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Engineering Graduation Project 2

Bike Campus Hub

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Disclaimer Statement

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Abstract

BikeCampusHub is a smart bike rental station system designed for students at university campuses. With the long distance between campuses, this project aims to provide an efficient and convenient mode of transportation for students which was inspired by European bike rental systems.

The system contains a smart bike, a connected vest wirelessly, and rental stations that communicate continuously. Students have two ways to access bikes either by using their student ID or by receiving a verification code on their mobile phones. The system tracks essential student information, including phone numbers, student IDs, names, and rental status, ensuring that a student cannot rent another bike until the previous one is returned. Additionally, students can view all stations on their phones to check their availability, whether they have bikes, and whether they are active or deactivated by the admin. The system also provides real-time updates on the remaining time to return a rented bike.

The admin has full control and visibility over the system through a dedicated dashboard and website, allowing them to monitor all student activities, manage bike rentals, track the location of each student via GPS on a real-time map, control rental timing for stations, and deactivate or activate the stations. The Firebase database serves as the centralised system for storing and managing all data.

The smart bike is equipped with an RFID system and communicates with the connected vest using ESP modules configured as an access point and client. The system also includes directional detection to activate LED lights, enhancing safety by indicating when the bike stops or changes direction. Additionally, a locking mechanism provides security by locking the bike at the station when the user doesn’t return it on time or when the user goes outside of the college boundaries.

BikeCampusHub offers a practical solution for student transportation within the university, combining convenience, security, and smart technology to improve campus mobility.

Chapter 1

Introduction

1.1 Statement of the problem

Campuses inside universities are Separated by long distances, Additionally they are getting expanded to accommodate students, who often need to move quickly and efficiently between classes, study areas, and other campus facilities. Not all universities like NNU for example can have cars inside for students, so they have to walk long distances which is not practical, it can be time-consuming and inconvenient, particularly during peak hours.
Rental systems in cities and colleges sometimes lack reliable and secure systems which
complicate the situation, limiting students' mobility and access to an friendly environment mode of transportation.

1.2 Objectives of the work

Bike Campus Hub project aims to create a smart bike rental system that improves student mobility on campus by providing a secure, efficient, and user-friendly transportation option. The system provides quick access for students to easily rent bikes using their ID cards or mobile verification, with a mobile interface to check bike and station availability.

Security is enhanced through RFID and a locking mechanism, in addition to a vest safety system. The system also features GPS tracking for real-time monitoring of bike locations, enabling administrators to oversee rentals, track usage, and ensure bikes are returned safely.

An admin dashboard and dedicated website offer control over station operations, including activation and deactivation. By promoting a sustainable alternative to traditional transport, BikeCampusHub aims to make campus travel more convenient.

1.3 Significance of our work

The BikeCampusHub project aims to address the need for efficient and secure transportation on university campuses by developing a system that serves both students and administrators. Our embedded system not only simulates but also enhances the features found in existing bike rental systems, ensuring practical usage for students and robust full control for administrators.

1.4 Organization of the report

This report is divided into several sections. The introduction provides an overview of the project. The second chapter defines the challenges, limitations, and preparation of the work. The third section details the literature review, and how our system manages the cons of existing systems. The fourth section discusses all work details, starting with the figures, followed by the hardware and software implementation. The last two chapters present the results we came up with. Finally, the conclusion summarizes the main points of the report and offers recommendations for future work.

Appendices are included to provide supplementary information and data relevant to the project.

Chapter 2

Constraints, and Earlier Coursework

2.1 Constraints

Our project, BikeCampusHub, is a 3 in one system involving three interconnected components: the vest, the bike, and the station. We faced challenges in powering the system, stability since it's movable, and communication.

1. **Internet Connection**

   Since we need centralized information and database interaction with software and hardware on both sides we need a reliable internet connection, stronger internet signal communication is done faster and better which we cannot always guarantee at the current college conditions.

2. **Power Supply and Component Compatibility:**

   Managing the power supply was challenging, we had to use three different types for each, taking weight and transporting into consideration. The variety in amperes and voltages required multiple voltage regulators to ensure that each IC and component received the correct amount of power.

3. **Locking Mechanism:**

   We searched for a strong locking system from both the local market and different suppliers and even tried making it from scratch. The locking mechanism for the station was not a simple task, and controlling the bike's brakes was even harder it didn't succeed the first time, and we had to go through various tests and methods to achieve a practical solution.

4. **Communication and Synchronization:**

   Since the vest acts as a client and the bike as an access point, ensuring reliable communication between these moving components was crucial. The bike and station needed to communicate accurately with a centralized database, which also interfaced with an admin website. The communication setup needed high accuracy since we are dealing with real-time data transmission between the Arduino and ESP modules.

5. **Hardware Shortages and Timing Issues:**

   We faced hardware shortages, we needed to set accurate communication between Arduino and ESP modules serially which took time due to differences in timing execution and data transmission. Fast information processing was crucial, as any delay could have caused significant challenges in controlling the system, including denying or allowing access. So we had to build and refactor the code carefully to gain maximum efficiency from the hardware microcontrollers.

   Magnetic lock generates electromagnetic fields when operated, so it affected RF and ultrasonic so we needed to isolate them and make sure they function properly.

GSM took too much effort, it is very sensitive to power. It requires a specific voltage, which is around 4.2, standard power supplies do not provide it.

2.2 Earlier Coursework

In preparation for our system, we conducted comprehensive research into global bike rental systems, especially since there are no such systems in the West Bank. We needed to fully understand how these systems function, from both technical and operational perspectives. We explored how bikes are tracked, the technologies used, and the policies of many rental companies. We also studied the structure and implementation of different components, including security mechanisms, user access methods, and tracking systems. Additionally, we saw many rental applications and what user experience they provided.

With our electrical, hardware, and software experience, we studied all aspects to design and implement the best model for our university.

Chapter 3

Literature Review

Bicycle-sharing systems are now integrated into the network of transport services since they seek to avoid traffic and pollution. Inspired by successful implementations in cities like Paris, New York, and Taipei, the development of these systems has improved their performance and predict users' interactions.

BSS and Its Components: To better understand user needs, Bicycle Sharing Systems (BSS) allow users to rent bicycles from automated stations. The satisfaction of users at this conceptual stage motivates the maintenance of an optimal supply of bicycles, ensuring ease of retrieval and enough space for returns, especially during peak times. The reviewed literature examines various parameters associated with non-motorized transport, including weather, space, and time factors. The proximity of docking stations to users' homes significantly increases the likelihood of system usage, making the strategic placement of stations crucial for maximizing benefits (Bachand-Marleau et al., 2012).

Predicting Bicycle Rental Behavior: One of the key challenges within the domain of BSS management is the ability to forecast the rental of bikes properly to ensure that the demand and supply are balanced. Traditional statistical models, for example, Poisson processes, have been frequently employed to project the future number of bike rental and return events. However, many authors pointed out that neither of the popular statistical packages would be helpful, as this rental behavior could be treated as random, which is incorrect, especially during demand bursts (Ghosh et al., 2017). Thus, more sophisticated methods, including Recurrent Neural Networks (RNN), were recommended for the improvement of predictive precision, employing both temporal and geographical parameters (Lu & Lin, 2020).

The paper "Rental Prediction in Bicycle-Sharing System Using Recurrent Neural Network" by Lu and Lin (2020) contains the adapted RNN model which predicts the volume of bike rentals and incorporates location features of rental stations including POIs. Their model incorporates features like historical rental data combined with spatial and temporal features to have a better predictive rental demand forecast compared to the conventional methods back then (statistical models).

Technological Advancements in Business Support Systems: According to Nayak, K. et al 2010, the integration of BSS with smart city technologies including IoT has also been an area of great interest. Current systems include GPS tracking, real-time data communication between stations and a central database, and mobile applications that allow users to check bike availability and station status. These advancements improved user experience and enabled administrators to have valuable data to control system operations.

Enhancements in Bike Campus Hub

We collected information about rental systems in various European cities, including the UK, Paris, and Belgium, as well as systems used in colleges, and here is how we maintained their common challenges.

Users sometimes struggle to find available docking stations, especially in peak times so we designed a mobile application where students can check remotely the availability of the stations since we created real real-time monitoring system.

We enhanced the security by allowing movement inside campuses only, unlike existing systems that allow bikes to be taken far away from campus. For example, Santander Cycle in Imperial College London includes stations far away from campus which might reduce security or make it harder for students to find bikes nearby.

Another issue users may not return bikes on time, causing docking congestion. In our system, if a user doesn't return the bike within the specified time by admin, the bike will be automatically locked. Moreover, users are unable to rent another bike unless the rented bike is returned.

Validation and theft are common problems, we ensured in our system bikes will be tracked all the time, the paths they take. Each rental operation will be associated with student id, name, phone number, and bike id, providing all transactions.

Future Directions: Despite these advancements, several challenges remain in the implementation of BSS, particularly in ensuring reliable communication between system components and maintaining the stability of mobile parts like bikes and vests. Additionally, the diversity in power requirements across different components necessitates the use of multiple voltage regulators, adding to the complexity of system design.

further work could be done by adding in more data such as real-time weather conditions to better predict when a trip is unsafe. In addition, the communication protocol between the various components is optimized so that latency is reduced and responsive time increases as low (maximum) to ensure prompt response to user requirements.

Designing a system considering the number of students, dedicated maintenance, and regular checks.

Chapter 4

Methodology

In this chapter, we will list all the hardware components used in our project and explain their functionality. Then, we will explain the workflow of the system and the interactions between the hardware components. Finally, we will describe the software interaction and the system design.

4.1 Hardware Components

4.1.1 Microcontrollers

Arduino Mega 2560 A microcontroller board

Based on the ATmega2560 is called the Arduino Mega 2560. It contains 16 analog inputs, 4 hardware serial ports (UARTs), a 16 MHz crystal oscillator, 54 digital input/output pins (of which 15 can be used as PWM outputs), a USB connector, a power jack, an ICSP header, and a reset button. because of its extensive collection of features, it is an all-inclusive microcontroller solution for our project's demands. Considering how many connected devices must connect to the microcontroller.

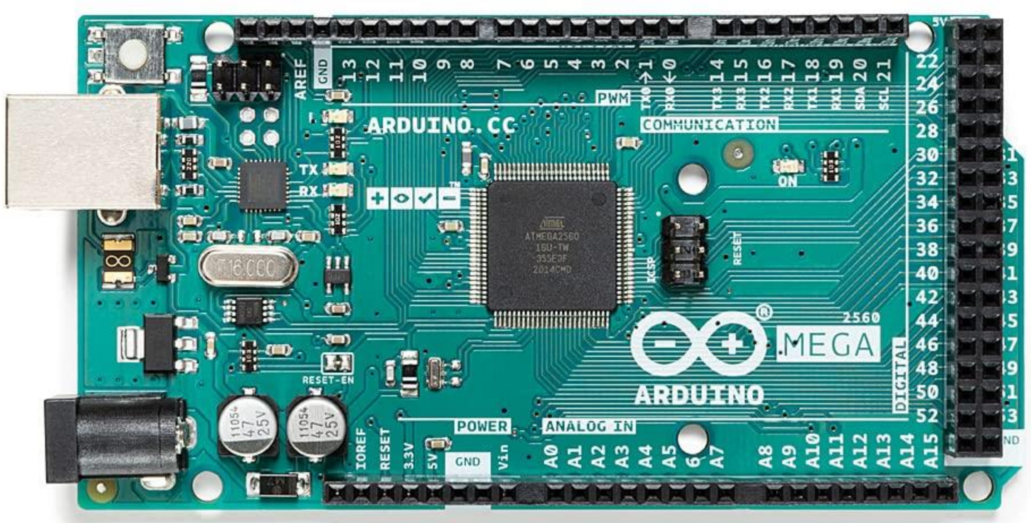


Figure 4.1: Arduino mega 2560

ESP32-DevKitC ESP32-WROOM-32U Core Board

ESP32-WROOM-32 is a powerful, generic Wi-Fi + Bluetooth® + Bluetooth LE MCU module that targets a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding. In our project we used it to connect to Wi-Fi and run a mobile application.

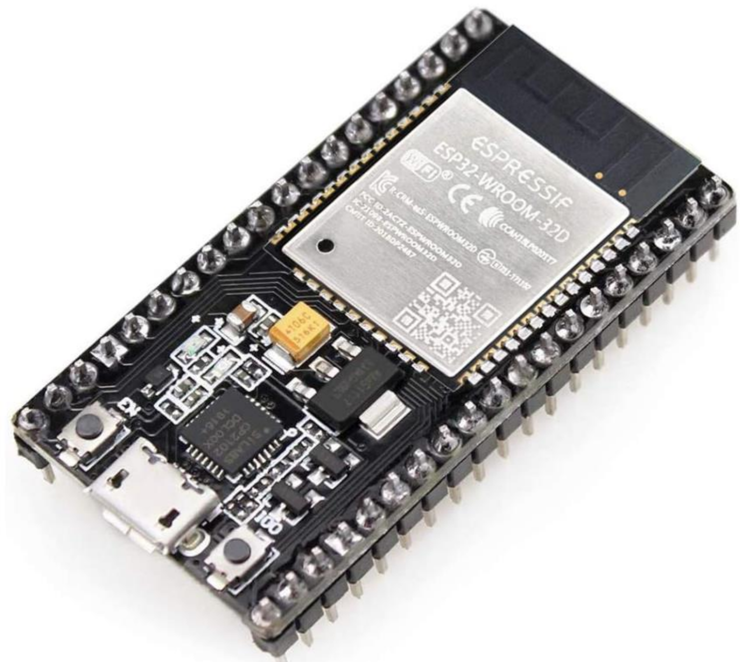


Figure 4.2: ESP32-DevKitC ESP32-WROOM-32U Core Board

4.3 Arduino Uno SMD R3 with ATmega328P MCU

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2010. The microcontroller board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.[1] The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable.[4] It can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts, such as a rectangular 9-volt battery. It has the same microcontroller as the Arduino Nano board, and the same headers as the Leonardo board.[5][6] The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

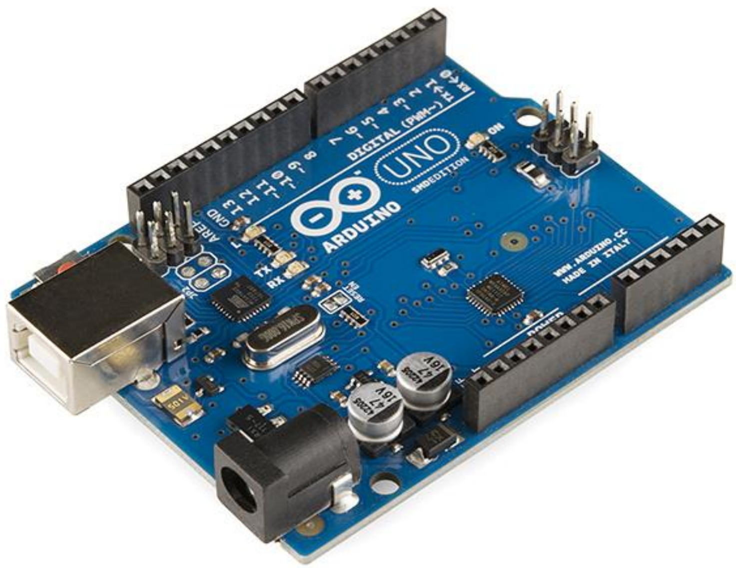


Figure 4.3: Arduino Uno SMD R3 with ATmega328P MCU

4.1.2 Motors and Drivers

Stepper Motor

J-5718HB2401 Stepper motor

Stepper motors convert electricity into rotation. Not only does a stepper motor convert electrical power into rotation, but it can be very accurately controlled in terms of how far it will rotate and how fast. Stepper motors are so named because each pulse of electricity turns the motor one step. Stepper motors are controlled by a driver, which sends the pulses into the motor causing it to turn. The number of pulses the motor turns is equal to the number of pulses fed into the driver. The motor will spin at a rate that is equal to the frequency of those same pulses. Stepper motors are very easy to control. Stepper motor drivers convert pulse signals from the controller into motor motion to achieve precise positioning. AC or DC Input. αST

EP Closed Loop Stepper Motors, 2-Phase Stepper Motor or 5-Phase Stepper Motor Drivers.

Figure 4.4: J-5718HB2401 Stepper motor

Figure 4.5: YS-DIV268N driver

4.1.3 Communication Modules

Gsm module sim800l

The SIM800L GSM/GPRS module is a miniature GSM modem that can be used in a variety of IoT projects. You can use this module to do almost anything a normal cell phone can do, such as sending SMS messages, making phone calls, connecting to the Internet via GPRS, and much more.To top it all off, the module supports quad-band GSM/GPRS networks, which means it will work almost anywhere in the world.

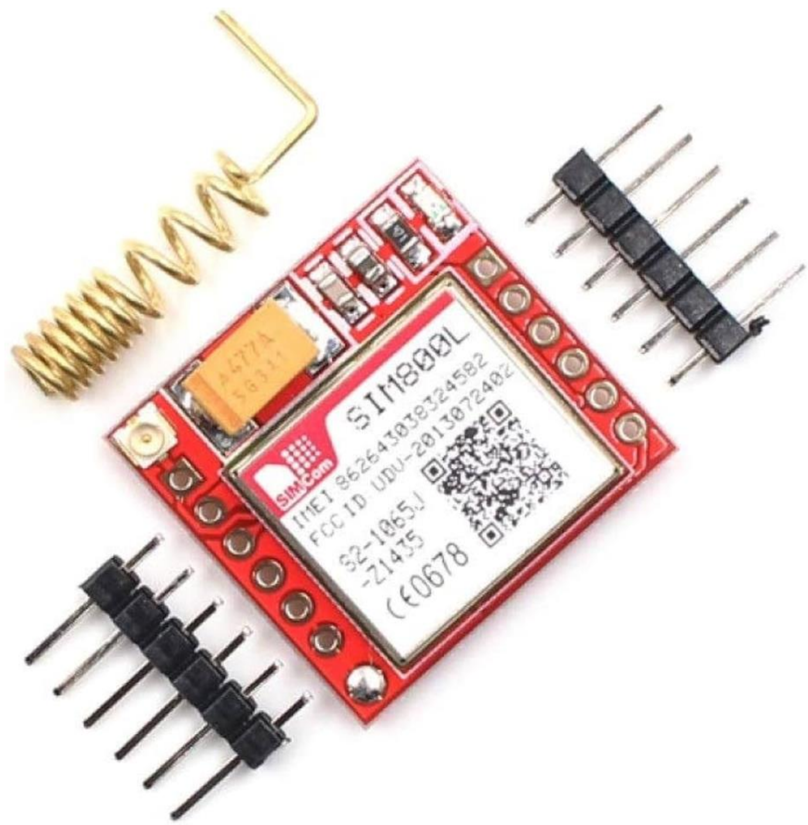


Figure 4.6: Gsm module sim800l

4.1.4 Sensors

MPU (MPU6050)

MPU6050 sensor module is a complete 6-axis Motion Tracking Device. It combines a 3-axis Gyroscope, a 3-axis Accelerometer, and a Digital Motion Processor all in a small package. Also, it has an additional feature of the on-chip Temperature sensor. It has an I2C bus interface to communicate with the microcontrollers. It has an Auxiliary I2C bus to communicate with other sensor devices like a 3-axis Magnetometer, Pressure sensor, etc. If a 3-axis Magnetometer is connected to an auxiliary I2C bus, then MPU6050 can provide complete 9-axis Motion Fusion output.

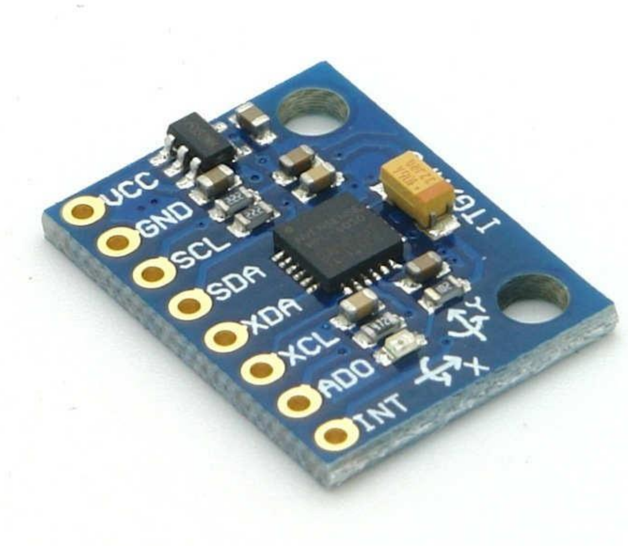


Figure 4.7: MPU6050 Module

HC-SR04 Ultrasonic Distance Measurement Module

The HC-SR04 is a popular ultrasonic sensor used for non-contact distance measurements. This sensor operates by emitting an ultrasonic sound pulse and measuring the time it takes for the echo to return to calculate the distance to an object. The HC-SR04 is reliable and accurate over short ranges, typically up to 4 meters. Use cases include parking sensors, obstacle avoidance in robotics, and interactive installations. The HC-SR04 module includes an ultrasonic transmitter, a receiver, and a control circuit. It emits a high-frequency sound wave and receives the echo reflected from a target object. The distance is calculated based on the time interval between sending the wave and receiving the echo.

Figure 4.8: HC-SR04 Ultrasonic Distance Measurement Module

LM393 Light Sensor Module LDR

The LDR Sensor Module is used to detect the presence of light / measuring the intensity of light. The output of the module goes high in the presence of light and it becomes low in the absence of light. The sensitivity of the signal detection can be adjusted using a potentiometer.

Figure 4.9: LM393 Light Sensor Module

GPS GY-NEO6MV2 NEO-6M module

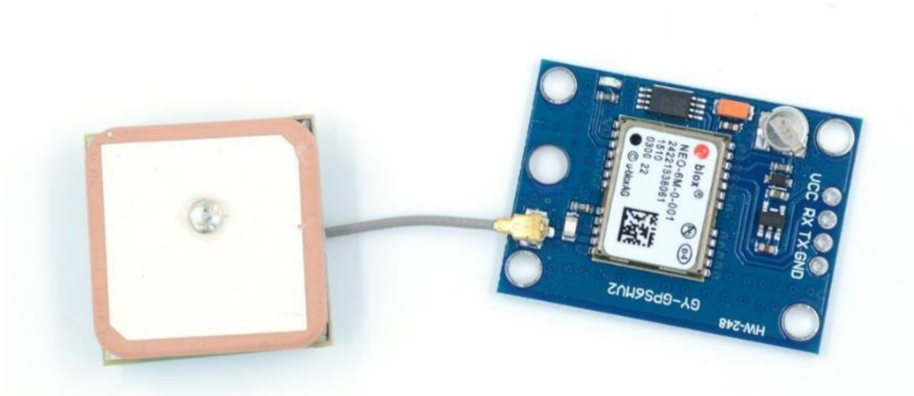


Figure 4.10: GY-NEO6MV2 NEO-6M GPS Flight Controller Module

4.1.5 Output Device

LCD and I2C

1602 I2C module is a 16-character by 2-line LCD display with Blue background and White backlight. The original 1602 LCD needs 7 IO ports to be up and running, but ours is built with Arduino IIC/I2C interface, saving you 5 IO ports. This LCD is ready to use because it is compatible with the Arduino Liquid Crystal Library. LCDs are great for printing data and showing values. Adding an LCD to your project will make it super portable and allow you to integrate up to 32 characters (16x2) of information. On the back of LCD display there is a blue potentiometer. You can turn the potentiometer to adjust the contrast. Notice that the screen will get brighter or darker and that the characters become more visible or less visible.

Figure 4.11: I2C LCD module 1602

Seven Segment Display

A seven-segment display is a form of electronic display device for displaying decimal numerals that is an alternative to the more complex dot matrix displays. Seven-segment displays are widely used in digital clocks, electronic meters, basic calculators, and other electronic devices that display numerical information.

Figure 4.12: WWZMDiB 4 Digit 7 Segment Digital Tube LED Display Board

LEDs 12v:

Light-emitting diodes (LEDs) are solid-state devices that transform electric energy into colorful illumination. LEDs do not waste energy since they use "cool" light generation technology, meaning that the low heat that is generated is not allowed to build up. What's more, LEDs are designed to be long-lasting and can be recycled as part of normal household waste because they don't contain hazardous chemicals or materials. One important but often overlooked aspect of LED lighting is the power supply required to operate these devices. In this guide, we will explain what LED power supply is and the different voltage options available. We will also discuss how you can determine which power supply you need for your LED lighting.

Figure 4.13: 12v LED

5volt LEDS:

A Super Bright 5mm LED is exceptionally bright with a wide beam angle, so they're suitable for use in your projects, illuminations, headlamps, spotlights, car lighting, and models. The 5mm LED can be used anywhere where you need low power, high-intensity reliable light, or indication.

Figure 4.14: 5volt LED

Laser

A laser module would include one or more laser diodes as well as some optical and electronic components that are used for running the diodes and beam shaping. All this is usually enclosed in a robust enclosure. The number of diodes used inside the module and its internal structure is set by module power output, laser beam parameters such us size (diameter) and divergence, and by other properties that are set by the application the laser module is intended for. The laser beam is emitted from 1 or more semiconductor laser diodes, then optically shaped, joined together and aligned to create a single and focused laser beam coming out of the aperture.

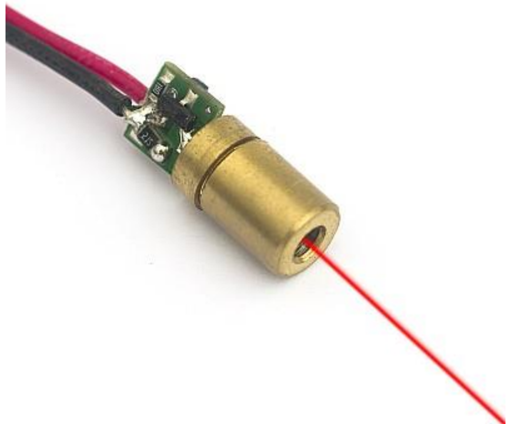


Figure 4.15 Laser module

2 Channel DC 5V Relay Module

The 2 Channels Relay Module is a convenient board that can be used to control high voltage, high current loads such as motors, solenoid valves, lamps, and AC loads. It is designed to interface with microcontrollers such as Arduino, PIC and etc. The relays terminal (COM, NO, and NC) is being brought out with a screw terminal. It also comes with a LED to indicate the status of the relay.

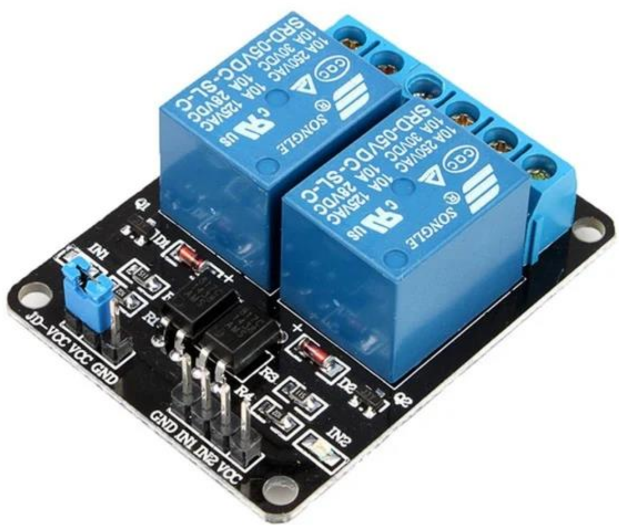


Figure 4.16: 2 Channel DC 5V Relay Module

4.1.6 Input Devices

RFID module-RC52

An RFID or radio frequency identification system consists of two main components, a tag attached to the object to be identified, and a reader that reads the tag. A reader consists of a radio frequency module and an antenna that generates a high-frequency electromagnetic field. Whereas the tag is usually a passive device (it does not have a battery). It consists of a microchip that stores and processes information, and an antenna for receiving and transmitting a signal. When the tag is brought close to the reader, the reader generates an electromagnetic field. This causes electrons to move through the tag's antenna and subsequently powers the chip. The chip then responds by sending its stored information back to the reader in the form of another radio signal. This is called a backscatter. The reader detects and interprets this backscatter and sends the data to a computer or microcontroller.

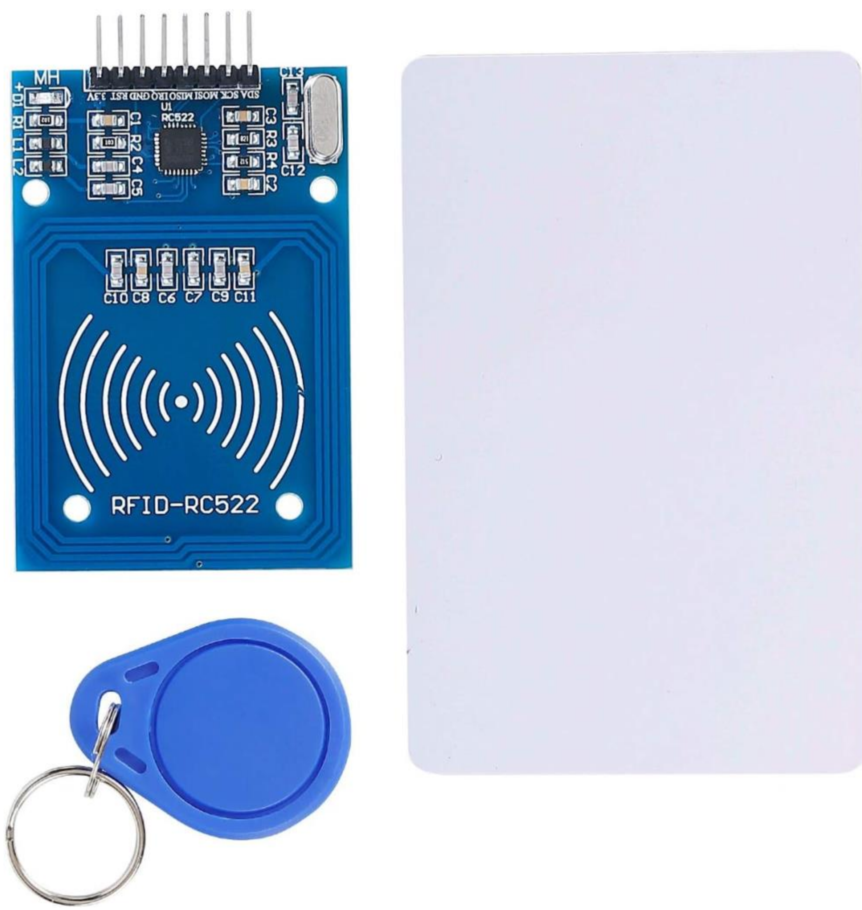


Figure: 4.17 RFID module-RC52

KeyPad 4×4

The 4x4 matrix keypad is a simple mechanism that resembles the numeric input on your computer keyboard, except that it has an additional '*,' '#' and 4 other auxiliary buttons that can be used for various functions in the application. The keypad is usually made of plastic materials and is relatively cheap compared to touchscreen displays. A 4x4 matrix keypad can be implemented separately or within the physical product itself, such as a security access controller, where it is used for PIN identifications. Either way, the mechanism of the mechanical keypad remains the same when hardware and firmware designers are concerned.

Figure 4.18 KeyPad 4×4

4.1.7 Power Components

Computer Power supply

Computer power supplies are designed specifically to power computers and their peripherals. They convert alternating current (AC) to low-voltage regulated direct current (DC) power necessary to run computer parts. The most important feature of these power sources is their efficiency. It is important that the input power to the power supplies is not wasted in heat generation. It provides various voltage output 3.3, 5, and 12 volts which provides the flexibility to use it for many devices and kits.

Figure 4.19: Seasonic 300W PC Power Supply, 100 → 240V dc Input, -12 V dc, 3.3 V dc, 5 V dc, 12 V dc Output

UPS Rechargeable Sealed Lead Acid Battery

A UPS Rechargeable Sealed Lead Acid (SLA) Battery is a maintenance-free, valve-regulated battery designed for reliable backup power. Its sealed construction prevents leaks, ensuring safe operation in various environments without the need for regular maintenance. The battery is rechargeable and offers a long service life, capable of recovering from deep discharges, making it ideal for repeated use in uninterruptible power supply (UPS) systems. Built with rugged construction and an impact-resistant case, it can withstand vibration, shock, and extreme temperatures, ensuring consistent and stable power output for sensitive electronic equipment.

Figure 4.20: UPS Rechargeable Sealed Lead Acid Battery 12V 7.5ah

Lithium Battery

A lithium battery is a type of rechargeable battery technology that leverages the unique properties of lithium, the lightest of all metals. Lithium batteries possess metallic lithium as an anode material. They are quite unique when compared to other batteries because of their high cost per unit and high energy density. A lithium battery operates on the principle of intercalation and deintercalation of lithium ions from a positive electrode material and a negative electrode material, with the most common type being the Lithium-ion battery.

Figure 4.21: 2500mAh Button Top 18650 Li-Ion Battery - 3.7V

Voltage Regulator

A voltage regulator module (VRM), sometimes called processor power module (PPM), is a buck converter that provides the microprocessor and chipset the appropriate supply voltage, converting +3.3 V, +5 V or +12 V to lower voltages required by the devices, allowing devices with different supply voltages be mounted on the same motherboard. On personal computer (PC) systems, the VRM is typically made up of power MOSFET devices.

Figure 4.22: DC-DC Adjustable Step-Down Voltage Regulator Module. 1.5-35VDC Output 2A

4.1.8 Other Devices

Magnetic Lock

An electromagnetic lock, magnetic lock, or maglock is a locking device that consists of an electromagnet and an armature plate. The principle behind an electromagnetic lock is the use of electromagnetism to lock a door when energized. The holding force should be collinear with the load, and the lock and armature plate should be face-to-face to achieve optimal operation.

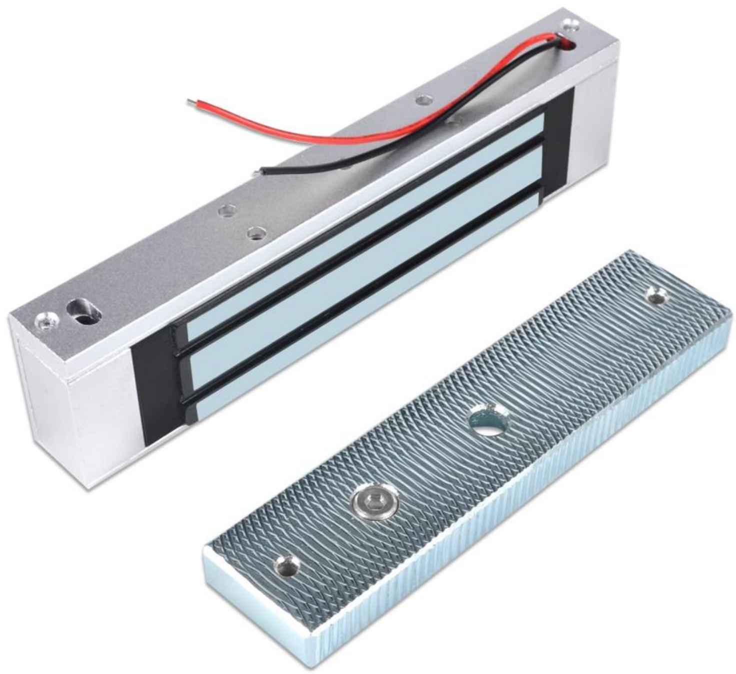


Figure 4.23 : Magnetic Lock

Pulleys

A pulley is a wheel on an axle or shaft enabling a taut cable or belt passing over the wheel to move and change direction, or transfer power between itself and a shaft. A sheave or pulley wheel is a pulley using an axle supported by a frame or shell (block) to guide a cable or exert force.

Figure 4.24: Pulleys

Breadboard

A breadboard was used to connect various components, such as the 5- and 12-volt power supplies, to the electronics that required these voltages.

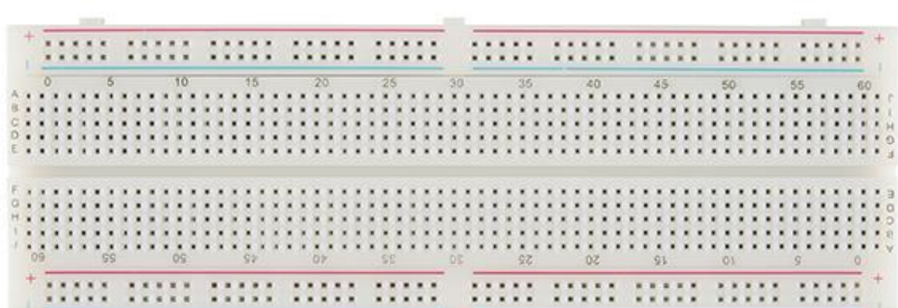


Figure 4.25: breadboard

Wires

We used many types of wires, jumpers, intercom, and buttery cables for various connections.

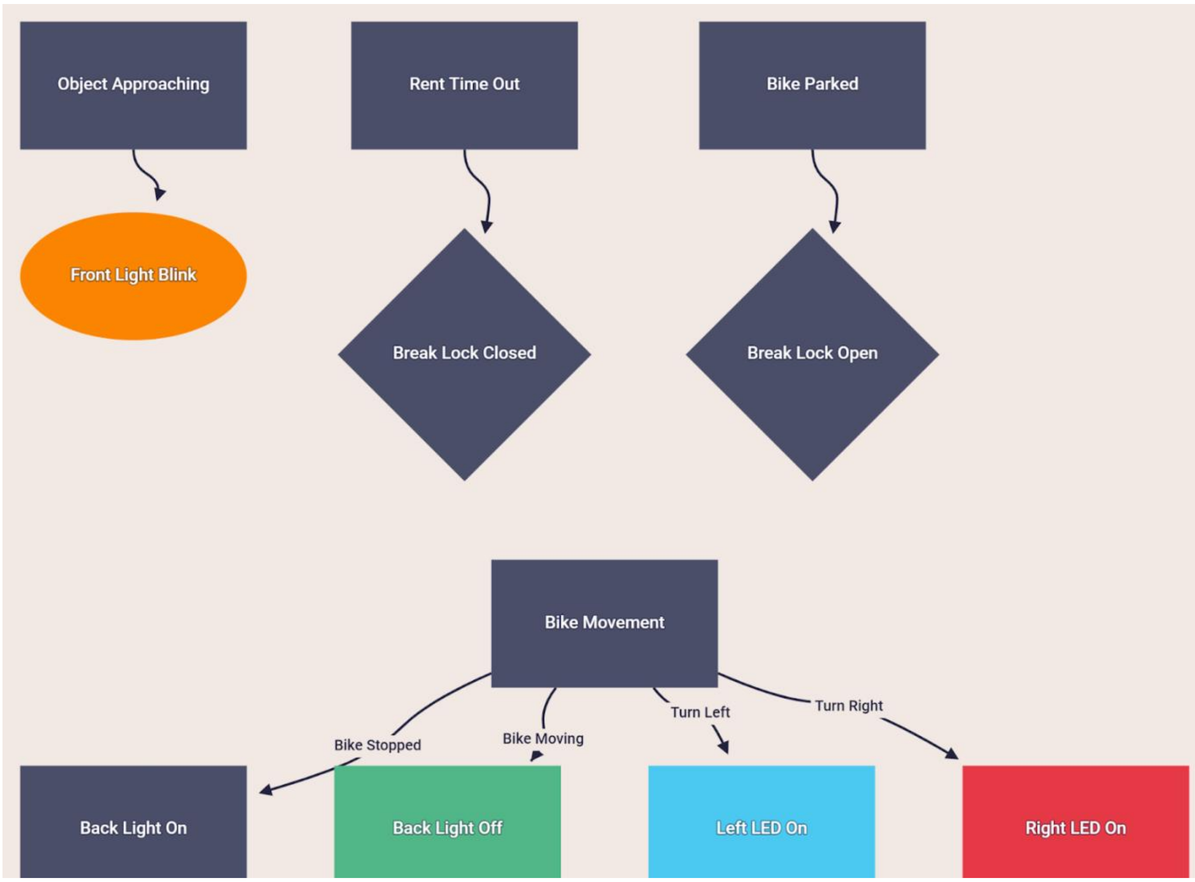
Figure: 4.25 jumpers

4.2 Hardware Implementation

4.2.1 flow chart

station:

Bike:

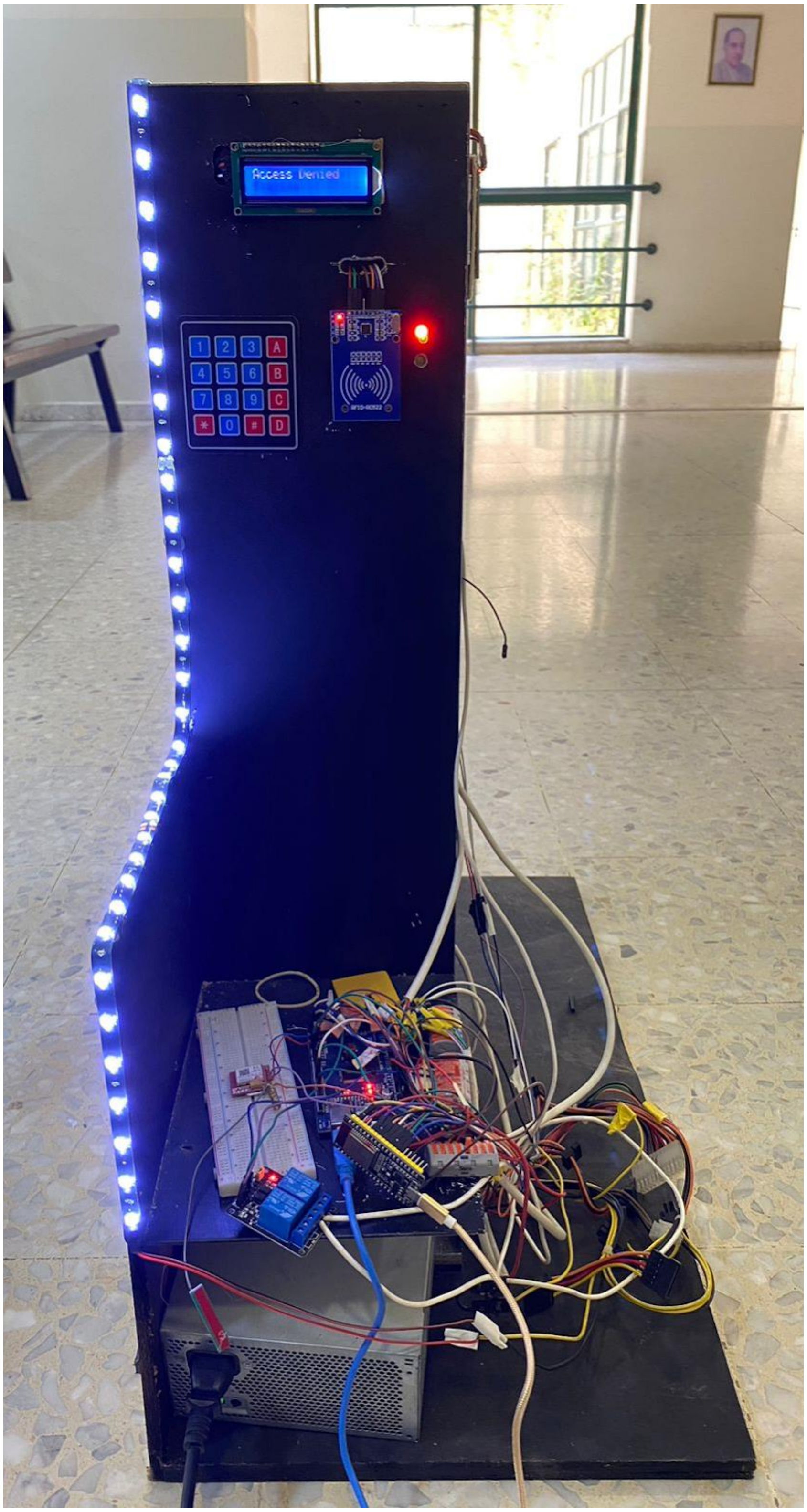

Object Approaching
Rent Time Out
Bike Parked
Front Light Blink
Break Lock Closed
Break Lock Open
Bike Movement
Bike Stopped
Bike Moving
Turn Left
Turn Right
Back Light On
Back Light Off
Left LED On
Right LED On

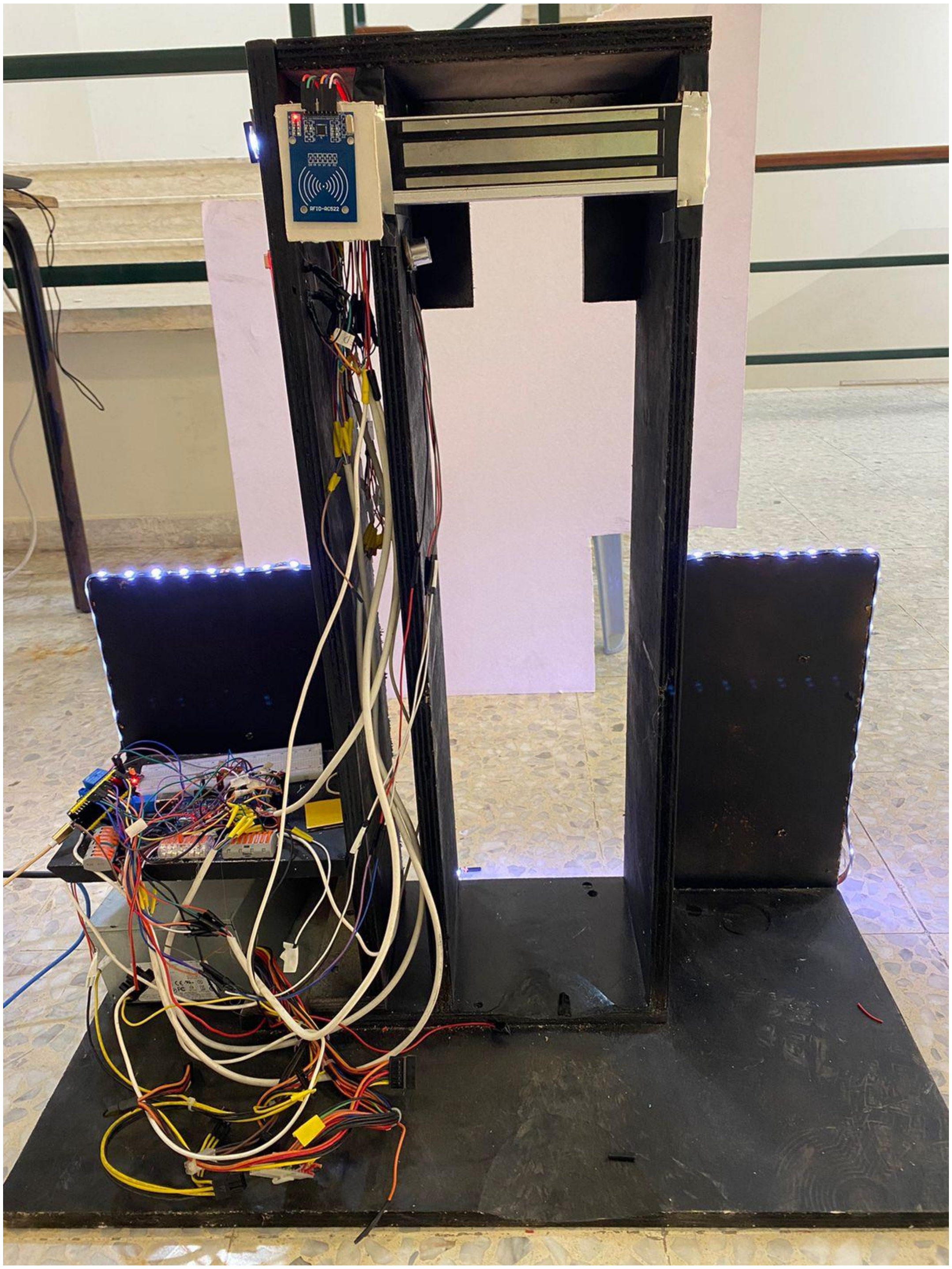
4.2.2 station

The first challenge was to decide how to choose a strong and reliable locking mechanism. Rental systems usually have specifically designed smart locks for secure docking and undocking rental bikes in public stations. The bike should be locked firmly inside the station, so we wanted a mechanism to handle bike weight and balance the bike while docking and undocking. We searched for many lock types, solenoid, bolts etc. those locks can't handle the weight of the bike and the position of the lock needs to be accurately located inside the plate. We tested big magnetic lock that handles up to 270 kg and it worked, we put the lock inside the station, and placed the plate in a well structured way on the bike in order to place the plate on the lock accurately.

The second challenge was to design a station that fits the bike and keeps its balance while unlocking, so we took accurate measurements and designed one. It had a problem, it wasn't strong enough so we needed to strengthen its structure.

These are some photos of the design evaluation:


Access Denied
1 2 3 A
4 5 6 B
7 8 9 C
* 0 # D


RFID-RC522

Bike Campus Hub station contains multiple components for user access and bike management. The station is equipped with two RFID readers, one for user access via a card and the other for reading the bike ID via a tag attached to the bike.

If the user doesn't have their card, they can enter their phone number on a keypad, which triggers a GSM module to send a random four-digit code to their phone. If the correct code is entered, access is granted, and the bike lock is opened. If not, access will be denied.

We used ESP32, which is connected serially with Arduino mega to receive students' info. ESP collects data such as card ID and phone numbers, in a real-time database, then it stores them in the real-time database. ESP reads from the firebase by connecting to wifi at 2.4 band, it compares the data to process the operations. For example, if the station is not available it reads that from ultrasonic stores it in the database then sends a command back to Arduino to deny access.

For user feedback, an LCD screen displays the station's status (active or out of service) and whether access is granted or denied. An ultrasonic sensor is integrated into the station to detect whether a bike is parked. A magnetic lock secures the bike when docked.

Access is denied when the bike is rented (i.e. when no bike is in the station), and it remains restricted until the bike is returned, ensuring the system can manage bike rentals efficiently.

The bike stations are distributed across four university facilities: Engineering, Art, Law, and Medicine. These stations are displayed on a map in the user application, with indicators showing the station's status (active or out of service) and whether bikes are available.

The system provides complete control to administrators through an admin website, where all stations and user data are visible in real time. The admin can monitor station activity, check availability, and manage user interactions, ensuring smooth operation of the bike rental system.

The computer power supply is used for the station, it provides multiple voltage outputs which gives us the flexibility to connect modules.

4.2.3 bike

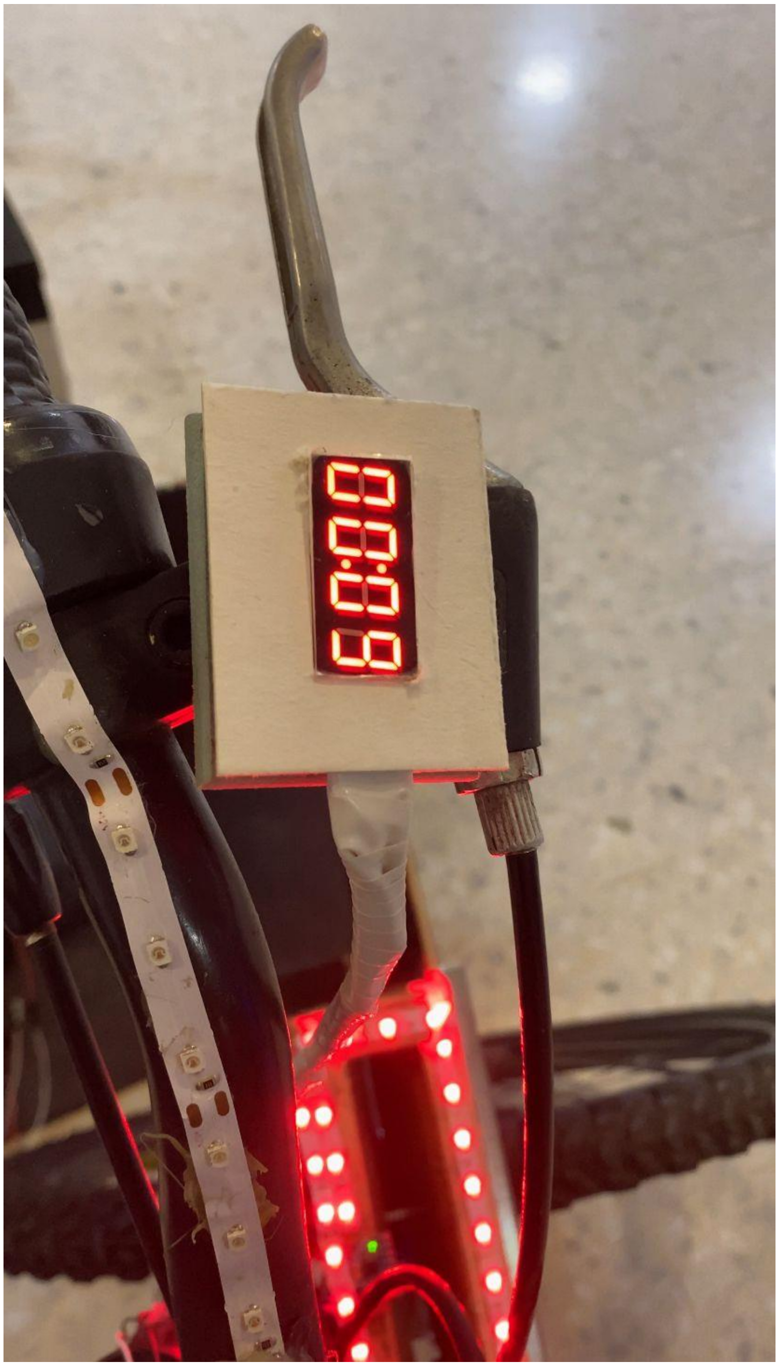
The bike is equipped with multiple smart and safety features to enhance the riding experience. It has 12V blue LEDs on both sides, controlled by an MPU connected to an ESP32. When the bike turns right, the right-side LEDs light up, and similarly, the left-side LEDs illuminate when turning left. A triangular 12V LED at the back of the bike lights up when the bike stops and turns off when it's moving.

To detect whether the bike is in motion, a laser and LDR system is used. The setup includes a sector-shaped piece of carton attached to the wheel, which interrupts the LDR values as the wheel spins, indicating motion. If the LDR value remains stable, it signals that the bike has stopped. For added safety, an ultrasonic sensor is connected to a 12V LED that starts blinking when an object approaches the bike or when the bike's upper frame gets too close to the ground, warning the rider to be cautious.

The bike's ESP32 acts as an access point (AP), wirelessly communicating with another ESP32 located in a smart vest (client). This setup provides additional safety, simulating the warning systems of a car.

For security, a stepper motor-based brake lock system engages when the user's rental time expires before returning the bike to the station. The lock opens once the bike is returned and secured at the station. A seven-segment display mounted on the bike provides a clear indication of the remaining rental time, ensuring the user is always informed while riding.

The timer counts to display the remaining time to return the bike,



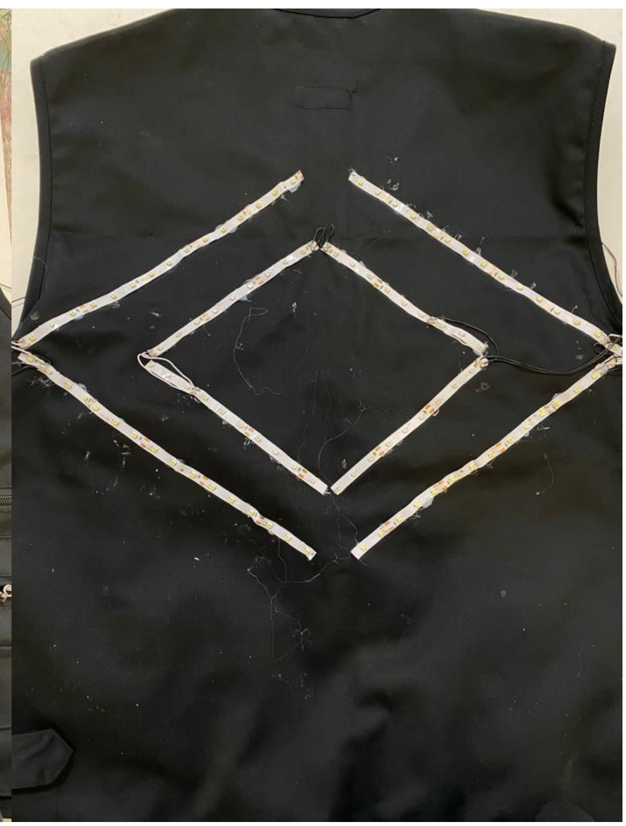
Locking mechanism used

Bike before Renewing:

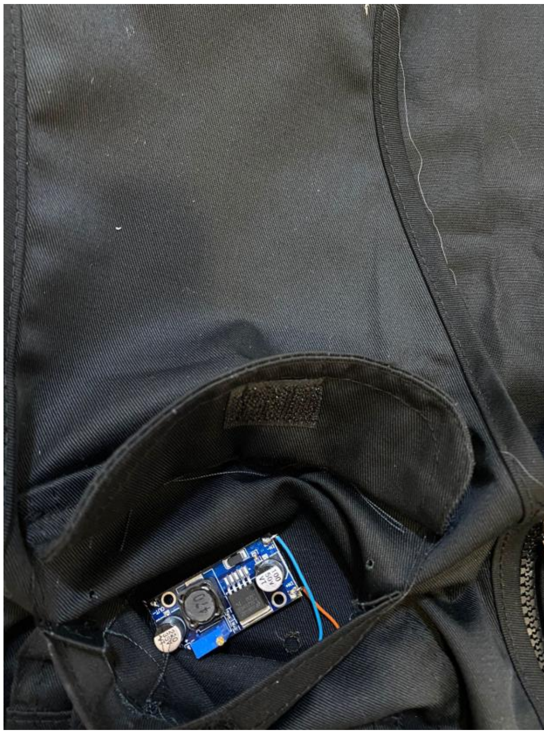
4.2.4 Vest

Searching for a vest to use was challenging. We needed to find a vest that could handle the hardware components and allow us to isolate them. The vest includes an ESP32 that functions as a client connected to a 2-channel relay to control three 12-volt LEDs. This ESP32 receives commands from an access point ESP32 located on the bike. When the bike turns left or right, the MPU on the bike detects the motion, and the access point ESP32 sends a command to the client ESP32 to light either the left or right LED wirelessly. Another command is sent when the bike stops: the LDR detects this, and when the bike stops, the center red LED blinks, turning off when the bike moves again. We also needed lightweight batteries, so we used lithium batteries and a voltage regulator to provide 5 volts to the ESP32 and relays. We ensured that everything was well isolated.

We took accurate measurements and sewed the strings to set the lights and the wires.



This is the vest after adding components:





Each component and wires are well isolated.

4.3 Software Implementation

4.3.1 Software Workflow

As we mentioned earlier, our hardware system is synchronized with a centralized database structure with which both the bikes and stations' ESPs communicate. All information is transferred from the Arduino Mega, located at the station, to the database through the ESP, and from the Arduino Uno on the bike. The admin has a dedicated website to access the system, and students have a mobile application to get the necessary station information.

Students can access the system either using RFID or phone numbers. Each RFID card is associated with a unique key, and to ensure the system is well-structured, each card is mapped to a specific student with a unique student ID, esp makes the research and compares entered info with data stored in the firebase. When a student tries to access the system by entering their phone number, the number is mapped to the student's name and ID. This is why, when a user accesses the system, the Arduino sends all the data serially to the ESP, which stores it in the database.

The bike ID is also read by placing a tag on the bike, which is scanned by another RFID reader located at the station. This ID is then associated with the user who accessed the bike.

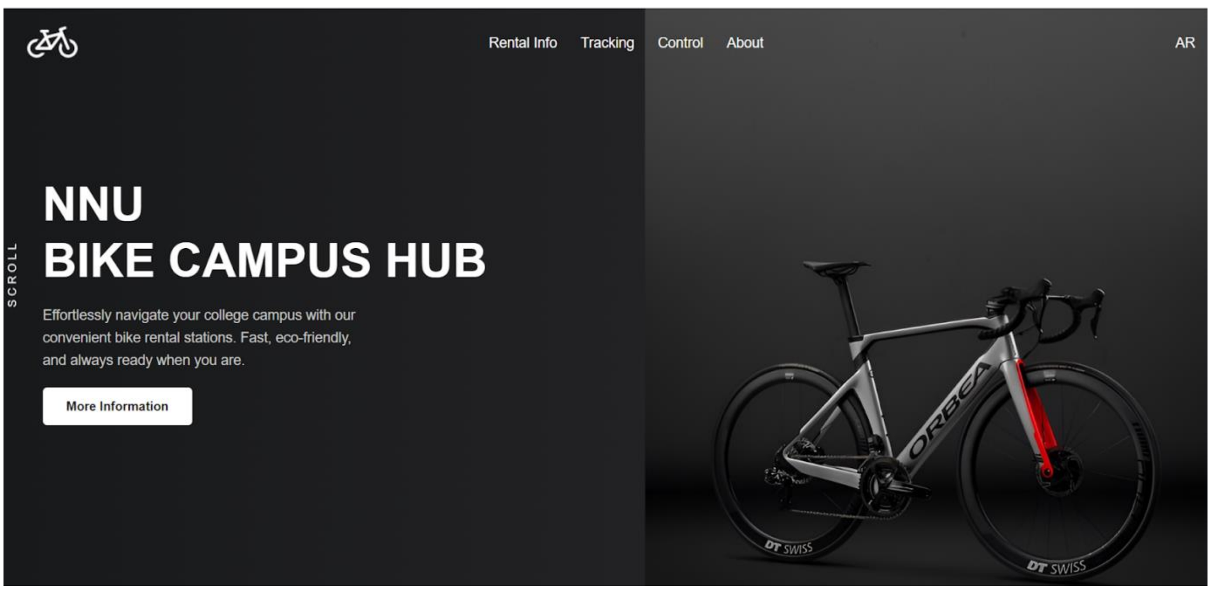
Several conditions must be checked: the student's rental status must be set to "false" to enable the rental process. During this time, the admin has set a rental timer, which is visible to the student either on the bike's display (via the seven-segment display) or on the app. If the timer expires and the student has not returned the bike, a timer flag is set to 1, and the ESP sends a command to the Arduino Uno on the bike to trigger the lock and apply the brakes. The bike status will remain "false," the timer counter will reset, and the flag will be set to zero once the bike is returned.

4.3.2 Admin Website

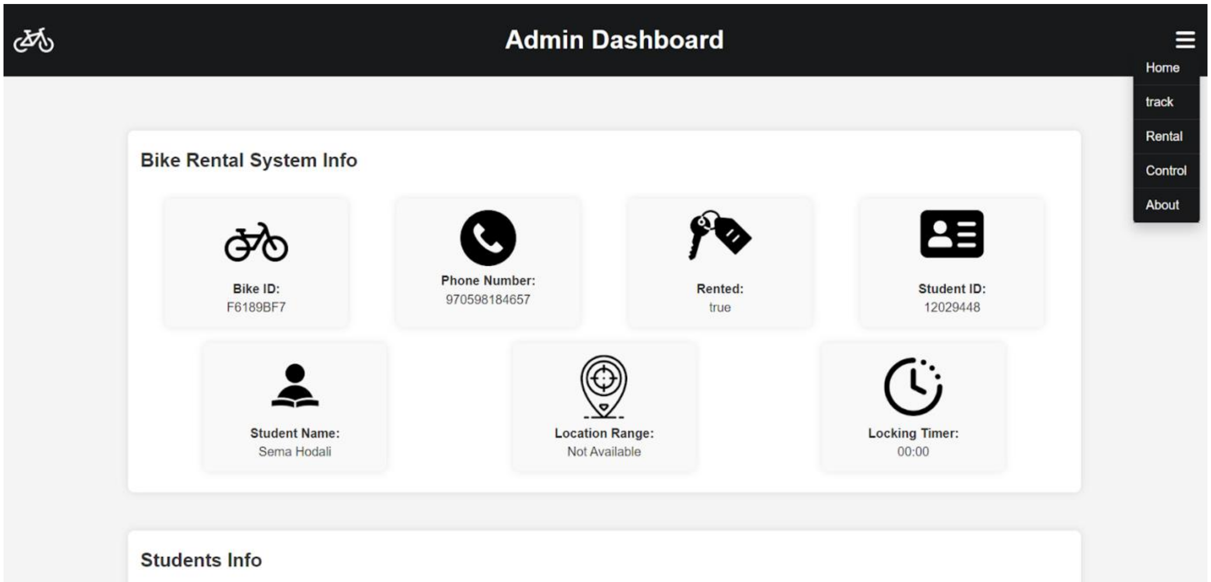
The admin has a homepage introducing them to the system, and an "About" page to instruct them on how to use the website. The "Rental Info" page represents the admin dashboard, which enables them to track all the information and data stored in the database. The "Tracking" page displays the locations of the bikes, including the bike ID, the student currently renting the bike, the distance traveled, and the status of the stations (whether they are available or not). Stations marked as unavailable will be shown in red, while available stations will be shown in green. Additionally, the admin has a control page that allows them to set the timer for each campus station and activate or deactivate stations.

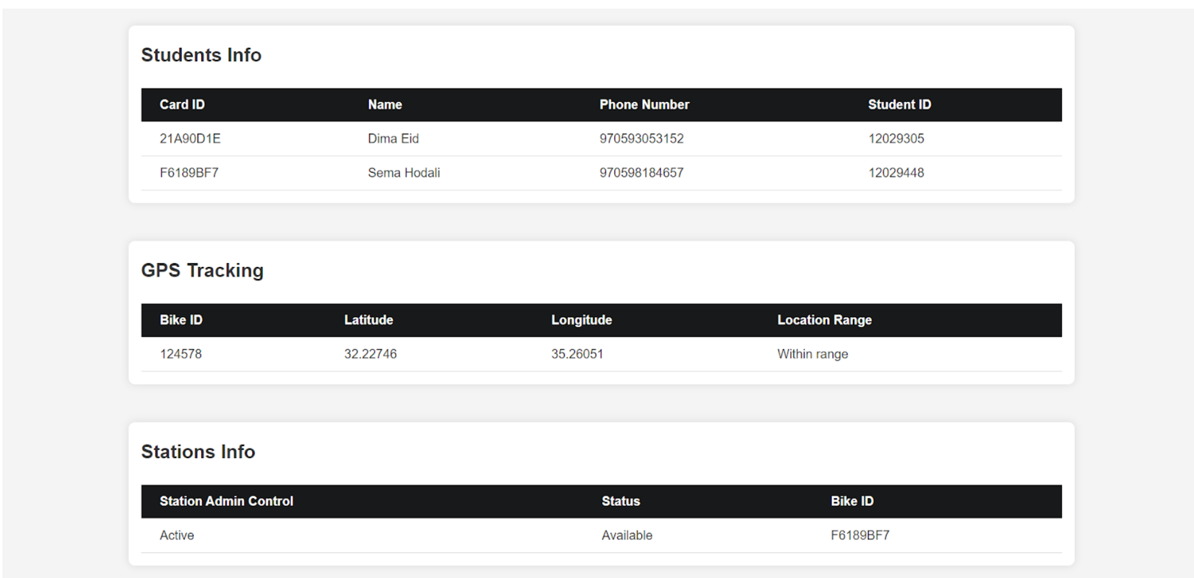
If students try to go beyond the university's boundaries, the ESP will send a command to the Arduino, triggering the motor and locking the bike. This is achieved by mathematically computing the central location of the university and the surrounding area.

Home Page contains all the sections

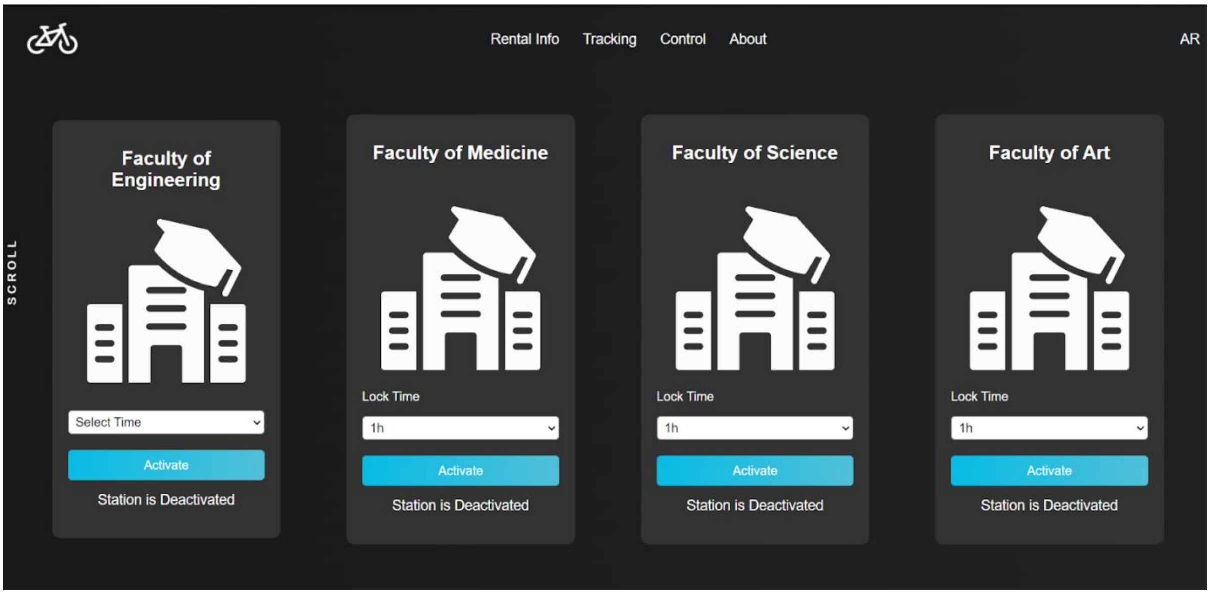


Admin dashboard in Rental info section

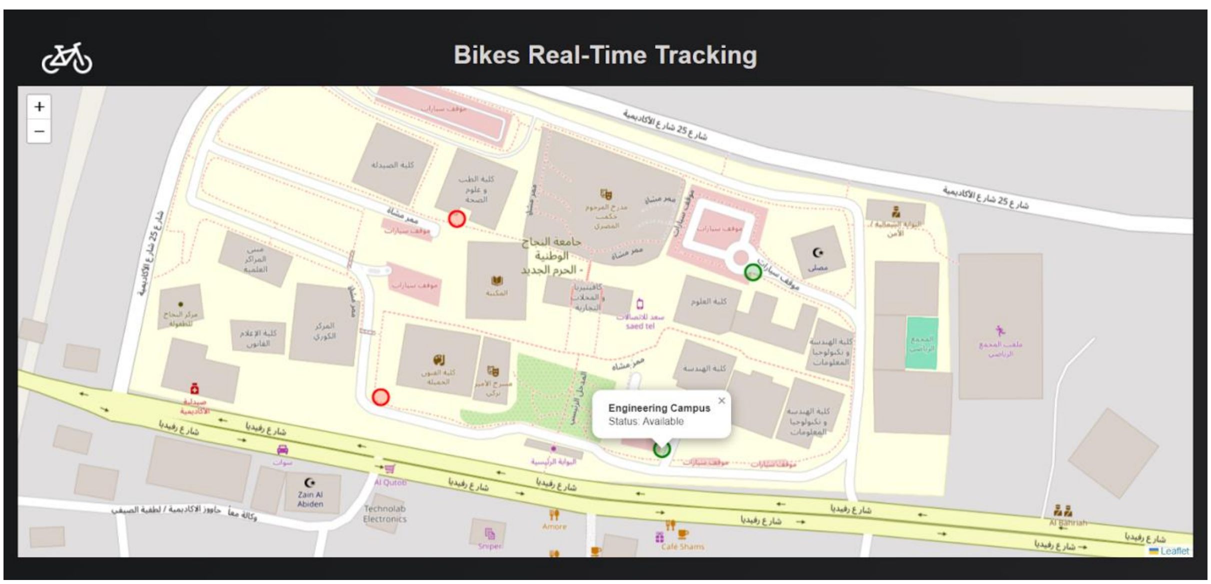


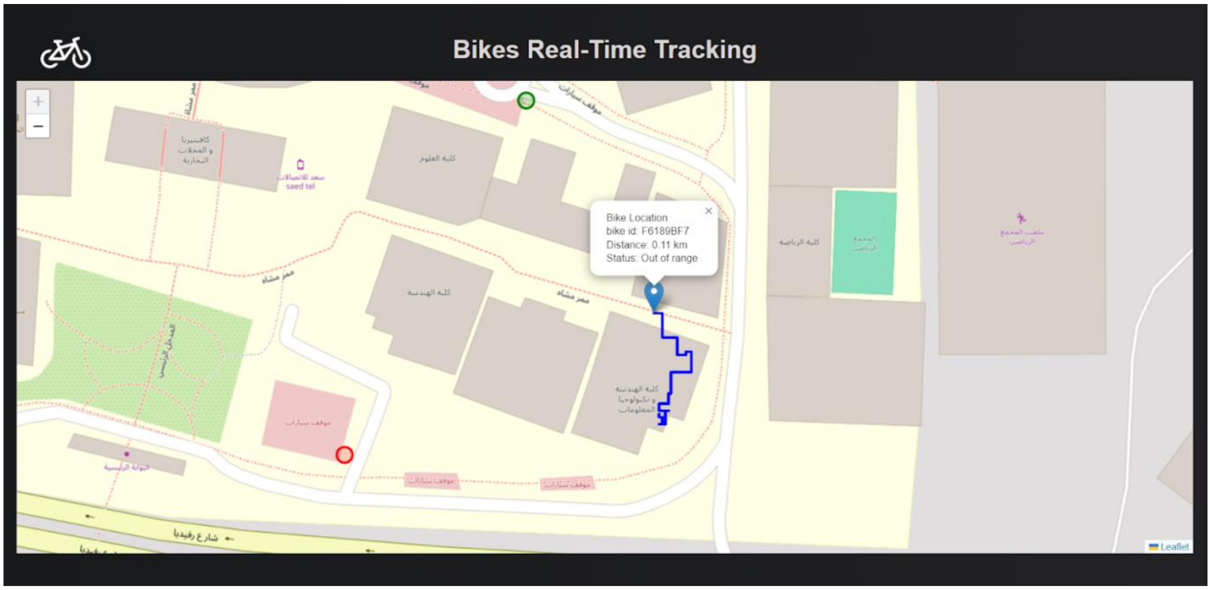


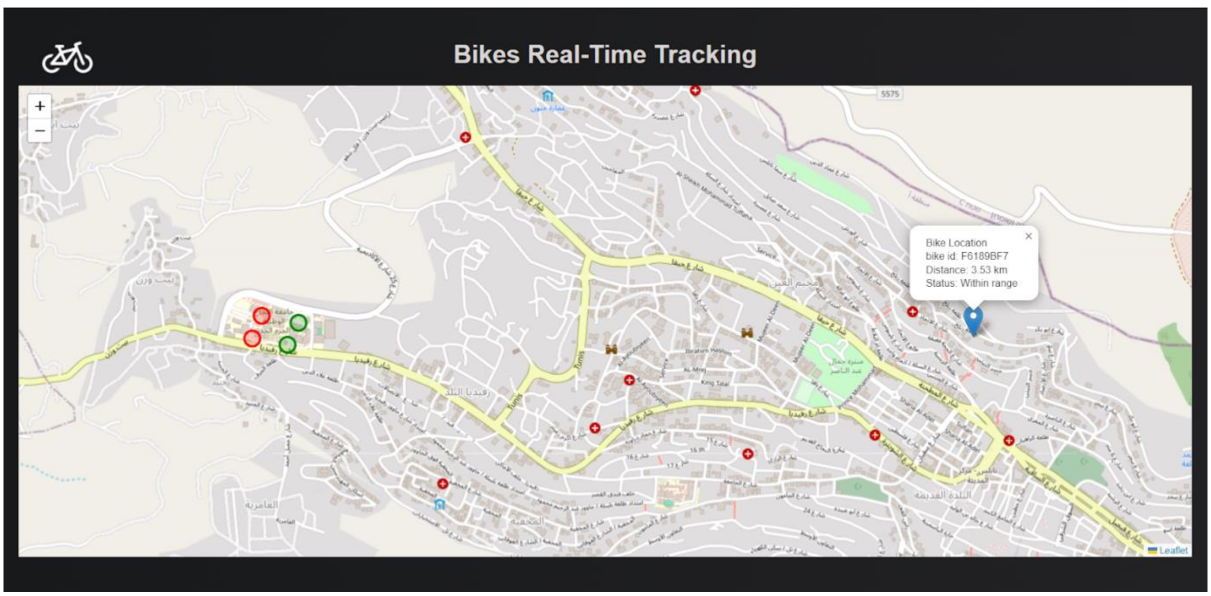
Control Page selecting station timer and activate and deactivate station.



Tracking page available stations are green, not available are red. Location is defined, as bike id, and distance traveled.

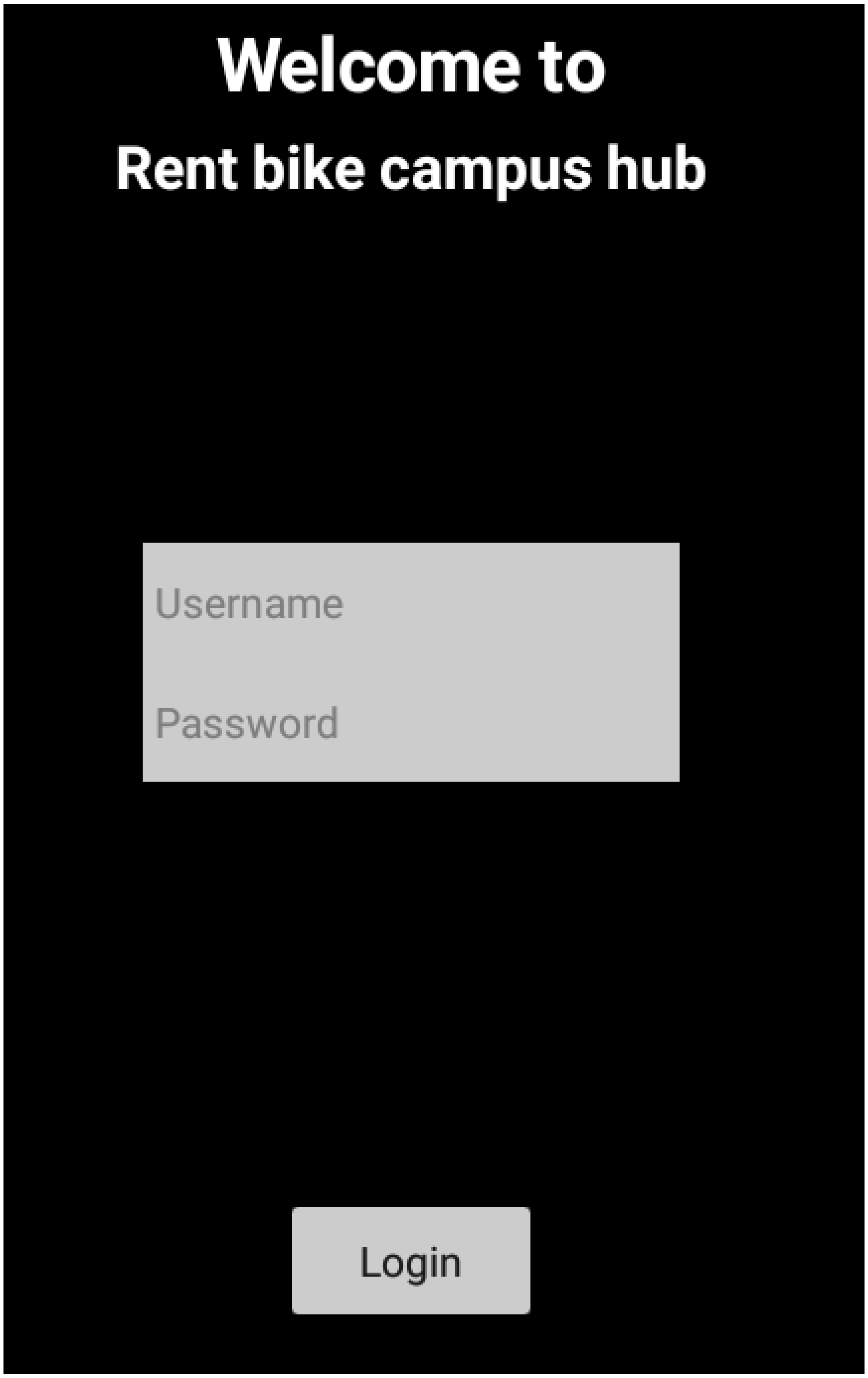



Bikes Real-Time Tracking
Bike Location
bike id: F6189BF7
Distance: 0.11 km
Status: Out of range
Leaflet

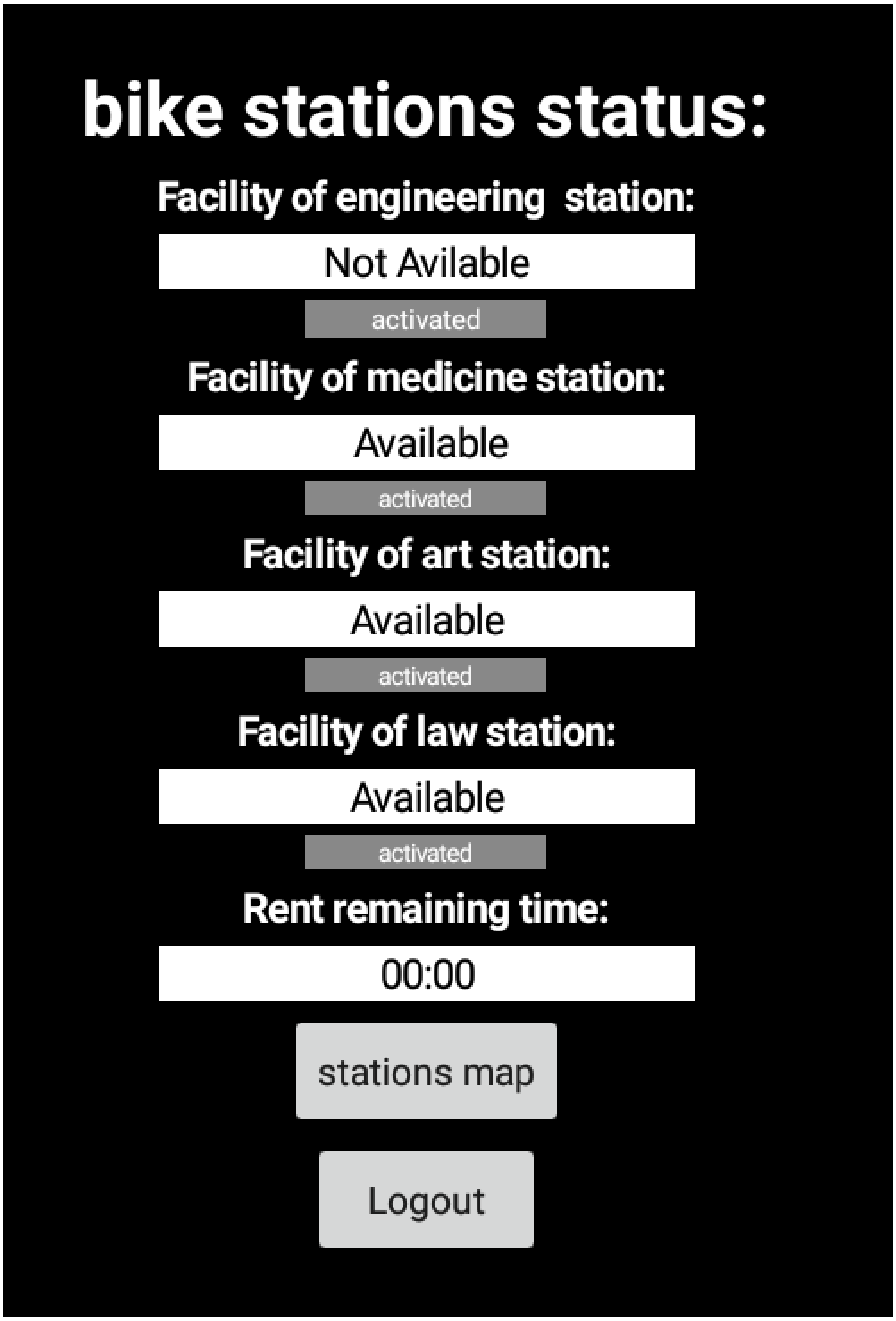

Bikes Real-Time Tracking
Bike Location
bike id: F6189BF7
Distance: 3.53 km
Status: Within range
Leaflet

4.3.3 User Application

The user phone application has three screens, first is for login with user Username and the user's card ID as a Password.



When Password is correct, the user login and monitor stations status screen which shows the status of campus stations and bike rent remaining time.



The third screen shows the location of all campus stations in the map with an indication if the station is active and available or not.

Chapter 5: Results & Discussion

In our journey to build a Bike Rent Hub system, we faced some challenges first with the type of bike lock that can bear the bike weight, we chose a magnetic lock.

With the breaks lock design and stepper motor type which can pull and close the bike breaks

There are some issues with esp serial communication with Arduino Mega and timing issues between them.

We solved our challenges by searching and asking persons with experience and taking advice.

Chapter 6: Conclusion and Future Work

6.1 Conclusion

We built a complete rental bike system for university campus for easier student transportation between facilities and saving their time.

Our system consists mainly of three component, first station where the bike parked ,it lock the bike by magnetic lock for security and has two way to access and open the lock, by access card or by phone number,and its deny any access if the bike is not parked.

Second, the bike has mpu to detect its direction and turn on LEDs according to it, and stepper motor located on the bike breaks to close it when the user used up all the time allowed and open the break if the bike parked again.

Finally the bike rider vest which indicate the bike direction wirelessly and show it with 12V LEDs to the back rider, with stop LED turned on if the bike is stopped.

This three component form a complete system with enhanced security and safety for better bike ride experience.

6.2 Future Work

1. **Create Predictive Maintenance**

   Implement maintenance algorithms that automatically alert the admin when the system requires maintenance based on usage data and sensor readings.

2. **Power Solution**

   Create smart UPS. Our system has rechargeable batteries, so we would like to create an automatic rechargeable system to detect the voltage of the batteries and charge them using a solar system or energy generated by bike movement to make it environmentally friendly.

3. **Scalability and Expansion:**

   The system could cover larger areas and have sufficient stations and bikes to cover users' demands, especially in peak times.

References

[1] Y. Lin, J. Xu, J. He, X. Meng, Y. Wang, and S. Wang, "Design and implementation of campus bike rental system from the perspective of sharing economy," in Proc. 2022 Int. Conf. Comput., Inf. Process. Adv. Educ. (CIPAE), Ottawa, ON, Canada, 2022, pp. 131-135. doi: 10.1109/CIPAE55637.2022.00035.

[2] Hungarian rental system, "Tbike bike sharing system," [Online]. Available: https://tbike.hu/en. [Accessed: Sept. 7, 2024].

[3] Delta Advanced Systems, "Professional supplier of Extra Low Voltage, Security, and Safety Systems," [Online]. Available: https://www.delta.ps/. [Accessed: Sept. 7, 2024].

[4] OnBikeShare, "Bike share for colleges," [Online]. Available: https://www.onbikeshare.com/bike-share-for-colleges/. [Accessed: Sept. 7, 2024].E. H.-C. Lu and

[5] Z.-Q. Lin, "Rental Prediction in Bicycle-Sharing System Using Recurrent Neural Network," IEEE Access, vol. 8, pp. 92262-92274, 2020, doi: 10.1109/ACCESS.2020.2994588.