, the calculation of brightness is given below.

= luminosity/4*pi*distance^2.
=36/ (4*3.1416*36^2) w/cm^2
= 0.00221w/cm^2=2.21mw/cm^2

[17] The average UV dose of 1.3 mJ/cm2 =1.3mWs/cm^2 was required for 1-log inactivation of SARS-CoV-2. Therefore, to disinfect an object from 36cm distance, time need for the robot = UV dose/Brightness

=1.3 /2.21 s

= 0.5s.

That means if we set the speed of the robot in a way that the robot keeps emitting 36w UV output for 0.5s on an object the object will disinfect from the covid virus. However, in a real case, we need to measure real luminosity using a photodiode and the time of disinfection will increase. For experimental setup and designing prototype we are proposing a robot size of 2ft*2ft*6ft where base will be 2ft*2ft*2.5ft. For better understanding a Computer Aided Design (CAD) of robot structure is depicted in Fig. 1

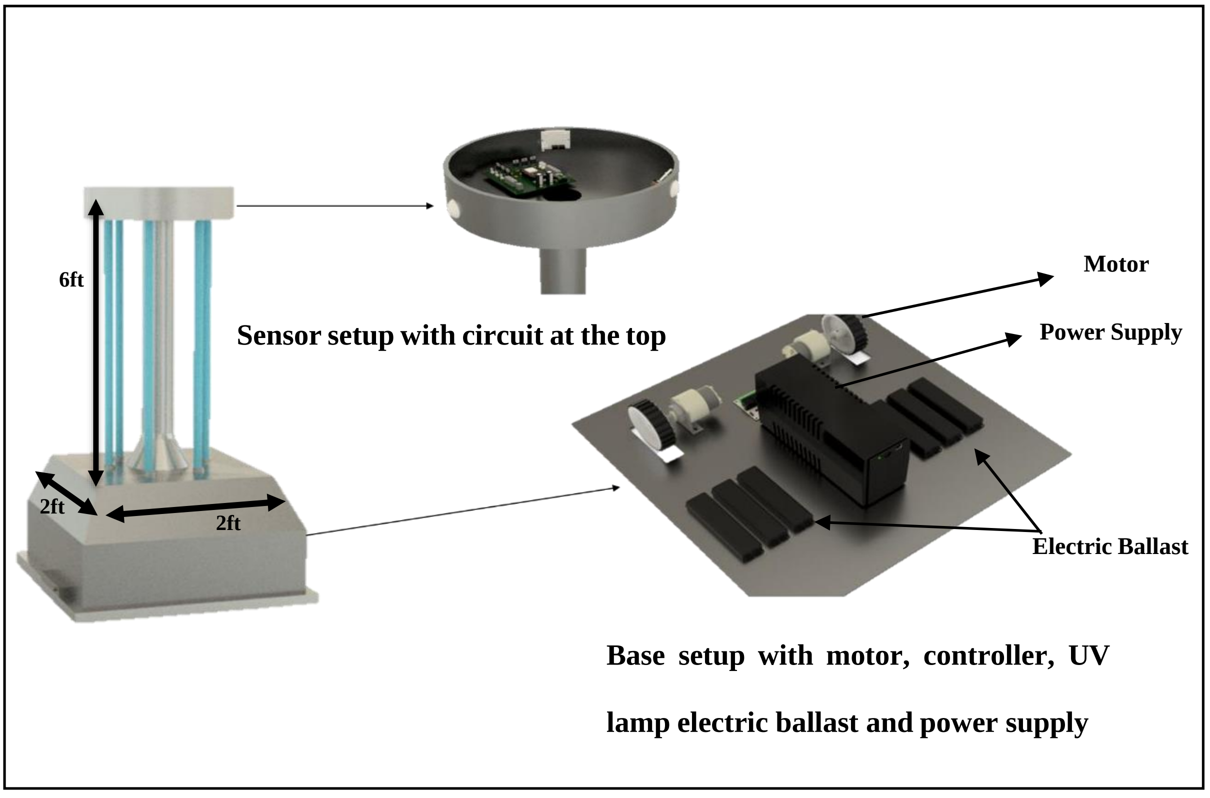


Figure 1: Computer-Aided Design for Sterilization System

In order to run the robot, it is essential to choose a proper motor so that system can operate smoothly. There are different types of DC and AC motors and lots of variations. However, for bulky and heavy robot a motor is needed which can work efficiently where higher torque is required. Here, DC planetary gear motor can be a good solution. The rating of proposed motor is added in Table I.

Motor Type	DC
Voltage	12V
Full Load Current	5A
Torque	0.96NM
Gear Type	Planetary
Gear Material	Metal
No Load Speed	300RPM
Shaft Length	20mm
Total Length	100mm
Stall Torque	16kgcm

Table 1: Motor Specification

In order to power up the 12V motor 5000mAH 60C LiPo battery is proposed as this motor's discharge rate is high. To powerup the whole system and charge the LiPo battery uninterrupted power supply can be a good solution and it can also provide support to 220V AC system with proper protections. System specification of uninterrupted power supply is given in Table 2

Input Voltage (V)	150-275 VAC
Output Voltage (V)	220-230 VAC
Frequency (Hz – KHz)	50Hz
Load Capacity	600W
Battery	2 pcs with 12V & 7.2Ah
Back up time (Full load)	30 Minutes (Full Load)
Dimensions	115 x 360 x 160mm

Table 2: Uninterrupted Power Supply Specification

The functional and non-functional requirements for our design are given below:

1.2.2 (b) Functional and Nonfunctional Requirements

	System Level	Component
Functional Requirement	• Sterilization system (depending on the area (1500-1800 sq ft) that we want to sterilize)	• 220V AC UV-C light • Battery management system • Relay • GPS • PIR sensor • Ultrasonic sensor • Li-po Battery-12V • Inverter with voltage booster
	• Control system	• DC motor • Wi-Fi adapter • Microcontroller • Motor Driver • Wheels
	• Algorithm for controlling the system	• Tremaux algorithm
	• User Interface	• Android Studio with Flutter UI development kit • PyCharm or Google Collab with GPU support • Arduino
Non – Functional Requirement	• Student temperature scanning system for precaution	• Temperature sensor (Infrared) • RFID reader • Antenna • RFID tag (passive tag) • Memory (cloud) • Buzzer • LED • 16*2 I2C Alphanumeric display.
	• Room status observation	• Wi-Fi • Display • Alarm • Air flow Sensor

Table 3: System Level and Component Level

1.2.2 (c) Component details:

Component details and Purposes:

Components	Details	Purpose
UVC light	• Type -Florescent Tube • Input voltage: 220V • Power: 36 Watt • Wavelength: 254nm • Tube Material: Quartz Glass • Brand: Philips • Application: Germicidal • Size: 4 feet	For disinfecting classrooms

Components	Details	Purpose
ESP32 Microcontroller	• Working voltage (V): 3.3V to 5.0V • Working current (mA): 240 • CPU Processors: Xtensa dual-core 32-bit microprocessor. • Memory: 320 KiB RAM, 448 KiB ROM • Wireless connectivity: • Wi-Fi: 802.11 b/g/n • Bluetooth: v4.2 BR/EDR and BLE (shares the radio with Wi-Fi) • Peripheral interfaces: • 34 × programmable GPIOs • 12-bit SAR ADC up to 18 channels • 4× SPI • × I²S interfaces • × I²C interfaces • 3 × UART	Main controller of robot and Wi-Fi, Bluetooth service provider
NEO7m GPS Module	• Frequency. 1575.42MHz-L1 C/A Code. • I/O Port. UART interface. • Protocol. NMEA 0183. • Hot Start Time. 10 sec. • GPS Channel. 16 Channels.	For accurate navigation system.
Relay (standard)	• Trigger voltage: 5V DC • Trigger current: 70mA • AC load voltage: 250/125V AC • Max. AC load current: 10A • Breakdown Voltage: 300 V peak • Switch Speed: 1ms	Control the inverter to operate sterilization system
MLX90614 Temperature Sensor	• Operating Voltage: 3.6V to 5V (available in 3V and 5V version) • Supply Current: 1.5mA • Object Temperature Range: -70° C to 382.2°C • Ambient Temperature Range: -40° C to 125°C • Accuracy: 0.02°C • Field of View: 80° • Distance between object and sensor:2cm-5cm (approx.)	Scan body temperature of students
HC-SR501 PIR Motion Sensor Module	• Voltage-4.8 V – 20 V • Current (idle)- <50 µA • Logic output-3.3 V / 0 V • Delay time-0.3 s – 200 s, custom up to 10 min • Lock time-2.5 s (default) • Trigger repeat: L = disable, H = enable • Sensing range <120 °, within 7 m • Temperature– 15 ~ +70 °C • Dimension-32 x 24 mm • screw-screw 28 mm, M2 • Lens diameter: 23 mm	For human or other animal detection

Components	Details	Purpose
Ultrasonic Ranging Module HC – SR04	▪ Working Voltage-DC 5 V ▪ Working Current-15mA ▪ Working Frequency-40Hz ▪ Max Range-4m ▪ Min Range-2cm ▪ MeasuringAngle-15 degree ▪ Trigger Input Signal-10uS TTL pulse ▪ Echo Output Signal-Input TTL lever signal and the range in ▪ proportion • Dimension-45*20*15mm	For object detection and path following
Li-po battery	• Voltage：12V • Number of cells：3 • Capacity：5000mAh. • Discharge: 60C ▪ Plug: XT60 and Deans Plug	Power the robot
RFID Card	• RF range: 13.56Mhz • Type: Proximity • RFID scanner module: RC522	Student id card which will be scanned for fetching information
RFID Reader RC522	• Working frequency: 13.56Mhz • Communication protocol: SPI • Input voltage: 3.3V • Working current: 13-26mA • Card reading distance：0～50mm. • Data communication speed: Maximum10Mbit/s	Set in robot to scan student id card for reading and writing information
BTS7960B Motor Driver	• Driver type: H-bridge • Supply voltage: 5.5-27V • Max. operating current: 43A • Signal voltage: 5V • PWM input frequency up to 25kHZ	Operate the high torque DC motor
DC Motor	• Operating voltage: 12V • Gear type: Planetary • Speed: 300 RPM	High torque DC motor will use for robot movement.

Components	Details	Purpose
3 Cell Battery Management System Circuit	• Input voltage: 12.6V • Over-charge voltage range: 4.25-4.35v ± 0.05v • Over-discharge voltage range: 2.3-3.0v ± 0.05v • Maximum operating current: 5-8A • Maximum instantaneous current: 9-10A • Short circuit protection: protection, delay self-recovery.	Low-cost solution for battery charging and it will ensure battery safety.
Power Inverter 12V DC to 220V AC	• Input voltage: 8-13V DC • Output voltage: 220V 50Hz AC • Power output: 240W • Under-voltage shutdown: 10.5VDC • Overload and short circuit shut down: Yes	Converts DC electricity to high voltage AC from 12V battery.
Alphanumeric LCD	• Display range:16*2 • Communication protocol: I2c • Screen: Blue	Will use for human machine interaction and display all information user want.
Buzzer	• Supply voltage: 2-4V • Decibels at 1 Meter: 70dB	Generate alarm if detects body temperature is high
LED	• Supply voltage: 2-2.4V • Max. current: 20mA • Luminous Intensity: 40-100mcd	Indicate machine operating conditions, communication system, hardware problem etc.

Table 4: Component Details and Purposes

The main purpose for this project is to create a disinfection system for educational institutions that is both efficient and affordable. With this in view, three different designs methodologies have been developed. The first design method will become a human-controlled system. In order to control it perfectly a specific person who is skilled with the system's operation for this method will be a need. The focus will be on IoT and autonomous-based systems for smart cleaning. The features of these methods will remain the same, but we will introduce image processing for human recognition and an app-based control system for IoT-based automated devices in the smart sterilizing system. Survey have been taken for the existing students of an institution as well as the guards and the cleaners. Due to the high student population, it has been observed that 80% of students do not feel safe despite the authorities' current security measures. However, the personnel working for this cause expressed that if we go on with a complete IoT-based system there might raise an issue of unemployment. Moreover, if the cleaners try to manage the machine when the high wavelength of ultraviolet light is on, they may get skin disease or, in the worst-case situation, become blind. On top of that, this system comes with other advantages too, and can eliminate bacteria and other germs with greater efficiency when compared with the common disinfecting liquids. The first model of the system will be kept in UB5 as that's the only building with the least crowd and can be monitored everything closely.

1.2.3 Technical and Non-Technical Consideration and Constraints in Design Process

There are several factors that have been taken into account in order to accomplish the project's goal. The standards and requirements have previously been covered in considerable detail. The selection of the appropriate components that will support the project's objective took a significant amount of time. Certain considerations were made during this time. The non-technical considerations might be referred to as non-technical considerations and the technical issues as technical considerations.

Technical Consideration:

Several technical considerations have been taken into account. Some of them are discussed below-

- **Design:** The system design refers to the software development of the required system. In order to construct proper hardware development, software development of the system is necessary. Multiple options (Eagle, Altium) are available to do that but in this project, the software (Proteus) utilized to design the circuit is student-friendly and easy to use.
- **Size:** The robot size proposed in the project is 2ft*2ft*6ft where the base will be 2ft*2ft*2.5ft which is quite big to handle compared to the other models available in the local market. However, considering the size of the UV lights which are 4ft in size each, the system has been designed in this particular size to make a good balance.
- **Effectiveness:** One of the major goals of this project is to build a highly effective sterilization system that can eliminate any kind of virus and bacteria providing the highest result. Considering that, UV-C lights with 254 nm has been chosen that provides the most effective result against virus and bacteria.
- **Component Availability:** The component list has already been discussed in compliance with the need. A significant quantity of power is needed because the system is rather huge and the majority of the components are rarely found in the local market. Therefore, the battery that is employed in the system was ordered from an overseas market.
- **Speed:** In order to operate the system in a considerable speed, a high-speed dc motor was required. So, planetary gear motor has been utilized to fulfil the need which has been ordered from the international market as well.
- **Safety:** Ultraviolet radiation has a very hazardous effect on human health. Skin irritation, skin cancer, and eye infection most of these diseases can be caused by extreme exposure to UV radiation. However, a system build-up with a key component of UV-C light while maintaining the safety issues of humans as well was quite challenging. Plastic shields, nitrile gloves, and tightly woven fabric have been utilized as protection from UV exposure.

Non-Technical Consideration:

Non-technical considerations refer to the consideration that does not include any part from design or technical staff. Some of them are discussed below-

- **Social:** The disinfecting system proposed in the project is a quite novel concept for the people of Bangladesh. People here are very much habituated to the chemical-based cleaning procedure which required a significant number of humans. In order to make them understand the cleaning procedure using this system, the design and the construction has to be fairly simple.
- **Environmental:** It has been already stated that the concept is very much new to the people as they are used to the past cleaning procedure. However, in the case of the environment, the effectiveness of each system has been significantly considered. The chemical-based procedure requires a large number of humans that is unable to provide an effective result. On the other hand, UV based system has the effectiveness of 99% in the case of elimination of viruses and bacteria.
- **Health:** Radiation-based sterilization has been demonstrated to be significantly more effective than techniques that use chemicals in terms of maintaining health. In contrast to chemical systems, which are totally reliant on people, the proposed devices sterilize items using radiation. However, the harmful effects of UV have been also taken into consideration.
- **Maintenance:** Being a novel system to people, it requires a different maintenance procedure than the regular one. However, the system will be a smart robot that will mitigate human interference. This functionality of the system requires an individual to operate and maintain the system with proper knowledge.
- **Cost**: The major goal is to provide pupils with a safe environment that enables them to learn. This system must first be economical for public entities to use. Above all, this system

needs to be affordable so that it may be used for disinfection by several forms of educational institutions.

The objective and the basic needs for this project have been discussed elaborately in previous sections. Each requirement has its own set of criteria to function successfully. A requirement may contradict any other system requirement. It could be difficult to meet both incompatible needs. An assumption has been done about the occurrence of the following constraints which are added below:

Technical Constraints:

- **Size & Weight:** The proposed system is quite big and heavy to control. It can be quite challenging to move the system from one place to another or from one floor to another floor without an elevator.
- **Component Accessibility:** In accordance with the specification, requirements as well as the system's dimension, some of the components like the LiPo battery, and planetary gear motor has been ordered from the international online market due to their unavailability in the local market.
- **Internet Issues:** This system was aimed to build for a long that will be able to operate easily from anywhere. A mobile app that will be used to control the system will require access to the internet to function smoothly. However, many institutions still do not have full-time internet facilities. So, IoT based system conflicts with the idea that without an internet connection no one will be able to communicate with the robot.
- **Safety:** Though this disinfection method has many advantages for students and staff, it has some drawbacks also. UV-C rays have a higher intensity than other forms of UV rays, the American Skin Cancer Society claims that they are not generally a risk factor for skin cancer. However, it may cause some skin irritation. So, in the time of utilizing this system, proper safety precautions must be taken.

Non-Technical Constraints:

- **Knowledge and Training:** The proposed system is an Internet of Things (IoT)-based system that will be managed over voice commands via a smartphone app which is a smart and user-friendly solution. However, the person in charge of the operation must be well-versed in the use of an app to control robots. So, it conflicts with other ideas and everyone may not be able to control the device.
- **Budget:** This approach will mostly be used by educational institutions. As a result, we want to make an affordable solution. However, for maximum capability, we have added six UVC lamps, each of which costs around 2500-3500 taka, significantly increasing the entire system price and conflicting with the idea of a low-cost solution.

1.2.4 Applicable compliance, standards, and codes

1.2.4 (a) Applicable Standards:

Criteria	Standard	Standard Name	Standard Detail	Purpose
Human Safety	ISO 15858:2016	UV-C Devices-Safety information-permissible human exposure.	ISO 15858:2016 specifies minimum human safety requirements for the use of UVC lamp devices.	To ensure human safety from sudden UV exposure.
Power Source	AIEE 18-1934	AIEE Standards for Capacitors.	The standards in this section apply to capacitors for the following types of service. (a) Power applications 1. Power factor correction. 2. High-frequency induction furnaces. 3. Capacitor motors. (b) Resonant shunts and filters. (c) Blocking capacitors (d) Power oscillator circuits	Maintaining all the power sources and factors correctly in order to supply power efficiently.

Criteria	Standard	Standard Name	Standard Detail	Purpose
Wires and Cablesfor Power Management	AIEE 30 -1944	Definitions and General Standards for Wires and Cables	These standards include definitions and standards of a general character that are applicable to wires and cables for power purposes.	Installation of a suitable power management system.
Object Detection	ISO 16001:2017	Earth-moving machinery —Object detection systems and visibility aids — Performance requirements andtests	ISO 16001:2017 specifies general requirements and describes methods for evaluating and testing the performance of object detection systems (ODSs) and visibility aids (VAs) used on earth-moving machines.	In order to detect objects on the way of the bot's sterilization process
Data Privacy managementsystem	ISO 27001	The international standard for data privacy	ISO 27001 relates to the way an organization keeps data accurate, available and accessible only to approved employees.	In order to ensure the management and the privacy of students' data.

Table 5: Applicable Standards

1.2.4 (b) Applicable Codes:

Criteria	Code	Code Name	Code Detail	Purpose
Broadband Powerline Communication Technology	IEEE 1901-2020	Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications.	Physical (PHY) and media access control (MAC) layers of broadband powerline communication technology for local area networks (LANs), Smart Energy, Smart Grid, Internet of Things, transportation platforms (vehicle) applications, and other data distribution are defined in this standard.	To control the physical and Media access layers of systems' broadband powerline communication technologies.

Criteria	Code	Code Name	Code Detail	Purpose
Data Privacy	IEEE 7002-2022	Data Privacy Process	The requirements for a systems/software engineering process for privacy-oriented considerations regarding products, services, and systems utilizing employee, customer, or other external user personal data are defined by this standard.	To ensure the privacy of students' data stored on cloud servers
Electrical Instruments for Acand Dc Current	IEEE/AIEE 33-1927	Electrical Measuring Instruments	The standards in this section apply to the following kinds ofindicating electrical instruments for direct current and for alternating current: (1). Ammeters (2). Voltmeters (3). Wattmeter (4). Reactive Volt-Ampere Meters (5). Frequency Meters (6). Power-Factor, Reactive-Factor, and Phase-Angle Meters	To protect the components froman excessivecurrent or voltage supply
Switch/Relay	IEEE 218-1956	Methods ofTesting Transistors	This standard deals with the methods of measurement of important characteristics of transistors.	In order to build better switching mechanisms.
Fuse	IEEE/AIEE 25-1958	Fuses Above 600 Volts	This Standard applies to the following types of devices designed for operation above 600 volts whether for indoor or outdoor service.	To protect the system from excessive voltage supply

Criteria	Code	Code Name	Code Detail	Purpose
Development of Application Software	IEEE 730-1998	Software Quality Assurance Plans	This standard applies tothe development and maintenance of critical software.	To develop a system operating application software.
Application Maintenance	IEEE 1219-1992	Software Maintenance	The process for managing and executing software maintenance activities is described.	To control the system properly, the application software should be kept in good working order.

Table 6: Applicable Codes

1.3 Systematic Overview/Summary of the Proposed Project

The thought of constructing a UV-based sterilization robot have come up in order to eliminate the largely manual disinfection techniques utilized in the past. The bot is capable of sterilizing both wall and surface area using engineering principles. The system will have the feature of avoiding individuals and other objects within a specific distance using PIR and Ultrasonic sensors. This design includes an RFID reader to secure the safety of pupils. Students' body temperatures will be measured with a temperature sensor and scanned with an RFID sensor to see whether they match the temperature of a covid patient. It will be an IoT-based disinfection system. A smartphone app will be utilized to construct a voice and keyboard command mechanism, making it easier to control. In addition to smartphone control, the system will also have a six-channel remote controller. The robot also sterilizes a space while following essential human safety precautions. The goal of this system's development is to provide the best possible disinfection performance at the lowest possible cost. The touch-free control mechanism, which does not require human intervention, is the most essential feature.

1.4 Conclusion

In this chapter, a brief discussion has been done regarding the proposed project. The concept of this project has been achieved considering the literature gap and background study. The objective of this project is the construction of a semi-autonomous sterilization bot that will sterilize the wall and surfaces of classrooms. Following that, general, functional, and non-functional requirements have been listed. A detailed component list including their purposes has also been added in this chapter. Since the technical and non-technical parts have also been taken into account, the constraints have not been avoided. Moreover, each of the parts and components considered in this project has been selected following some applicable standards and codes. However, a summary has also been included of the proposed project. A 3d model of the suggested design has also been given for better demonstration.

Chapter 2

Project Design Approach [CO5, CO6]

2.1 Introduction

The minimal number of bacteria that may remain on surfaces after regular cleaning is obtained by using ultraviolet (UV) sterilizing technology. After the widespread coronavirus outbreak, a proper ultraviolet ray-based disinfection system within an accessible price range has become extremely desirable, especially for educational institutions. The challenges caused by a lack of an effective disinfection system were briefly mentioned in the preceding chapter. The project's objective is to build a low-cost, semi-autonomous ultraviolet ray disinfection system for educational institutions of all types that will require minimal human interaction throughout the cleaning process. The project's objective has been established in light of the problem statement. Three distinct design methodologies have been considered in accordance with the problem definition and project objective. On the environment and people alike, each of the ways has some beneficial and negative effects. The following chapter will provide a brief explanation of each design approach. However, the optimal solution out of the three designs has also been taken into account. This chapter now additionally includes the method for choosing the best solution and an analysis of each design based on some fundamental standards.

2.2 Identify multiple design approach

In pursuit of appropriate designs, extensive research has been conducted. The project's defined objectives and requirements might be designed in a variety of ways. Three design approaches have been taken into account based on the project's goal. These three designs' whole conceptual framework was drawn from a number of academic publications and articles. The functionality, usability, impact, cost, and other essential aspects of the three designs have also been taken into consideration. These methods have been put forth in accordance with some key principles. Identification of three designs are below-

<u>Design 1:</u>

The first strategy was a system of ***human control for disinfection***. This strategy was chosen based on the prevalent cleaning method used in the community. The first feature is **motor operation**, the second feature is a **sterilization system** and the third feature is an **alert system.** The system will be operated using the fewest number of humans. The system will use radiation to generate an efficient result and will be able to eradicate the highest proportion of germs. The Block diagram of the manual control system based on human command is given below-

Human Control Disinfecting System:

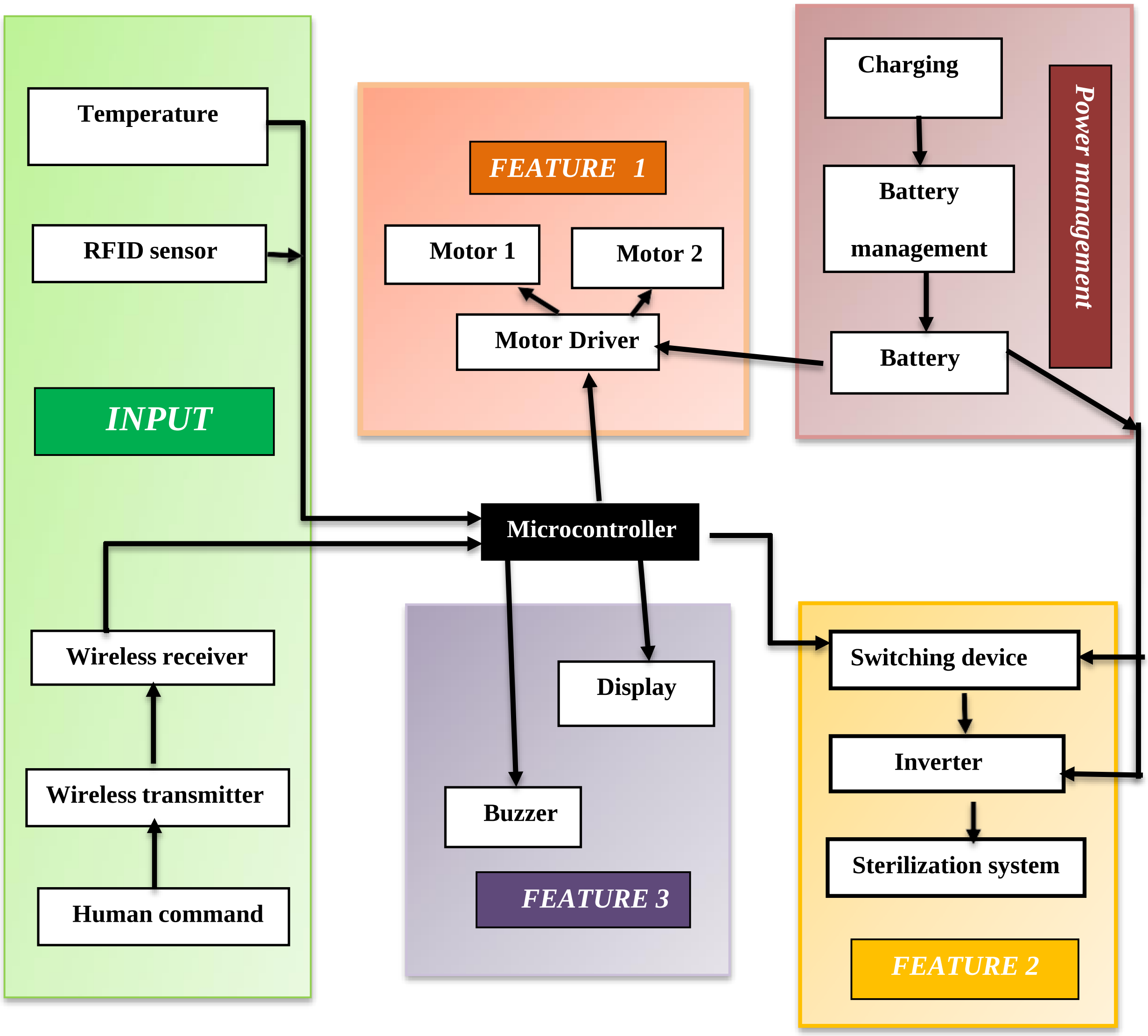


Figure 2: Block diagram of manual control system based on the human command.

<u>Design-2</u>

The ***IoT-based disinfection system*** is the second proposed design approach. The main part that sets this approach apart from earlier design methods is the functionality of the app controls. The number of features for this methodology are three. The first and the second feature will remain the same as the previous one but the third feature here will be **human and object detection**. The block diagram of IoT based control system is given below

IoT-Based Disinfecting System

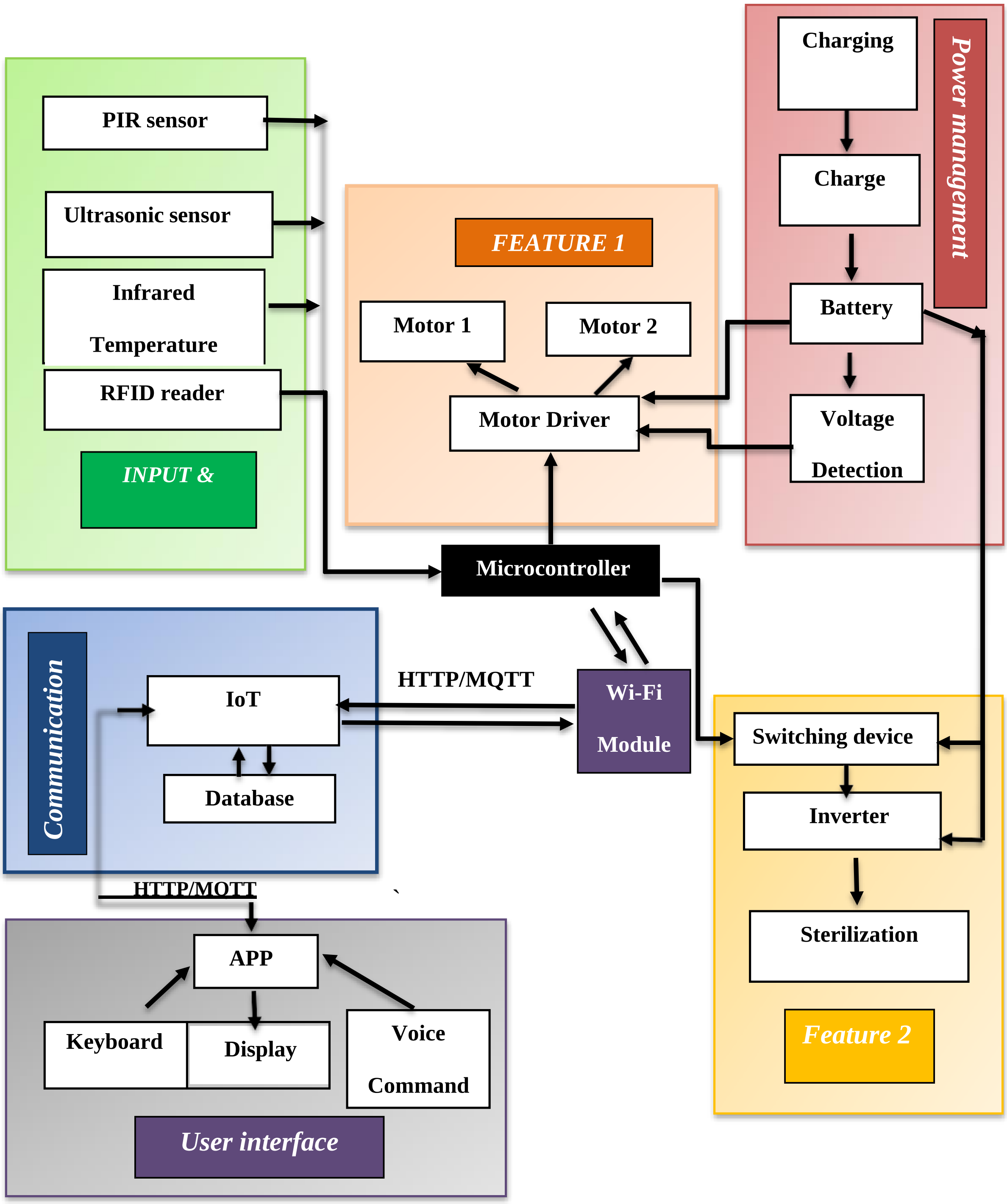


Figure 3: Block diagram for IoT based disinfecting system

Design-3:

The ***Autonomous Disinfection System*** is the final design approach for this system. This robot will be completely autonomous and won't need any sort of human assistance. [18] Another major area in the field of autonomous mobile robots is mapping. The environment map is frequently utilized in autonomous mobile robot navigation systems and plays a vital role in navigation and global path planning. The system will automatically change locations and sanitize them. The system will cost substantially more than the other two approaches due to its autonomy. The system's features will remain the same for all the design methods, but they will vary in terms of functionality, mode of operation, cost, and other important factors. Moreover, the battery management system is completely different in this method. Fig. 4. depicts the whole process in the block diagram below:

Autonomous Disinfecting System

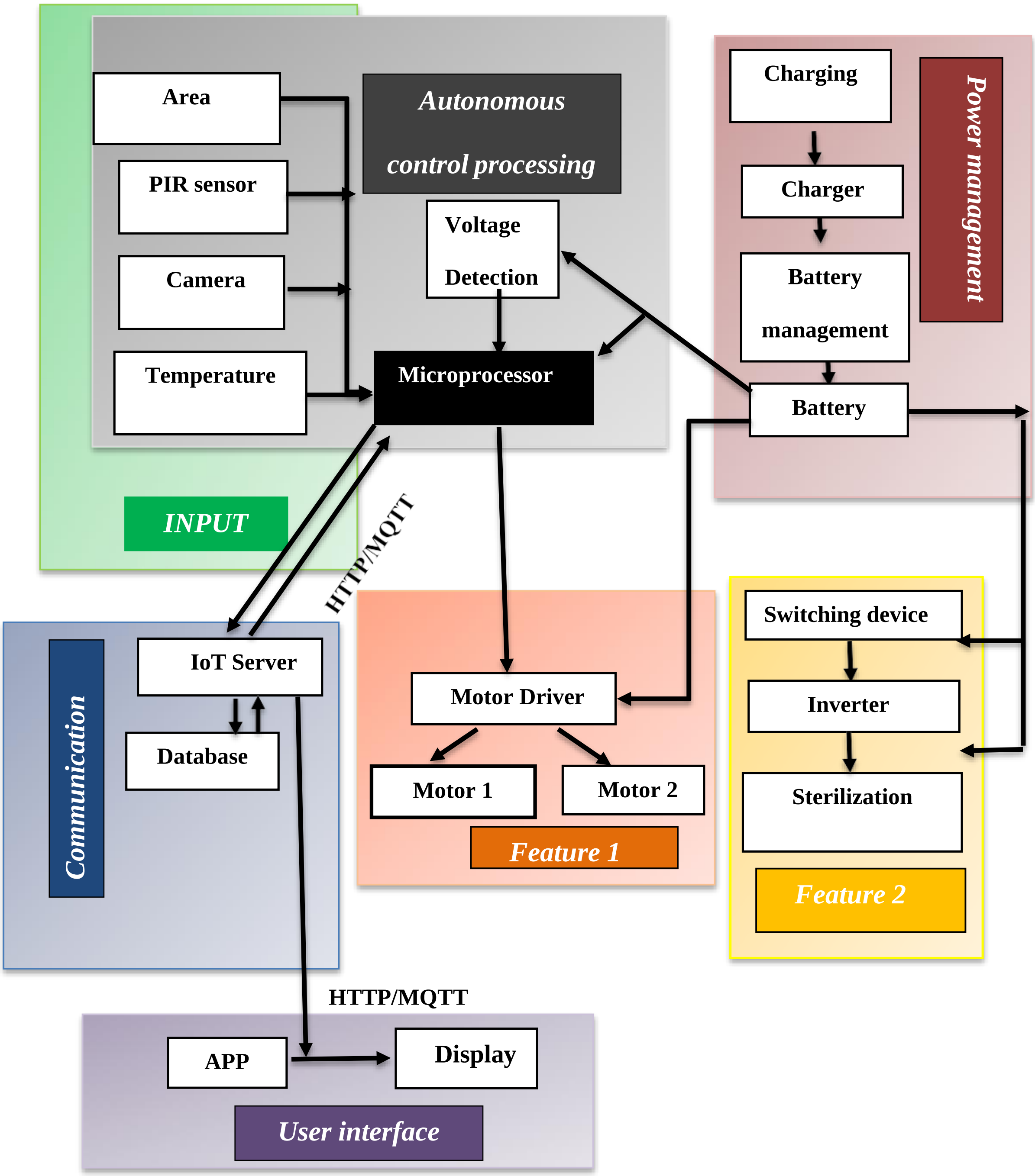


Figure 4: Block diagram for the fully autonomous disinfecting system

2.3 Describe Multiple Design Approach

In this section of the chapter, each design description has been briefly discussed and evaluated. This description has included necessary block diagrams for a better demonstration of the designs.

- ***Human Control Disinfection System***

The first model is a design approach for controlling the robot based on the human command. In Fig. 2, three features have been incorporated into this design with a wireless control system. Three components go to the microcontroller as input including two sensors. When human commands are sent to the microcontroller through a wireless trans-receiver microcontroller will enable the feature according to commands. To run the robot, two motors and two freewheels have been proposed. The system will have three features to function. Description of these features are given below-

- **Feature 1(Motor Operation)**

Motors will run according to the microcontroller command with the help of the motor driver as the microcontroller will not be able to provide enough current. If a user sends a command from the transceiver to move the robot forward, or backward, the microcontroller will operate the motor.

- **Feature 2(Sterilization System)**

The disinfecting/sterilization system will run, which is one of the main objectives. As sterilization systems run on high AC voltage, we will operate the system from a microcontroller using a switching device as a relay. The relay will trigger the inverter circuit to run the sterilization process.

- **Feature 3(Alert System)**

The final feature of our system is student checking at the gate to ensure covid safety protocol. For this, we are using an RFID scanner for scanning ID cards and an infrared temperature sensor for checking students' temperature. If the temperature of a student is higher than the average temperature buzzer will play a sound to alert authorities and it will block the student's entry until the temperature becomes normal. If a student is quarantinedit will not allow the student to entry in university. To show all the data and feedback a display will be added. For power management, a charging unit needs to be set where the robot will charge properly and safely. As this is a manually controlled robot, people will need to move it to the charging station using a wireless transceiver. Finally, the robot has become ready to start disinfection after completing all of the conditions.

❖ ***Internet of Things (IoT) Based Disinfecting System***

The Internet of Things (IoT) is a set of logical procedures that allow data to be transmitted and processed on the cloud where modernization and structural improvement are necessary. The aspects of the IoT-based design approach will be the same as those of the human control designsystem. The user interface and communication system are different from the previous design. A four-stage layer can be used to define the architecture of an IoT system. The IoT solutions are usually described by this IoT architecture. For our IoT system four layers are explained below:

- **Sensors and Actuators:** In the proposed system different sensors like PIR, Sonar, Temperature, and RFID is used as input, and motors, UV lamps are there as output. Sensorscollect the data and sends to the controller after processing. Similarly, different output devices collect data from microcontroller and operate accordingly.

- **Internet Gateway:** This robotic IoT system introduces quicker and safer gateway using firebase authentication system. A client server must transmit a JSON Web Token in the authorization header of the HTTP request to the backend API in order to authenticate a user and connect with the database. The token is verified by the API Gateway before the system accepts data connection, thus no additional code needs to be added to the API to handle authentication.

- **Data Processing:** This IoT system's data processing section controls by ESP32 microcontroller. ESP32 microcontroller receives the sensor data and sends to server after processing as well as collect different data from server to operate devices and send feedback consequently. Another data processing unit is mobile app which is developed by the team to process, monitor and manage data easily. Mobile app enables remote access to manipulate and monitor data from wherever users are.
- **Application:** For interfacing between IoT devices and network Firebase real-time database will be used for communication. The IoT device's actions and the types of data it generates will all be handled by the Firebase real-time database.

The aspects of the IoT-based design approach will be the same as those of the human control design system. The user interface and communication system are different from the previous design. A mobile app will control the entire system in this method for communication. The system will be controlled by a mobile app using voice and keyboard commands. The HTTP/MQTT protocol will be utilized for internal communication. The microcontroller will run features after getting commands via the app. Description of the features are given below-

- **<u>Feature 1 (Motor Operation)</u>**

DC motors will be used to move the robot around. A motor driver will be used to link dc motors to the microcontroller for increased voltage.

- **<u>Feature 2 (Sterilization System)</u>**

With the exception of the usage of an inverter here to properly operate the sterilizer system, the sterilizing process will stay the same as with the prior design technique.

- **Feature 3 (Human and Object Detection)**

Ultrasonic and PIR sensors will be utilized to detect objects and humans. The temperature of the human body will be measured using a temperature sensor. To ensure the safety of other students, an RFID scanner will be used to compare the temperature of the human body to the temperature of covid patients. Moreover, in the power management system, voltage detection will also be utilized to determine the battery level.

For mobile app there are total seven pages which starts with login and registration page. For authentication registration and login is important. After login homepage appears where three features are showing inside three buttons for monitor and control. At the bottom of home page three cards defines recent updates like battery voltage, last sterilization process working time, daily student scanning numbers. When user press control button robot controlling graphical user interface comes which is designed like a joystick and easy to control. If users enter sterilize page, it shows gauge meter defining sterilization process completion in percentage format. There is a button to operate sterilization process at the bottom of gauge meter. After that two-feedback monitoring system is added which is current state and mode of operations. Current state give update from robot directly that robot is stop or working or if any human is detected. Mode of operation defines the feature like is it sterilizing or scanning student RFID for COVID check. Final button of homepage is Covid Scan which gives us report about student temperature and quarantine details. If any student is found with temperature greater than 102^{o} F mobile app will show maybe ha can be covid positive and need to send him in quarantine. The UI of app interfaces are given in Fig. 5.

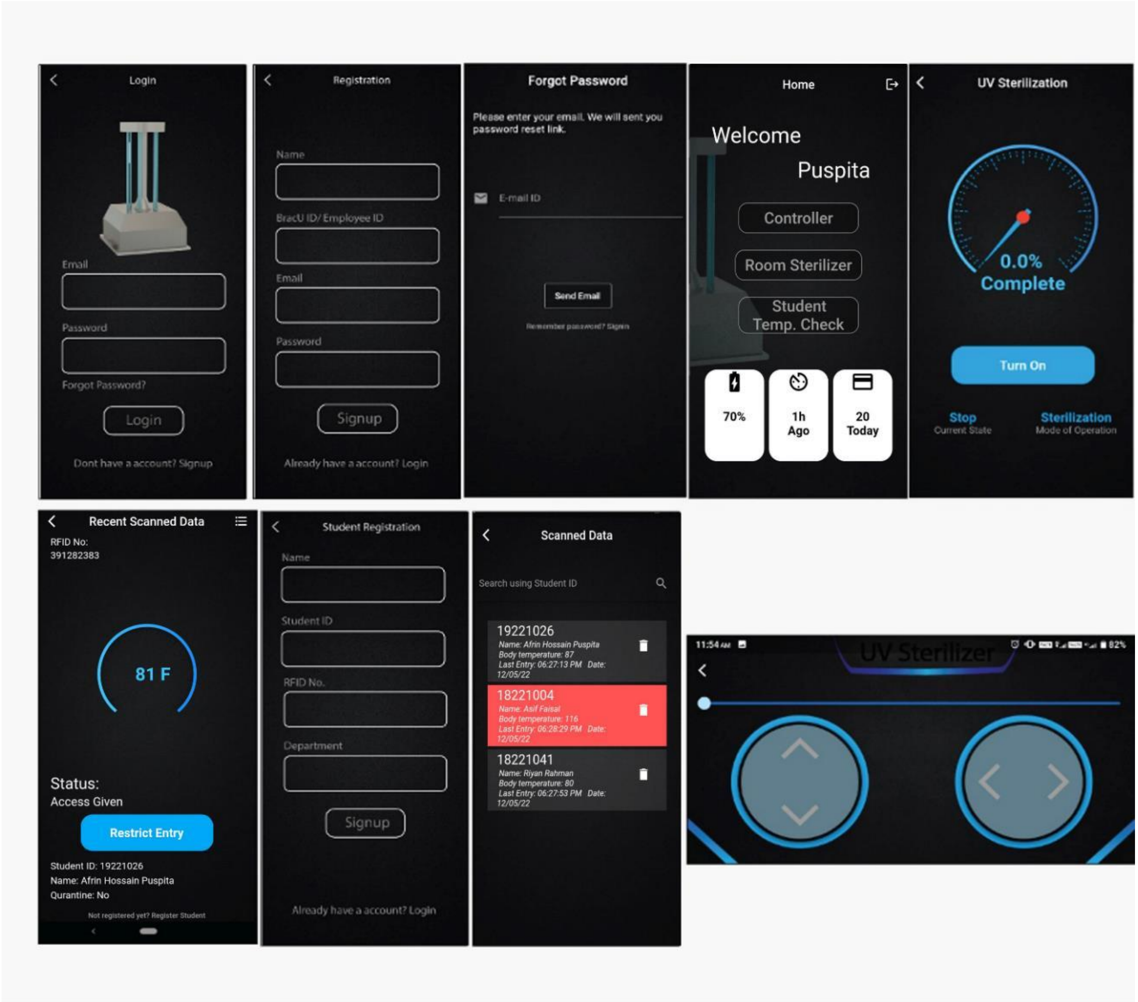


Figure 5: UI Designs of Mobile Application

❖ Autonomous Disinfecting System:

The ***autonomous*** disinfection robot is designed with various in-built processes to provide thebest cleaning outcomes.

➢ **<u>Feature 1 (Motor Operation)</u>** When the robot is turned on, the responsible authority will have to choose between automated and manual modes, based on the sort of path it must cross. To make the robot function on a complicated path, voice commands are used, whereas, for a basic track, sensor-based automated path-follow methods are used to complete the disinfecting operation.

- **<u>Feature 2 (Sterilization System)</u>** This part will not differ from the other design techniques. A relay with a high ac current will regulate the sterilization system. A relay will be linked to an inverter, which will convert dc current into high ac current.
- **<u>Feature 3 (System Automation)</u>** Instead of using a microcontroller, we will utilize a microprocessor (Raspberry Pi, Jetson Nano) in this technique. Microprocessors have more memory space and a data processing speed of around 1GHz. Microcontrollers, on the other hand, have a limited memory area and a processing speed of 8 to 50 MHz as a result, the system will work faster and store more data in this approach than in other approaches. We will employ the system that will be used in an IoT-based system for human interaction. camera will be utilized to detect objects and students in this case. A camera will be used to recognize the student's face, and a temperature sensor will be used to determine the student's body temperature also. In any event, PIR and Ultrasonic sensors will be utilized to detect people and things if the camera fails to detect them. The sensors were employed to guarantee that humans were completely protected from ultraviolet radiation. Google mapping will beused to avoid barriers and navigate the system automatically. The system will include a self-charging function. When the system's battery level drops, a charging mechanism will be built so that it may recharge itself. A voltage detector will be utilized to determine the system's battery level. Without any human intervention, the entire procedure will be controlled by the system. After completing all the conditions, the robot is ready to begin the disinfecting process.

2.4 Analysis of Multiple Design Approach

To verify the three different designs to fulfil our objectives, we have found different pros and cons for different designs. To find out the functionality we have simulated those circuit designsand get a conclusion about which one is more functional.

Circuit simulation result based on different cases is briefly explained below:

Case 1: Human-Controlled Circuit

In this case, we have simulated all the features according to our design requirement using proteus software. Proteus is a software where both schematic design and simulation can be done easily. As per our requirement, we have chosen Arduino UNO as a microcontroller consisting of 13 digital pins and 6 analog pins. All the features with explanations are discussed below:

UV light control system:

Most important feature is operating UV lamp which will be controlled by a 5V relay. Relay module circuit is designed with proper protection circuit and connected to A3 PORT. Flyback diode is added to ensure safety of relay from reverse voltage spike. We have used NPN BJT instead of optocoupler because we are using same voltage source to power the microcontroller and relay. So, BJT is cost effective solution and we do not need optocoupler to isolate power supply. When relay is switched it turn on the UV lamps which is shown as a 220V bulb.

Motor control:

Next, for controlling two 12V DC motor we have chosen L293D motor driver as BTS motor driver is not available for proteus. L293D motor driver IN pins are connected to A0, A1, D0, D5 PORTS so that motor operating direction can be changed. As we do not need to change the speed, we fixed EN pin as 5V constant. If Arduino receive serial command like 'f', 'b', 'r', 'l' from Bluetooth device motor move at front, back, right, left positions accordingly.

Communication:

0(RX) and 1(TX) pin of Arduino is connected with Bluetooth HC05 TX RX pin respectively. Though we wanted to use 6 channel transceivers, this component is not available in proteus. However, most of the communication devices use Serial communication and programming is same. So, we are simulating communication method using Bluetooth. Another HC05 is set as master mode to send command to slave device which is connected to Arduino. These two

Bluetooth components communicates via virtual PORT of computer.

Student temperature checking system:

RFID simulation is showed using another Arduino microcontroller as RFID module for proteus simulation is not available. RFID communicates via SPI communication protocol. We have tested RFID by generating RFID code from slave Arduino and send to master Arduino microcontroller via SPI interface. We have generated 3 RFID code from salve controller and found our RFID system is working. For SPI communication PORT 10,11,12,13 has used. After RFID scan our task was to scan temperature of that student and we wanted to use infrared temperature sensor rather than using common temperature sensor like DHT22, LM37. So, we have used TC74 temperature sensor and it uses I2C communication. We have connected temperature sensor at Arduino A4, A5 PORT which is I2C port of Arduino. After RFID scan temperature sensor sends temperature data through I2C protocol. At A2 PORT a buzzer is connected. If any temperature read found greater than 102^{o} F buzzer will buzz and LCD display will show that student have fever. 16*2 LCD display is connected with UNO board which uses D2, D3, D4-D9 pins. This display is best for showing simulation output as a feedback and connection is easier than TFT display.

Power management system:

We need 5V power supply to power different components like LCD, relay, Arduino and need 12V to power motors. For this we have designed our own battery management circuit. We have used step down transformer and rectifier to convert 220V AC voltage to 12V DC power supply. A capacitor is used to make pure DC wave signal. This 12V will charge the 12V battery and battery will be work to power the device when AC power will not available. 7805 linear 5V voltage regulator is used to generate 5V easily and power devices. In the battery management section for 1 cell the TL431 typically serves as a 2.5V reference, although additional resistors can vary that voltage. The TL431 begins to conduct if the battery voltage is higher than 4.2

volts, driving the base of the BD140, which drives a load on its collector. Visible evidence of this is LED. A sequence of four diodes serves as the load instead of as a resistor. Constant voltages independent of discharge current across the transistor and the diodes. Total 3 cells create 12.4V. The schematic diagram of human controlled system is shown in *Fig. 6*.

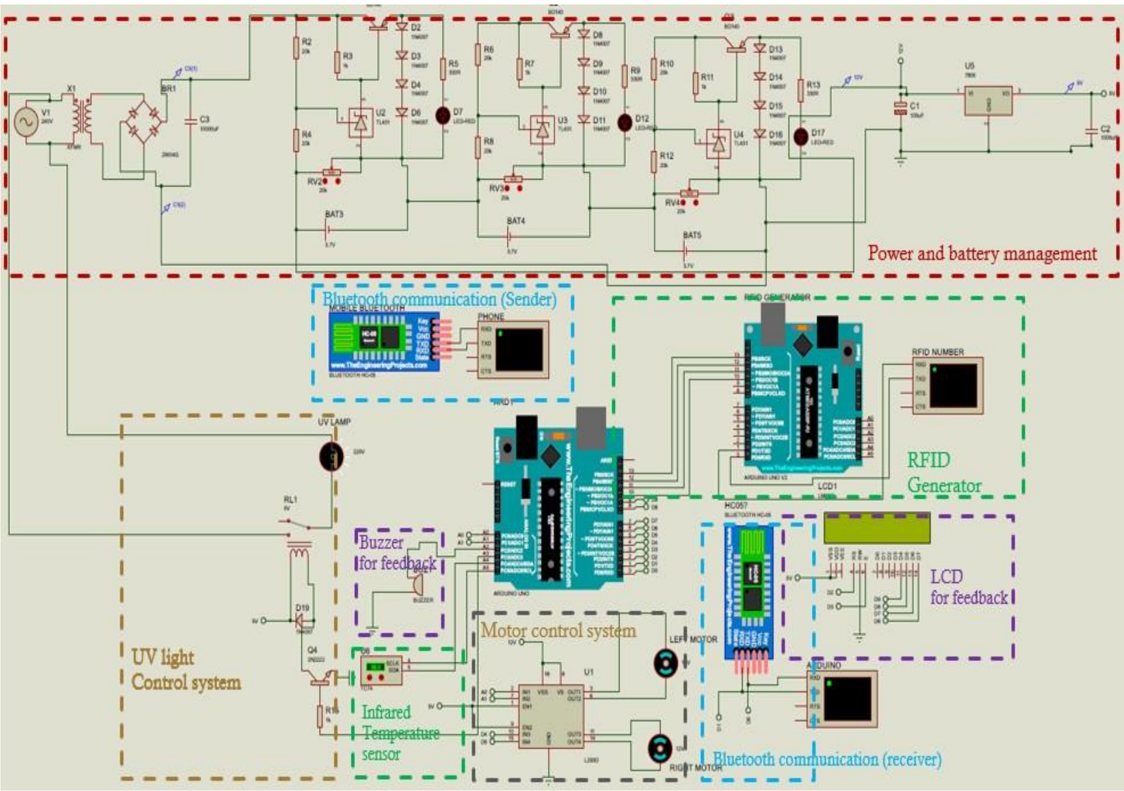


Figure 6: Simulation Procedure of Human-Controlled Disinfecting System

Case 2: IoT Controlled Circuit

In this case we have simulated all the features according to our design requirement using proteus software and it's almost like human controller circuit simulation except little changes which are explained below:

UV light control system:

UV light control system is same as before. However, in Arduino Maga's different port is connected now for sending the command. Besides that, PIR sensor is added which will help to detect human movement and any human movement detection means opening UV light is not safe. So, if PIR sensor detects human, it will not allow to operate sterilization process and will forcibly stop the lights. This will ensure safety a lot.

Motor control: As user will control the robot using mobile app and monitor from mobile app, user may not need to attend that place. There is a risk of collision while running the robot. To avoid this Sonar sensor is added which will detect nearest object and will avoid it. Rest of the part is same as human controlled system.

Communication:

IoT based system mainly focuses on the communication over internet. However, there is not component in proteus software where we can communicate via internet. So, we have tested it again using Bluetooth devices like human control system.

Student temperature checking system: For SPI communication Arduino Mega uses port 51 and 52. That is why whole system is connected to different ports now. Rest of the part and explanation is same as human controlled system.

Power management system: In power management circuit there is changes also. We have incorporated HI-Link *HLK*-5M12 AC-DC 220V to *12V* 5W Switching Power Supply instead of transformer and rectifier for energy efficiency and light weight design. Then, battery management system remains same but when converting 5V we have used buck regulator circuit instead of 5V linear power supply. LM2576 will help to power circuits more efficiently and safely as there is a feedback option. **T**he schematic diagram of IoT controlled system is shown in *Fig. 7*.

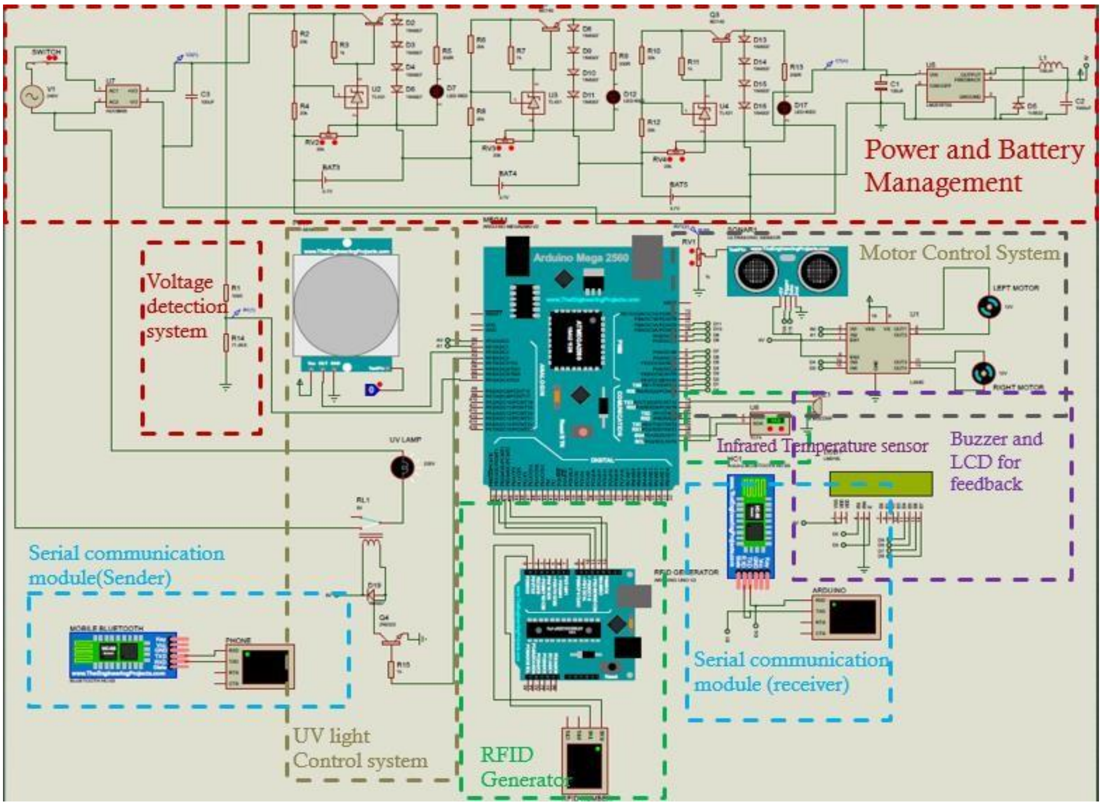


Figure 7: Simulation Procedure of IoT Based Disinfecting System

Database Management System:

Important part of this design is testing database and arrange real-time database according to design requirement. As we are using Google Firebase, we have finalized the data structure and it will save data in JSON format. The *Fig. 8* depicts the data structure and formatting of database.

Figure 8: Firebase Real-Time Database and Exported Data from Database

Case 3: Autonomous Controlled Circuit

As there is currently no software where we can simulate Raspberry-Pi based system circuit, simulation is not possible for this case using any software. Moreover, price of these components is very high that it is hard to afford.

Autonomous-based system design is one of our project's methodology designs. We have completed designing the alternative circuit design strategies. However, we have reviewed a number of research papers and studies on autonomous-based system design. For a robot to be autonomous, the first thing that it needs to do is navigate independently eliminating the human factor. For an autonomous mobile robot operating in an indoor setting, the goal of this research is to achieve both high-accuracy location and map creation. [18] To lessen the indoor location error, a time difference of arrival (TDOA) hyperbola locating technique based on ultra-wideband technology and the Taylor series expansion algorithm has been developed. The Taylor expansion algorithm and ultra-wideband technology showed accuracy in detecting the location and position. The proposed feature line matching in combination with map design has been able to satisfy the requirement for robot navigation.

In this study, a sophisticated mapping system for rooms and other enclosed spaces is shown. [19] The use of the Scanse Sweep distance measuring sensor, which collects data using the LIDAR (light detection and ranging) technique before being evaluated by a PC software program, will be discussed in this paper. In variously shaped rooms, complicated systems' navigation has been tested. These test situations and the outcomes highlight the paper's advantages, such as the fact that the outlines were created entirely automatically. The distance between any object and the robot has been calculated using a variety of methods throughout the ages, but like with everything else, the system was ineffective and was not suited for usage in severe environments.

The researchers' strategy in this work is based on the alternating execution of two essential processes: map creation and autonomous robot navigation in an unfamiliar environment. Range measurements are gathered here. to create a small-scale model of the community. By removing irrelevant or contradictory information, this representation is subsequently incorporated into the global map that has so far been built. A local path has been created from the robot's current position to the target during the navigation phase utilizing a path planning method. The robot moves down the path until it reaches the explored area's edge, limiting if it encounters unanticipated obstacles. [20] The real-time performance of the suggested strategy is shown by experimental data for a mobile robot called the NOMAD 200 in both static and moderately dynamic situations.

Thus, after doing some keen research, it was visible that performing the aforementioned processes including real-time simulation for our third design of approach would be a challenge for us within a period of one year. Through our autonomous-based design, we wanted to build a completely automated machine that would navigate on its own while avoiding obstacles using Google mapping. Light detection and ranging technology has been anticipated for auto navigation. That specific technology will map out the entire room and save its architecture in the cloud itself. From there it will be very easy to access the different layouts of different rooms while the robot spontaneously disinfects the entire space without human maneuvering. Now, our autonomous design system uses little to no external communication and would run on a single algorithm. The system also uses a camera for facial recognition, and it will also help in the mapping of the indoor room for a better model. Other than that, there will also be ultrasonic, PIR and temperature sensors embedded within our robot whose functionalities were discussed beforehand. In addition to using light detection and ranging technologies, significant procedures have also utilized to create the aforementioned autonomous-based system. However, removing the extra camera and the laser light technology from the entire design will leave the system unchanged from the IoT-based disinfection system. A huge downside to living in a third-world country is that it is very difficult to get access to the high-level technology which was mentioned in the above paragraph. This is also because of the high cost that we would have to bear in getting any of the above here. Hence, in doing so, the overall cost of the entire project would inflate and our disinfecting system for educational institutions would not be affordable anymore. In addition, with the given time frame of only a year, achieving something this complex proved to be a challenge and we were hoping to further our research in the foreseeable future.

2.5 Conclusion

In this chapter, three designs have been put forth in accordance with the project's goal. The first design methodology is a disinfection system that is operated by humans. This design drew inspiration from society's standard cleaning procedure. With the best results, this cleaning process utilizes the fewest people. The IoT-based disinfection system is the second recommended technique. The characteristics of this design approach are the same as before. However, because ultraviolet radiation serves as the system's primary function, both the advantages and disadvantages of UV-C light have been carefully examined. In consideration of this, our design method incorporates app-based control to limit direct human engagement throughout the cleaning process. The autonomous disinfection system is the final design phase. This design approach is totally self-sufficient in terms of movement and charging. The system will navigate on its own using google maps and clean the surface. With this benefit, human involvement will be eliminated completely. The autonomous system will be more computerized and powerful, but because the system is designed for academic institutions, it will cost considerably. An IoT-based system, on the other hand, will be a very affordable alternative that is also simple to operate and, most importantly, will give students a 99.98 percent safe environment. An analysis of a matrix table has been done to support the best solution.

Chapter 3

Use of Modern Engineering and IT Tool. [CO9]

3.1 Introduction

This project presents the building of a UV-C sterilization system, which will be the most affordable and effective method for disinfecting school institutions. The system will also have a feature for identifying staff members and students who will show early coronavirus symptoms. Human involvement in chemical-based sterilization has been practiced for a long time, but it has never been proven to be effective. The approach will thereafter be IoT-based, which will reduce the need for direct human engagement in cleaning local spaces including classrooms. Additionally, throughout the bot’s operation, a few sensors that can detect people and objects will be incorporated. Proper software integration will enable all of these functions and the entire hardware operation to work properly. The use of appropriate IT tools can result in proper software implementation. In our digital age, thousands of IT tools are accessible. However, the proper selection of IT tools appears to be a significant difficulty for researchers and developers among all of them. A variety of tools are also available for hardware development. Choosing the right hardware tools in accordance with the design criteria is indeed challenging.

3.2 Select Appropriate Engineering and IT Tools

Software and hardware tools have been chosen based on the project's requirements. For better demonstration, a table listing the tools and their functions has been added below:

	System Level Design	Modern Engineering Tool Name	Purpose
Software	Simulation and Programming Platform	Proteus	Electronic circuit design, simulation, and drawing.
		Arduino IDE	Provides a text editor for coding. To upload programs and communicate with the system, it establishes a connection with the Arduino hardware.
	Data storage Platform	Firebase	Firebase provides a real-time database and tools for tracking analytics.
	App Development Platform	Android Studio	Android Studio provides a unified environment for building apps for Android phones, tablets, Android TV, and other Android devices.
	3D Design of Sterilizing System	Fusion360	Fusion 360 allows for the creation of 3D designs and toolpath creation.
	3D Animation Short	Maya	Maya is a professional 3D animation, modeling, simulation, and rendering toolset, designed for creating realistic characters and models.
Hardware	UV-C Intensity Measurement	Irradiance Meter	Make instantaneous measurements to determine the watt per square meter UVC irradiation.
	Air Quality Measurement	PM2.5	PM2. 5 detects any particulate matter with a diameter of 2.5 micrometers or less, including smoke, tiny dust particles, vehicle exhaust, and aerosols.

Table 7: Selection of Modern Engineering Tool

The choice of a contemporary engineering IT tool was made after comprehensive study and research. There are numerous software programs available for each of the aforementioned work purposes. The tools have been chosen, nonetheless, after taking a few crucial considerations into account. Table VII displays the range of IT tools used for work purposes. Below is a detailed explanation of each tool's application in the context of software simulation has been shown-

- **<u>Proteus:</u>** In case of designing the circuits proteus has been used. This IT tool was specifically chosen after taking into account some important factors. The factors are mentioned below-
    - Easy to design two-dimensional circuits
    - Simulation of various circuits can be done on personal device.
    - Circuit design on the Proteus takes less time
    - There is almost no chance of any electronic component burning or getting damaged.

For designing circuits, there are a number of alternatives to Proteus, including Multisim, Tinker CAD, MATLAB, etc. The fact that Proteus has numerous component libraries, including Arduino, microcontrollers, Bluetooth scanners, etc. makes it unique.

- **<u>Arduino IDE:</u>** The open-source Arduino IDE is a tool used to create and upload code to Microcontrollers in both software and hardware projects. A microcontroller that is directly connected to every component will execute each instruction in the proper sequence. Operating platforms including Windows, Mac OS X, and Linux are all compatible with the IDE program. The Arduino IDE is a low-cost IT tool that doesn’t require an external programmer (burner). Additionally, programming with the Arduino IDE is indeed simple. Since Proteus supports the Arduino IDE, this tool was specifically chosen for coding purposes.

- **Firebase:** One of the crucial features of the system is to identify the temperature of the human body every time he or she tries to enter the institution. This requires reliable software that is not only easy to operate but also provides accurate results. Firebase has been found perfect for this operation. Real-time database and analytics tracking tools are provided by Firebase. It also provides reliable and extensive databases with fast and safe hosting. Firebase, an alternative to Fire store, offers more compression and includes a variety of services, including databases, notifications, analytics, machine learning, etc.

- **Android Studio**: After that, a unique controller should be used to regulate the entire system. A smartphone app will be used to control the system as it will be a semi-autonomous one. A mobile app will be used to operate the robot's entire communication system. A suitable IT tool must be utilized to construct this app. Android Studio has been chosen to complete the task.

- **Fusion 360:** 3D modeling has been designed of the entire system in order to effectively visualize the design as a whole and its requirements. Modern 3D modeling, such as better control over details, offers a level of design depth that is not possible with rough sketches or 2D designs. Additionally, it permits engineers and researchers to investigate the physical components of a design without giving in to physical constraints. Fusion 360 software has used to carry out a 3D modeling structure.

- **Maya:** A 3D animation film can be quite helpful for a clearer explanation of the system's operation. For residents in Bangladesh, the proposed disinfection system is a fairly novel idea. A 3D animation video with all the characteristics can be a wonderful alternative to visualize in order to help people comprehend the functioning. Maya has been used to prepare the 3D animation video.

- **UV-C Sensor Module (GUVC-T21GH):** Illuminance is measured using a photodiode-type UV sensor module. Light energizes the electrons in the photodiode, creating an electric current. In response to brighter light, the current will be stronger. A measurement of this current is then made, and the result can be either a digital or analog output. The particular model of the UV-C sensor module that has been utilized here is GUVC-T21GH.

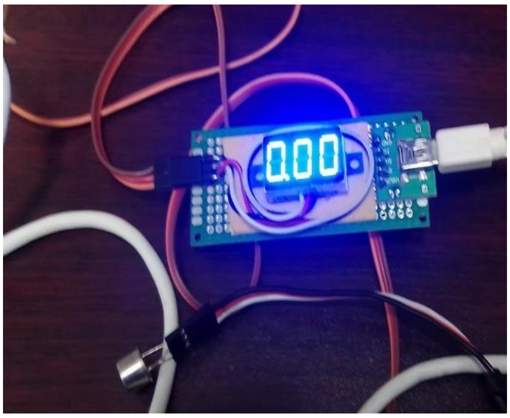


Figure 9: UV-C Sensor Module (GUVC-T21GH)

Alternative ultraviolet modules include GUVA-S12SD and UVM-30A, although their characteristics and methods of use differ significantly from the module selected for this project in a number of important ways. Keeping that in mind, the optimal UV-C sensor module has been used.

- **PM2.5 Sensor**: The main objective of this project is to sterilize the wall and surface area. For that, a system with ultraviolet rays will be constructed. In order to understand the outcome, it is important to have a sensor that can measure the air quality. PM2.5 will be utilized to fulfill that purpose

3.3 Use of Modern Engineering and IT Tools

- **Proteus**

The system's design must be thoroughly understood to develop the software design. A circuit design, drawing, and simulation tool can be used to implement this specific design. The three aforementioned factors are all included in proteus, a tool for constructing circuits. With the aid of this tool, the software circuit implementation has been done. Below is a detailed explanation of how Proteus was used for simulating two of the three proposed designs:

To begin with, it is always better to start by downloading the most recent version of the mentioned software as not all the components of electric circuitry are present in the given component library. In such cases, additional libraries needed to be installed according to a system's requirement. For both proposed designs, the main circuit was divided among several sub-circuits for a better understanding and reduced complicacy. Thus, the first model from the proposed designs was divided into a few different parts which cover the power and battery management circuit, communication module, RFID Generator circuit, a couple of feedback circuits, Infrared Temperature sensing circuit, UV Light Control system circuit, and lastly the motor control systems for simulating the mobility of the system. The procedure to incorporate all these into a single circuit is as follows:

I. Downloading the most recent version of Proteus.
II. Installing arduino library within proteus as the system uses an arduino UNO as a programmable circuit board. Arduino being a microcontroller has a less sophisticated programmable interface and a minimized power consumption. The code or list of commands for arduino can then be directly uploaded to the model without actually being connected to the hardware itself. In this case, the written code was from the addition of various parts taken from open-source platforms.
III. Next, while working with the power and battery management circuit, it is compulsory to notice the use of 3 cells in the suggested design as the system would be using 3-cell LiPo based on the system's power requirements. Apart from the basics of a battery management circuit, a shunt regulator diode, "TL431" was used to amplify the voltage level within the circuit.

IV. For the communication module, our system was incorporated with a two-way Bluetooth connection which allows the entire system to transfer data to and from it. To achieve this, an additional library was installed within the software.

V. Along with the Infrared Temperature circuit, the RFID Generator circuit was used to scan different RFID tags. Based on the received temperature value, the Bluetooth module would then send an appropriate warning to the user via the LCD module. Apart from this, the buzzer would also start ringing according to the warnings sent by the Bluetooth module. As the RFID Generator circuit was meant to be a different entity, the use of a second Arduino UNO board can be seen within the circuit.

VI. For the UV-C light control system circuit, the UV light was represented by a basic lamp. However, the system was incorporated with a relay circuit with an added flyback diode from the opposite direction. The purpose of this flyback diode is to protect the relay circuit in case of a short circuit or an initial voltage spike.

VII. Lastly, for the mobility of the entire system, the design uses four DC motors connected to a motor driver taken from the initial components library.

Moving on to the second circuit, this design is almost the same as the first simulation. However,there were some changes due to the additional features and most importantly the communication system. They are:

I. The power and battery management circuit in this version would be accompanied by a buck converter. This is a DC-to-DC step-down power converter and is used to step down voltagewhile stepping up current from the circuit’s input supply. Apart from this, a voltage regulator circuit was used in both of the designs known as IC7805. The purpose of this is to maintain a stable voltage irrespective of any voltage fluctuations.

II. The communication of the entire system was designed to be executed completely via Internet but as that was not possible to achieve while simulating, Bluetooth communicationwas used for carrying out or receiving commands.

III. Due to the added functionalities in the second design, two more sensors were incorporated by downloading their individual Proteus libraries. The PIR sensor was used to check for any human presence from a pre-determined distance. The ultrasonic sensor, however, was used to detect any object in the robot's path of movement. If so, the system would then change its path while avoiding the object completely.

- **Arduino IDE:**

The Arduino IDE is an open-source software platform that allows programmers to efficiently build software code. For a better understanding:

i. It can be used to write and upload code to microcontrollers for both software andhardware applications.

ii. Incorporates features like software editing, building, testing, and packaging in a simple-to-use program while boosting developer productivity.

iii. The Arduino IDE is cross-platform and can operate on Microsoft, Linux, and Windowsoperating systems.

iv. No external programmer (burner) is required.

- **Android Studio**:

An IoT-based disinfection system has been chosen as the most suitable option to follow the project goal. A mobile application that we developed following the project goal will be used to control the entire system via a smartphone. But initially, it can be challenging to create a new mobile application. For both students and professionals, android studio can thus be a simple solution for developing mobile applications. Further points include:

- Android Studio provides a strong development environment.
- Both students and professionals can easily generate mobile applications using this software.
- For creating apps for android phones, tablets, android TV, and other devices, android Studio offers a unified workspace.
- Android studio has a faster user interface through which different layers and in-app editing can be done efficiently.
- As it utilizes firebase, the mobile app allows us to save and change data along with having a quick and feature-rich emulator.

➢ **Firebase:**

As mentioned earlier, one of the system's most important characteristics is its ability to detect a person's body temperature each time that person tries to enter the facility by scanning an RFID tag. This calls for dependable software that is not only simple to use but also yields precise results thus firebase has been discovered to be ideal for this procedure. Additional points include:

i. Firebase offers real-time directory and analytics tracking technologies.
ii. Grant the user secure access to the database directly from the code.
iii. Firebase also contains a range of services, such as databases, notifications, analytics, machine learning, etc.

➢ **Fusion 360:**

In Bangladesh, the system development concept that is being suggested in this project is relatively novel as the community has limited knowledge of radiation-based systems. Construction of this system for students and other educational institution workers is the project's main objective. The concept of creating a 3D model of the suggested system has beenput into the effort to better illustrate the concept. A 3D model's design requires it to be trustworthy and easy to understand. To be more transparent:

i. Fusion360 has superior 3D modeling capabilities.
ii. Capacity to produce 3D designs, toolpaths, and simulated testing for specific designs.
iii. Fusion360 was chosen specifically over AutoCAD because it was more affordable while offering a range of functionalities.

- **Maya:**

The significance of a 3D animation video cannot be emphasized when trying to comprehend how the system works. The 3D animation film will accomplish the same goal as the 3D system model in terms of aiding viewers in developing a thorough understanding of the system. To elaborate:

i. Maya has been used to create simplistic but professional 3D animation videos.
ii. The said software has consistently proved to be the industry standard for 3D modeling and animation.

Maya is better suited for massive studio projects.

- **UV-C Sensor Module (GUVC-T21GH):** The key component of the system is UV-C light. Precise UV sensors can be used to measure the intensity in order to regulate radiation and guarantee full therapy success. The particular model of UV-C sensor, GUVC-T21GH has been used to here to measure the intensity. Features and applications of this module are below-

Features:

a. Operating with a single supply voltage
b. Increased voltage output
c. Hypersensitivity
d. Adequate solar vision.
e. Compact size.

Applications

a. Pure UV-C surveillance.

b. Sterilization Lamp Monitoring.

Alternative ultraviolet modules include GUVA-S12SD and UVM-30A, although their characteristics and methods of use differ significantly from the module selected for this project in a number of important ways. Keeping that in mind, the optimal UV-C sensor module has been used.

- **PM2.5 Sensor**: The proposed disinfecting system will be utilized to eliminate the bacteria and viruses in the air using UV-C light. For this purpose, a particular sensor has been employed to the system known as PM2.5. PM2. 5 detects any particulate matter with a diameter of 2.5 micrometers or less, including smoke, tiny dust particles, vehicle exhaust, and aerosols. Specific quantity of air is passed through by a light beam inside the sensor, and the light beam is then scattered by the airborne particles. The amount of scattered light is measured and used to determine the particle content in the air sample. N95 is an alternative of PM2.5 sensors which is a costly option, and the features does not meet with the project requirement. Required time range for building the system was very short and during the implementation period the sensor was not available. In future, this sensor will be incorporated with the system to measure the air quality.

3.4 Conclusion

A system cannot be developed without the appropriate choice and application of IT tools. This chapter includes a comprehensive overview of the choice and application of modern engineering IT tools that are both appropriate for system development and very simple to use. For project management, planning, assuming, and designing the system, all available technologies and applicable tools have been utilized.

Chapter 4

Optimization of Multiple Designs and Finding the Optimal Solution. [CO7]

4.1 Introduction

Multiple design strategies were briefly described in chapter 2 along with the required block diagram. Three different design techniques can be used to assess the system proposed in this project. Each design was developed in accordance with the project's objectives. The project is focused on constructing a system that will provide all sorts of educational institutions with a cost-effective disinfection solution. Despite the fact that each system has the same features, there are differences in the components that will be used to build each system. The cost of the first design method will be incredibly low, but the risk of ultraviolet radiation to people will stay the same. This issue can be resolved by the second design strategy. In this scenario, a semi-autonomous system that excludes direct human input will be used. The final design process will be wholly autonomous and completely free of intervention from humans. The final design might be the greatest option, but the expensive components needed to make the system fully autonomous will drive up the overall cost. A costly system cannot fulfill the project's requirements; hence the second methodology can be selected as the best option. This choice has been made taking into account a few key standards, which will be briefly covered in this chapter.

4.2 Optimization of Multiple Design Approach

Research has been conducted to evaluate the three designs in light of various factors, including price, effectiveness, usability, manufacturability, impact, sustainability, maintainability, etc. The most effective solution for the project has been determined due to this research and analysis.

Optimization of design 1 (Human Controlled System):

The human-controlled system is the first design methodology (Fig. 2). This design's functionality is fairly simple and uncomplicated. On the basis of the functionality, a software implementation has been created. Compared to the other two systems, this system's hardware can be manufactured rather easily. Since the system is human operated, a person must use physical force to control it. That seems quite easy as people are habituated to cleaning an area using the same method. The UV light, however, gives this system some uniqueness. A person may unintentionally be exposed to ultraviolet light, which is particularly hazardous to human skin, while moving the system from one place to another place. Additionally, the efficiency of sterilization may vary for this system design since humans cannot always maintain the same strength and speed. Sustainability and maintenance are interrelated to one another. The more the system will be maintained the more it will sustain. This system architecture may last longer than the other two because it is less complex to construct. Therefore, the probability of sustaining less is quite minimal. For the impact part, three factors—health, culture, and society—have been considered. Although the cultural and societal aspects of this system design are considerable by humans, the operator and students will still experience health problems due to abrupt UV exposure and ineffective sanitation. Finally, because the system is less complex than the other two systems, the cost is likewise acceptable.

Optimization of design 2 (IoT Based System):

The second design methodology is the IoT-based system (Fig. 3). A four-layer architecture is followed for proper IoT system construction. This system's functionality is quite different compared to the human-controlled system. The aspect of the system operation is completely different. A mobile app will be utilized to control the whole system. Consequently, a communication component has been developed to connect the mobile app with the system's microcontroller. The third feature of the system is human and object detection. PIR and

Ultrasonic sensors will then be integrated into the system. The communication part and the sensors incorporation made the whole functionality part a bit trickery. Depending on that, the hardware manufacturability will become a bit different than the previous one. Mobile application utilization will become the whole control process much easier as it will mitigate human intervention directly. A person can easily control the system using a mobile app from a certain distance. The maintenance for this system can be a bit harder than the previous one as the sensor will be incorporated externally. One must be very careful while cleaning the system. As the system is a little bit complex, the sustainability of this system is less. In case of impact, people have less knowledge about IoT-based systems. The sterilization efficacy is substantially higher, but it is less socially and culturally accepted than a system supervised by humans. Last but not least, the cost compared to the human-operated system is slightly higher because there are significantly more components in this design.

Optimization of design 3 (Automated Disinfecting System) :

The automated disinfecting system is the third design methodology (Fig. 4). The system operates entirely differently from the two earlier prototypes. However, every aspect of this system is totally automated. Google Maps will be used for auto-navigation during this automation procedure. The system will have a 360-degree camera installed that can recognize individuals and objects at a specific distance. In this situation, image processing techniques will be applied. Therefore, the entire functioning will be rather complicated. Consequently, it will be challenging to manufacture. The system will have a dedicated charging station where it can fully recharge itself. As the system is automated, so there will be no human involvement in the cleaning procedure. So, the system's usability is extremely easy. The maintenance of this system is harder than the previous two. A person with proper knowledge is necessary for the maintenance of the system. Being higher in complexity scale, the probability of sustainability is much less. However, this system provides the most effective sterilization outcome. In case of impact, people have barely any idea about automated systems. But in the case of health, the level is higher than the prior two. Finally, the cost of the system is the highest as the components here utilized are very high cost.

A thorough comparison of design methodologies, as well as their benefits and drawbacks, has been conducted. An appropriate disinfection system might be created using an IoT-based design process. The comparison table is below-

Features	**Design 1** **Human control disinfecting system**	**Design2** **IoT Based disinfecting system**	**Design 3** **Autonomous disinfecting system**
Sterilization System Configuration	ATMEGA2560-16AU 8bit Microcontroller	Tensilica Xtensa LX6 microprocessor	Broadcom BCM2711 SoC with a 1.5 GHz 64-bit quad-coreARM Cortex-A72 processor
Technical Complexity	One way communication	Requires Wi-Fi connection to one time communication.	Expensive and unavailable components in Bangladesh
Communication Setup (User Interphase)	Wireless Transmitter	App Control	Autonomous navigation
Safety Assurance	No safety	Proper Safety	High Safety
Cost Efficiency	Lowest	Lowest	Higher

Table 8: Comparison Between Multiple Design Approaches

A comparison table has been shown among the different design methodologies. The extensive discussion is below-

Sterilization System Configuration: Each of the design methodologies will have a different processor through which the systems will get the human commands. In accordance with the features and functionality, three different types of processor and microcontrollers have been chosen.

Technical Complexity: The first design methodology has one way communication facility; however, the optimal solution will be the second design methodology as the third design methodology is way more expensive and most of the components are not available in Bangladesh.

Safety Assurance: Ultra-violet based lights are the key component and the damaging effect that causes UV radiation is not new. Keeping the damaging effect in mind, different sensor has been incorporated with the system. The first design method does not have any safety assurance whereas the other two design have PIR sensor incorporated with the system.

Cost Efficiency: A few things must be kept in mind while creating this system, the major goal of this project is to provide a safe educational environment for the students. First and foremost, this system must be cost-effective for public institutions to use it. It must also be relatively simple to operate so that even someone with a moderate level of education can operate it. Keeping all conditions unchanged, the optimal solution is the IoT based system. Although an autonomous system will be a smart system, the cost of construction is exceptionally high, raising the overall cost of the system. As a result, it will be difficult for all types of academic institutions to employ it.

After considering all the facts, it can be stated that an IoT- based disinfection system is the most beneficial system for all academic institutions.

4.3 Identify Optimal Design Approach

The best option for cleaning surfaces and walls has been determined to be an IoT-based disinfection system. A matrix table with certain basic criteria has been given for better demonstration. Numerous factors might be taken into account, but in this case, a few crucial factors have been picked to correctly analyze the system.

Criteria		Three Design Approaches		
	Weights	**Human Disinfecting system**	**IoT Disinfecting System**	**Autonomous Disinfecting System**
		Score	Score	Score
System’s Functionality	21	10	17	19
Manufacturability	20	11	16	20
System’s Usability (Operation)	16	15	12	7
System’s Maintenance	12	12	10	7
Sustainability	13	6	11	9
System’s Impact	10	8	7	5
Cost Relevance	8	3	5	7
❖ **Scores**	100	65	78	74
❖ **Rank**		3	1	2
❖ **Rank**		**NO**	**YES**	**NO**

Table 9: Justification of Optimal Design Solution Matrix by Analyzing Multiple

An optimal disinfection system might be constructed using an IoT-based design method by using the matrix table and its scoring. The justification of each criterion has discussed below-

System’s Functionality: This system design also has a direct impact on how it functions.

Although designing an autonomously based bot is one of our near-term goals and the design part has not been completed yet, extensive study has been done on this topic. Based on it, knowledge has been gained about the intricate functioning of the design, which raised the functionality part's score over that of the other two systems. Since the human-controlled system is less sophisticated than the other two, it received a lower score. Semi-autonomous will be a feature of the IoT-based system. The design phase has been completed, and thus it can be easily determined how complicated the design is and assign a score according to that complexity.

Manufacturability: Each design's ability to be manufactured depends on how well each design process works. The human-based design incorporates the fewest functionalities and sensors. As a result, it received the lowest rating for this section. However, an IoT-based system received a moderate level score because it had more features and functionalities than a disinfection system that relied on humans. For autonomous-based systems, this segment receives the highest score as it is fully autonomous and has more features.

System's Usability (Operation): The ease of each system's operation techniques was taken into account while determining each system's usability score. Humans have been included in chemical-based disinfection for a very long time. As a result, individuals feel more at ease utilizing a human-based sterilization system than they do with the other two, which raised theusability component's score. It will be a remote control as well as an app control system in the IoT scenario. Nowadays people are quite habituated to using smartphone apps or remote controls, so using an IoT-based system shouldn't be too challenging for them. However, in the case of an autonomous system, the majority of people are still unfamiliar with the idea, makingit incredibly challenging for them to operate it appropriately. Following that, for autonomous and IoT-based systems, scoring has been done precisely taking into account all of theaforementioned factors.

System's Maintenance and Sustainability: The maintenance and sustainability of a system are interrelated. The system will last longer the more it is maintained. Because of the extensivefunctionality of an autonomous system, maintenance costs and system failure rates would be significant. Additionally, a person needs a comprehensive understanding of the entire system for high maintenance, which is still unclear to a lot of people. As a result, both segments' overallscores for the autonomous system decrease. However, the level of functionality for IoT-basedsystems is not very significant. As a result, the rate of maintenance and system failures decreases. The combined score for both portions rises as a consequence. It entirely depends onhumans for systems that are controlled by humans. No matter how well-maintained a cleaner may be, they will not be able to work consistently. Following that, the ratings for both segmentshas been modified.

System’s Impact: Three factors-health, culture, and society-have been taken into account for the impact section. When it comes to health, radiation-based sterilization has been shown to be far more successful than methods that use chemicals. The Internet of Things and autonomous systems use radiation to sterilize objects, whereas chemical systems are entirely dependent on humans. In this situation, IoT and Autonomous received greater scores. However, if we focus on the cultural and societal aspects, the conception of persons in society has previously been discussed. Their beliefs are what form the culture. Therefore, IoT and autonomous systems receive a lower score than human-based systems. Additionally, this lowers the overall rating for both radiation-based systems compared to human-controlled systems.

Cost Relevance: The main objective is to give students a secure atmosphere that allows them to educate. In order for public institutions to employ this system, it must first be cost-effective. This system must, above all, be economical so that different kinds of educational institutions can utilize it for disinfection. Thereafter, we performed the cost relevance evolution while taking into account the budget for various design methodologies. The autonomous-based system received a higher score as a result of the intricacy of its design, which ultimately increased the system's cost. Due to sophisticated configuration, the other two systems' expenses are also impacted, and as a result, they received a corresponding score.

Based on the table, it can be concluded that design 2 offers the best option. Depending on sensors and modules another weightage table has been created to find out the optimal design. Depending on some basic criteria, sensors and modules for three systems 2 weightage table have been created. The demonstration is below-

Features		**Three Design Approaches**		
	Weights	**Human Disinfecting system**	**IoT Disinfecting System**	**Autonomous Disinfecting System**
		Score	Score	Score
PIR Sensor	20	0	20	0

Features		Three Design Approaches		
	Weights	Human Disinfecting system	IoT Disinfecting System	Autonomous Disinfecting System
		Score	Score	Score
Ultrasonic Sensor	15	0	15	0
Infrared Temperature Sensor	15	15	15	15
PM2.5	17	17	17	17
Wi-Fi Module	13	0	13	13
Area Navigation Module	10	0	0	10
LCD Screen	10	10	0	0
Total	**100**	**42**	**80**	**55**

Table 10: Optimal Solution Based on Simulation of Sensors and Modules

PIR Sensor: The key component of the system is the ultra-violet lights that will be utilized in sterilization process. The radiation of UV is extremely harmful for human skin. PIR sensors have been integrated into an automated disinfection system and Internet of Things (IoT) to protect human skin.

Ultrasonic Sensor: Object detection is one of the crucial features for each design methodology. In order to detect object from a specific distance, ultrasonic sensor have been installed with the IoT based system. In case of autonomous disinfecting system, a 360-degree camera will be used for object detection.

Infrared Temperature Sensor: The system has a feature of determining students 'body temperature to identify individuals with early virus attack symptoms. An infrared temperature sensor has been utilized with all of the design methodologies to determine body temperature.

Wi-Fi module: One of the objectives of the project is to mitigating human involvement in the sterilization process. Both IoT and autonomous based system has Wi-Fi modules through which they will connect with the mobile application and other necessary devices.

Area Navigation Module: The autonomous based disinfecting system will be a complete automated disinfecting system that will have a feature of navigating area using LIDAR. The other two systems will have controlling devices to get operated by user.

LCD Screen: The ultraviolet light status and student access in the institution will be presented on an external LCD screen of the human-based disinfection system. The other two systems won't need an external LCD screen because they'll be connected to more than two smart gadgets. The highest rating for an Internet of Things-based solution is displayed in both tables. The conclusion that an IoT-based system is the best option may therefore be made from both tables.

4.4 Performance Evaluation of Developed Solution

Three design techniques have been suggested for the project in order to accomplish its goal. Inline with that, two design approaches were designed, and the simulation components are depicted in *fig 6* and *7*. However, a detailed description of the features that have been incorporated into the system design will be provided in this section.

Human controlled system:

It has been already stated that this system design includes three features. Each feature functionality has been shown below-

- **Motor Operation:** Motor operation is the first feature of the system design. In the case ofthe human-controlled system, the motor operation is very straightforward. The motors will be connected to the microcontroller directly and will move in accordance with the human command received from the microcontroller. In order to move the system forward, one hasto press ‘F’, and to move it back one has to press ‘B’. The right and left motor operations will be commanded in a similar way and the results will also show in accordance with the command.

The complete operation has been shown below.

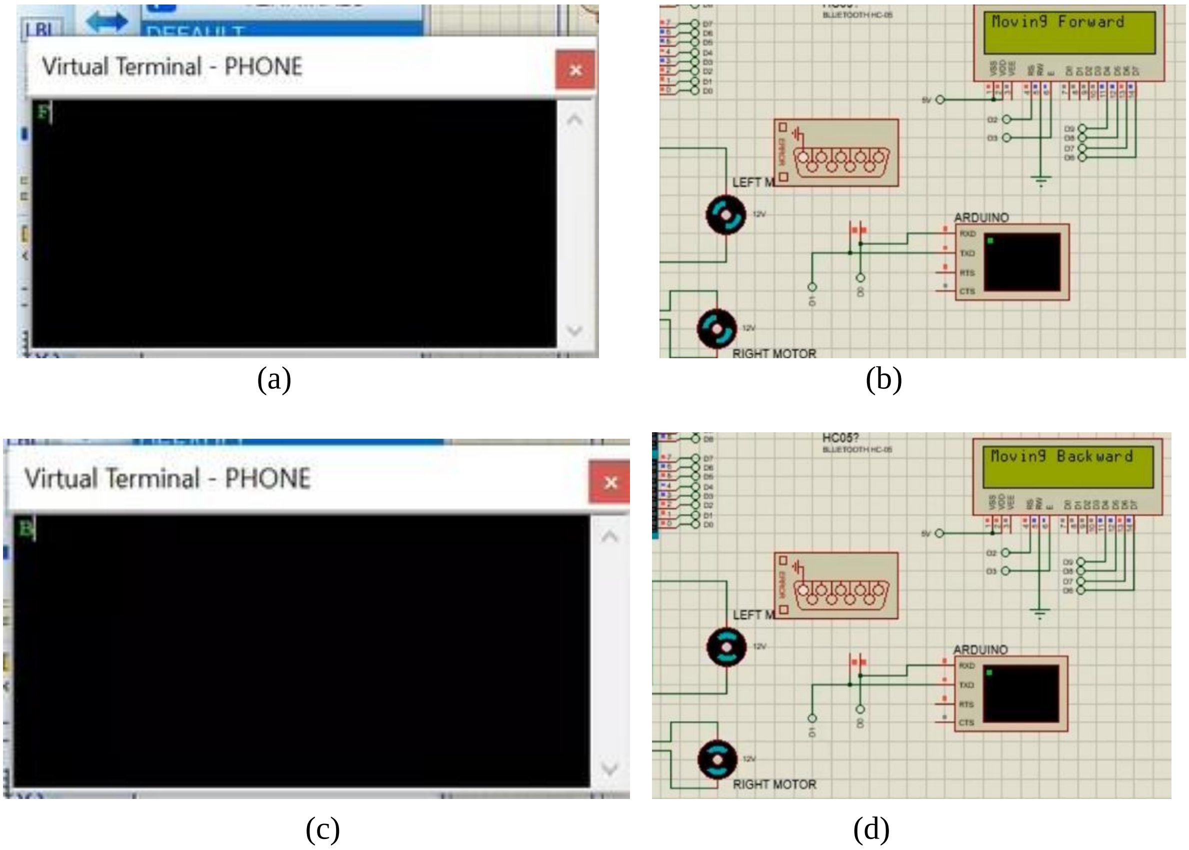


Figure 10: Motor operation of the human-controlled system (a) Virtual terminal showing 'F' as forward command (b) Forward motor operation showed in LCD screen (c) Virtual terminal showing 'B' as backward command (d) Backward motor operation showed in LCD screen.

- **Sterilization System:** The second feature here is the sterilization system. The complete operation has been shown below-

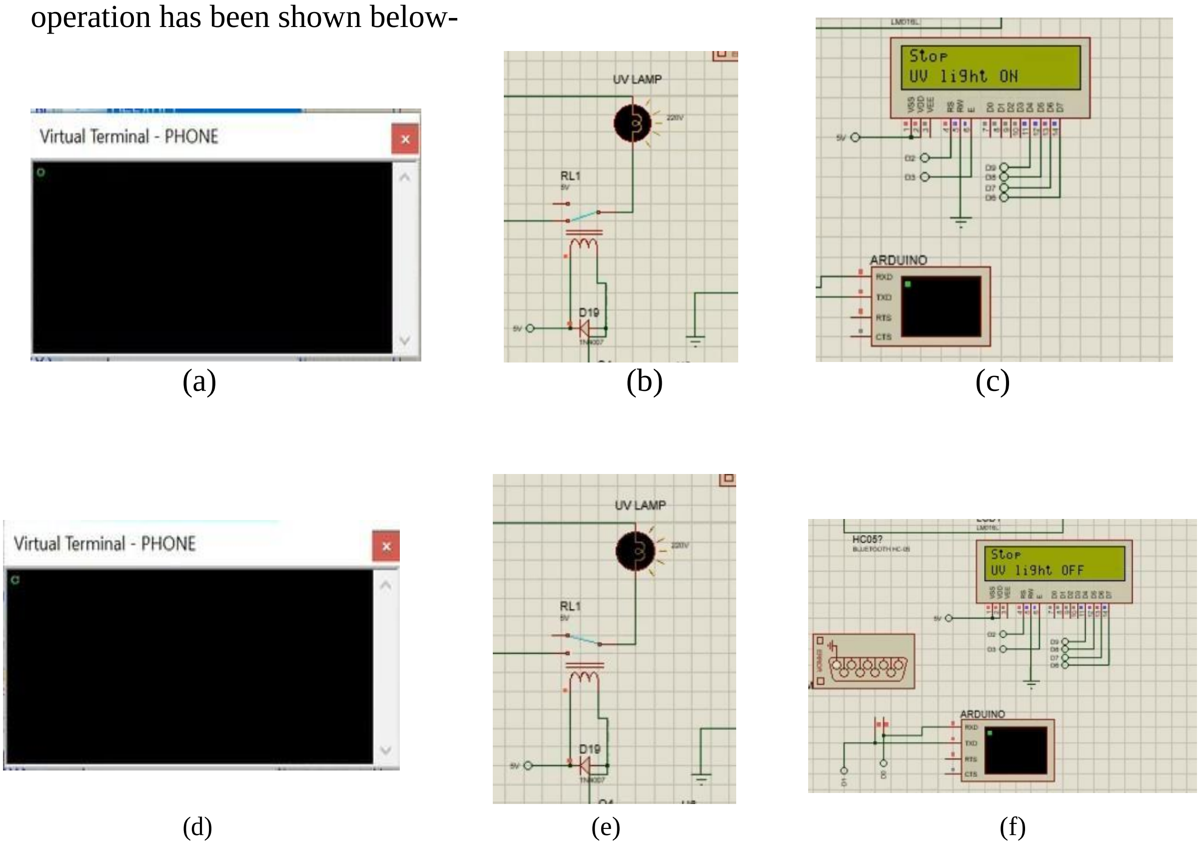


Figure 11: Sterilization system showing by UV light status in human controlled system. (a) Virtual terminal showing 'o' as UV light ON command (b) UV light in 'ON' status (c) LCD screen showing UV light ON (d) Virtual terminal showing 'c' as UV light OFF command (e) UV light in 'OFF' status (f) LCD screen showing UV light OFF.

In case of starting the sterilization process, the ultraviolet lights need to get turned on. Following that, one needs to press 'o' showing in the virtual terminal in Fig. 11(a). The relay will get down and the lights will turn on which has been shown in Fig. 11(b). The LCD screen of the system will simultaneously show UV light on. In case of switching off the lights, one needs to press 'c' which has been shown in Fig. 11(d). The relay will change its position according to the command and the lights will turn off that has shown in Fig. 11(e). The sterilization process will remain to continue in the presence of humans as the controller here will be an individual. Moreover, the object detection process is also manual in this design process.

❖ **Alert System:** Identification of a person entering the institution with a high body temperature is the final feature. The system has a threshold temperature of 40 degrees Celsius. Anyone whose temperature is higher than this threshold point will not be allowedentry into the institution because their access will be refused, and the security will be alertedby the alert system. The complete operation has been shown below-

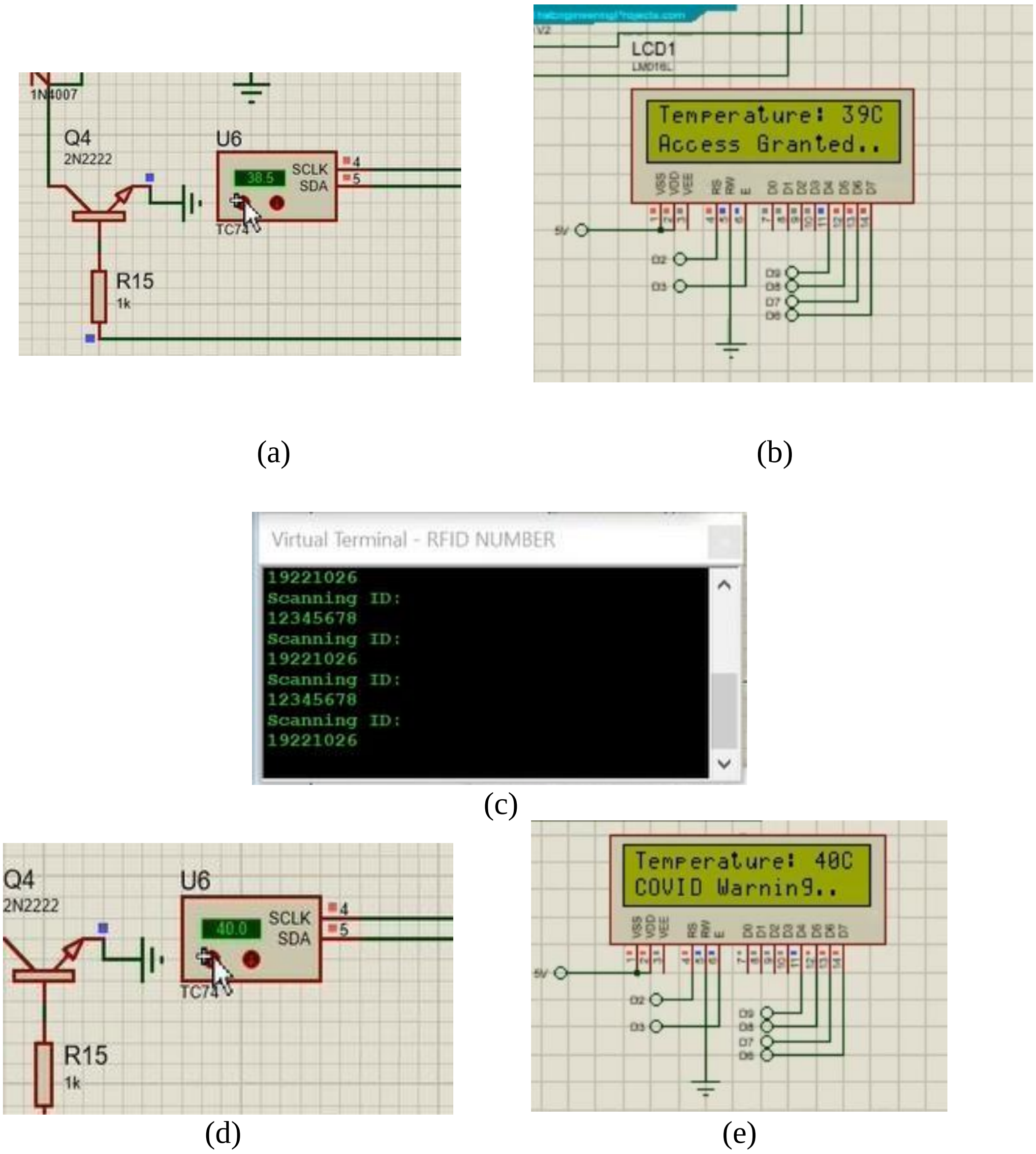


Figure 12: Student's accessible procedure in institution of human control system (a) Temperature set at 38.5-degree Celsius (b) Access granted for 39-degree Celsius body temperature (c) Virtual terminal showing student ID number (d) Temperature set at 40-degree Celsius (e) Access granted for 40-degree Celsius body temperature.

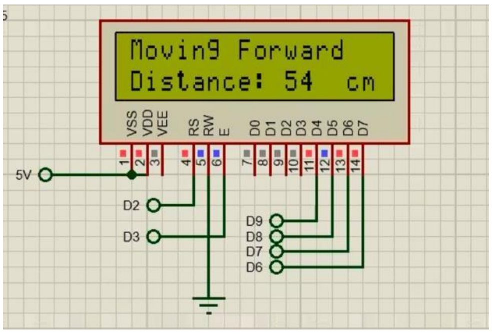
In the aforementioned process, two cases have been considered. A student's access to the institution has been granted with a temperature lower than 40 degrees Celsius showed in Fig. 12 (a) and (b). On the other hand, access has been denied due to having a higher temperature higher or equal to 40 degrees Celsius showed in Fig. 12 (c) and (d). So the buzzer will buzz to alert security.

IoT Disinfecting System:

The features will remain same for this system design except the third one. Each feature functionality has been shown below-

- **Motor Operation:** Motor operation will remain same in this system design. After getting the commands from the microcontroller through mobile application, the motors will movein accordance to the command. However, the third feature of the system is human and object detection. For detecting objects, the ultrasonic sensor has been attached with the main control panel. As a result, whenever the motor will move, the system will detect objectand will show the distance of the object with the status of motor operation. The complete motor operation with object detection has been shown below-

(a)



(b)

Figure 13: Motor operation of IoT system (a) Virtual terminal of giving commands to the system (b) System is moving forward with a distance of 5cm from the object.

- **Sterilization System:** The sterilization system will depend on the status of UV light. Complete operation is shown below-

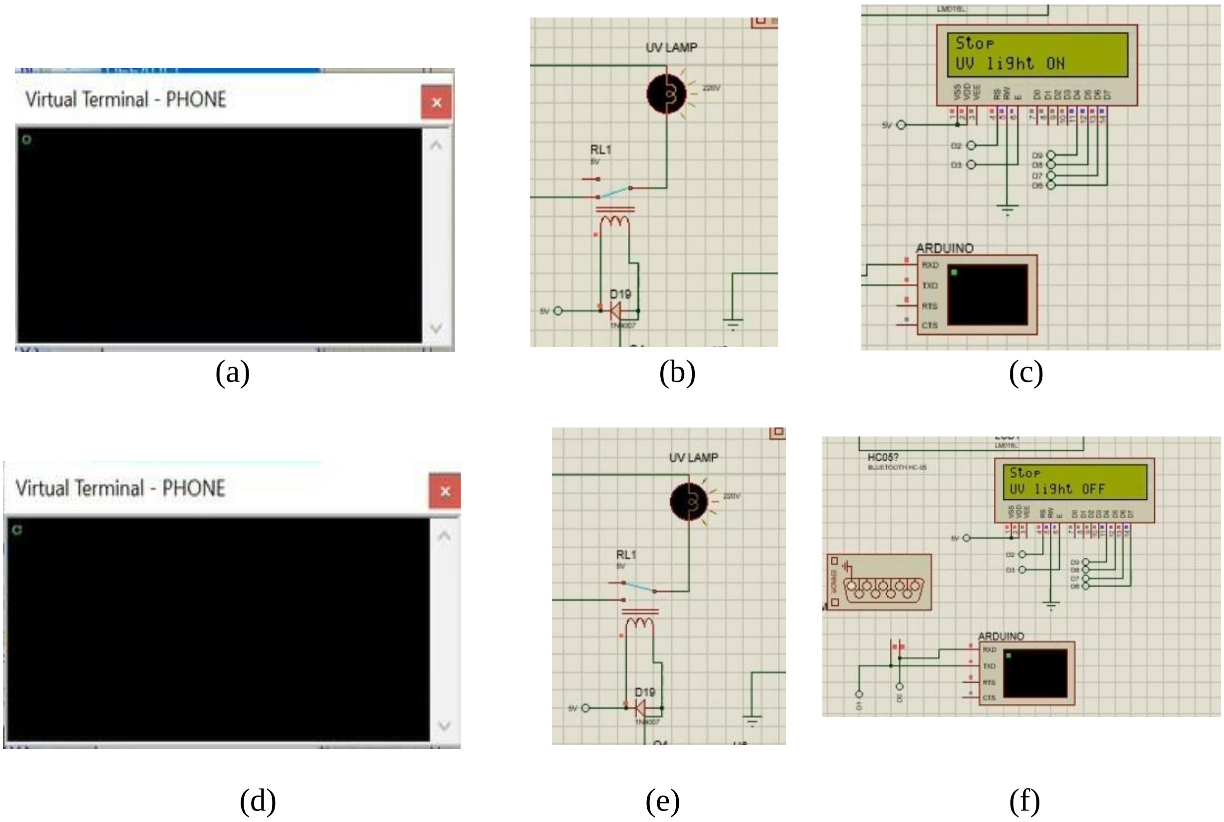
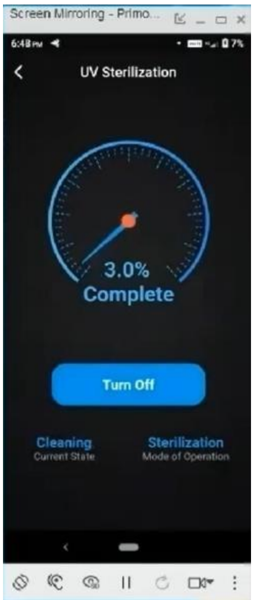
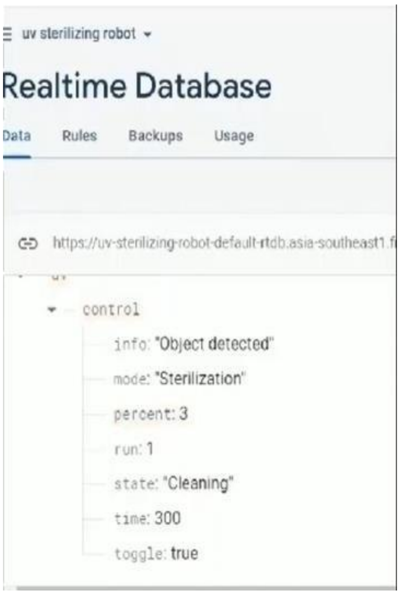


Figure 14: Sterilization system showing by UV light status in IoT system. (a) Virtual terminal showing 'o' as UV light ON command (b) UV light in 'ON' status (c) Device screen showing UV light ON (d) Virtual terminal showing 'c' as UV light OFF command (e)UV light in 'OFF' status (f) Device screen showing UV light OFF.

In case of hardware development, same procedures have been followed. The robot will be in a constant position while sterilizing a particular room. The percentage of sterilization will be shown on the mobile application as well as the information regarding sterilization will be saved in the database. In Fig. 15. the hardware test has been shown-



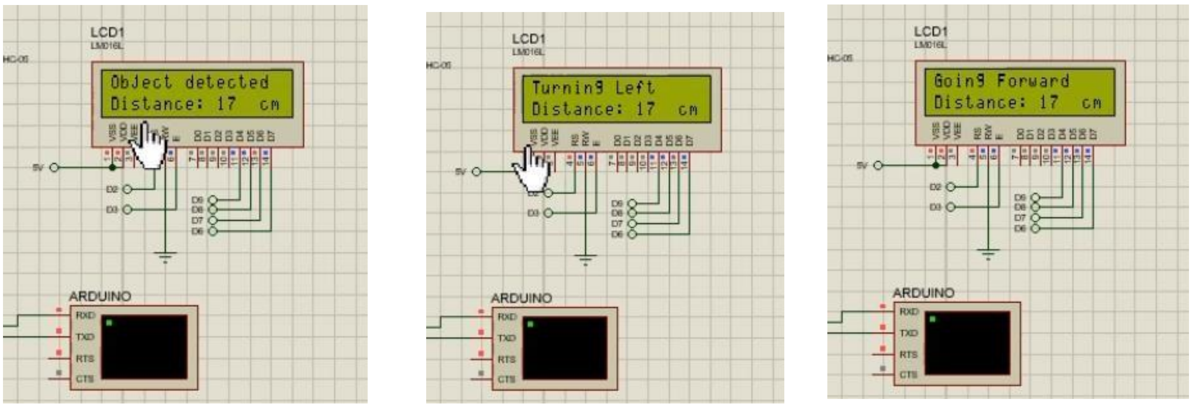


(a) (b) (c)

Figure 15: Sterilization process testing. (a) Mobile application page showing the percentage of sterilization. (b) UV system sterilizing room in a constant position (c) Data regarding sterilization stored in database.

- ❖ **Human and Object Detection:** The third feature of the system is human and object detection.

  <u>Object Detection:</u> The ultrasonic sensor has been attached to the main control panel for detecting objects. As a result, whenever the motor moves, the system will detect the object and will show the object's distance with the status of motor operation.



(a) (b) (c)

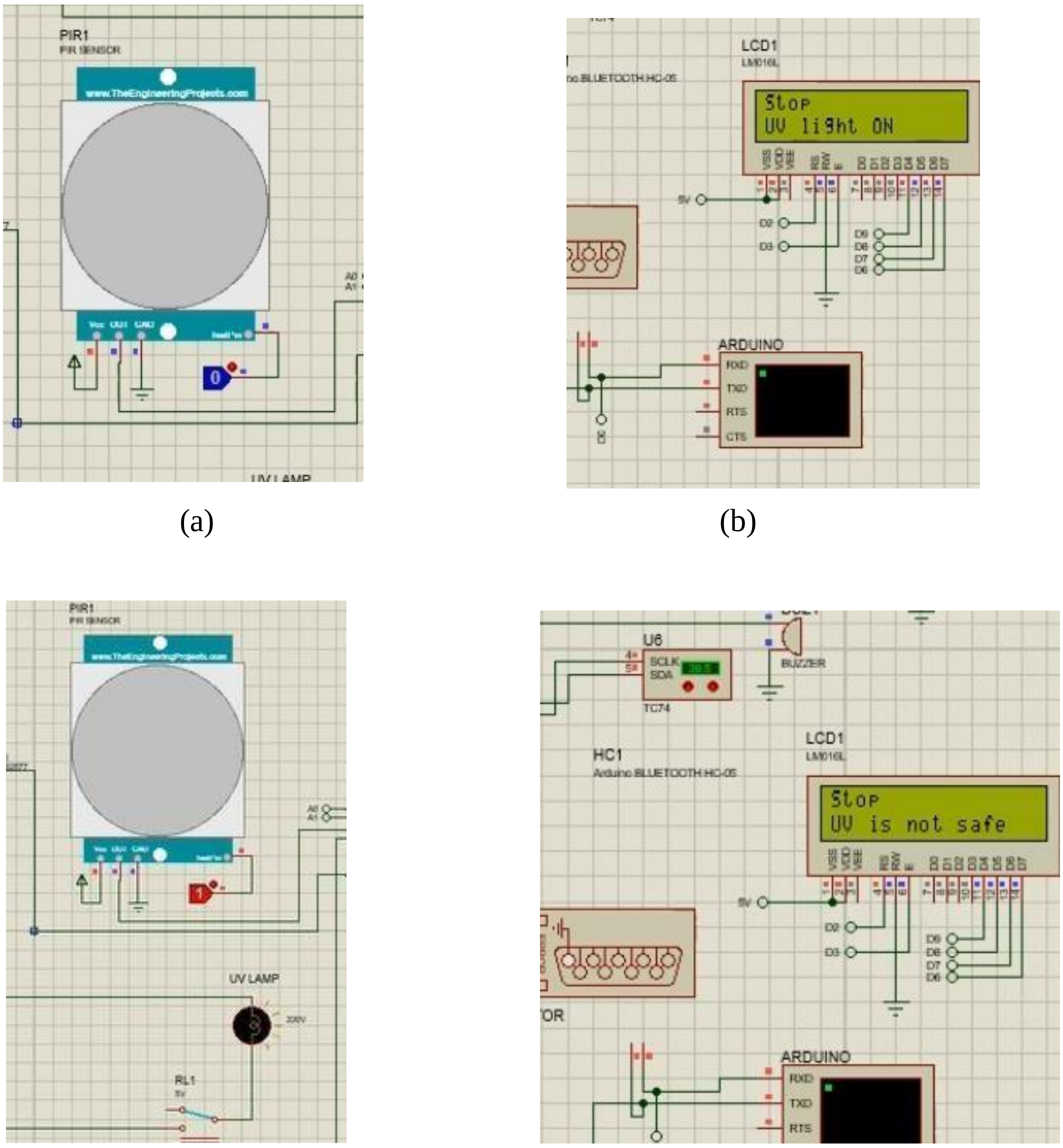
Figure 16: Motor operation along with object detection. (a) Object detected at 17 cm from the system (b) System turned left after detecting the object (c) System again going forward changing its way from the object.

The object detection in case of hardware development provided the accurate result same as the software simulation results. As soon as the object has been detected, the system will change its direction for further sterilization process. In Fig. 17. the hardware test has been shown.

(a) (b) (c)

Figure 17: Object detection testing (a) System detected the object (b) System moving left after object detection (c) System now moving forward to continue sterilization process.

<u>Human Detection:</u> The PIR sensor has been integrated into the system to detect people within a 36-meter range while keeping in mind the UV sensitivity fact. Whenever the system will detect a human within the range the system will get turn off by itself. In the system design, switch 0 indicates the turn on status of UV light in the absence of humans and switch 1 indicates the turn off status in the presence of human. The operation has been shown below-

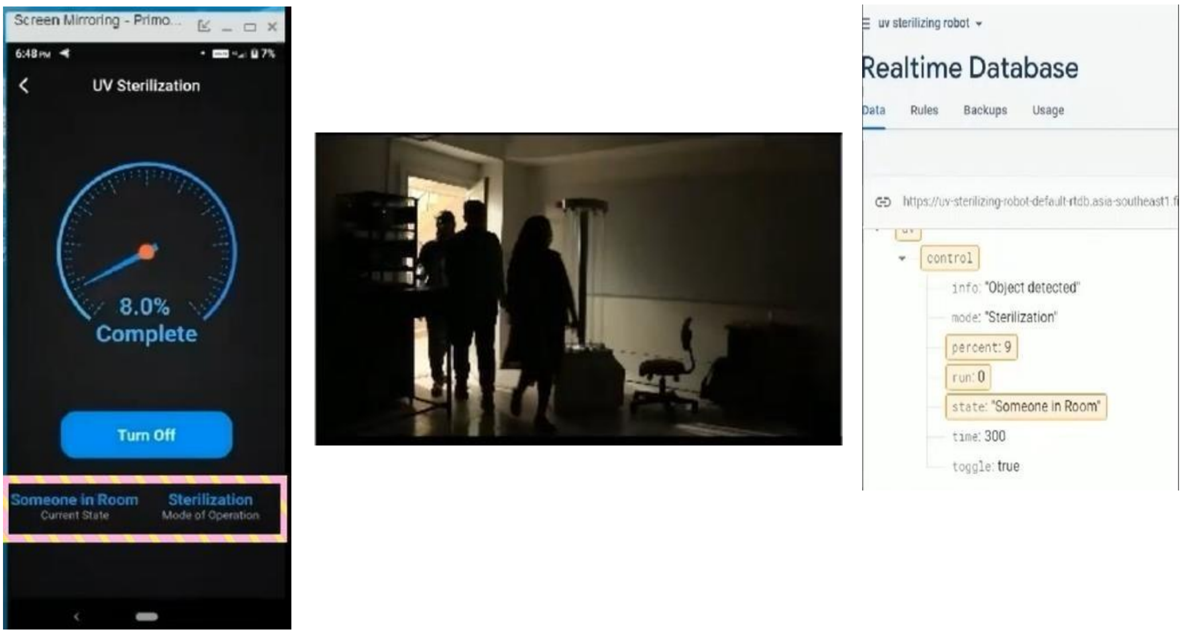


(a) (b)

(c) (d)

Figure 18: PIR sensor detecting humans in IoT system. (a) UV light is ON in the absence of human. (b) Device screen is showing turn on status of UV light (c) UV light is OFF in the presence of human (d) Device screen is showing turn off status of UV light.

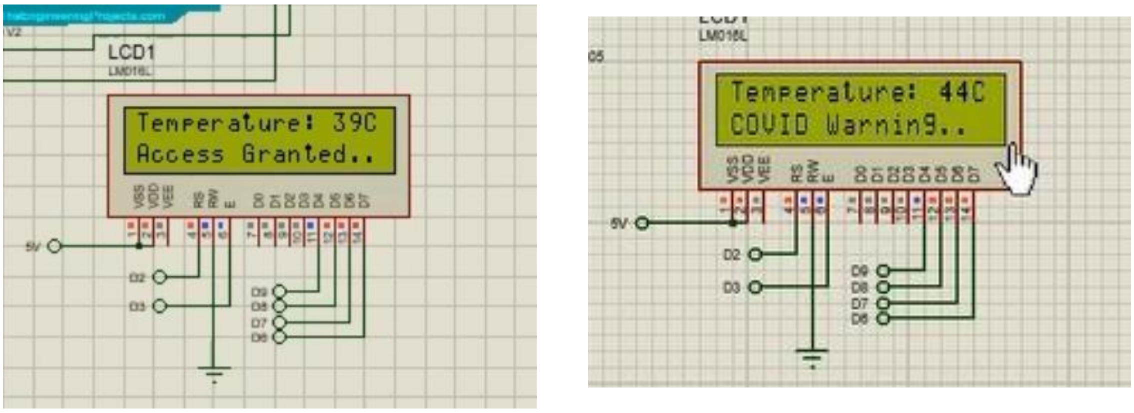
In case of hardware development, the system will automatically turn off as soon as detecting human within the range of 36m. This data will be saved in the database. In Fig.19. the hardware test has been shown-



(a) (b) (c)

Figure 19: Human detection testing (a) Mobile application of showing human detection and paused sterilization status (b) Real time database storing data of detecting human (c) System got turn off automatically after detecting human within the range of 36m.

❖ **<u>Temperature Detection:</u>** This procedure will remain same with the first design methodology. A threshold temperature has been set at 40-degree Celsius. A student with greater than this threshold value will not be allowed in the institution as the temperature sensor will detect it and will send a notification of access denied in the device through RFID scanner. Anyone having temperature below the range will be allowed to enter in the institution. The operation has been shown below-



(a) (b)

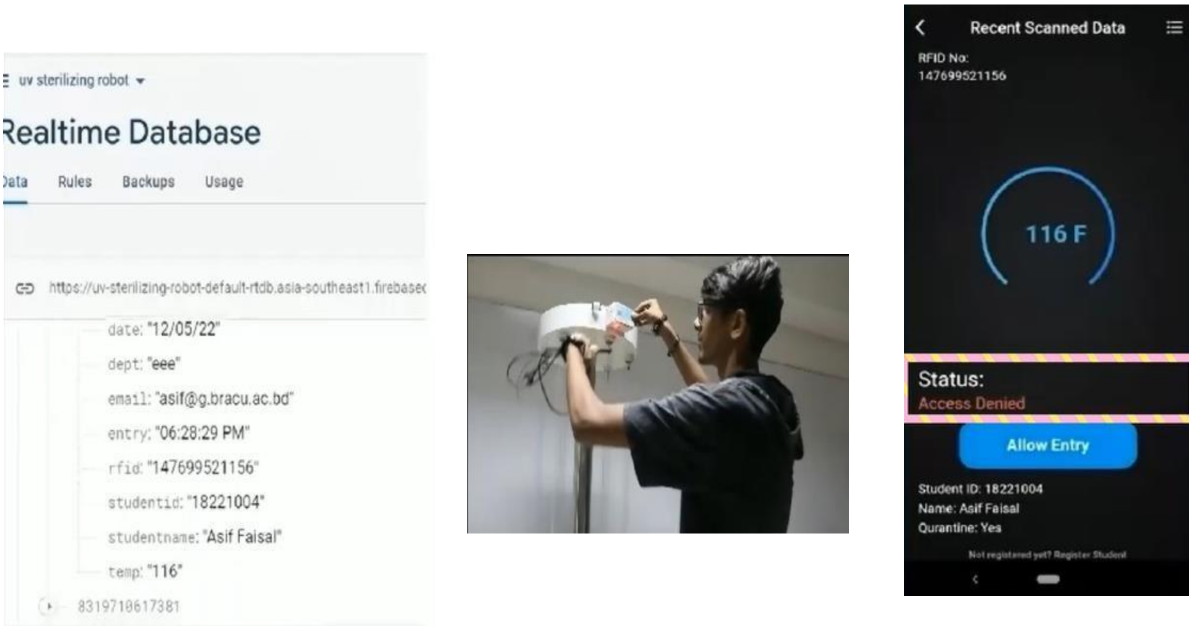
Figure 20: Student's accessible procedure in institution of IoT system (a) Access granted for 39-degree Celsius body temperature (b) Access denied for 44-degree Celsius body temperature.

The procedure and results for detecting temperature of students in case of hardware development has been shown below-

(a) (b) (c)

Figure 21: Student's temperature detection and ID card scanning process through RFID scanner (a) Real-time database storing students' personal information including temperature. (Access Given) (b) Student scanning ID cards through RFID scanner. (c)Mobile app showing students' temperature and the access status (access is given below 100F temperature).

However, students having higher temperature than 100F will not be allowed in the institution. This testing procedure has been done using a soldering iron as no one was having higher temperature then 100F.



(a) (b) (c)

Figure 22: Student's temperature detection and ID card scanning process through RFID scanner (Access Denied) (a) Real time data base storing students' personal information including temperature. (b) Student scanning ID card through RFID scanner. (c)Mobile app showing students temperature and the access status (access is denied over 100F temperature)

Additionally, the app will also show how many students have been accessed through RFID scanner in the 'Home' page and their detailed access status in 'student data' page.

(a) (b)

Figure 23: Number of accessed students and details of students in mobile app. (a) Home page showing number of students accessed in the institution (bottom right) (b) Scanned data page showing detailed information of students accessed through RFID scanner.

The functionality of the system has been extensively explained in the previous sections. The performance of each sensor has been shown previously in the circuit verification section. However, each of the sensor's functionality has been separately shown and explained in this section. Moreover, the hardware implementation has been also shown that provides accurate result same as the software simulation result.

Autonomous Disinfecting System: The third design methodology is the autonomous disinfecting system which system design is quite complex and it requires a longer period to design accurately. The system will be fully autonomous and in order to construct it as automatic system, LIDAR will be utilized. LIDAR will be used to avoid barriers and navigate the system automatically. A camera will be utilized to detect objects and students in this case. A camera will be used to recognize the student's face, and a temperature sensor will be used to determine the student's body temperature also. In any event, PIR and Ultrasonic sensors will be utilized to detect people and things if the camera fails to detect them. The sensors will be employed to guarantee that humans were completely protected from ultraviolet radiation. The system will include a self-charging function. When the robot's battery level drops, a charging mechanism will be built so that it may recharge itself.

A table has been shown below to verify each system functionality with the objective and requirements-

System Functionality	Human Controlled System	IoT Based Disinfecting System	Autonomous Disinfecting System
❖ Sterilization Process	✓	✓	✓
❖ Human Detection		✓	✓
❖ Object Detection		✓	✓
❖ Temperature Detection and ID Card Scanning Process	✓	✓	✓
❖ App Based Control Process		✓	
❖ Real Time Database		✓	
		VERIFIED	

Table 11: Functionality Verification of Each System Design

A system has been proposed in the project that will disinfect walls and surfaces utilizing ultra-violet radiation within an affordable cost range. The IoT based disinfecting system has been chosen as an optimal design solution considering number of factors. The sterilization process and the ID card scanning process including temperature detection will remain same for each of the design methodology. However, the objective of the project demands object and human detection considering smooth and safe sterilization process. The human controlled system does not have any feature of detecting human or object. The autonomous disinfecting system will have a 360-degree camera in order to detect objects and human from a specific distance. However, due to its sophisticated functionality and the inaccessibility of its expensive components on the local market, the construction of an autonomous disinfection system is currently not feasible. Moreover, significant amount of time is required for proper construction of an autonomous based system. The IoT based system in that case fulfilling all the objective of the project as it can detect object and human within a range of 36m utilizing a very reasonable but effective sensors named Ultrasonic and PIR sensor. The whole system will be operated using a mobile application. The system will also store required data such as students' personal information, their access status in institution depending on their body temperature, sterilization percentage, status of UV light and human and object detection in the real time database and will also display in the mobile app. Table XI shows that the IoT-based disinfecting system verified all the functionality described in the objective and in the required part.

4.5 Conclusion

A brief discussion of how the best design process was chosen has been undertaken in this chapter. IoT appears to be the most effective design methodology out of the three solutions. To make the selection, a few variables were taken into account. A major flaw in the human-based approach is that human interaction is required during the cleaning process. This disadvantage entails prolonged sterilizing time, limited area coverage, challenging control management, and a skin cancer risk. All of these issues have been addressed in the second design strategy, though. IoT-based systems can be controlled remotely from a safe distance with the least amount of human interaction. It also requires less sterilizing time with a bigger coverage area. This system's price range is likewise within the reach of any educational institution. This system meets all the objectives proposed in this project. On the other hand, the third design methodology provides the most efficient outcome but due to high-priced components and unavailability of components, the system cannot be the optimal solution for this project.

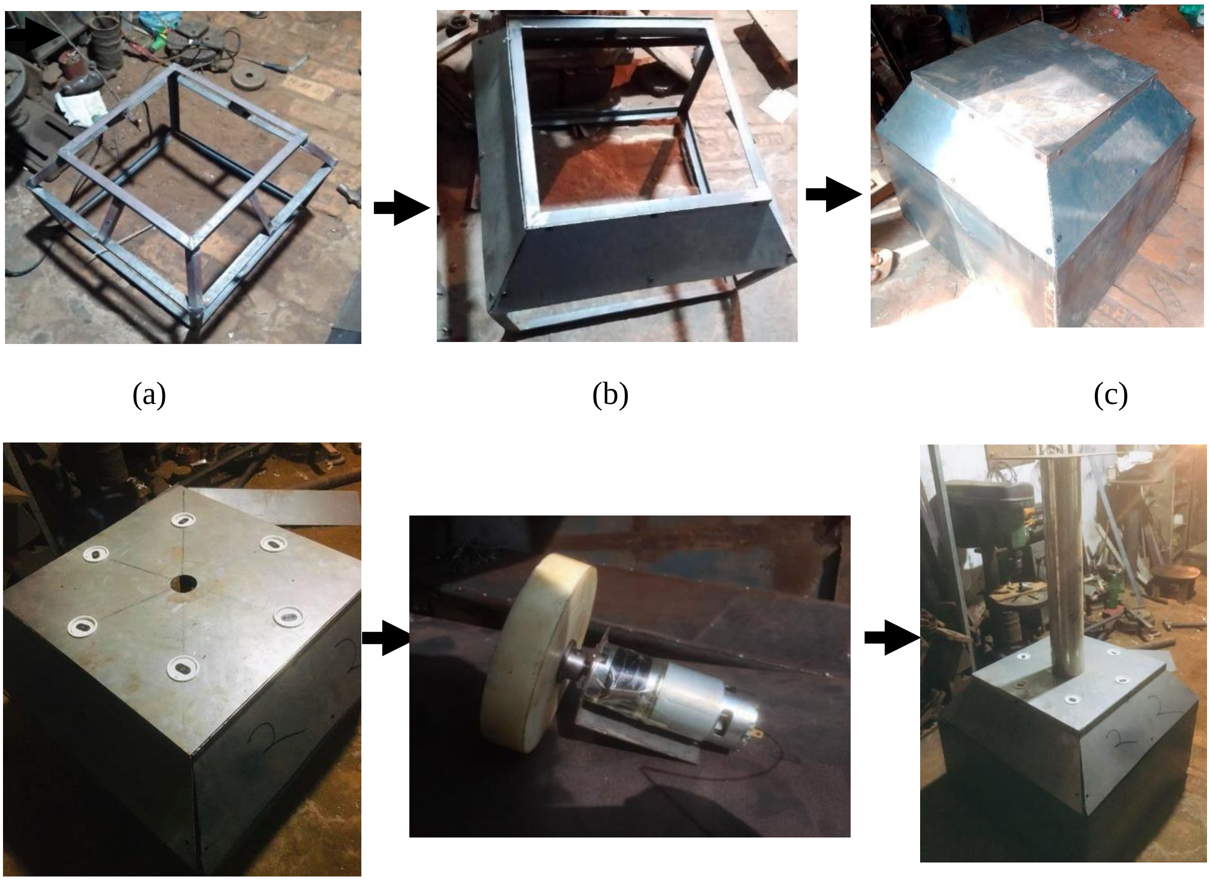
Chapter 5: Completion of Final Design and Validation. [CO8]

5.1 Introduction

The detailed architectural and technical drawings (the blueprints) of all the project's physical components are developed during the final design phase. The entire mechanical prototype configuration has been completed in two stages, as was previously stated. There has been a significant amount of discussion about the first setup. In this chapter, a brief discussion of the last phase, which includes the outcome analysis, will take place. The chapter will provide a thorough discussion of the project's functionality, including whether or not the main objectives are being met.

5.2 Completion of Final Design

After a number of test procedures and evaluations of the weighting table, the best solution for this project has been found. The functionality of the system, however, cannot be properly realized without the performance evaluation. The prototype needs to be put up initially in order to evaluate performance. The explanation of the prototype configuration for the entire system is separated into two sections. The first part focuses on the mechanical design before the UV light setup with the system, and the second part deals with the design after the UV light setup with the system. This section discussion will be restricted to the first part of the prototype setup. The setup pictures are shown in Fig. 24.



(a) (b) (c)

(d) (e) (f)

Figure 24: Mechanical Part of The Disinfecting System Before UV Light Setup (a) The primary posture of the setup (b) Body Surface Setup (c) Execution of Lower Body Setup (d) UV light holder setup (e) Design of motor (f) Final model before setting UV lamp.

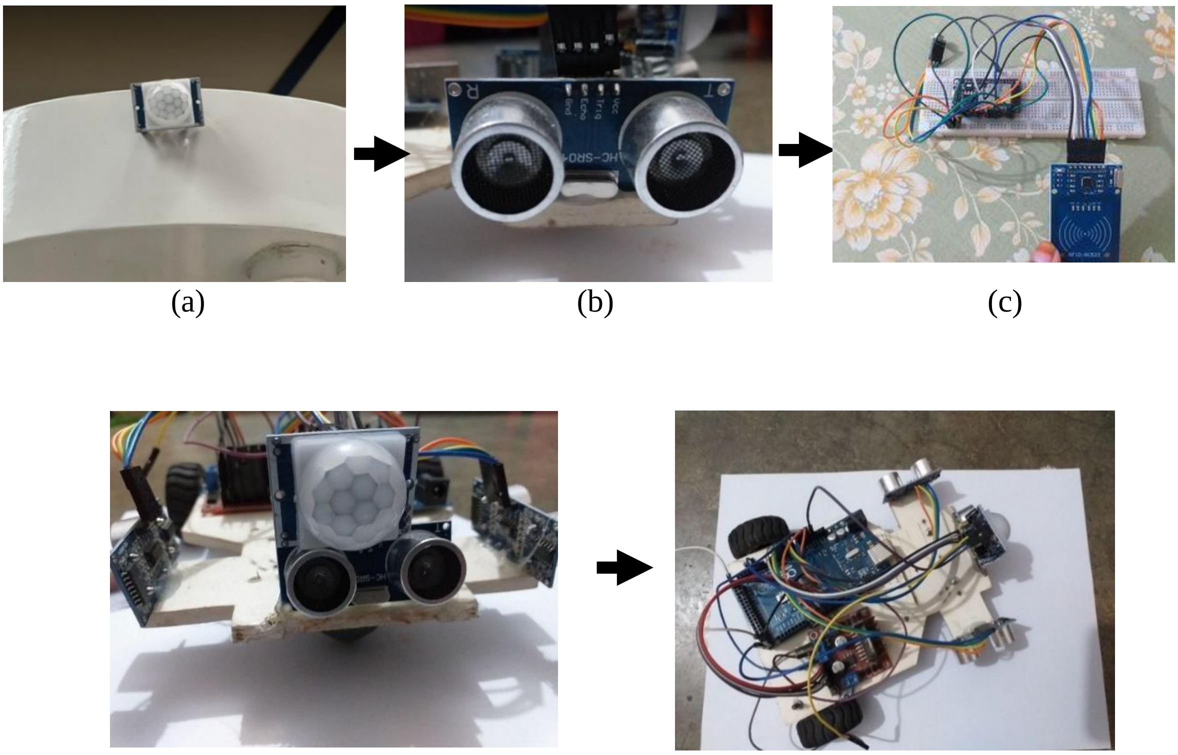
The system's lower section body was constructed using mild steel (MS) sheet. Mild steel sheets, also known as structural steel sheets, are simply sheets of steel that can be used to create a vast array of objects and structures. Due to the low levels of carbon present inside them, mild steel plates-also referred to as plain-carbon steel and low-carbon steel-are incredibly robust. Mild steel typically contains between 0.05% and 0.25% of carbon by weight. First, a lower body stand made of MS Sheet has been manufactured. The stand's initial posture is depicted in Fig. 24(a).

The body surfaces have been put together to fill in the empty spaces of the lower body part's stand. The shapes of these surfaces differ from one another. Four of them are trapezoidal and six are rectangular in shape. Mild steel sheet is used for all of the surface materials. Using screws, the body surfaces have been attached to the stand. Fig. 24(b). depicts the system's surface configuration.

The entire configuration for the lower body section is shown in Fig. 24(c). The system will disinfect the classrooms using six UV lights. Six light holders will be employed to connect these lights to the system. The lower portion of the body has six light holders attached to it, while the upper portion of the body has another six light holders attached to it. Fig.24(d). displays six light holders mounted to the system's lower portion.

A planetary gear motor has been used with the system to power it as a whole. Planetary gear motors can handle heavier loads since the internal sun gear meshes with several outer gears at once. Planetary gear motors are the best choice for high torque, high RPM applications like industrial machines because they can distribute the load over a number of contact points. Furthermore, the motor shaft has been designed to transfer energy from the motor to the application area. For the system, nylon wheels have been chosen. In addition to being exceptionally robust, offering high load capacities, good wear and tear resistance, and the ability to withstand the occasional collision without breaking, nylon wheels are also quite cheap when compared to other materials with similar features. Fig.24(e). shows the whole design of the motor shaft, nylon wheel, and mount.

The stainless-steel stands is the structure that joins the lower and top halves of the body. In particular, this stand was chosen rather than a glass one so that the UV lights wouldn't bounce off of one another. In Fig. 24 the complete mechanical design before the setup of UV light has been shown. The system and the components are quite sensitive and can provide unwanted results during the testing period. To avoid sudden burn out of components or unexpected system shut down and to test the functionality of the sensors, this test case robot has been constructed and utilized. Here, Arduino has been used to build the robot that interact with the real world through the sensors. The robot showed below in Fig. 25.



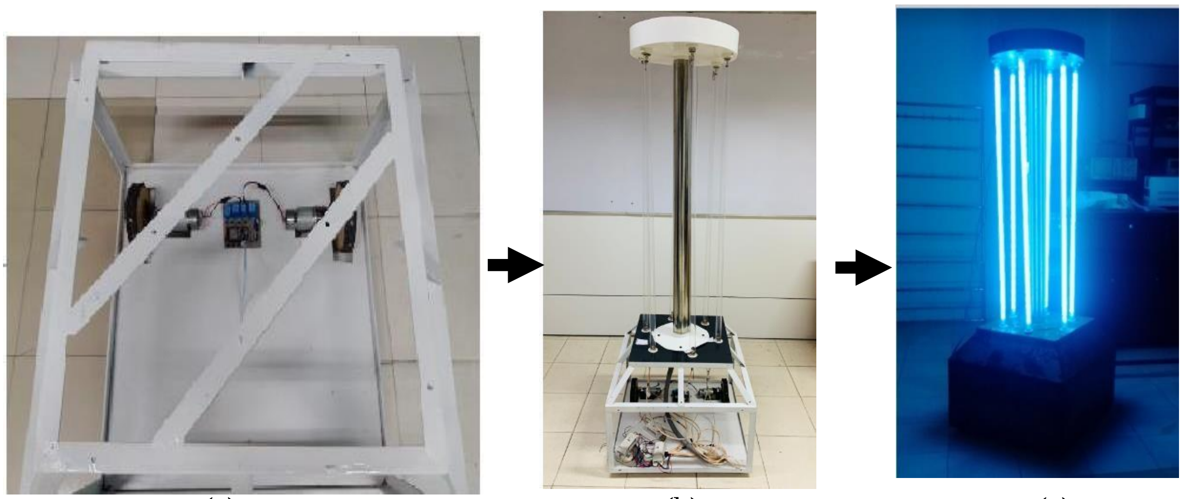
(a) (b) (c)

(d) (e)

Figure 25: Initial test scenario of PIR, Ultrasonic sensor, and Temperature sensor with RFID Reader (a) PIR Sensor (b)Ultrasonic Sensor (c) RFID Reader with Temperature Sensor (d) Sensors are attached in test robot (e) Test Robot.

The system and the components are quite sensitive and can provide unwanted results during the testing period. To avoid sudden burnout of components or unexpected system shutdown, this test case robot has been constructed and utilized. Here, Arduino has been used to build a robot that interacts with the real world through the sensors. In order to demonstrate the understanding of the system development, a 3d model has been prepared previously (Fig.1) which has been followed during the mechanical construction.

The second and final phase of the design refers to the mechanical design after setting up the UV light. After the six UV-C lights are installed, Fig. 26 shows the whole systematic design.



(a) (b) (c)

Figure 26: Systematic design implementation of the disinfecting robot (a) Motor and control circuit setup in lower body (b)Execution of ultra-violet light and ballast (c) complete model after setting UV light and main control circuit.

A controller circuit has been developed in order to manage the system. Controlled connections between electronic parts have been made using a printed circuit board. The ESP32 Microcontroller is a crucial part of this printed circuit board. The microcontroller and other components are directly linked. The microcontroller will receive the commands, and it will then operate the entire system as instructed.

In order to save the UV lights from burning out, six electric ballasts have been used. A light without a ballast will quickly increase its current consumption and risk becoming unmanageable. When a ballast is installed in a light, the power is stable and the ballast controls the energy to prevent current rises even when the lights are linked to high power sources. Fig. 26(b) shows the UV light and ballast setup with the system. A 5V power supply is needed to power up different components of the system and needs 12V to power motors. For this, a convenient battery management circuit has been designed. A 1200VA UPS has been added to the system as a consistent power supply in order to power up the entire device. Next, he UV-C lights were up to set up with the system. The device will need six UV lights to cover a 360-

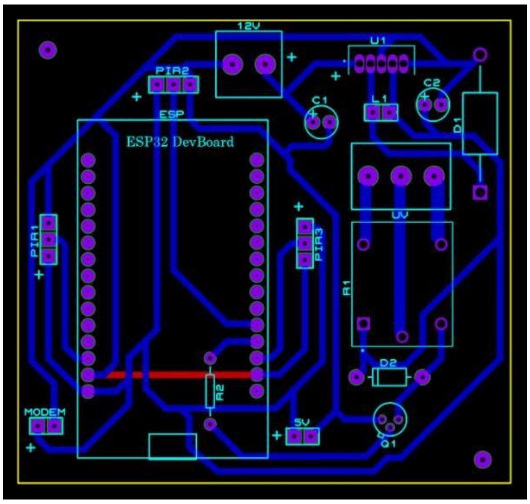
degree region in this case. Each light is four feet in length, uses 36 watts of power, and has a wavelength of 254 nm. The lights have been attached to the system through the light holders. Fig. 26(c) shows the complete model of the sterilizing system and main controller circuit without any sensor installment. Next, the sensors have been attached to the system. The system is a UV radiation-based system that has a harmful effect on human health. Keeping that in mind, the PIR sensor is the first sensor that has been installed in the system and it will detect humans within a specific range. The PIR sensor has been attached to the top of the surfaces of the whole system in order to identify humans of every length. The entire system will turn off automatically just after a human will be detected by the system during the sterilization period. The second sensor which has been incorporated into the system is the ultrasonic sensor. One of the key features of the system is object detection. In order to do that, an ultrasonic sensor has been installed with the system. In order for this sensor to properly detect the object, it is connected to the middle portion of the system. The third sensor is the temperature sensor. The system has a feature of measuring students' body temperature to determine the early stage of any virus attack. Following that, a temperature sensor has been added to the system that will determine students' body temperature whenever they will try to enter the institution. The temperature sensor has been added to the RFID part. RFID will have a separate ID for each individual student. Students' personal information including their body temperature will be saved in cloud storage through the separate ID of the RFID reader. A smartphone application will be used to operate the whole system. Consequently, the application and microcontroller will be directly coupled. Through its SPI / SDIO or I2C / UART interfaces, a communication bridge will be established between the smartphone application and the system. The system with all sensor setup has been shown below-

Figure 27: Mechanical part of the disinfecting system after sensors setup.

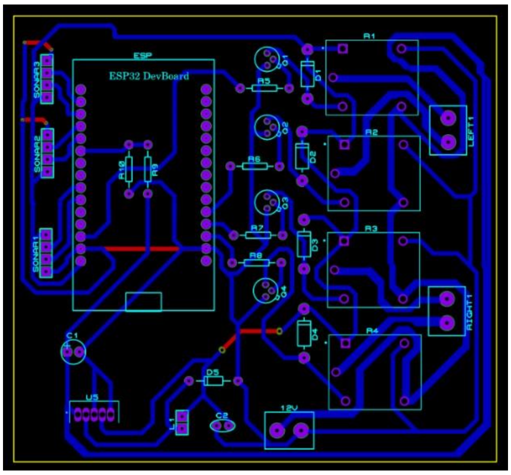
- **Design of Printed Circuit Board:**

The major part of designing a PCB board is to do proper PCB routing. Wire routing also referred to as just routing, is a phase in the design of printed circuit boards (PCBs) and integrated circuits in electronics. While designing a PCB board, a few key considerations must be made. To guarantee the correct operation of the circuit in all load and environmental situations, the trace width must be chosen appropriately. A PCB's traces must be wide enough to accommodate the current flowing through them because they are used to transport electrical signals. Next, PCB traces carrying analog and digital signals must be maintained apart, especially if the digital signal is high-frequency. Every PCB must include at least one ground plane since it gives all connections the same frame of reference for monitoring voltages. Maintaining enough distance between PCB traces and pads is crucial. As a result, short circuits are prevented during the manufacturing and assembly processes for PCBs. It is required to use short, straight traces wherever possible to connect components. It is ideal for the traces on the layer next to it to be positioned perpendicularly if the majority of the traces on that layer follow a particular direction. This lessens the occurrence of crosstalk between tracks. Power and analog signal traces must be positioned on specific layers in order to minimize the capacitive coupling caused by traces placed above and below large ground planes. Thermal pads are essential during wave soldering multilayer boards or products with a high copper concentration. In comparison to traces carrying digital or analog signals, power and ground signals must be on thicker traces. Improper connections between signals and power lines are less frequent since they can carry more electricity and are distinguishable even from other power lines by a quick visual inspection. It is always preferable to stay away from acute angles and right-angled curves since they can cause interruptions at high frequencies that can threaten the integrity of the signal by increasing interference, radiation, and reflections.

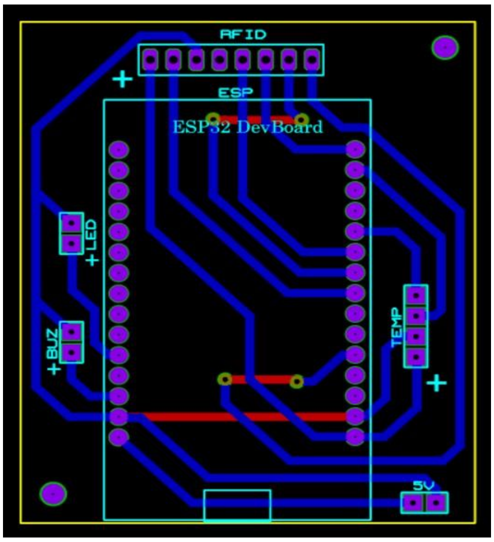
The system was designed with a single-layer footprint, as shown in Fig. 28(a), (b) and (c) to make it more concise. The ultrasonic part has been attached with the control section of circuit board so that the system can identify the objects during sterilization period on its way.



(a)



(b)



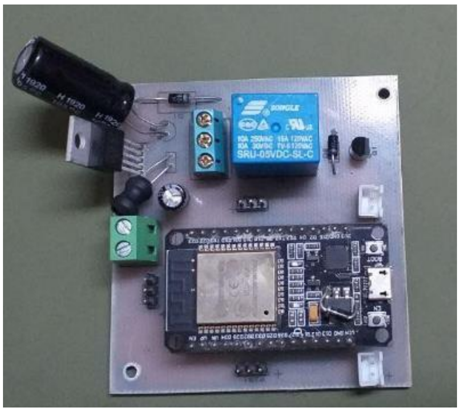
(c)

Figure 28: Design of printed circuit board (a) PCB of PIR (b) PCB of ultrasonic and main controller circuit (c) PCB of RFID and temperature sensor.

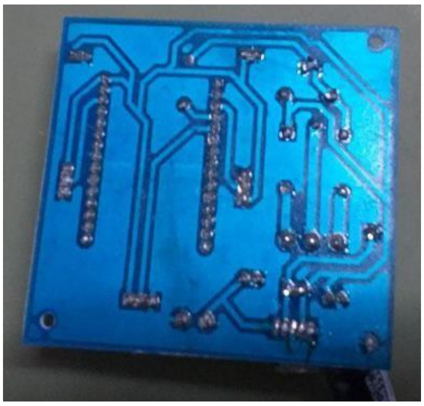
➢ **Implementation of Printed Circuit Board:**

In accordance with the PCB design methodology, the required PCB boards of the system have been designed. Incorrect PCB routing techniques can cause PCB boards to burn out. These are the primary three causes: extreme heat, unsuitable component spacing, technical blunder, or component failure. This requires an individual to have proper knowledge of PCB board design.

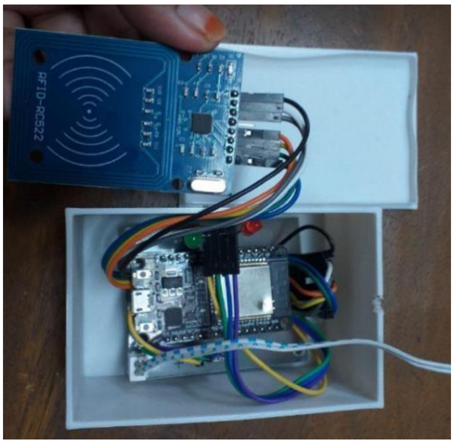
The PCB boards of this project have shown below-



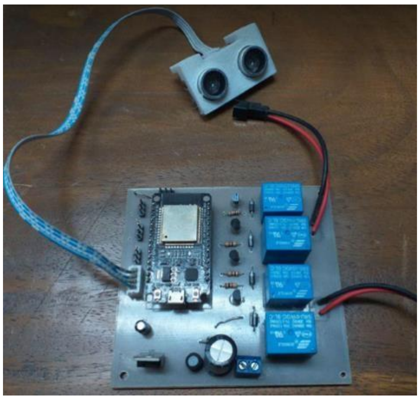
(a)



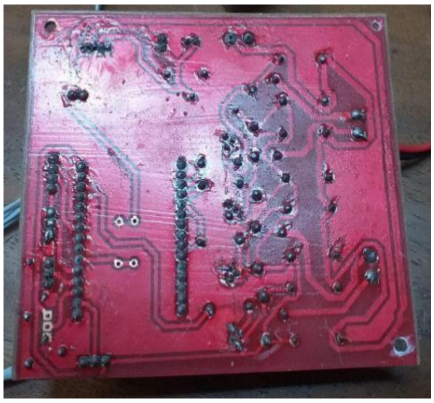
(b)



(c)



(d)



(e)

Figure 29: Implementation of PCB boards (a) Implemented PCB Board of PIR sensor (Front) (b) Implemented PCB Board of PIR sensor (Back) (c) Implemented PCB Board of a temperature sensor with RFID (d) Implemented PCB Board of the control board with Ultrasonic sensor (Front) (e) Implemented PCB Board of the control board with Ultrasonic sensor (Back).

PCB of PIR Sensor: PIR sensor has been integrated into the system in order to detect individuals from a particular distance. A PIR sensor can work in a variety of ways, such as by connecting with a breadboard to get more or less accurate results. In that situation, the application is simpler and more affordable than PCB insertion. To pass the current and ensure appropriate operation, a sizable number of wires were employed to connect the breadboard and PIR sensor. In that situation, PCB may be a bit pricey, but the connection between the PIR and PCB is quite strong because it doesn't need any kind of wire connection. Both the front and back parts of the circuit board of PIR sensor have been shown in Fig. 29 (a) and (b).

PCB of Temperature sensor and RFID: One of the crucial features of the system is to detect body temperature using a temperature sensor. The temperature sensor has been attached to the RFID scanner so whenever a student will try to enter the institution, he/she needs to scan their ID card through which their body temperature including their personal information will be stored in the database and will display in the mobile application. As a connection had to make between two crucial components, a printed circuit board has been chosen to avoid any kind of connection failure. In addition to being connected to the system, the two parts were moreover attached inside a white box. The setup has been shown in Fig. 29 (c).

PCB of Ultrasonic Sensor: A smooth sterilizing procedure is ensured by the inclusion of an ultrasonic sensor in the system for object detection. Along with the control board, the sensor has been affixed. Because of this, anytime the motor continues to sterilize something, it will detect an object that is in the process of being sterilized. To connect the PCB's control board to the ultrasonic sensor and ensure optimal functionality, a printed circuit board has been designed. The prototype picture of the system has been shown below

The prototype picture of the system has been shown below-

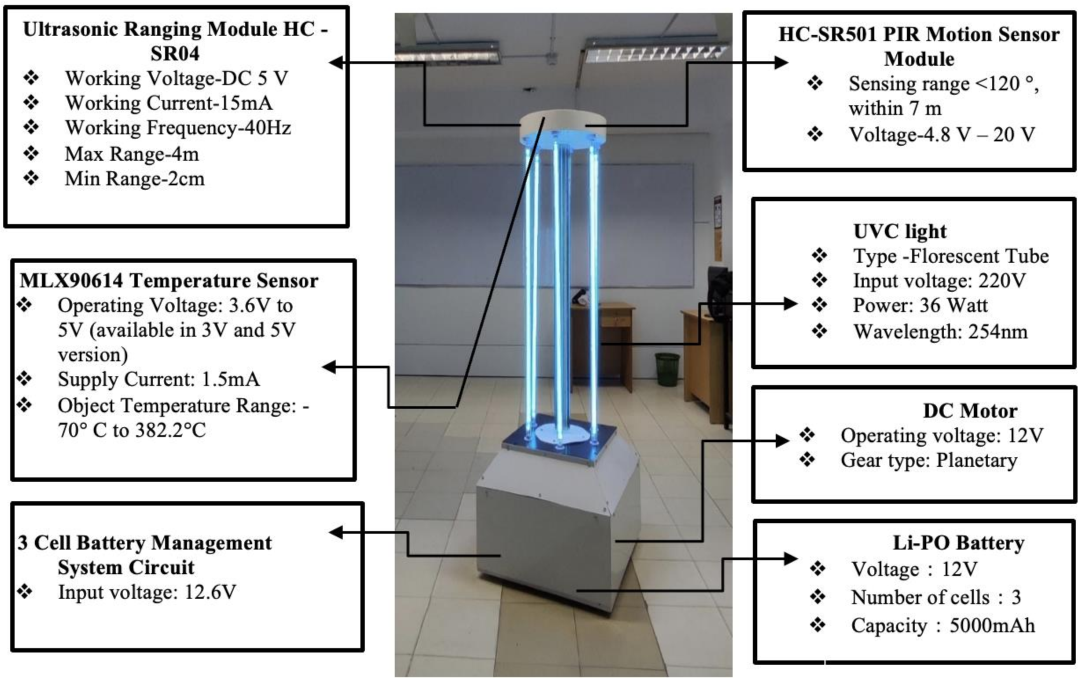


Figure 30: Final design of prototype

5.3 Evaluate the Solution to Meet Desired Need

This section will discuss how the developed system will meet all the specifications and primary goals. The objective of the project has been discussed extensively in previous sections. The main goal of the project is the construction of a radiation-based sterilization system that will sterilize the surfaces and walls of a classroom.

The second requirement is to eliminate human intervention during the sterilization process. The past cleaning procedures required a bunch of humans working at the same time but still were unable to provide effective results. In order to solve this issue, a mobile application has been designed that will mitigate complete human interference during the cleaning procedure.

The third requirement is to build a cost-effective cleaning solution. The system which has been built is not a novel construction. There are countries around the world where these types of systems are available with different designs and features but all of them are very expensive to afford. As the system has been built for educational institutions, a solution has to be affordable for all public and private institutions.

The system chosen for this project has been extensively analyzed through some key factors.

- **Control Management**

The project's first design approach calls for human engagement in the cleaning process, but the damage caused by ultraviolet radiation is constant. A modern control system built on the Internet of Things has been established to tackle that. The complete system can be managed by a mobile application. Using a mobile app, a person with the proper interpretation can simply operate the system from a secure distance. The UI design of the mobile application has been shown in Fig. 5 where the control panel and other pages have been shown and explained in proper manner.

- **Utilization Flexibility**

The semi-autonomous IoT-based system will be operated via a mobile device. The functionality of a mobile app can be understood by someone with only a basic understanding of how to use a phone. Using an email account and a password they created themselves, a person can quickly access the application. To comprehend the entire control technique, it may take one to fifteen minutes. Even without the operator, a student can still use the app and operate the system. The UI designs have been depicted in Fig. 5 where 8 pages of the mobile application have been shown. Each of the page will make the system utilization quite flexible.

- **Area Coverage**

Although three alternative design techniques are presented in this project, the fundamental elements are the same. To sterilize areas, ultraviolet radiation has been introduced into the system. However, because the first design is human-operated and human participation is required throughout the cleaning phase, they may cover less space because it may become difficult for a person to physically move around the entire system. The IoT-based system's greatest coverage area will be achieved because the entire system will be operated via a mobile app. Several test cases have been done where the IoT based system had covered more spaces while operating using mobile app.

- **Duration Of Sterilization**

For a typical-sized classroom, the time needed to sterilize the space using an IoT-based system is approximately 9 to 10 minutes. Based on the room's dimensions and the location of the objects within it, this time frame can be altered. Another important issue that affects the first design approach is the human's pace, which might alter the sterilization time. For human based system, the required time for sterilizing an average classroom is 18-20 mins whereas the IoT based system disinfected an average classroom within 10-15 mins.

- **Classroom Safety Assurance**

The second and third design approaches will both provide the same level of safety guarantee. Both systems will function without any help from people. As a result, both systems will effectively sterilize the desired location while covering the largest feasible area. But if human administration is involved, a smaller space won't guarantee the classroom's safety as much.

- **Cost Efficiency**

A quick analysis of the three types of designs' costs has been done. The cost assessment is heavily influenced by the design's utility and complexity. Although the human-based system is relatively inexpensive, it does not reduce human involvement, which is the project's primary goal. On the other hand, while the autonomous system produces the most effective results, the cost of building is very high, which also fails miserably of the project's objectives. IoT-based systems are therefore the best option for academic institutions weighing cost and other factors. The cost benefit analysis has been briefly discussed and shown including calculation in the later sections.

The best design process has been chosen after taking these variables into account that has all the features to meet the project goal.

Graphical Representation of UV Sterilization Process:

The system's moving speed is computed using the exposure period necessary for SARS-CoV-2 inactivation. Practical calculations have been performed using the GUVC T21GH UV sensor module. [21] The log-reduction dosage was found to have a median value of about 10.6 mJ/cm^2, whereas the true value is probably about 3.7 mJ/cm^2. Each UV lamp is 36W and produces 15W. Fig. 31 displays measurements from an irradiance power meter in a closed environment at different positions. The output value is found in voltage unit which is decreasing when distance increases. To get better conclusion data is needed to be converted into UV intensity in mW/cm^2 unit. To convert the voltage into UV power intensity all data are needed to multiply by 5.0 and the equation will be:

$$P = V * 5.0$$

here,

P = UV power intensity (mW/cm^2)

V = Sensor Voltage(V)

Using this equation for every voltage at different positions are converted into UV power intensity level and Fig. 18 is generated. The reaction varies significantly with positions, as shown in Fig. 18,and this variability is very high.

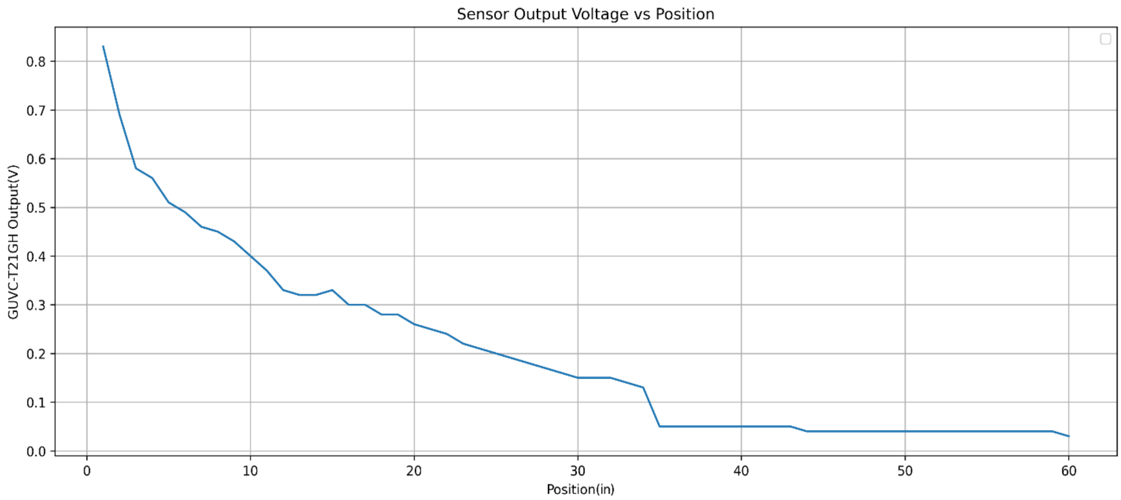


Figure 31: Sensor voltage levels that were recorded in a room at various positions while running UV lamps.

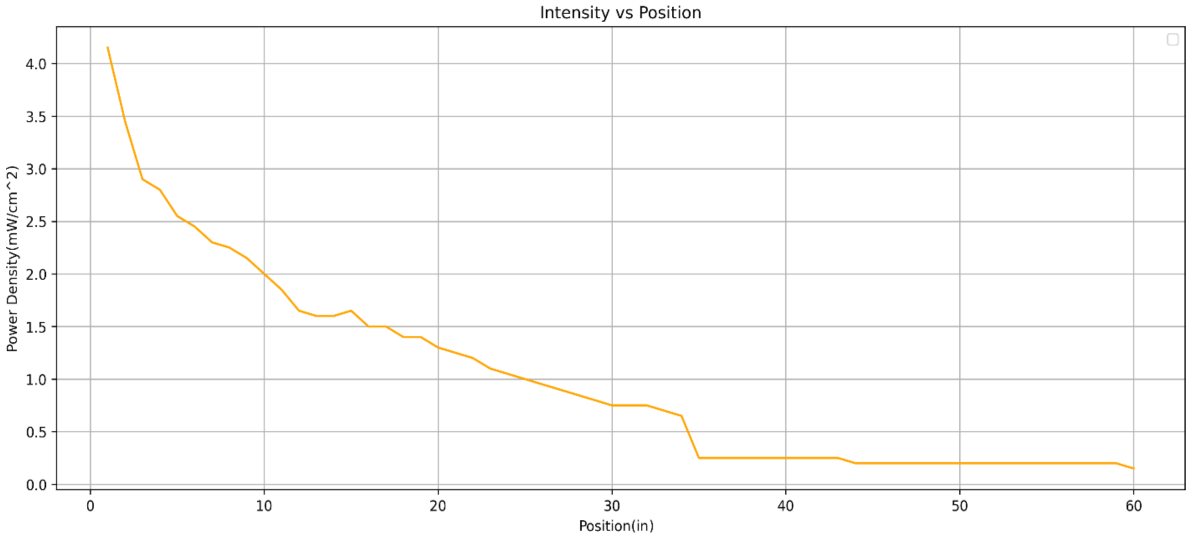


Figure 32: Levels of intensity that were calculated from sensor voltage level in a room at various positions. The irradiance power meter's measurements of total intensity take into consideration both visible and UV-C power.

As per Fig. 32, UV power intensity is not the same everywhere and it is not possible to get the same amount of energy at everywhere at the same time while running the robot or keeping the robot at fixed positions. In different environment, different objects are setup at various positions. So, in that case to ensure the inactivation process highest time to inactive germs is needed to be calculated and it will ensure objects at highest distance is getting 10.6 mJ/cm^2 energy. There is a relation between power and energy which is:

$$E = P * T$$

Here,

P = Power (W)

E = Energy (J)

T = Time(s)

This equation is also work for per unit area. To measure the appropriate time, power intensity unite mW/cm^2 is needed to convert in W/cm^2 unit which equation is shown below.

Convert to W/cm^2: (Value in mW/cm^2 ÷ 1000)

For example,

Convert to W/cm^2: (4.15 mW/cm^2 ÷1000) = 0.00415 W/cm2

Now we need to use the below equation to find the exact time to get constant energy which is 10.6mJ/cm^2 or 0.0106J/cm^2 from UV source at per unit area.

$$T = (0.0106 \div P)\ s$$

Here,

UV Energy = 0.0106J/cm^2

T= time(s)

P = UV power intensity

For example,

If an object is placed 1cm distance from the UV source,

The time to reach 10.6mJ/cm^2 dose = (0.0106J/cm^2 ÷ 0.00415 W/cm2) = 2.55 seconds

If an object is placed 34cm distance from the UV source,

The time to reach 10.6mJ/cm^2 dose = (0.0106J/cm^2 ÷ 0.00065 W/cm2) = 16.3 seconds

In this way we have calculated all possible time to reach 10.6mJ/cm^2 UV dose at different positions for different UV power intensity which is depicted in Fig. 33. The values found in Fig. 33. is the different cycle time at different positions to operate the UV lamp. To ensure germs are deactivated properly another parameter need to be considered which is warm-up time. Before flow starts, lamps need to have enough time to warm up, usually 2 to 5 minutes.

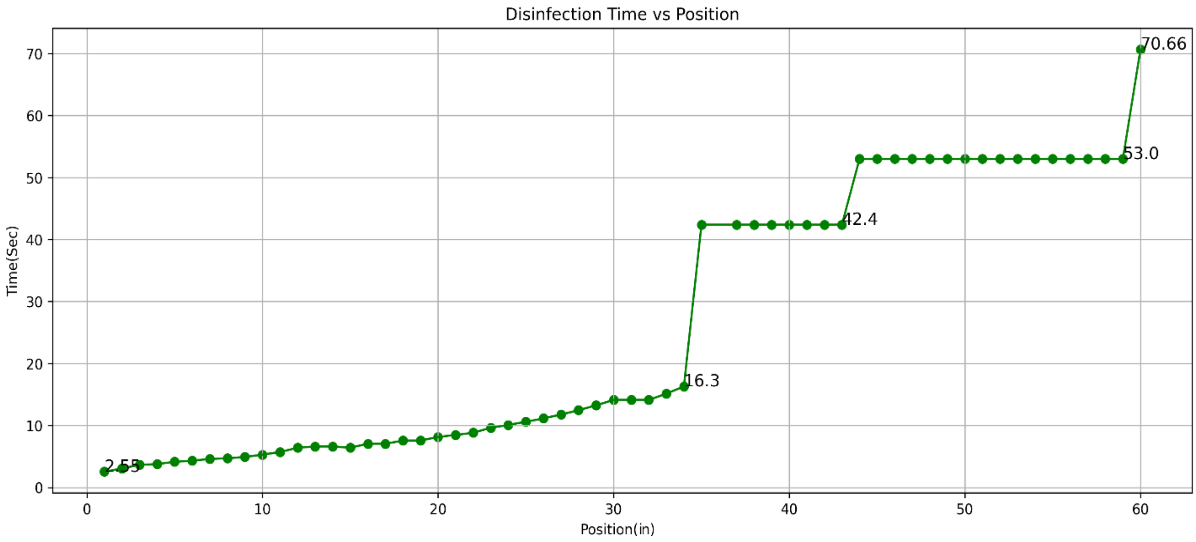


Figure 33: Different cycle time at different positions to operate UV lamp.

For better visualization the object position how affect in cycle time calculation system of the robot is shown in Fig. 34.

Figure 34: Robot position for different objects

In *Fig.34* it is clear that for one position of the robot it faces at least three different objects at different positions and at the same time 1 foot and 3 feet away objects will not get the same energy. That is why the robot will calculate the cycle time for 3 feet distance so that all nearby objects get at least 10.6mj/cm^2 UV dose. In the future, it will be possible to determine if an object has been thoroughly sanitized or not using these graphical representations.

5.4 Conclusion

The prototype has been constructed and tested for the intended project, in conclusion. Both the sensors' accuracy and the coding errors have been fixed. This chapter has a brief discussion on system development. Additionally, each component's functionality has been defined along with it. Additionally, graphs have been used to show how efficiently UV-C radiation has been shown to be effective in eliminating germs.

Chapter 6: Impact Analysis and Project Sustainability. [CO3, CO4]

6.1 Introduction

The project purpose, various system design approaches, and the best option among all of them are briefly discussed in the previous chapters. Based on a number of essential factors, including area coverage, disinfection time, cost-effectiveness, operational flexibility, and many others, the best solution was identified. The second design process is the best choice since it satisfies all the objectives listed in the objective. The effect of this solution on the environment will be extensively examined in this chapter. The environmental section is further broken down into five sub-points: sociological, health, safety, legal, and cultural concerns. The impact of the solution will be affected strongly by each component. Here, the effect on each component will be explored. The sustainability of the system will be the next topic discussed in this chapter. The environmental, social, technical, and economic issues have been separated into four categories for this section once again. Based on the ESG rating methodology, this aspect has been assessed. This chapter also includes a matrix table for easy visualization, along with a brief explanation.

6.2 Assess the Impact of the Solution

Infections caused by microorganisms have become far more common, posing a serious threat to our daily lives. The main reason for the constant growth of these infections in humans is related to the rapid multiplication of dangerous microorganisms. Furthermore, inadequate sanitization and a lack of effective disinfection methods have made a crucial impact. Since all academic institutions were closed for almost 1.5 years due to a severe coronavirus outbreak, finding a feasible alternative has become a requirement for the government. The aim of the proposal is to develop a system of a cost-effective and time-saving semi-autonomous disinfection system for academic institutions. Covid-19 has wrought devastation throughout the world since its emergence in late December 2019, and education, like any other essential industry, has been particularly badly impacted. Due to the coronavirus outbreak students, schools, colleges, and institutions have all suffered significant consequences. The SARS-coronavirus, which is a distinct virus from the present SARS-CoV-2 virus, is destroyed by UV-C radiation. In order to comprehend the effects of the optimal solution, four aspects have been taken into consideration. These factors have been briefly discussed below-

- **Societal:** The educational industry, which is the backbone of a society that has been severely affected by the coronavirus epidemic, will be able to recover to its prior position in a short amount of time using this semi-autonomous system. A temperature sensor will be used to determine if anybody is affected by a coronavirus and can block their access to the educational institution so that it would not spread to other students. As a consequence, the system might be effective in reducing the negative impact on students' health as well as addressing the safety of academic institutions with low effort and human involvement.

- **Health:** The alcohol-based cleaning methods has been prolonged practice that may guarantee a microorganism-free atmosphere of 60-70 percent. In order to increase the effectiveness, various cleaning procedures have been considered. However, UV-C based sterilization process has been proved to be the best. This research has described the design of a semi-autonomous system that has the potential to destroy 99.98 percent of microorganisms in a short period utilizing UV-C light. It will also be a smart cleaning procedure that eliminates human intervention.

- **Safety:** The system proposed in this research will disinfect the air and surface utilizing UV rays. Though it gives the best result in disinfecting particular areas, exposure to UV rays leads to skin diseases. A lack of knowledge about the negative impacts of UV disinfection might lead to unwanted accidents.

- **Legal:** The proposed approach is a novel development in the concept of Bangladesh. Therefore, there are no established legal guidelines for the use of UV-based devices. However, after the construction, the robot will be registered by the Department of Drug Administration. The Consent form for the Directorate General of Drug Administration has also been included in the section on ethical considerations for utilizing UV radiation for disinfection.

- **Cultural:** Various sterilizing procedures are in use all around the world. All of these solutions require the participation of people and are known to be time-intensive. The cleaning of all types of institutions and health centers is mostly done with alcohol-based solutions that involve human participation. These procedures have been followed for a long period for disinfecting surfaces.

Nevertheless, with all of the advantages and disadvantages in mind, most disinfection robot manufacturers today strive to employ ultraviolet light for efficient sterilization.

6.3 Evaluate the Sustainability

Sustainability is a project-based work strategy that balances the environmental, social, technical, and economic components to meet current requirements yet without impacting subsequent generations. We are developing a semi-autonomous system to sterilize the classrooms of educational institutions for the greater safety of tomorrow's generation. This system will be an IoT-based UV-C disinfecting bot and will achieve a 99.8 % success rate in eliminating bacteria.

To evaluate the project, firstly we have to talk about the component's lifetime.

Components	Lifetime
❖ UVC light	9000 hours.
❖ ESP32 Microcontroller	100000 EEPROM write/erase cycles.
❖ 4G LTE Hotspot Modem	lifetime
❖ Relay (standard)	40,000 hours
❖ MLX90614 Temperature Sensor	10+ years.
❖ HC-SR501 PIR Motion Sensor Module	4-7 years
❖ Ultrasonic Ranging Module HC - SR04	9-10 years
❖ Li-po battery	300 and 500 charge/discharge cycles
❖ RFID Card	3-5 years
❖ RFID Reader RC522	3-5 years
❖ DC Motor	30,000 hours-40,000 hours
❖ 3 Cell Battery Management System Circuit	300 to 500 charge cycles
❖ Power Inverter 12V DC to 220V AC	5-10 years
❖ Alphanumeric LCD	60,000 hours
❖ Buzzer	2000 hours
❖ LED	50,000 hours

Table 12: Component Lifetime

The table mentioned above has detailed information about the life time of components. Here the UVC light is the key component that will be used sterilize walls and surfaces. These lights have a guarantee of disinfecting area up to 375 days.

The system has some significant features of identifying humans and objects and measuring temperature as well. Temperature sensor and ultrasonic sensor have a lifetime of approximately more than 10 years. However, PIR sensor has a lifetime of 4 to 7 years.

The RFID card and RFID reader will be used for id card scanning procedure which has a lifetime 3 to 5 years approximately but can be differ depending on the usage.

The lithium-ion battery and the 3-cell battery management system circuit both has a lifetime of 300 to 500 charge cycles but it will not remain same. Depending on the usage it will continuously degrade. Since all the parts are changeable, users may easily purchase and replace them when they break out.

The most effective disinfection system now in use is the UVC system. Given that, the project's objective has been established. The project benefits society, the environment, and public health. The environment is not being harmed by it. Additionally, it is a residential sterilization method that is eco-friendly, introduces consumers to new technology, and helps them save time and lives.

A significant number of researches have been conducted and surveyed all the stakeholders, possible clients, friends, and family, along with personnel who are currently working in the cleaning sector. These surveys were conducted using the ESG rating methodology. ESG stands for environmental, social, and governance. Investors can evaluate a company's performance in relation to its competitors in the same industry and to companies in other industries by allocating an ESG score. Following that, the rating system has been taken into account to compare the sustainability of each of the proposed design approaches. After considering all the results, surveys, and responses to the ESG measures, we attempted to display the results as a form of decision matrix which is given below:

It is noticeable from the overall scores that all the systems had highs and lows on different criteria. But individually each aspect has been described briefly below-

Process	Sustainability Criteria				
	Social (35)	Economical (30)	Technical (20)	Environmental (15)	Score (100)
Human Controlled System	30	26	5	8	69
IoT-Based Disinfecting System	28	22	14	13	77
Autonomous Disinfecting System	25	18	16	13	72

Table 13: Sustainability Decision Matrix by Analyzing Weight Scores

Social: In the context of social, it can be seen that the human controlled system has the highest score among all. A system is more socially acceptable if the people around us accept the concept or understand the basic design of the whole system. The term "human-controlled system" in this context refers to a chemical-based sterilization system that also incorporates human interaction. The concept is socially more acceptable than other concepts and so it has increased the social segment's score. The IoT-based system is a partially autonomous system that may be controlled via apps. A system is considered semi-autonomous if it may be indirectly managed by a person via a mobile application. Therefore, most members of society are inexperienced with the entire process. In contrast, few people are familiar with the system when compared to autonomous systems. An autonomous system is one that moves independently and cleans surfaces. This approach is entirely new in comparison to the previous one because most people use cell phones and are familiar with how to use mobile applications. The IoT-based system has therefore received a higher rating than the autonomous system in light of this. [22] Although there are many other options like mercury and excimer lamp, the UVC LED (275 nm) demonstrated greater SARS-CoV-2 disinfection activity compared to the mercury lamp (254 nm) and the excimer light (222 nm).

Economical: The next part of the economical section states that the smaller the cost, the higher the score. [23] The current UVC robots have a huge average market price of around 55,165 USD. Because of this, the autonomous disinfecting system received the lowest grade because its component parts are quite expensive due to its intricate design. Additionally, some of the parts utilized in google maps and the 360-degree camera for human identification are not supplied in the local markets. It's conceivable that the project team will have to order them from overseas. Therefore, the high delivery cost and high cost of the components naturally increased the system's overall cost. Components that are sold in local markets can be used to construct an IoT-based system. The cell phone that will be used to operate the system is also extremely reasonably priced for residents of the community. As a result, it outscored the autonomous system. The original design strategy used a human-operated system, which is incredibly simple to build and doesn't require any extra modules to function. In comparison to the other two system designs, the system received the highest score.

Technical: The next factor affecting the system's technical complexity is how modern technology is used to create the right designs. Autonomous gained the highest rating in this aspect because of how intricate the design was. The preceding section covered how the fundamental parts of the system are also fairly challenging to find on the local market. The parts that make up the autonomous system are highly powerful and well-equipped. The IoT-based system, on the other hand, can be built using simple parts that are readily available in local marketplaces. These parts don't necessarily need to be highly complex and feature-rich. Additionally, IoT-based systems do not need the two most expensive parts of an autonomous system, a 360-degree camera and LIDAR. It is possible to substitute sensors for these expensive parts. The system is far less complex for the first design than it is for the other two design techniques. The other two systems scored much lower because of their fewer complex architectures.

Environmental: Lastly, the environmental part focuses on the effectiveness of the sterilization process in accordance with proper safety protocols. The human-controlled system scored lower in this section because its impact on the environment is less effective than that of the other two designs, whereas autonomous and IoT scored equally since they will have the same impact on the environment. The matrix scoring table led to the conclusion that IoT Based Disinfecting System has a higher overall score, and this result will help us decide how sustainable our design is.

Next, qualitative data have been gathered and performed a SWOT analysis of the strengths, weaknesses, opportunities, and threats related to our project. We did it by considering some points that are tabulated below:

SWOT Analysis

	Positive	Negative
	Strengths	**Weaknesses**
Internal	➢ RFID scanning will be present to create a human recognition system. ➢ Can be used not only for room sterilizing but also for germ safety against any other microorganisms. ➢ UV-C is much better to use here as its ability to kill all kinds of microorganisms, including drug-resistant bacteria.	➢ High cost of UV-C Tube Lights for one time. ➢ Low processing power and the system is slow.
	Opportunities	**Threats**
External	➢ Scope of more research & sustained development. ➢ As maintenance on regular basis is needed, there might be a scope of recruitment of technical person, which will open a door to be employed.	➢ Continuous surveillance may be needed for regular usage. ➢ UV Radiation directly on the skin may cause irritation.

Table 14: Swot Analysis of Design and Development of Disinfecting Robots for Academic Institutions

It can be seen from the table above that the positives of the tabular SWOT Analysis outweigh the threats and weaknesses. This is also because of the importance of a disinfecting mechanism in educational institutions.

The proposed design can instantly get the details of an individual through their assigned RFID tags and show information like body temperature, etc. This system will also be able to disinfect all kinds of bacteria that are usually not visible to any human eye. Not only has this but through our system employment increased as technical professionals are needed to oversee the system. In addition, by moving on further in technological advancement, more research can be carried out on how to improve our mechanism. Moreover, despite the design being sustainable, it works with low processing power. Also, continuous use of UV-C lights can be risky but it will be fine if done under strict surveillance.

The model will be cost-effective so that it can be easily afforded by all kinds of institutions, hence it can be said that this design will be economically sustainable. No outside pesticides or strong chemicals are used in disinfecting the surroundings while using this robot. Thus, it can easily be said that this design can bring environmental sustainability. While designing this model, we came across some health hazards but tried to overcome most of them. It is also designed to be used under strict supervision so that no accidents occur at any given time while the robot is functional. Thus, we can conclude that this design is somewhat sustainable according to a safety perspective.

No outside pesticides or strong chemicals are used in disinfecting the surroundings while using this robot. Thus, it can easily be said that this design can bring environmental sustainability.

While designing this model, the project team came across some health hazards but tried to overcome most of them. It is also designed to be used under strict supervision so that no accidents occur at any given time while the robot is functional. Thus, it can be concluded that this design is somewhat sustainable according to a safety perspective. As a result, after going through both the decision matrix and SWOT analysis, it can be said that the project is sustainable depending on the various social, economic, technical, and environmental factors, etc.

6.4 Conclusion

The impact and sustainability of the ideal solution have been discussed in this chapter. Here, the impacts of the five components have been thoroughly examined. The semi-autonomous system will be able to eliminate 99% of bacteria and, recognize a virus attack by measuring a student's body temperature. It also guarantees a secure and healthy atmosphere for the students by eliminating 99% of microorganisms. Additionally, as the system is brand-new, there must be some legal requirements to follow that have not yet been defined. But because the system will be structured based on health, the allowance must be confirmed by the relevant authorities including the DGDA. For long-term sustainability In-depth research has been done on 4 criteria. All three designs have taken these elements into account. These descriptions were created using the matrix table as a guide. IoT-based systems scored higher in the chart because they are built with cheap, readily available components from local markets. The technology also has a very positive impact on the environment. A SWOT analysis of the project's opportunities, threats, strengths, and weaknesses has also been covered in this section.

Chapter 7: Engineering Project Management. [CO11, CO14]

7.1 Introduction

Project management that is entirely concerned with engineering projects is known as engineering project management. It is the activity of initiating, organizing, directing, carrying out, and concluding a team's work in order to accomplish particular objectives and satisfy particular success criteria within a given time frame. The project utilizes a radiation-based sterilizing system to disinfect schools. The system development will be carried out in accordance with a predetermined timetable and certain predefined parameters. To achieve the objective, a project plan with few responsibilities has also been adopted. This chapter will discuss the entire project plan and its detailed timetable. A well-designed plan that is used to plan every step of the process serves as the project's foundation and organizational tool. It is obvious that, a project plan will lead in the greatest possible outcome if correctly implemented.

7.2 Define, Plan and Manage Engineering Project

Three design options for educational institutions are put forth in this project, each of which will take around a year to develop. Human-based system, IoT-based system, and autonomous system are the three proposed design methodologies. Using IT tools for circuit design and simulation with the proposed design, the software circuit has been constructed. The construction of the IoT-based system has been identified as the best design strategy out of the three designs. Specifically, the communication unit and the power management unit of this design set it apart from the other two design methodologies. A number of UV-C lights will be utilized for efficient sterilizing. The device will be able to detect individuals and objects within a specified range while sterilization will take place. The system includes a feature that will recognize an individual with early corona symptoms. The system will be controlled through a smartphone app that will be developed.

The project of developing a radiation-based disinfecting system cannot be successful without following a good project strategy. As it is almost a novel idea in the perspective of Bangladesh, the system development required a specific project plan. A plan was created at the outset based on the objective. Each group member who participated in the system's development was given a distinct task in line with their level of expertise. One year has been adopted as the project's overall duration. So, keeping that in mind, each team member began adhering to a specified time frame for each task. In order to finish the tasks within a certain time range, a gant chart was initially constructed. The level of work responsibility that each member has completed in accordance with the date has been also shown in this chart.

Additionally, a logbook has been maintained that has the all the details of the work responsibilities and the corrections that were asked to perform by the supervisor as well.

DESIGN AND DEVELOPMENT OF DISINFECTING ROBOT FOR ACADEMIC INSTITUTION

PROJECT LEADER:	Afrin Hossain Puspita
PROJECT START:	Thu, 10-Feb-2022
Display Week:	52
Timeline of FYDP-C:	74

10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

TASK	RESPONSIBILITIES	START	END	DAYS	WEEKS		%DONE
Slide prepare							
1st Progress Presentation	Namira Tahsin	10-Oct-22	20-Oct-22	10	2		100%
2nd Progress Presentation	Namira Tahsin	26-Nov-22	6-Dec-22	11	2		100%
	Afrin Hossain Puspita	26-Nov-22	6-Dec-22	11	2		100%
App Development							
Connect the App in Database	Afrin Hossain Puspita	10-Nov-22	30-Nov-22	20	3		100%
Temperature Scanning System Design	Asif Faisal	20-Aug-22	27-Aug-22	7	1		100%
	Afrin Hossain Puspita	20-Aug-22	27-Aug-22	7	1		100%
Hardware Development							
1st Progress Presentation							
Finalising Components	Afrin Hossain Puspita	7-Oct-22	13-Oct-22	6	1		100%
Prepare the Test-case Robot	Afrin Hossain Puspita	16-Oct-22	26-Oct-22	10	2		100%
Test the PIR & Sonar Sensor	Afrin Hossain Puspita	16-Oct-22	26-Oct-22	10	2		100%
2nd Progress Presentation							
Simulation	Afrin Hossain Puspita	10-Nov-22	28-Nov-22	18	3		100%
PCB Design	Afrin Hossain Puspita	28-Nov-22	29-Nov-22	2	1		100%
PCB Print	Afrin Hossain Puspita	29-Nov-22	3-Dec-22	5	1		100%
Implementation of PCB in Main System	Afrin Hossain Puspita	3-Dec-22	5-Dec-22	2	1		100%
Practical Testing of the System	Asif Faisal	5-Dec-22	5-Dec-22	1	1		100%
	Riyan Rahman Saad	5-Dec-22	5-Dec-22	1	1		100%
	Afrin Hossain Puspita	5-Dec-22	5-Dec-22	1	1		100%
Video Making & Editing							
1st Progress Presentation	Afrin Hossain Puspita	26-Oct-22	28-Oct-22	3	1	EEE400C	100%
2nd Progress Presentation	Asif Faisal	5-Dec-22	6-Dec-22	2	1		100%
Data Collection							
Functionality Check of UVC Light	Afrin Hossain Puspita	25-Oct-22	25-Nov-22	30	5		100%
	Riyan Rahman Saad	25-Oct-22	25-Nov-22	30	5		100%
Testing the Data	Asif Faisal	25-Oct-22	25-Nov-22	30	5		100%
Application Preparation for Ethical Consideration							
	Namira Tahsin	29-Oct-22	30-Oct-22	2	1		100%
	Afrin Hossain Puspita	29-Oct-22	30-Oct-22	2	1		100%
Apply Ethical Consideration							
	Asif Faisal	4-Dec-22	5-Dec-22	2	1		100%
	Riyan Rahman Saad	4-Dec-22	5-Dec-22	2	1		100%
Report Writing							
Chapter 1 to Chapter 2	Namira Tahsin	27-Oct-22	30-Oct-22	4	1		100%
Chapter 3 to Chapter 7	Afrin Hossain Puspita,Namira Tahsin	5-Nov-22		30	5		100%
				30	5		100%
Chapter 8	Riyan Rahman Saad	6-Dec-22		1	1		100%
				1	1		100%
Work on Sustainibility, Ethical Consideration,Economic Analysis	Afrin Hossain Puspita	4-Dec-22	6-Dec-22	3	1		100%
	Namira Tahsin	4-Dec-22	6-Dec-22	3	1		100%
Cost Benefit Analysis	Riyan Rahman Saad	30-Oct-22	15-Dec-22	46	7		100%
	Afrin Hossain Puspita	30-Nov-22	5-Dec-22	6	1		100%
Checking Report	Afrin Hossain Puspita						
Work on Gantt Chart & Budget	Asif Faisal	25-Nov-22	22-Dec-22	27	4		100%
Checking data	Riyan Rahman Saad	25-Nov-22	22-Dec-22	27	4		100%
	Asif Faisal	25-Nov-22	22-Dec-22	27	4		100%
	Namira Tahsin	25-Nov-22	22-Dec-22	27	4		100%
	Afrin Hossain Puspita						

Figure 35: Project Plan of the system

7.3 Evaluate Project Progress

Project Planning:

After making the Gannt chart in accordance with the time and work responsibility, it became necessary to manage and maintain the chart as well. Initially, the entire project plan was divided into three sections. The first section has been picked so that a suitable project proposal could well be prepared. Compared to the time that was chosen in the Gant chart, this section took a long period. The reason behind that is the group members did not have enough knowledge about the system development. So, each of the members had to go through many research papers and studies to make the project proposal. Moreover, some of the members needed to take help from other members to complete the decided work responsibility within the timeframe. Undoubtedly, the first stage of the Gant chart was quite challenging for all the members.

The software development for the system was done in the second section of the Gant chart. Since everyone had done enough study and had access to sufficient resources for software development at the outset, this phase of the plan went quite smoothly for everyone. All of the members were quite successful to follow the Gant chart and the time frame appropriately.

The system's hardware development will take place in the third section of the diagram. Hardware development takes a lot of time since nothing ever goes as planned. The members in this section must respect to both the timeline and the software architecture. The most alarming fact is the availability of components and their proper operation. Therefore, for a successful development, the members need to keep in mind a number of factors.

Project planning is a discipline that deals with how to finish a project in a specific amount of time, typically with specified stages and resources. The construction of a radiation-based sterilizing system for academic institutions is the main focus of the project. There were four active participants, including three supervisors, in the one-year project plan. The entire plan has been split into three parts. Hardware implementation and demonstration, software simulation, and project proposal. Each of the three divisions was given a time frame of four months approximately. An extensive study on the project topic and its relevance to the community has been done for the proposal section. Numerous important considerations, like financial range, health concerns, system operations, etc. were taken into consideration because the project was being done for academic objectives. A written document has been used at the beginning of each part to list each person's duty as well as the time period. An alternative group member has been chosen for each responsibility so that if anyone makes a mistake with the project work, the alternative member can give him/her a hand. Weekly meetings were scheduled, both in person and virtually, to inform everyone about their tasks. Additionally, group members were required to provide updates to their managers once a week during a certain time period. Following each and every step the whole project plan has been executed successfully.

Detailed Budget

The project's aim is to develop an Internet of Things-based disinfection system for academic institutions, and to that end, a budget has been created and thoroughly reviewed. Narrative reasoning for the budget is provided in this part. The narrative accomplishes two goals it shows how the expenses were determined and it explains why the cost seemed necessary. The budget has been provided below:

SL No.	Component Name	Quantity	Price (BDT)	Remarks
1	Mechanical Body	1	36,418	
2	ESP32 Controller	1	420	The location of the central command center for the UV bot.
3	PCB	3	1500	The primary functions of PCBs are to mechanically support and connect electrical components of a circuit.

SL No.	Component Name	Quantity	Price (BDT)	Remarks
4	Wi-Fi adapter	1	600	In order to link the UV bot to the internet so that it may use the internet to function.
5	Capacitor 100mF	3	30	In order to use electrostatic energy whenever it can be supplied to the circuit in order to retain it in an electric field.
6	Li-Po batteries	1	2,150	The microcontroller and other low-power consuming components in the robot, such as the sensors, will be charge up.
7	Power Inverter 12V DC to 220V AC	1	700	To convert the DC current into AC current
8	Relay	1	65	Configured as a UV lights switching mechanism of the UV bot.
9	Alphanumeric LCD display	1	415	It will display all the data to the operational team.
10	Buzzer	2	20	To notify security if any early signs of COVID are noticed among the students.
11	Heat Shrink Tube	2	48	A plastic tube that may be shrunk to provide insulation for stranded and solid wire conductors, connectors, joints, and terminals in electrical wiring
13	SMPS 12V, 30A	1	1450	A switching regulator is used in an electronic power supply system to efficiently transmit electrical power.
14	Magnet	10	650	Magnets act as transducers, converting energy from one form to another.

SL No.	Component Name	Quantity	Price (BDT)	Remarks
15	Cable	5	165	A conductor or collection of conductors used to transport telecommunication signals or electric power from one location to another in electrical and electronic systems
16	UV lights	1	21,000	To Disinfect surfaces with high efficiency withina short period of time while minimizing human intervention
17	Ballast	1	9000	By regulating the voltage across the bulb and the current through the lamp, an electronic ballast will convert power frequency to a very high frequency to initiate the gas discharge process.
18	MLX90614 Temperature Sensor	1	1,100	It will be utilized to determine the student's body temperatures.
19	LED	5(approx.)	5	It will be utilized as an alternative to the buzzer to notify security.
20	RFID Reader RC522 RFID Card	1 5(approx.)	250 25	To increase the safety of the educational environment by scanning their information.
21	Ultrasonic Ranging Module HC - SR04	1	85	In the case of object identification and obstacle avoidance.
22	HC-SR501 PIR Motion Sensor Module	1	120	It will be employed to determine either people oranimals within a 21-foot radius.
23	LCD Battery Capacity Monitor	1	1950	Users of a battery management system may keeptrack of induvial battery cells.

SL No.	Component Name	Quantity	Price (BDT)	Remarks
24	Battery Voltage Tester	1	250	
25	Voltage sensor module	1	120	
	Net Total	**50**	**78560 /-**	

Table 15: Budget for Design of the Entire System

Risk Management and Contingency Plan

Even though our system is designed to benefit the surrounding, it is not without risk. It might cause major harm if not checked. We have closely reviewed the project's risky components, and following that, we have prepared appropriate solutions, including contingency plans. Even though each participant in the project has an equal understanding of the whole project, each will be individually responsible for each part of the project. Along with the participants, Bitflex Company will also offer its service to ensure data entry privacy. A table with the risk factors, solutions, and contingency plans has been also utilized below to address them-

Risk Type	Risk Level	Responsible Individuals	Risk Solution	Contingency Plan
Ultra-violet Ray	HIGH	Afrin Hossain Puspita	Use mobile apps to avoid direct human contact and use UV glasses to ensure proper safety	A six-channel remote controller will be used
Ozone Gas	LOW	Asif Faisal Riyan Rahman	The duration of operation will be less than 10 minutes	If necessary, the operating time will be further reduced
Human Detection	MEDIUM	Afrin Hossain Puspita	Industrial grade PIR sensor	Image processing
Object Detection	LOW	Afrin Hossain Puspita	The industrial-grade sonar sensor	Laser distance sensor
Data Entry Privacy	HIGH	Bitflex Company and Namira Tahsin	Google authentication key	App verification
Shock Hazard	HIGH	Afrin Hossain Puspita Riyan Rahman	Utilization of shunt capacitance or fuse	Fuse implantation

Risk Type	Risk Level	Responsible Individuals	Risk Solution	Contingency Plan
Temperature Detection	LOW	Asif Faisal Namira Tahsin	Infrared temperature sensor	Usage of digital thermometer

Table 16: Analysis of Risk Factors and Solutions

In this project, as UV-C light will be utilized, it can be harmful if any human is directly exposed. It can cause skin burns as well as eye problems which is why we leveled it as high risk. In order to solve the problem, gloves and necessary glasses will be utilized so that skin burns and eye problems can be avoided. Moreover, continuous usage of UV-C rays produces ozone gas, which can cause odor and coughing. An ozone sensor will be used to measure the ozone level to overcome this problem as a result the risk level is low for this type of risk. The communication server is another risk type as important data will be stored and also to communicate properly with the system. As a result, it carries a medium level of risk. To avoid this level of risk, MQTT and HTTP protocol will also be used with data encryption. Next, the risk of shock has been rated as high since setting up the power management system can electrify a person. Unexpected accidents can result from a lack of safety measures or from being unaware, both of which could be exceedingly hazardous for a person. Then there's object detection, which is a low-level risk, for which we're utilizing an ultrasonic range module as a solution. Furthermore, human detection is classified as having a medium risk level type. Even if we use an ultrasonic sensor, the PIR sensor will verify if anyone is in the room so that the system may function freely. Next, temperature detection is of low-level risk type and we are using an infrared temperature sensor for the solution. Lastly, viral fever coronavirus-affected alert is of high-risk level as this is a contagious disease and it can transmit from human to human which is why we will be using a buzzer, LED, and RFID reader to block the access of the infected person.

Safety Consideration

For academic institutions, a concept has been developed to build a disinfecting system that employs ultra-violet radiation. Since then, it has been modified throughout time to become a reliable method of deactivating germs and protecting humans from deadly infections. In addition, in the fight against covid-19, UV-C disinfection lights have become a prominent subject recently. The risks associated with our project have also been widely researched. We have identified several threats that may cause individuals to be concerned. Ultra-violet light is the system's key component and a major concern for users. There are more than six UV-C lights for proper room sterilizing that have been used in the system. It is dangerous if it's not correctly placed and the necessary safeguards aren't taken. In terms of the skin, accidental exposure to ultra-violet radiation causes severe skin irritation. Again, the eyes have no outer protective layers, they are perhaps the most vulnerable organ to ultraviolet rays. So, with these considerations in mind-

- Plastic shields for eye protection.
- Nitrile gloves for hand protection can be used.
- Tight woven fabrics can be utilized to shield other regions of the body.
- Additional surgical masks will be provided as protection of ozone gas.
- Human access will be restricted to areas where ultraviolet-C radiation would be used.
- The medical backup will be available for people exposed to ultraviolet radiation accidentally.
- Warning sign board will be provided where ultra-violet radiation will be utilized.

However, full-room disinfection necessitates the removal of all persons from that area. Individuals especially the person in charge of the system should wear suitable personal protective equipment (PPE) during the disinfection process.

7.4 Conclusion

In this chapter, the project plan has been extensively discussed. A proper project plan makes a project successful from every possible way. Taking that into account, a Gant chart has been shown in this section with proper time frame, project members name and their completed work level. Along with that, a log book has maintained that has all the details of work responsibility and the corrections from the supervisor. But a project never goes in accordance with the plan. The difficulty level of the management of the project plan has also discussed here. Moreover, a detailed budget, projects risk management with the contingency plan and safety measurements have also been taken into account in this chapter.

Chapter 8: Economical Analysis. [CO12]

8.1 Introduction

Costs and benefits are essentially assessed as part of the economic study. To help with better resource allocation, initiatives are first ranked according to their economic viability. Its objective is to assess how a project would affect welfare. This project has introduced a radiation-based sterilizing technology that is both efficient and affordable. Prior sections have covered the goal, prerequisites, design process, and performance assessment of the ideal solution. However, in order to compare the system's impact with the cost of production, an appropriate economic solution is required. The price comparison of the three design techniques as well as the models that are currently available on the market will be covered in this chapter. Additionally, calculations and mathematical techniques have been used to determine the other expenses of the system, including the operating cost, maintenance cost, opportunity cost, and some crucial estimations.

8.2 Economic Analysis

Economic analysis employs the project's economic price, which is converted from the market price by subtracting profit, other sales and costs, and tax, to provide a preliminary estimate of the product's true price. Some research should be done considering some key factors before going through an economic analysis.

The system proposed through this project is a novel concept in the perspective of Bangladesh. At first, the components availability in the local market, the technology used for different features and the strategies, algorithms have been followed to complete the project. This can be demonstrated in a well manner using Derived Demand Analysis. Inclination of a demand for a product from using another product is known as derived demand. For example, if the demand for cricket ball increases, the demand for leather and sewing threads will increase proportionally as well. So, if the demand of the system increases, the demand for the components will apparently increase in local and international market.

Sterilization of classrooms with the best outcome is the project's main objective. However, UV-C lights are the most important element for sanitizing a classroom that has been utilized in the project. The skin of humans is adversely affected by ultraviolet light. Therefore, the importance of human safety cannot be overlooked. The economic analysis has been significantly impacted by the extensive procedures that have been taken to safeguard human safety.

Apart from that, there are some other issues such as continuous internet access, regular maintenance of the system and other social and environmental issues have also been taken into consideration.

Economic Estimation of Cost of the System:

The project's costs have been calculated for each of its several components. The explanations for each sector are provided below, along with the required computations and economics-related details.

Opportunity Cost:

Opportunity cost is the profit that is sacrificed when one option is chosen over another. The idea serves merely as a reminder to weigh all viable options before making a choice. In the project three design methodologies have been proposed where the second design methodology has been selected as optimal solution based on the project goal. The third design methodology is better in case of operating the system. Moreover, human and object detection will be more appropriate than the optimal solution. However, there are some couple of issues that will take place during the construction period of the system. Those are-

- Construction period is long.
- Complex design and functionality.

- Unavailability of components in local market.
- Expensive components (LIDAR & 360-degree camera).

Calculation:

IoT based system price= 78555 BDT [From Budget]

Autonomous Robot price = 85248 BDT [From Budget]

Opportunity Cost = Autonomous Robot price - IoT based system price

= (85248-78555) BDT

= 6693 BDT

Therefore, if someone chooses to use an IoT-based system, they must sacrifice the chance to receive an additional 6693 BDT for each machine.

Environmental Cost:

The environmental cost for this project is relatively low. The system will concentrate on cleaning the classrooms so there will be less release of material waste into the environment. High-energy photons in UV light are the finest renewable energy source that will never run out, while the other parts are recyclable as well. Ozone gas emissions, however, has not been protected in the system, which could be a concerning issue for people with breathing problem.

Economic Externalities

The system's features, including the ability to disinfect an area using ultraviolet radiation, are novel in the disinfection industry. After the COVID attack, there is now a huge global demand for an efficient sterilizing system. The price will be significantly lower than that of similar products on the market. So, it is possible that the initiative will have positive economic effects. However, the device will also be able to detect any virus infection in its early stages by monitoring body temperature. Nevertheless, there are potentially unfavorable externalities to creating the market as well.

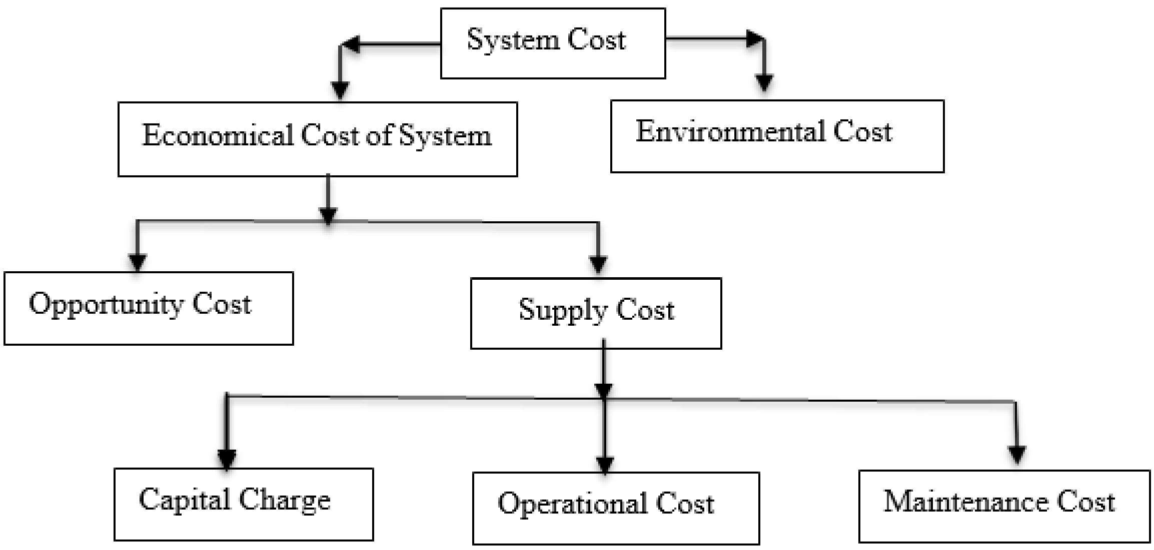


Figure 36: Economical estimation of the cost of using the Sterilization system.

The study indicated three designs with three different budgets in order to account for the various demands on filtration.

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
❖ UVC Light	6	2500	15,000
❖ Temperature sensor	1	1,480	1,480
❖ RFID sensor	1	188	188
❖ Motor Driver	1	680	680
❖ Motor	2	1500	3000
❖ Microcontroller	1	740	740
			21,088/-

Table 17: Design 1 Price (Human Control Disinfecting System)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
❖ UVC Light	6	2500	15,000
❖ PIR Sensor	4	100	400
❖ Temperature sensor	1	1,480	1,480
❖ RFID sensor	1	188	188
❖ Ultrasonic sensor	3	95	285
❖ Motor Driver	1	680	680
❖ Motor	2	1500	3000
❖ Wi-Fi Adapter	1	600	600
❖ Microcontroller	1	740	740
			22,373/-

Table 18: Design 2 Price (IoT-Based Disinfecting System)

Component	Quantity	Unit Price (BDT)	Total Price (BDT)
❖ UVC Light	6	2500	15,000
❖ Lidar	1	20,500	20,500
❖ PIR Sensor	4	100	400
❖ Temperature sensor	1	1,480	1,480
❖ Camera	1	3000	3,000
❖ Motor Driver	1	680	680
❖ Motor	2	1500	3,000
❖ Microprocessor	1	12000	12,000
			56,060/-

Table 19: Design 3 Price (Autonomous System Design)

8.3 Cost-Benefit Analysis

System Cost

The detailed budget has been shown previously in the *table. XIV*. The actual cost that is required to construct the disinfecting system is 78555 BDT.

Operating Cost

The proposed system will be completely powered by a rechargeable Uninterrupted Power Supply (UPS). It has a load capacity of 600 Watts and a backup time of 30 minutes for full load. Now, it's been calculated that to disinfect one room completely our system needs to run for about 10 minutes and it can be hoped that the system can disinfect up to 12 rooms per day. Thus, for a twelve-month period the system needs:

Time required to charge Uninterrupted Power Supply: 3 Hours (3 x 60 = 180 minutes)

It can disinfect 3 rooms with one complete charge as the UPS will give a backup for about 30 minutes. Thus, to disinfect 12 rooms UPS needs to get charged 4 times.

In a day system needs get to charge for: 4 x 180 = 720 minutes.

Here, as the system is designed for academic reasons, we are omitting out all the Fridays in a calendar year.

So, in a year the UPS needs to be charged for: 720 x (365 – 52) = 225,360 / 60 = 3756 hrs./year

Finally, energy consumption = 3756 x load capacity = (3756 x 600)/1000 = 2253.6 KWh

Again,

If 1 unit of electricity is 5.614 BDT

Operating Cost = 5.614 x 2253 = 12,651.7 BDT annually

Hence,

For a month the operating cost would be: 12651.7/12 = 1054.3 BDT

Maintenance Cost

For any electrical component, it is estimated that all components can last for at-least a couple of years. However, if any component malfunctions, it can be easily replaced by a small amount of only 500 BDT annually. Additionally, it was estimated that the labor cost for controlling our proposed design cannot be over 10,000 BDT on a monthly basis.

8.4 Evaluate Economic and Financial Aspects

The total cost for implementing our design from scratch was roughly 76,000 BDT. If we are thinking about going commercial with our design, we are leaving out the labor cost and maintenance cost altogether. Being new in this market, we were hoping to get a 15% profit on each sold unit. The return on investment (ROI) however, might vary with each progressing year in this line of business.

Return on investment (ROI) – Net income / Cost of Investment x 100

Net income = Profit per annum

Cost of investment = units sold per year x system implementation cost

Internet of Things-based disinfection system	
❖ System implementation cost	76,000 BDT
❖ Profit margin for each sold product	15%
❖ Units sold (assumption)	5
❖ Selling price per unit with profit	87,400 BDT
❖ Profit per unit	11,400 BDT
❖ Profit per month	57,000 BDT

Internet of Things-based disinfection system	
❖ Profit per annum	684,000 BDT
❖ Return on investment (ROI)	15%

Table 20: Estimating Annual Profit of IoT-Based Disinfection System (1st Year)

It has been estimated that the market grows 30% annually. Hence, for the following year,

Internet of Things-based disinfection system	
❖ System implementation cost	76,000 BDT
❖ Units sold (assumption)	6
❖ Selling price per unit with profit	90,820 BDT
❖ Profit per unit	14,820 BDT
❖ Profit per month	88,920 BDT
❖ Profit per annum	1,067,040 BDT
❖ Return on investment (ROI)	23.4%

Table 21: Estimating Annual Profit of IoT -Based Disinfection System (2nd Year)

For the third year,

Internet of Things-based disinfection system	
❖ System implementation cost	76,000 BDT
❖ Units sold (assumption)	8 BDT
❖ Selling price per unit with profit	95,266 BDT
❖ Profit per unit	19,266 BDT
❖ Profit per month	154,128 BDT
❖ Profit per annum	1,849,536 BDT
❖ Return on investment (ROI)	40.56%

Table 22: Estimating Annual Profit of IoT -Based Disinfection System (3rd Year)

[25] 723,221 COVID-19 cases have been recorded as the second wave of the Novel Coronavirus attacks the world. The lack of an efficient disinfection treatment has led to an increase in the number of viruses and germs attacking people worldwide. Chemically based remedies are primarily used by people in every field. Due to strong demand for and a shortage

of disinfection systems, the market is growing every year. While preparing this annual profit statement, assumptions were made in the hopes that the project would be viable and stable enough to last the next 5-8 years. The government itself is engaged in this sector of research, thus investing in it will be profitable. [24] Multiple UV-based systems such as UVD robot, TMiRob etc. are available in the global market. Among all of them, two disinfecting systems that provide similar services like the proposed system in the project have been chosen for effective comparison.

Robot & Systems	SEIT-UV (29)	ADIBOT-S (30)	UVC Disinfecting System for Academic Institutions
Features			
1. UV Light	8	16	6
2. UVC Power	288watt	1240watt	216watt
3. UV Wavelength	254nm	253.7nm	254nm
4. UV Coverage Area	360 degrees	360 degrees	360 degrees
5. Disinfection Time	10 minutes	7 minutes	15 minutes
6. Total Weight	120kg	100kg	150kg
7. Operation Time	3 Hours	6 Hours	2 Hours
8. Charge Time	3 Hours	6 Hours	2 Hours
9. Human Detection	No Sensor	PIR Sensor	PIR Sensor
10. Communication	Wi-Fi	Bluetooth	Wi-Fi, Bluetooth
11. Camera	3D	RGD-B	No Camera
12. LIDAR	2D	Dual HD	No Lidar
13. Control System	Automatic	Automatic	App Control
14. Safety Feature	LED Lights	Sound Alert	Buzzer
15. Ozone Gas Existence	Does Not Exist	Does not Exist	Exists
16. Warranty	Limited Warranty	3 years	No Warranty
Price (BDT)	10,95,078	20,27,168	76,092

Table 23: Comparison Between Market Products and Designed Project

[*Source https://milvusrobotics.com/products/seit-uv (SEIT-UV)

https://www.schoolspecialty.com/ADIBOT (ADIBOT)]

The table compares the proposed system with two other comparable systems that are available on the global market. The system that is being proposed for this project is intended to offer academic intuitions services. This system's primary goal is to sanitize the surfaces and walls of a specific space. Six UV lights that each have a wavelength of 254 nanometers and a 36W input power rate have been included into the system. UV light with a wavelength of 254nm provides the best result against microorganisms. It takes roughly 15 minutes to properly disinfect an ordinary classroom. The other two systems have UV light sources with wavelengths of around 254 nm and eight (SEIT-UV) and sixteen (ADIBOT), respectively. each of the system requires 7-10mins to sterilize an average room area. The system has the ability to recognize individuals and objects at a particular distance utilizing practical sensors. But in the other two models 3D and RGD-B camera have been utilized which are highly expensive and quite difficult to insulate with the system. Additionally, both systems are fully automated and have operating hours of approximately 3 hours (SEIT-UV) and 6 hours (ADIBOT), respectively. As a result, they require longer charging times than the system that is being suggested. The suggested IoT-based system, which will be run using a mobile application, has to be charged for two hours in order to run for two uninterrupted hours. Therefore, taking into account all important aspects of each system, a cost analysis has also been performed, which demonstrates that the suggested system is significantly more affordable and capable of meeting all project requirements.

8.5 Conclusion

The project's feasibility, durability, and profitability are determined by economic and financial analysis. This analysis will help with market assessment, policy development, and long-term industry planning. The comparison among three proposed system and with other available models in the market have shown in this chapter with proper reasoning as well.

Chapter 9: Ethics and Professional Responsibilities (CO13, CO2)

9.1 Introduction

Making wise choices in every part of engineering while focusing on ethical and professional obligations is crucial for an expert engineer to develop into a proficient and professional specialist. Ethical problems are one of the most important parts of any research. One of the advantages society grants to those with engineering training is the ability to apply one's expertise in respected and meaningful work environments. Thus, engineers are morally committed to a wide range of communities' contributions. Professional engineering responsibility addresses engineers' ethical duties in their professional relationships with clients, employers, colleagues, and the general public.

9.2 Identify Ethical Issues and Professional Responsibility

A set of guidelines that will direct the research designs and procedures are called ethical considerations in research. Making the optimal judgments practical in terms of the environment and the community people live in is an aspect of ethics. There are several reasons why it is crucial to follow ethical standards when conducting research. First, principles enhance the objectives of the research, including knowledge, truth, and mistake prevention. When working on a project, ethical considerations may significantly reduce risk, improve successful outcomes, foster trust, and strengthen reputations. Engineering initiatives today are designed to make people's lives simpler. So, during the course of this project's development, efforts have been made to uphold ethical and professional obligations to the best of people's abilities. Engineers should be aware of their ethical responsibilities to improve people's lives and retain public trust in the projects that new engineers and/or business owners seek to construct or deliver. The project aims to build an IoT-based disinfecting system for educational institutions to ensure a microorganism-free environment for students. The key component that will be utilized to sterilize walls and surfaces is UV-C light. After numerous research, it has been found that a UV-C light with 254 nm provides the most effective result in the case of killing viruses and bacteria. However, the negative impact of UV-C radiation on humans has been also taken into account. Following the both pros and cons the ethical issues have been identified after extensive research. The issues are below-

- Regular check-ups will be done of an individual who will in charge of maintaining the UV disinfecting robot in case of UV exposure at any point in time.

- Being an IoT-based project, keeping the sensitive data of all the students secure will be of the highest priority.

- Unlicensed medicine and equipment can cause devastation in any place; thus, we will register our device under DGDA (Directorate General of Drug Administration). The consent form of DGDA is given below:

CONSENT FORM

License to UV-C-BASED system for the purpose of disinfect.

.... is hereby licensed to UV-C BASED system specified below for the purpose of disinfect air and surfaces at …………………………

This license is subject to the conditions prescribed in part............................. of the Drugs Rules, ……………………………………

Names of Drugs

Date................................. Licensing Authority...............................

Form 1: Consent from for DGDA permission

The following steps will be taken to uphold professional responsibilities and ethical standards in our project:

- The authorities of respective institutions will provide the necessary approvals and safety instructions before the first round of experiments is carried out.

  The consent form of BRAC University is given below:

CONSENT FORM

Inspiring Excellence

BRAC UNIVERSITY

.... is hereby requesting to utilize UV-C BASED system specified for the purpose of disinfect air and surfaces of classrooms that includes all kinds of safety protocols.

Date.................................. Authority................................

Form 2: Consent from for BRAC University permission

- As most of the cleaning personnel are not habituated to evolved technology, we will try to keep the system as user-friendly as possible. We will also take responsibility to organize a training session with all the personnel in charge of the disinfecting system.

- We will collect all the components of our project from reliable sources and not through back-channeling so that we can protect our design from any unforeseen system failure which can lead to an accident.

- Those that stand to gain the most from the system will receive the highest priority from us. The system will benefit students, teachers, and other staff members equally as it will be designed for educational institutions.

Since the system building is still in the early stages, the aforementioned ethical issues have been picked after extensive research. After the hardware is configured, there may be a numberof aspects that we will take into account.

9.3 Apply Ethical Issues and Professional Responsibility

Training Session: The system that is being proposed for this project is an IoT-based system that will be managed through a mobile app. For the people of Bangladesh, the system is relatively new. Therefore, the person in charge of operating the system must have sufficient knowledge about UV radiation, IoT-based system functionality, and control method. For all of the system's operators, this demands for a thorough training session. In Bangladesh, there are numerous private and public NGOs that organize training sessions for a variety of objectives to train people in a certain subject. For managing any IoT-based disinfection system, there is currently no specific NGO or agency that offers training sessions. However, once individuals are aware of how this approach benefits human health, conducting training sessions won't take as much time.

Legal: The significance of registering the system with a government agency is undeniable in order to maximize the benefits of the system that has been proposed in this project. Ultra violet radiation exposure can lead to serious skin conditions. Students will directly be impacted by the system because it will be used in educational institutions. The system will be registered by the DGDA (Directorate General of Drug Administration) in order to guarantee their adequate safety. The Ministry of Health and Family Welfare supervises Bangladesh's main drug regulatory body, the DGDA, which falls under its supervision. Additionally, each educational institution's authority's consent will need to be obtained in addition to that. The technology will initially be tested in the electrical and electronics building at BRAC University. The project team has therefore obtained the letter of authorization from the chairperson of the EEE department. The chairperson has asked that certain guidelines should be followed while using the system. During the system testing process, all rules and regulations were followed appropriately. The appendix part includes the chairperson's signed consent form.

Ethics of Welfare: Human skin is dangerously affected by ultraviolet radiation. Its tremendously favorable effect against microorganisms, however, cannot be disputed. Some crucial safety assurances have been made by some significant procedures with both of these items in mind. These safety factors have previously been covered in-depth. The system's major characteristic of automatically identifying individuals and turning off is because there are no natural resources that will be used in this project to mitigate the impact of ultraviolet radiation.

9.4 Conclusion

As professionals, engineers play a tremendous role in society. The profession is committed to serving humanity in an ethical and selfless way. The project is fundamentally a cutting-edge technology with a potential to provide students with secure learning environments. Upholding all moral and professional norms that an engineer should adhere to is completely our responsibility as engineers. If these guidelines are adhered to, people will be more inclined to use this project for their regular needs. Additionally, it will enhance stakeholder and client communication, which will eventually boost the project's reputation.

Chapter 10: Conclusion and Future Work

10.1 Project Summary/Conclusion

A thorough understanding of sterilization and disinfection is necessary for infection control. Recently, COVID-19 has developed into a significant threat to human civilization. Due to the coronavirus's high risk of transmission and high infectiousness, as well as a lack of adequate cleaning methods, educational institutions were shut down for more than 18 months. They may once again shut their doors if the number of coronavirus victims increases. In the past, disinfection techniques used to be largely manual, but they eventually shifted toward being more mechanical, automatic, and intellectualized. Then, using engineering principles, the thought of constructing a UV-based sterilization robot has come up that is capable of sterilizing both pathogenic and nonpathogenic germs and successfully sanitizing a surface. The system will have the feature of avoiding individuals and other objects within a specific distance using PIR and Ultrasonic sensors. This design includes an RFID reader to secure the safety of pupils. Students' body temperatures will be measured with a temperature sensor and scanned with an RFID sensor to see whether they match the temperature of a covid patient. It will be an IoT-based disinfection system. A smartphone app will be utilized to construct a voice and keyboard command mechanism, making it easier to control. In addition to smartphone control, the system will also have a six-channel remote controller. Our robot also sterilizes a space while following essential human safety precautions. The goal of this system's development is to provide the best possible disinfection performance at the lowest possible cost. The touch-free control mechanism, which does not require human intervention, is the most essential feature.

10.2 Future Work

As the year passes, new discoveries and advances are designed to make technology more precise and useful. Similarly, in the disinfecting sector, new and more efficient development is underway in order to make human life safer guarded. In this project, we created an IoT-based disinfection system for educational institutions. However, as an autonomous robot, the system could be more self-sufficient and will be able to sterilize a densely crowded region at low cost at regular intervals. [25] Hence, the system's structure will be tested with an emphasis on path and coverage planning. A 360-degree rotate camera must be included with the system for human and object detection instead of sensors. In this instance, image processing will be crucial. Area navigation will also play a significant role in the system. It will be utilized to prevent any major obstacles and ensure proper navigation. Since the robot will be fully automated the battery control system will also be automatic. So, the robot will have a self-charging configuration. Furthermore, it will function without the need for human intervention. Many more innovative ideas can be adopted to make disinfection mechanisms safer, more dependable, healthier, and more efficient.

Chapter 11: Identification of Complex Engineering Problems and Activities.

11.1 : Identify the attribute of complex engineering problem (EP)

	Attributes	Put tick (√) as appropriate
P1	Depth of knowledge required	√
P2	Range of conflicting requirements	
P3	Depth of analysis required	√
P4	Familiarity of issues	√
P5	Extent of applicable codes	
P6	Extent of stakeholder involvement and needs	
P7	Interdependence	

Depth of knowledge required

The goals of complex engineering activities are exploration, investigation, analysis, fabrication, and development of hands-on experience with complex engineering challenges. In the context of Bangladesh, the proposed methodology represents a completely new idea. As a result, Bangladesh's geographic location including the society, culture, and legal issues have also been taken into consideration during the entire design process. In addition to it, numerous other factors were taken into account. For example, UV radiation will be used for disinfection. UV light's benefits and drawbacks have both been taken into account. Risk factors and safety considerations have also been included in that calculation. All of these concerns hence require thorough research. Following that, a large number of research articles, journals, and literature reviews have been extensively assessed.

Depth of analysis required

A comprehensive analysis of the features and components was also carried out and scored through the Justification matrix table and IEEE applicable standards. On its route to sterilize places, the technology will be able to detect people and objects within a specific distance. In order to fix the range, a number of calculations and analysis have been additionally done. Generally, the initial symptom of any viral attack is having a high body temperature. Following that, a feature has been incorporated in the system where students' temperatures will be taken and stored in the database in order to assure protection from any kind of viral attacks. This Analysis of the temperatures of each student will decide his allowance in the institution. There is a specific amount of ultraviolet light with different wavelengths on the market. However, the system's integrated UV lights have a particular wavelength of 254 nm, which is excellent for disinfection. Numerous calculations and analyses have also been made on the system's operation, including how long it will take to sterilize an average classroom, what will happen after it detects people and objects, how it will communicate with a mobile app, and other factors. Without all these assessments, it will be difficult to achieve the goal of this project.

Familiarity of issues

The proposed design in this project is an engineering approach that has been taken to achieve micro-organism-free educational institutions. However, the system covered by this project is an Internet of Things (IoT)-based sterilization system. An IoT based can be thoroughly explained by the IoT architecture. This architecture includes- sensors and actuators, internet gateway, data processing, and application layers. Each layer has been briefly followed and utilized during the entire process of the system design. In order to follow the architecture, previously gained engineering knowledges have also been used for perfect construction. Every stage of building has involved the employment of various engineering tools relevant to the engineering educational field. The list of tools and their purpose have also been discussed. However, building the system in accordance with the IoT design architecture utilizing the necessary knowledge acquired before is therefore the current challenge.

11.2 Provide reasoning how the project address selected attribute (EP)

The project has been the subject of much research in articles, papers, and journals. Since the system development that this project was based on was fairly new to individuals, it was an inevitable requirement. The knowledge acquired from the studies has been applied to make it a complicated engineering challenge, uncover issues, look for solutions, find preferable techniques, work to locate suitable components, and examine budget planning, sustainability, risk management, and safety considerations. Citing numerical data has been used to support arguments. Therefore, it can be said that the project falls within the category of in-depth research and analysis. Additionally, although the project's difficulty has been characterized as a pretty standard one, the solutions that have been proposed through the project tend to be a bit unusual or novel.

11.3 Identify the attribute of complex engineering activities (EA)

	Attributes	**Put tick (√) as appropriate**
A1	Range of resource	√
A2	Level of interaction	√
A3	Innovation	
A4	Consequences for society and the environment	√
A5	Familiarity	√

Range of resource

The approached system is a novel development in the context of Bangladesh and so people here have minimal knowledge about a radiation based sterilizing system. All of them are still depends on chemical-based sterilization system. So, the design of the system needed a large number of resources to aim the goal. Wide range of resources are available to design this IoT based system. Many studies have conducted around these topics but none satisfies our requirements considering social, cultural, legal factors. These factors vary from country to country or society to society. This variation causes difference in the selection of components also. These differences were counted during the design procedure. Most of the components required for the proposed design are available in the local market but a few of them might need to be purchased from international online market platforms.

Level of interaction

The proposed project's design has been developed using a particular design architecture and past engineering expertise. To achieve the purpose of this research, a significant number of studies have been done on the design process. Due to the system's IoT foundation, a specific design architecture with four layers was employed to satisfy the requirements. However, simply sticking with the layers was insufficient to build the entire system. To make the best use of the layers, a substantial proportion of prior engineering context information was applied. The resources and materials that have been employed are all appropriately tied to the engineering context and have thus worked nicely with the architectural layers.

Consequences for society and the environment

Viral infections affect a significant percentage of Bangladesh's population. One of the main causes of this is the usage of chemical-based radiation system. People from this community still rely on chemicals to clean up localities. They have little idea about the benefits of adopting a radiation-based sterilizing technology. A design for a radiation-based sterilizing system has been put forth following extensive research. The effects of society and the environment were taken into account during the design process. In comparison to the use of chemicals, the system will produce better results. The probability of virus attacks will significantly reduce. As a result, everyone, including students, will be less vulnerable to viral attacks. Moreover, certain safety factors have also been taken into account considering the drawbacks of this system. Therefore, the probability that the system will have a negative impact on society or the environment is quite modest.

Familiarity

The current sterilizing methodology being utilized commercially throughout the world is radiation-based sterilization. To the Bangladeshi people, however, it is an entirely new idea. Bangladeshis still use chemicals to keep their surroundings clean. They are largely unaware of the advantages of using radiation-based sterilization techniques. In order to inform individuals from this community about its benefits, the method described in this proposal would be the initial step. A variety of engineering tools applicable to the engineering sectors were used in the system's design. The system will achieve greater results for disinfecting areas than chemicals do.

11.4 Provide reasoning how the project address selected attribute (EA)

A large number of resources, including finance, equipment, and physical structures for the installation of hardware, would be required to complete the project. A significant prerequisite for carrying out the hardware configuration was an R&D lab. The users and relevant authorities for the authorization and legal concerns have been contacted where the system will be deployed. The project thus satisfies A1 and A2. This IoT-based system will undoubtedly have a positive impact on society, health, and the environment because it will be a novel option for educational institutions. The project's issue statement is to assure microbial-free classrooms using a radiation-based technology that will be an affordable fix for all educational institutions and will reduce direct human involvement. Since there are currently projects on disinfecting surfaces with UVC radiation, this is not entirely a new problem for those outside of Bangladesh. However, in this study, the system will identify people who have early signs of a virus attack as well as disinfect surfaces. Therefore, it is also reasonable to state that the project completion A4, and A5 attributes.

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FYDP (P) Spring 2022 Summary of Team Log Book/ Journal

	Final Year Design Project (P) Spring 2022		
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General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

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Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC/Individuals
9/02/2022 **(Member Meeting)** [Google Meet]	All Member	Find out topic	All Member	N/A; As it was an introductory meeting
10.02.2022 **(ATC Meeting)** [Google Meet]	All Member	**1.**Finalize title **2.**Find out problem statement. **3.**Prepare objective	**Task 1:** All Member **Task 2:** Afrin,Namira **Task 3:** Riyan, Asif	**Task 1:** Completed. **Task 2:** partially completed. **Task 3:** Need to change the objective
12.02.2022 **(Member Meeting)** [Google Meet]	All Member	**1.**Work on title **2.**Problem statement **3.**Objective	**Task 1:** All Member **Task 2:** Afrin,Namira **Task 3:** Riyan, Asif	**Task 1:** Completed **Task 2:** Completed **Task3:** Still working
15.02.2022 **(ATC Meeting)** [Google Meet]	All Member	**1.** Discussion on how to write multiple design approach. **2.**How to write literature review **3.**Relevancy of current and future industry **4.**Specification & requirements	**Task 1:** Afrin,Namira **Task 2:** Asif, Riyan **Task 3:** Riyan **Task 4:** Afrin,Namira	**Task 1:** Convert the flow chart to block diagram **Task 2:** Read ref. paper to work on lit. review **Task 3:** Relevancy of current industry was missing **Task 4:** Partially completed
17/02/2022 **[Individual Work]**	Afrin	Making multiple design approach draft	Afrin	Completed
20/02/2022 **(Member Meeting)** [In Person]	Afrin, Namira	Making block diagram for design	Namira	Completed
22/02/2022 **(ATC Meeting)** [Google Meet]	All Member	**1.** Design selection **2.**Correction of objective and problem statement **3.**Specification (correction)	**Task 1:** Afrin **Task 2:** Riyan, Asif **Task 3:** Afrin,Namira	**Task 1:** Completed **Task 2:** Need to improve **Task 3:** Need to work on non-functional requirement
02/03/2022 **(Member Meeting)** [Google Meet]	Asif was absent	**1.**Specification and requirement (Correction) **2.**Concept note review	Afrin, Namira	**Task 1:** Completed **Task 2:** Completed
07/03/2022 **(ATC Meeting)** [Google Meet]	All Member	1.Applicable standard and codes **2.**SWOT analysis **3.**Stakeholder's review and progress presentation 1 slide making	**Task 1:** Namira **Task 2:** Afrin **Task 3:** Riyan, Asif	**Task 1:** Completed **Task 2:** Completed **Task 3:** Improve presentation slide
09/03/2022 **(Member Meeting)** [Google Meet]	All Member	**1.**Slide making **2.**Correction of objective problem statement	**Task 1 and 2:** Asif, Riyan	**Task 1:** Completed **Task 2:** Need to change some points
10/03/2022 **(Member Meeting)** [In Person]	All Member	**1.**Correction of concept note **2.** Update problem statement, objective	**Task 1:** Afrin, Namira **Task 2:** Asif, Riyan	**Task 1:** Completed **Task 2:** Partially completed
12/03/2022 **(Member Meeting)** [Google Meet]	Afrin, Namira	**1.**Conclusion and future work **2.**Applicable standard and code **3.** Component list	**Task 1:** Afrin, Namira **Task 2:** Namira **Task 3:** Afrin	Completed

FYDP (P) Spring 2022 Summary of Team Log Book/ Journal

13/03/2022 **(Feedback from ATC)** [Email]	All Member	**1.** Relevancy to current and future industry need to revise. **2.** In a bullet point mention 3/5 point as objectives. **3.** Non-functional requirement needs to review. **4.** Conflicting requirement is wrong it's more like constraints. **5.** Image caption is missing **6.** Add general requirement in concept note	**Task 1:** Riyan **Task 2:** Asif, Riyan **Task 3:** Afrin **Task4:** Afrin **Task 5:** Afrin **Task 6:** Afrin	**Task 1:** Completed **Task 2:** Partially completed **Task 3:** Completed **Task4:** Completed **Task 5:** Completed **Task 6:** Completed
16/03/2022 **(Member Meeting)** [Google Meet]	All Member	Reviewing concept note and progress presentation 1 slide	All Member	Completed
21/03/2022 **(ATC meeting)** [Google Meet]	All Member	**1.** Feedback on progress presentation 1	All member	**Task 1:** Need to improve presentation slide (problem statement, objective, add background research) **Task 2:** need to change the gannt chart
22/03/2022 **(In person meeting with ATC Chair)** [University]	Afrin, Namira	**1.** Non-functional requirement revised by ATC	Afrin, Namira	Completed
24/03/2022 **(In person meeting with ATC Chair)** [University]	Afrin	**1.** Remove the calculation from general requirement **2.** Add comparative study on project proposal	**Task 1:** Afrin **Task 2:** Afrin	**Task 1& 2:** Completed **Task 3:** Completed
28/03/2022 **(ATC Meeting)** [Google Meeting]	All Member	**1.** Prepare budget on 3 design approaches **2.** Start work on project proposal	**Task 1:** Asif, Riyan **Task 2:** All Member	**Task 1:** Completed **Task 2:** Partially completed
30/03/2022 **(Member Meeting)** [Google Meet]	All Member	**1.**Scope & Objective **2.** Impact and risk management **3.** Comparative study table **4.**Explanation of comparative study **5.** Sustainability	**Task 1:** Riyan **Task 2:** Asif **Task 3:** Afrin **Task 4:** Namira **Task 5:** Riyan	**Task 1:** Completed **Task 2:** Completed **Task 3:** Completed **Task 4:** Completed **Task 5:** Completed
04/04/2022 **(ATC Meeting)** [Google Meet]	Namira was absent	**1.** Add design summary in the last part of objective **2.** Update the budget in excel sheet **3.** Add a table on risk management **4.** Slide making for final progress presentation	**Task 1:** Riyan **Task 2:** Afrin **Task 3:** Afrin,Asif **Task 4:** Asif	**Task 1:** Completed **Task 2:** Completed **Task 3:** Completed **Task 4:** Partially completed

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06/04/2022 **(Member Meeting)** [Google Meet]	All Member	**1.** Expected outcome **2.** Methodology **3.** Slide changing	**Task 1:** Namira **Task 2:** Afrin **Task 3:** Namira,Afrin	**Task 1:** Completed. **Task 2:** Completed. **Task 3:** Completed.
11/04/2022 **(ATC Meeting)** [Google Meet]	All Member	**1.** Change the point of problem statement, objective, ethical consideration **2.**Add background research on slide **3.** Revise the SWOT analysis **4.** Revise the safety consideration	**Task 1:** Riyan **Task 2:** Riyan **Task 3:** Afrin **Task 4:** Namira	**Task 1:** Again, need to change those point. **Task 2:** Completed. **Task 3:** Completed. **Task 4:** Completed.
13/04/2022 **(Member Meeting)** [Google Meet]	All Member	**1.** Project plan **2.** Revise the SWOT analysis and non-functional requirement **3.** Safety consideration	**Task 1:** Asif, Riyan **Task 2:** Afrin **Task 3:** Namira	**Task 1:** Completed. **Task 2:** Completed. **Task 3:** Completed.
18/04/2022 **(ATC Meeting)** [Google Meet]	All Member	**1.** Change the point of problem statement, objective **2.** Maintain a sequence of ethical consideration **3.**Remove last two points on safety consideration **4.**Add comparison on 3 designs	**Task 1:** Riyan **Task 2:** Riyan **Task 3:** Namira **Task 4:** Afrin	**Task 1:** Again, need to change those point. **Task 2:** Completed. **Task 3:** Completed. **Task 4:** Completed.
21/04/2022 **(ATC Meeting)** [Google Meet]	All Member	**1.** Change the points of problem statement, objective. **2.** Change the points of ethical consideration	**Task 1:** Riyan **Task 2:** Riyan	**Task 1:** Again, need to change those point. **Task 2:** Again, need to change those point.
23/04/2022 **(Member Meeting)** [Google Meet]	All Member	Practice of mock presentation	All Member	Completed. (Time taken 9:30 sec)
24/04/2022 **(Member Meeting)** [Google Meet]	All Member	Practice of mock presentation	All Member	Completed. (Time taken 9:46 sec)
25/04/2022 **(ATC Meeting)** [Google Meet]	All Member	Final mock presentation	All Member	**1.**Presentation time was okay. **2.** Need to change problem statement, objective, ethical consideration. **3.**Need to change the points of constrains

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26/04/2022 **(Member Meeting)** [Google Meet]	Afrin, Namira	Change the points based on ATC comment	Afrin, Namira	Completed
27/04/2022 **(Member Meeting)** [Google Meet]	All Member	**1.**Change the points of problem statement, objective and ethical consideration **2.** Maintain a sequence of background study **3.** Revised all points	**Task 1:** Riyan, Afrin **Task 2:** Riyan **Task 3:** Afrin, Namira	**Task 1:** Completed **Task 2:** Completed **Task 3:** Completed
28/04/2022 **(Member Meeting)** [Google Meet]	Afrin, Namira	**1.** Attributes of complex engineering problems (EP) **2.** Attributes of complex engineering activities (EA)	**Task 1:** Namira **Task 2:** Riyan	**Task 1:** Completed **Task 2:** Completed
29/04/2022 **(ATC Feedback)** [Email]		**1.** Problem statement and background research section-cite the sources of information **2.** Grammatical mistakes noticed throughout, try to correct. **3.** Limited references, you must cite all sources.	**Task 1:** Asif, Riyan **Task 2:** Afrin **Task 3:** Riyan	**Task 1:** Did not completed problem statement. background research completed. **Task 2:** Completed. **Task 3:** Completed.
29/04/2022 **(Member Meeting)** [Google Meet]	Afrin, Namira	**1.** Change the problem statement. **2.** Change the Impact. **3.** Change the literature review in concept note and proposal 4. Review and Changed the all part of Asif Faisal (Lit. Review, Impact, Project Plan)	**Task 1:** Riyan **Task 2:** Afrin, Namira **Task 3:** Afrin, Namira **Task 4:** Afrin,Namira	**Task 1:** Completed. **Task 2:** Completed. **Task 3:** Completed. **Task 4:** Completed

FYDP (D) Summer 2022 Summary of Team Log Book/ Journal

	Final Year Design Project (D) Summer 2022		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Afrin Hossain Puspita (19221026)	afrin.hossain.puspita@g.bracu.ac.bd	01703810924
Member 2	Riyan Rahman Saad (18221041)	riyan.rahman.saad@g.bracu.ac.bd	
Member 3	Asif Faisal (18221004)	asif.faisal@g.bracu.ac.bd	
Member 4	Namira Tahsin (18221015)	namira.tahsin@g.bracu ac.bd	
ATC Details:			
ATC 5			
Chair	Dr. Abu S. M. Mohsin	asm.mohsin@bracu.ac.bd	
Member 1	Taiyeb Hasan Sakib	taiyeb.sakib@bracu.ac.bd	
Member 2	Md. Ehsanul Kabir		

General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP (D) Summer 2022 Summary of Team Log Book/ Journal

Date/Time/Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC/ Individuals
02.06.2022 (**Member Meeting**) **[In-Person]**	All Member	1.Design 1 & 2 Code 2.Design 1 & 2 Simulation **(2nd June to 17th June)**	Task 1: Asif Task 2: Riyan **(Alternative Member for Design 1 & 2-Afrin)**	N/A as it was an introductory meeting session.
06.06.2022 (ATC Meeting) **[In-Person]**	All Member	1. Motor Rating Details 2. Data Storage Platform Finalization (Local/Cloud) 3. Optimal Solution of Software Design (Matrix) 4. Design 1 Simulation(Human Control)	Task 1: Afrin Task 2: Asif Task 3: Namira & Afrin Task 4: Riyan & Asif	Task 1: Completed. Task 2: Have not started yet. Task 3: Partially Completed Task 4: Still working on this.
11.06.2022 (**Member Meeting**) **[Google Meet]**	All Member	1.Discussion on Design 1 Simulation	Task 1: Riyan & Asif	Task 1: Still working on this
13.06.2022 (**ATC Meeting**) **[In-Person]**	All Member	1.Discussion on the Points of Slide. 2. Show the simulation of design 1 and 2	Task 1: Afrin, Namira Task 2: Riyan & Asif	Task 1: Change the scoring of design solution matrix, last two points of objective and conclusion Task 2: Still working on this
16.06.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Riyan	1. Informed about the Submission of Design 1 & 2 on 18th June	Task 1: Riyan & Asif	N/A as submission date was declared before the work started.
20.06.2022 (ATC Meeting) **[In-Person]**	Afrin was absent due to sickness. Namira, Asif, Riyan were present.	1. Present Design 1&2 in front of ATC 2. Show the Slide of Progress Presentation 1	Task 1: Riyan, Asif Task 2: Namira,Afrin	Task 1: **Designs were incomplete**. Use a potentiometer in the object detector. Add a threshold temp for temperature detection. Show the saved data in the cloud interface. Task 2: Completed.

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22.06.2022 **(In person meeting with ATC chair)**	Afrin, Namira	1. **Full design 1 showed by alternative member.** 2.Showed the Slide points	Task 1: Afrin Task 2: Namira	Task 1: Completed and approved by ATC Task 2: **(a)**Modify the markings for optimal design matrix. **(b)** Modify the 2nd last point of ethical consideration. **(c)**Expected outcome and Impact were advised to remove from slide.
27.06.2022 (ATC Meeting) **[In-Person]**	Riyan was absent due to sickness. Namira, Asif, Afrin were present.	1. Full design 2 showed by alternative member. 2. Motor ratings were showed by Afrin. 3.Present Design 1&2 again in front of ATC	Task 1: Afrin Task 2: Afrin Task 3: Asif	Task 1: Completed Just add the simulation video in the slide. Task 2: Completed **Task 3: Designs were incomplete & rejected.**
28.06.2022 (**Member Meeting**) **[Google Meet]**	All Member	The practice of progress presentation 1	All Member	Completed (Time taken 8:27 minutes.)
29.06.2022 (**Member Meeting**) **[Google Meet]**	All Member	The practice of progress presentation 1	All Member	Completed (Time taken 8:20 minutes.)
30.06.2022 (**Progress Presentation Day**) **[Conference Room]**	All Member	The presentation was given by all members.	All Member	1. To visualize the design, we need to add a 3D model.(For every part) 2. Measures the robot's height, weight, and width. 3. Budget justification.

FYDP (D) Summer 2022 Summary of Team Log Book/ Journal

04.07.2022 (ATC Meeting) **[In-Person]**	Afrin	**<u>Work plan after Midterm</u>** 1. App development (July 1-July 30) 2. Simulation or calculation of design 3- Autonomous **(July 1-July 30)** **(Alternative Member for Design 3- Namira)**	Task 1: Asif, Afrin Task 2: Riyan	Task 1: UI design of app, APK design
07.07.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Asif	1. App UI design	Task 1: Asif, Afrin	Still working on it
18.07.2022 (ATC Meeting) **[In-Person]**	All Member	1. Show the UI design of the app	Task1: Afrin, Asif	UI design is ok.
MID WEEK-(19.07.2022 to 28.07.2022)				
21.07.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Asif	1. Log-In and Sign-in page design of apk 2.Database connection to the app	Task 1: Asif Task 2: Afrin, Namira	1. Done. 2. Still working on it.
01.08.2022 (ATC Meeting) **[In-Person]**	All Member	1. Show the Log-In and Sign-in page design	Task 1: Asif	Log-In and Sign-in page design is ok.
08.08.2022 (ATC Meeting) **[In-Person]**	All Member	1.Show 3D Design Model 2. App Design	Task 1. Afrin Task 2: Asif	Show 3D Design Model and app design is ok.
13.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	1. Prepare the slide for progress presentation 2. 2. Start report writing. (Problem statement, objective) 3. Add the table of motor rating and power supply specification 4. Functional Verification of Multiple Design Solutions (for simulation)	Task 1: Afrin Namira Task 2: Namira Task 3: Afrin Task 4: Afrin	1. Slide prepare is done. 2.Done 3. Done 4.Done

FYDP (D) Summer 2022 Summary of Team Log Book/ Journal

17.08.2022 (ATC Meeting) **[In-Person]**	All Member	1. Show the slide of progress presentation 2.	Task 1: Afrin, Namira	1. Add statistical data to the problem statement. 2. Calculation of Sterilization period. 3. Change the last two points of the conclusion. 4. Add system-level design in IT Tool. 5. Add the purpose of budget. 6. Take the data of using irradiance meter.
19.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	1. Correct the slide according to the ATC comment. 2. Autonomous design comparison **(alternative member start the working)**	Task 1: Afrin, Namira Task 2: Riyan	Task 1: Done. Task 2: Incomplete
22.08.2022 (ATC Meeting) **[In-Person]**	All Member	1. Show the slide of progress presentation 2.	Task 1: Afrin, Namira	1. Change the last two points of the objective. 2. Prepare the animation video. 3. Check Reference. 4. Add the acknowledgment of ICT Division.
23.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	1.Writeup of APP functionality 2.Connect the app login, sign in and Id scanning part to the database 3. Add the consent form	Task 1: Afrin Task 2: Afrin, Namira Task 3: Namira	1. Done 2. Already Done in Past Week 3. Done
23.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	1. Review the report.	Task 1: Afrin, Namira	Still working.

27.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	1. Review the report and submit it to ATC Panel.	Task 1: Afrin, Namira	Done
29.08.2022 **(ATC Meeting)** **MOCK PRESENTATION** **[In-Person]**	All Member	Mock Presentation and report review from ATC	All Member	1. Add the consent form in slide 2. Practice the presentation so that it will cover in time 3. EP/EA discussion. 4. Colored the design box so that it looks good to the audience
30.08.2022 (**Member Meeting**) **[Google Meet]**	Afrin, Namira	Change the slide according to ATC comment	Afrin, Namira	Done
31.08.2022 (**Member Meeting**) **[Google Meet]**	All Member	Practice the mock in 6 times	All Member	Done

FYDP (C) Fall 2022 Summary of Team Log Book/ Journal

	Final Year Design Project (C) Fall 2022		
Student Details	**NAME & ID**	**EMAIL ADDRESS**	**PHONE**
Member 1	Afrin Hossain Puspita (19221026)	afrin.hossain.puspita@g.bracu.ac.bd	01703810924
Member 2	Riyan Rahman Saad (18221041)	riyan.rahman.saad@g.bracu.ac.bd	
Member 3	Asif Faisal (18221004)	asif.faisal@g.bracu.ac.bd	
Member 4	Namira Tahsin (18221015)	namira.tahsin@g.bracu ac.bd	
ATC Details:			
ATC 5			
Chair	Dr. Abu S. M. Mohsin	asm.mohsin@bracu.ac.bd	
Member 1	Taiyeb Hasan Sakib	taiyeb.sakib@bracu.ac.bd	
Member 2	Md. Ehsanul Kabir		

General Notes:

1. In addition to detail journal/logbook fill out the summary/key steps and progress of your work
2. Reflect planning assignments, who has what responsibilities.
3. The logbook should contain all activities performed by the team members (Individual and team activities).

FYDP (C) Fall 2022 Summary of Team Log Book/ Journal

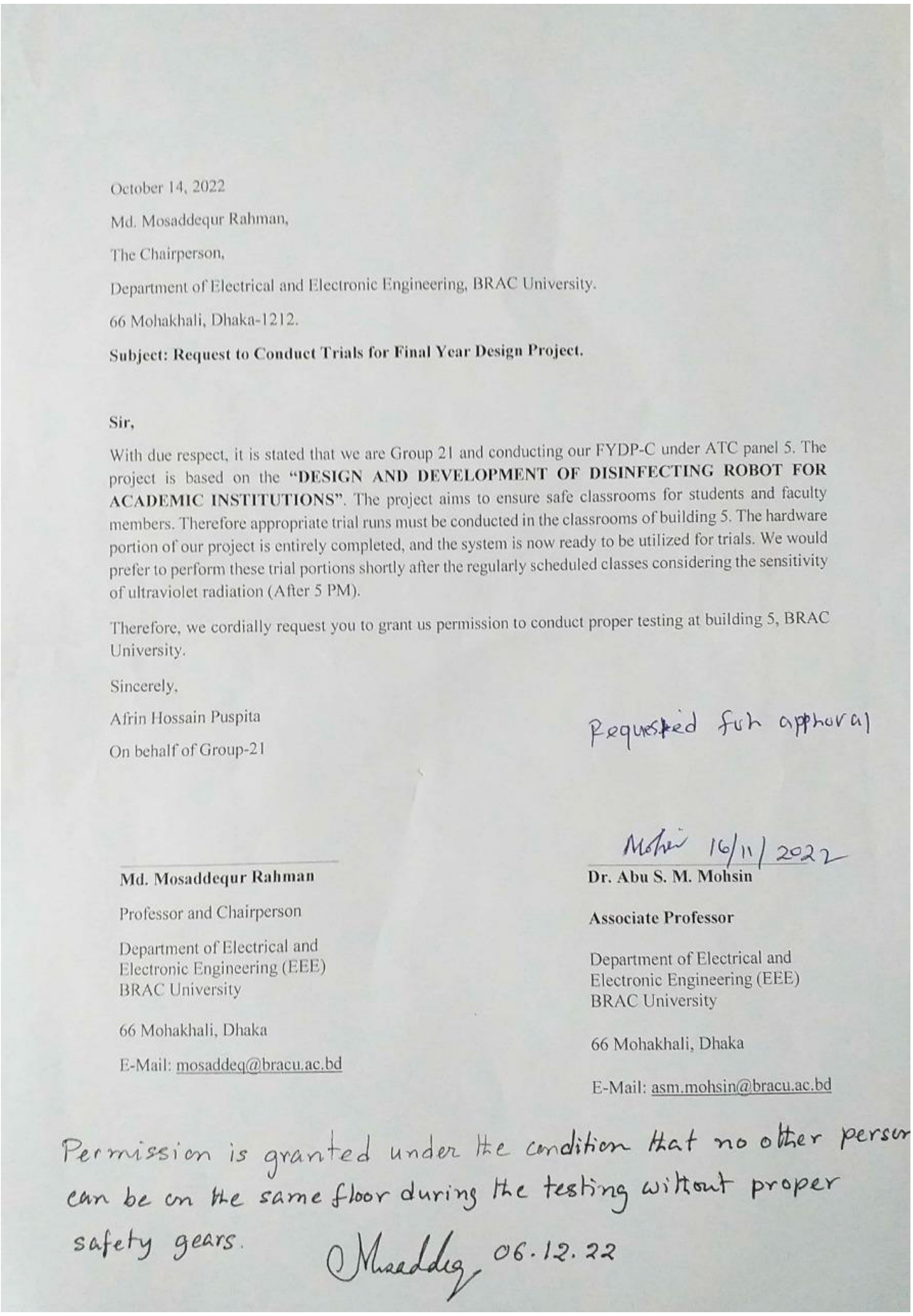
Date/Time/ Place	Attendee	Summary of Meeting Minutes	Responsible	Comment by ATC/ Individuals
Meeting Started In 2nd week and University was off for Durga Puja (04.10.2022 to 05.10.2022)				
12.10.2022 **(ATC Meeting) [In-Person]**	All Member	Task 1: Start designing the project Task 2: Sensor's setup in hardware	Task 1 & 2: Afrin	Task 1 & 2: Still working on this
03.10.2022 **[In-Person]**	Afrin	Start the setup of sensors hardware	Afrin	PIR sensor is working and successfully set in the main robot
10.10.2022 **[In-Person]**	1. Afrin 2. Namira	1. Order all the required components 2. Start to prepare the slide for progress presentation 1	Task 1: Afrin Task 2: Namira	Task 1: Completed Task 2: Partially Completed
12.10.2022 **(ATC Consultation) [In-Person]**	1. Afrin 2. Namira	1. Problem faced on economic analysis 2. Consult with Taiyeb Hasan Sakib sir	Task 1 and 2: Afrin, Namira	Problem Solved and work is done.
16.10.2022 **[In-Person]**	1.Afrin 2.Namira	1. Prepare a test case robot (minibot) 2. Slide checking and correction	Task 1: Afrin Task 2: Namira	Completed
20.10.2022 **[In-Person]**	Afrin	1. Setup the pir and sonar sensor in test robot 2. Check the functionality of UVC lights using irradiance meter	Task 1: Afrin Task 2: Riyan	Task 1: Partially completed, sonar is calibrated and detect the object form the safe distance Task 2: Done
23.10.2022 **[In-Person]**	Afrin	1. Record the video in different angle for two sensors 2. Compare our system to others robots (economic comparison)	Task 1: Afrin Task 2: Namira	Task 1: Completed Task 2: Completed
26.10.2022 **(ATC Meeting) [In-Person]**	All Member	1. Record the video again and evaluate the functionality for two sensors. 2. Slide check		Task 1: ATC advised to record the video again and evaluate the functionality for two sensors Task 2: Need to precise the points of economic analysis and sustainability
29.10.2022 **[In-Person]**	1. Afrin 2. Namira	Check the slides again and email it to ATC	Namira	Partially Completed, but did not send the video, as functional video of the sensors is still editing by Afrin
31.10.2022 **[In-Person]**	All Member	Practice the mock in 3 times	All Member	Done
03.11.2022 **(Progress Presentation Day) [Conference Room]**	All Member	The presentation was given by all members.	All Member	Task 1: Advised to check the irradiance data
MID WEEK-(04-11-2022 to 11.11.2022)				

13.11.2022 **[In-Person]**	1.Afrin 2.Asif	1. Check the circuit design of RFID and Temperature sensor 2. Set the circuit of RFID and Temperature sensor in breadboard 3. Test the circuit	Task 1: Afrin, Asif Task 2: Afrin Task 3: Asif	Completed
15.11.2022 **[In-Person]**	1.Afrin 2.Namira	1. Need to start the final Report (chapter 1 to 3)	Task1: Namira	Task 1: Completed
16.11.2022 **(ATC Meeting)** **[In-Person]**	1.Afrin 2. Namira Riyan and Asif were absent	1. Showed (Taiyeb Hasan Sakib sir) the RFID and temperature sensor working video 2. Asked the technical and non-technical consideration and constrain part for report writing	Task 1and 2: Afrin	Completed
19.11.2022 **[In-Person]**	1. Afrin 2. Namira	1. Report writing (Chapter 4 to 5) 2. Chapter 6 to 7	Task 1: Afrin Task 2: Namira	Completed
23.11.2022 **(ATC Meeting)** **[In-Person]**	All Member	1. Give the work update on hardware setup	Afrin	ATC told to send the full final report, and functionality video by next week
25.11.2022 **[In-Person]**	1. Afrin 2. Namira	1. Chapter 8 to 9 2.Chapter 10 to 11 3.Chapter 8 (Cost benefit analysis)	Task 1: Namira Task 2: Afrin Task 3: Riyan	Completed
28.11.2022	Afrin	1. Completed the PCB Design of all sensors and controller circuit 2. Prepare the final slide	Afrin	Done
03.12.2022	1.Afrin 2. Asif	1.Set all the components on PCB board and test it 2. Set the PCB circuit on the system 3.Take the videos on the system	Task 1: Afrin Task 2: Afrin, Asif Task 3: Afrin, Asif and Riyan	Done
04.12.2022	1. Afrin 2. Namira	1. Check the reports and make the table of contents 2. Plagiarism check 3. Video Editing	Task 1: Afrin, Namira Task 2: Afrin Task 3: Asif	Task 1: Done Task 2: Similarity index was 5% Task 3: Partially completed
07.12.2022 **(ATC Meeting)** **[In-Person]**	1. Namira 2.Afrin Riyan was absent	1.showed the final report, slide, and functional video	Afrin, Namira, Asif	Tasks were nicely completed and Taiyeb Hasan Sakib sir advised us to practice the presentation.
09.12.2022 **[In-Person]**	1. Afrin 2. Namira 3.Asif	Task 1: Modify Chapter 4 Task2: Modify the functional video	Task 1: Namira and Afrin Task 2: Asif	Task 1: Completed Task 2: Completed
11.12.2022 **[In-Person]**	All Member	1. Send the final report to Bracu library 2. Mock practice	Task 1: Afrin Task2: All Member	Completed

FYDP (C) Fall 2022 Summary of Team Log Book/ Journal

14.12.2022 **[In-Person]**	All Member	Mock practice	All Member	Time taken: 7.10 min
20.12.2022 **[In-Person]** **[ATC Chair]**	Afrin	As 22nd December is our final report submission so we need to update the report	All Member	1.Update use of modern tool 2. Add payback period in the economic analysis 3. Add the hardware test cases in performance evaluation

Appendix 1



October 14, 2022

Md. Mosaddequr Rahman,

The Chairperson,

Department of Electrical and Electronic Engineering, BRAC University.

66 Mohakhali, Dhaka-1212.

Subject: Request to Conduct Trials for Final Year Design Project.

Sir,

With due respect, it is stated that we are Group 21 and conducting our FYDP-C under ATC panel 5. The project is based on the **"DESIGN AND DEVELOPMENT OF DISINFECTING ROBOT FOR ACADEMIC INSTITUTIONS"**. The project aims to ensure safe classrooms for students and faculty members. Therefore appropriate trial runs must be conducted in the classrooms of building 5. The hardware portion of our project is entirely completed, and the system is now ready to be utilized for trials. We would prefer to perform these trial portions shortly after the regularly scheduled classes considering the sensitivity of ultraviolet radiation (After 5 PM).

Therefore, we cordially request you to grant us permission to conduct proper testing at building 5, BRAC University.

Sincerely,

Afrin Hossain Puspita

On behalf of Group-21

Requested for approval

Mohsin 16/11/2022

Md. Mosaddequr Rahman

Professor and Chairperson

Department of Electrical and
Electronic Engineering (EEE)
BRAC University

66 Mohakhali, Dhaka

E-Mail: mosaddeq@bracu.ac.bd

Dr. Abu S. M. Mohsin

Associate Professor

Department of Electrical and
Electronic Engineering (EEE)
BRAC University

66 Mohakhali, Dhaka

E-Mail: asm.mohsin@bracu.ac.bd

Permission is granted under the condition that no other person can be on the same floor during the testing without proper safety gears. Mosaddeq, 06.12.22

Fig.1: Agreement Form signed by BRAC University EEE Department Chairperson

Appendix 2

Code to operate the motors of the robot using the mobile app:

Code:

```
#include "FirebaseESP32.h"
#include <WiFi.h>
int i = 0;
String receivedChar = "s";
char ssid[] = "UVwifi";
char password[] = "12345678";
FirebaseData firebaseData;
int pir = 1;
int uv = 0;
const int ftrigPin = 26;
const int fechoPin = 27;
const int ltrigPin = 14;
const int lechoPin = 35;
//define sound speed in cm/uS
#define SOUND_SPEED 0.034
long fduration,lduration;
float fdistanceCm,ldistanceCm;
void setup() {
  // put your setup code here, to run once:
  Serial.begin(115200);
  connectWifi();
  Firebase.begin("https://uv-sterilizing-robot-default-rtdb.asia-
southeast1.firebasedatabase.app/", "08SHBsD6qmaz0OziTMIB47DDl733nPbJdUbmf3Qo");
pinMode(ftrigPin, OUTPUT); // Sets the trigPin as an Output
  pinMode(fechoPin, INPUT); // Sets the echoPin as an Input
  pinMode(ltrigPin, OUTPUT); // Sets the trigPin as an Output
  pinMode(lechoPin, INPUT); // Sets the echoPin as an Input
  //BTSerial.begin(9600);
  pinMode(15, OUTPUT);
  pinMode(2, OUTPUT);
  pinMode(4, OUTPUT);
  pinMode(13, OUTPUT);
  pinMode(22, OUTPUT);
}
void loop() {
  fsonar();
  lsonar();
  if(fdistanceCm<50){
  receivedChar = "b";
  delay(5000);
  receivedChar = "l";
    Firebase.set(firebaseData, "/control/info", "Object detected");
```

```
  }
  else{
    Firebase.set(firebaseData, "/control/info", "No object Nearby");
  receivedata();
  }

  if (receivedChar == "s") {
    Serial.println("Stop");
    stopp();
  }
  if (receivedChar == "f") {
    Serial.println("Going forward");
    forward();
  }
  if (receivedChar == "b") {
    back();
  }
  if (receivedChar == "l") {
    rightforward();
    leftback();
  }
  if (receivedChar == "r") {
    leftforward();
    rightback();
  }
  if (receivedChar == "G") {
    rightforward();
    digitalWrite(15, LOW);
    digitalWrite(2, LOW);
  }
  if (receivedChar == "I") {
    leftforward();
    digitalWrite(4, LOW);
    digitalWrite(13, LOW);
  }
  if (receivedChar == "J") {
    leftback();
    digitalWrite(4, LOW);
    digitalWrite(13, LOW);
  }
  if (receivedChar == "H") {
    rightback();
    digitalWrite(2, LOW);
    digitalWrite(15, LOW);
  }
}
void leftforward() {
  digitalWrite(15, LOW);
```

```
  digitalWrite(2, HIGH);
}
void leftback() {
  digitalWrite(15, HIGH);
  digitalWrite(2, LOW);
}
void rightforward() {
  digitalWrite(4, HIGH);
  digitalWrite(13, LOW);
}
void stopp() {
  digitalWrite(4, LOW);
  digitalWrite(13, LOW);
  digitalWrite(15, LOW);
  digitalWrite(2, LOW);
}
void rightback() {
  digitalWrite(4, LOW);
  digitalWrite(13, HIGH);
}
void forward() {
  rightforward();
  leftforward();
}
void back() {
  rightback();
  leftback();
}
void receivedata() {
  // get value
  if (Firebase.getString(firebaseData, "control/command/")) {
    Serial.print("receivedChar: ");
    Serial.println(firebaseData.stringData());
    receivedChar = firebaseData.stringData();
  }
}
void connectWifi() {
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("................................");
  Serial.println("WiFi Connected. ..IP Address:");
  Serial.println(WiFi.localIP());
  Serial.println("............................... ");
}
void fsonar(){
```

```
  digitalWrite(ftrigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(ftrigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(ftrigPin, LOW);
  fduration = pulseIn(fechoPin, HIGH);
  fdistanceCm = fduration * SOUND_SPEED/2;
  Serial.print("Front Distance (cm): ");
  Serial.println(fdistanceCm);
  delay(100);
}
void lsonar(){
  digitalWrite(ltrigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(ltrigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(ltrigPin, LOW);
  lduration = pulseIn(lechoPin, HIGH);
  ldistanceCm = lduration * SOUND_SPEED/2;
  Serial.print("left Distance (cm): ");
  Serial.println(ldistanceCm);
  delay(100);
}
```

Appendix 3

Human detection using PIR sensor and UV light control system:

Code:

```
#include "FirebaseESP32.h"
#include <WiFi.h>
int i = 0,c=0;
String receivedChar = "s";
char ssid[] = "UVWifi";
char password[] = "12345678";
FirebaseData firebaseData;
int pir1 = 0, pir2=0;
int uv = 0;
void setup() {
  Serial.begin(115200);
  connectWifi();
  pinMode(2,OUTPUT);
  Firebase.begin("https://uv-sterilizing-robot-default-rtdb.asia-
southeast1.firebasedatabase.app/", "08SHBsD6qmaz0OziTMIB47DDl733nPbJdUbmf3Qo");
  digitalWrite(2,LOW);
}
void loop() {
 receivedata();
 senddata();
 if (uv == 1) {
   Serial.println("UV on");
   digitalWrite(2, HIGH);
   for (int j = 1; j <= 100; j++) {
     senddata();
     Firebase.set(firebaseData, "/uv/control/percent", j);
     c=1;
```

```
    Firebase.set(firebaseData, "/uv/control/state", "Cleaning");
    delay(700);
    if (Firebase.getInt(firebaseData, "uv/control/run/")) {
      Serial.print("uv: ");
      Serial.println(firebaseData.intData());
      if (firebaseData.dataType() == "int") {
        uv = firebaseData.intData();
      }
      if (uv == 0) {
        Serial.println("UV off");
        Firebase.set(firebaseData, "/uv/control/state", "Stop");
        Firebase.set(firebaseData, "/uv/control/run", 0);
        Firebase.set(firebaseData, "/uv/control/toggle", false);
        digitalWrite(2, LOW);
        break;
      }
    }
  }
  Serial.println("UV off");
  Firebase.set(firebaseData, "/uv/control/run", 0);
  Firebase.set(firebaseData, "/uv/control/toggle", false);
  digitalWrite(2, LOW);
  Firebase.set(firebaseData, "/uv/control/state", "Stop");
   Firebase.set(firebaseData, "/uv/control/percent", 0);
   c=0;
}
if (uv == 0) {
  Serial.println("UV off");
  digitalWrite(2, LOW);
  c=0;
```

```
  }
}
void senddata() {
  pir1 = digitalRead(13);
  pir2 = digitalRead(4);
  Serial.println(pir1);
  Serial.println(pir2);
  if (pir1 == HIGH||pir2 == HIGH) {
    uv=0;
    Serial.print("People In the Room!");
    digitalWrite(2,LOW);
    Firebase.set(firebaseData, "/uv/control/state", "Someone in Room");
    Firebase.set(firebaseData, "/uv/control/run", 0);
  }
  else {
    //Firebase.deleteNode(firebaseData, "/uv/control/state");
    Serial.println("UV is safe to use!");
    if(c!=1){
    Firebase.set(firebaseData, "/uv/control/state", "Ready to start");
    }
  }
  delay(1000);
}
void connectWifi() {
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("................................");
```

```
  Serial.println("WiFi Connected. ..IP Address:");
  Serial.println(WiFi.localIP());
  Serial.println("............................... ");
}
void receivedata() {
  // get value
    if (Firebase.getInt(firebaseData, "uv/control/run/")) {
    Serial.print("uv: ");
    Serial.println(firebaseData.intData());
    if (firebaseData.dataType() == "int") {
      uv = firebaseData.intData();
    }
  }
}
```

Appendix 4

RFID based attendance system with temperature checking:

Code:

```
#include <Adafruit_MLX90614.h>
#include <SPI.h>
#include  <RFID.h>
#include "FirebaseESP32.h"
#include <WiFi.h>
char ssid[] = "UVwifi";
char password[] = "12345678";
FirebaseData firebaseData;

const char* ntpServer = "pool.ntp.org";
const long gmtOffset_sec = 21600;
const int daylightOffset_sec = 0;
#define SDA_DIO 4
#define RESET_DIO 5
RFID RC522(SDA_DIO, RESET_DIO);
int temp =0;
Adafruit_MLX90614 mlx = Adafruit_MLX90614();
void setup() {
  Serial.begin(115200);
  pinMode(13,OUTPUT);
  pinMode(14,OUTPUT);
  while (!Serial);
  SPI.begin();
  RC522.init();

  Serial.println("Checking for Student ID Card:");
  if (!mlx.begin()) {
```

```
    Serial.println("Error connecting to MLX sensor. Check wiring.");
    while (1);
  };
   connectWifi();
    digitalWrite(13,LOW);
    digitalWrite(14,LOW);
  Firebase.begin("https://uv-sterilizing-robot-default-rtdb.asia-
southeast1.firebasedatabase.app/", "08SHBsD6qmaz0OziTMIB47DDl733nPbJdUbmf3Qo");
  Serial.println("===============================================");
  configTime(gmtOffset_sec, daylightOffset_sec, ntpServer);
 // printLocalTime();
}
void loop() {
  if (RC522.isCard())
  {
    String rfid="";
    RC522.readCardSerial();
    Serial.println("Card detected:");
    for(int i=0;i<5;i++)
    {
    rfid = rfid + String(RC522.serNum[i],DEC);
    }
    Serial.println(rfid);
    Serial.println();
    delay(1000);
    bodytemp(rfid);
    Serial.println();
    delay(500);
  }
  delay(1000);
}
```

```
void bodytemp(String rfid){
  temp = mlx.readObjectTempF();
  if(temp>100){
  digitalWrite(14,HIGH);
  }
  else
    digitalWrite(13,HIGH);
  Serial.print("Body temperature = "); Serial.print(temp); Serial.println("*F");
  String adress= "/student/"+rfid+"/temp";
  Firebase.set(firebaseData, adress, String(temp));
  Firebase.set(firebaseData, "/info/robot/lastscan", string_To_long(rfid.c_str()) );
  printLocalTime(rfid);
  digitalWrite(14,LOW);
  digitalWrite(13,LOW);
}
void connectWifi() {
  WiFi.begin(ssid, password);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
    digitalWrite(13,HIGH);
    //digitalWrite(14,HIGH);
  }
  Serial.println("................................");
  Serial.println("WiFi Connected. ..IP Address:");
  Serial.println(WiFi.localIP());
  Serial.println("............................... ");
}
long long string_To_long(const char sl[]) {
    long long int n = 0;
```

```
    for (int i = 0; sl[i] != '\0'; i++) {
        char c = sl[i];
        if (c >= '0' && c <= '9')
            n = n * 10 + (c - '0');
    }
    return n;
}
void printLocalTime(String rfid){
  struct tm timeinfo;
  if(!getLocalTime(&timeinfo)){
    Serial.println("Failed to obtain time");
    return;
  }
  Serial.println(&timeinfo, "%A, %B %d %Y %H:%M:%S");

  Serial.println("Time variables");
  char timeHour[12];
  strftime(timeHour,12, "%r", &timeinfo);
  Serial.println(timeHour);
  char Day[10];
  strftime(Day,10, "%D", &timeinfo);
  Serial.println(Day);
  Serial.println();
  String entry= "/student/"+rfid+"/entry";
  Firebase.set(firebaseData, entry, String(timeHour));
  String date= "/student/"+rfid+"/date";
  Firebase.set(firebaseData, date, String(Day));
}
```