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A Low-Cost Smart Office Design Framework Using Arduino

Ssemwogerere Rajab[1,2,3], Nabagesera Veronica Kawalya[4], Melese Alemsra Tsehayu[5], Logose Masitula[1], Wamwoyo Faruk[1,2], Rahman Shiddiqur[6], Ekwaro Dominic[2], Mbalyowere Pasis Maritah[4], Nambobi Mutwalibi[1], Sayo Nakeleh Turay[3], Mugerwa Derrick[1], Kasagga Usama[1], Seguya Asad[1]

[1]Department of Computer Science & Information Technology, Islamic University in Uganda, Kampala, Uganda
[2]College of Computing & Informatics Technology, Makerere University, Kampala, Uganda
[3]School of Information and Software Engineering, University of Electronic Science & Technology of China, Chengdu, China
[4]School of Computer Science, Neijiang Normal University, Neijiang, China
[5]School of Computer Science and Engineering, University of Electronic Science & Technology of China, Chengdu, China
[6]School of Information and Communication Engineering, University of Electronic Science & Technology of China, Chengdu, China
Email: srajab@std.uestc.edu.cn, nabageseraveronicak@gmail.com, alemsratsehayumelese@gmail.com, logosemastula@gmail.com, faroukissa85@gmail.com, shawon.rohman232@gmail.com, dominicnoelchris@gmail.com, maritahspasis@gmail.com, twalib67@gmail.com, sayoisha@gmail.com, deromatickibuli@gmail.com, kasaggau@iuiu.ac.ug, sgyasad@yahoo.co.uk

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Abstract

The main motive of our research work is security enhancement and light energy conservation. This paper describes a study investigating the potential of a controlled office solution by integrating the Internet of Things (IoT) with wireless sensor networks (WSNs). A prototype of a smart office is developed using a global system of mobile Bluetooth and Radio Frequency Identification (RFID) technology. The user can turn on and off the fan remotely at any time. This prototype focuses on security and provides human-friendly assistance when in or out of the Office by integrating a mobile application platform. The innovative automated smart Office is designed with intelligent Security doors, lights, alarms, temperature humidifiers, and bright Liquid Crystal Display (LCD) screens for viewing. Our study has opened up virtual possibilities for producing cheap innovative frameworks in this Generation of IoT and the fifth Generation (5G) technology. Therefore, when implemented, this innovation will ease and improve human quality of life. So, this paper aims to provide a low-cost, effective Internet of the things-based automated smart Office.

Keywords

Intelligent Office Automation System, Wireless Sensor Networks, Internet of Things, Ultrasonic, Radio Frequency Identification, Arduino

1. Introduction

An office is a built environment where people in an organization work to provide a particular service or handle particle activities [1]. In line with Office, the popularity of using home automation technology is increasing daily. More research in recent years has focused on the Internet of Things (IoT) under the home domain as the most important research area of IoT [2]. However, humans spend much of their day in offices (almost 8 hours in Office at Work). Hence, offices should also be made much more comfortable to protect human health, reduce risk, and improve employee efficiency [3] [4]. An office can be made more comfortable like a home with automated lighting, remotely controlled and monitored using a smartphone. In simple terms, this can be called an Intelligent Office [5]. This kind of Office can be achieved using modern advanced technologies which are advancing day by day, for example, the 5th generation technology [6], Artificial Intelligent (AI), and the IoT [7]. Karol Furdik defined a smart office as an application of the IoT covering all features supporting intelligent behavior in the work environment of office rooms [8]. After and during busy office hours, it is so difficult to be so keen to switch on and off the lights when in and out of the Office after Work.

In addition, controlling the air condition of the place since weather is dynamic and being so vigilant to the security matters of who is authorized to access an office and who is not. But with an automated smart office, everything becomes a myth. People prefer simple ways to improve their lifestyles using the latest advanced technologies in this modern era. Therefore, any new advancement that promises to enhance their lifestyle is immediately grabbed and adopted. Automation has existed since the 1970s with various concepts [9] [10]. Despite the advancements in technology and services, automation has not yet fully penetrated many African communities and societies [11] [12]. For example, Uganda, a country in eastern Africa, is famously known as a pearl of Africa [13]. Many office owners still manually open and close doors and windows and switch on and off the fan. The conventional wall switches are located in different parts of the office, thus necessitating the manual process of switching them on or off. It is hard to control all appliances running and to monitor their performance.

Additionally, most offices still use padlocks to enhance security at work premises. If the keys are lost, doors or sometimes windows are broken to gain access. These actions increase maintenance costs, create unnecessary movements of office occupants, especially during busy office hours, and even make them pay less attention to the office workloads due to an uncomfortable workplace. Sometimes they forget to switch off the lights and electric appliances like the air conditioners when they leave the office. Therefore, this calls for automated smart office systems that operate effectively and create a comfortable workplace environment where users feel at home [14]. Smart automation systems have developed over time and have always tried to provide efficient, convenient, and safe ways for inhabitants to access their places [15] [16] [17] [18]. Based on the built-up access models, similar technologies have been copied and implemented in designing this low-cost intelligent office framework. A lot of research and findings about smart offices have been done, making our module accessible and remotely controlled via a Bluetooth module.

Most existing research mainly focuses on individual modules such as security and lighting [19] [20] [21], which leaves the concept of an intelligent office incomplete. The available built-up and complete systems are complex, require internet connectivity, and are not affordable for low-class startup businesses. Hence the concept of innovating this low-cost smart office design framework.

This system uses Bluetooth technology that controls several components in and around the office using an Android smartphone. The three main modules of our framework are: security, energy efficiency, and cost-effectiveness compared to the other available automated smart office frameworks.

The Objectives of the Low-Cost Smart Office Framework

- The proposed framework provides a prototype smart office design that users can easily use.
- To provide an Arduino implementation for real-time applications of many sensor hardware and software with no internet connectivity.
- To design a low-cost automated smart office System locally controlled using a smartphone and based on Bluetooth technology.
- To provide user-friendly graphical mobile interfaces to control and monitor their offices remotely.
- To secure Identification and authentication of users using the Keypad and RFID security metrics.

2. Related Works

Many related findings, articles, and papers about smart office automation systems are mentioned and referred to, focusing on different controlling subsystems, and the results of various publications from different papers are discussed in this segment.

On the aspect of smart work and living in an office, [4] presents a smart office with subsystems; lighting, heating, security, and alarm system, on which sensors extract real-time data from the environment that is controlled and processed by the ARM controller giving the output to the fan, bulb, buzzer that makes a reaction when the systems exceed the magnitude and intensity value. They also analyze weak and insecure security systems and recommend using the fingerprint identification biometric module for a highly secured system due to the fast and growing technologies that need a highly secured system instead of using the RFID that can be stolen and used that specific Identification to enter. Their proposed system is limited since it may require internet connectivity for efficiency, which inversely calls for more costs.

The Work of Chakrapani Selvaraj [17] further explains the concept of smart office automation, whose main motive is to save electricity, considering switching on and off the fan and the light automatically based on sunlight intensity sufficiency within a small interval. He uses the Light Dependent Resistor (LDR) that senses the sunlight intensity, a Passive Infrared (PIR) sensor that senses the motion of human beings, Logic gates, a Voltage comparator, and an Electromagnetic relay. He also thought of the occurrence of any problem in the circuit. They went further by providing both automatic and manual modes that could be interchanged accordingly in case of any problem arises to avoid interruptions.

Arun Radhakrishnan and Vuttaradi Anand's [22] focus on light and bears two aspects, human presence and intensity of light. It uses a PIR sensor (Parallax 555 - 28027) to first checks the availability of any occupant in the room that tracks any movements present, then uses LDR (NORP 12) to check the intensity of light that is needed, sufficient and satisfactory for the users and then switches on the sufficient light in case the light is low.

Sharma HK and M Sharma [23] proposed a home security system using IoT that uses a handheld mobile phone for controllability to either allow or deny access to the home using IoT using the Raspberry Pi, PIR sensors, a fingerprint module, and a motor that is connected to the Raspberry Pi when the PIR sensors detect the presence of any human beings, the relays are activated then lights are switched on, on the side of accessing the home, someone is first verified by fingerprint scanning and if it matches, they will be granted access, if they don't match they will be denied access, their face will be captured, sent by the camera to the homeowner using the telegram application so that the owner can verify the person trying to access his home, and then can either allow or deny access to that person.

Jay P. Sipani, Riki H Patel, and Trushit Upadhyaya [24] developed a fully automated, accurate smart system that could correct values of the temperature and humidity using wireless sensor networks such as the temperature and humidity sensors (DHT11) for sensing the environmental conditions, liquid crystal display (LCD) for displaying the results or the output, SIM900A GSM module to act as a communication unit, measure temperature, and humidity values which range from 0˚C to 50˚C and 20% - 90% respectively. When the temperature exceeds the maximum, the cooling peripherals are automatically turned on, and an SMS is also sent to the mobile device and displayed on the LCD.

3. Methodology

When designing the low-cost smart office design framework, our case study was made on a big room partitioned into two offices (The academic registrar and the secretary) plus one corridor. But we concentrated mainly on the main Office of the Academic Registrar. However, also the other Office was catered for. The system was composed of two different security modules, the outer door and the inner door, as illustrated in the flowchart (see **Figure 1**), and also accompanied by two other modules, namely, the temperature and humidity module and the

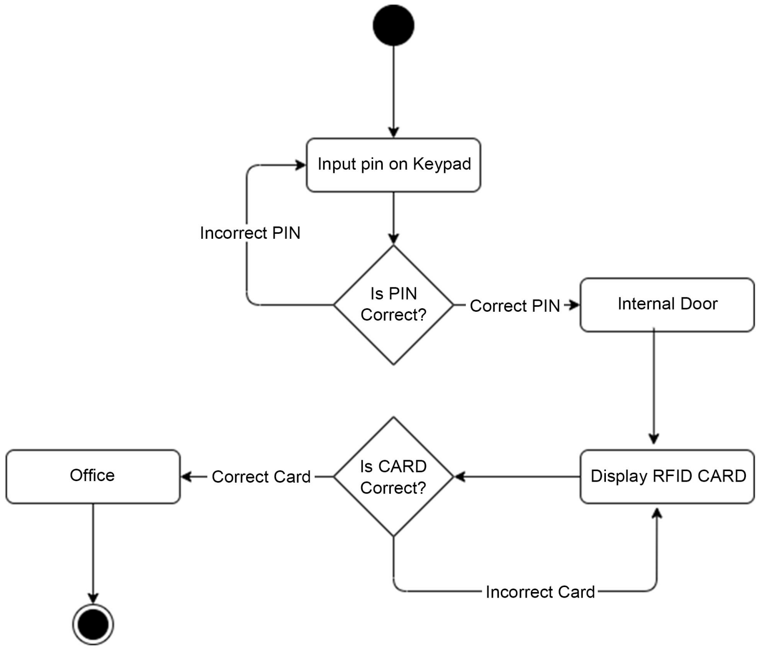

Figure 1. Flow chart of the system's outer and inner doors security part.

lighting module. The temperature and humidity sensor (DHT11) is placed inside the main Office, and lights are allocated into different places, one in the main Office, another in the office corridor, and the other in the secretary's Office. We can also use an Android smart mobile with a simple application to switch the lights in the offices and corridors on and off.

3.1. Authorization and Authentication Process of the External Door Module

The initial stage, or lowest process of our smart Office, is about how to access our Office. Someone has to bear a four-secret digit pin. This pin is pressed using the keypad as these hidden characters are displayed on the LCD 16 × 2-character screen. When the pin is correct, the servo motor will open the door, and this person will be granted access through the first entrance of the Office. The door is locked again after a small delay of about five microseconds. In case the pin is wrong, a single beep of the buzzer is triggered, then the user will be given a trial of three times to gain try to put in the pin. If the pin is wrong three times attempts, the buzzer will be triggered. The setup work flow of this outer door is demonstrated in Figure 2.

3.2. Authorization and Authentication Process of the Inner Door Module

When access has been granted to the user through the first door, the ultrasonic sensor (HC-SR04) located just opposite the outer door starts measuring the user's distance using ultrasonic **transducers** emitting ultrasonic sound waves. When the user gets close to the door in a range of 4 cm, a single beep of the buzzer is triggered to notify someone inside about someone just getting close to

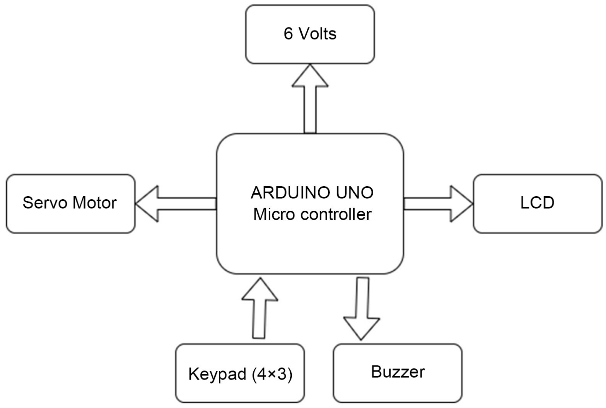

Figure 2. Set up the connected components to the Arduino UNO of the outer door.

the Office, and the user's distance is always displayed on the LCD screen in the Office. The Radio frequency identification system (RFID) helps to authenticate the user when accessing the Office. It uses electromagnetic fields to uniquely identify tags or objects and uses a communication model via radio waves between the readers and tags. The RFID reader emits radio waves using the radio frequency signal generator. If the user presents the right tag having the right serial key that was initialized in the database, a short piezoelectric alarm is triggered, and a green signal LED bulb placed just above the door goes on, signifying the user that they have been granted access and servo motor opens the door. The door is locked again after a small delay of about five microseconds. A red LED bulb goes on when a wrong card is presented for office access, signifying the user that they are using the wrong card and aren't meant to access the Office. When the user makes more attempts using the wrong card more than three times, a long piezoelectric alarm tries to notify the surrounding about an intruder trying to access the Office.

The security module is based on an RFID, a keypad that requires user pin input and is authorized to access the Office. An infrared sensor module is responsible for automatically controlling the outdoor light system. When it detects infrared radiation in its surrounding environment (a human), it puts on the lights. The Bluetooth module controls indoor lights in different sub-sections of the Office and electronic appliances (fan). A mobile interface platform provides an interface for a user to control the Office, turn the lights and the fan on, and view the temperature and humidity conditions. So, with our smart Office, we can see and know the temperature and humidity conditions using the smart Android phone interface plus also the liquid display (LCD) screens in the smart Office. The DHT11-Temperature humidity module is used as a temperature and humidity sensor. It has a dedicated NTC to measure temperature and an 8-bit microcontroller to output the current temperature and humidity values as serial data. When high temperatures are detected (temperature $\geq 26^{\circ}C$), the fan starts automatically, and (temperature $< 26^{\circ}C$), the fan stops automatically. The mobile platform controls and monitors light and the electronic appliance (fan). This is also well demonstrated in **Figure 3**, showing all the sensor-connected devices and components connected to the Arduino Mega microcontroller.

3.3. The Lighting Module of the Main Office, Secretary, and Corridor

The main Office is automated with the lighting system and uses the Android smart mobile phone. When the user enters the main Office, the secretary's Office, or the corridor, the PIR sensor perceives the difference in the infrared Energy based on warmth emitted by humans in motion. These changes trigger the light. And when the user is in the Office, they can switch on and off the lights using an Android smartphone application connected to the system using the Bluetooth module.

3.4. Temperature and Humidity Module

This subsystem uses the DHT11 temperature and humidity (see **Figure 4**). The DHT11 measures the relative humidity by using the humidity sensing component that holds the moisture and compares the density of water vapor and the density of water vapor at the saturation point, which changes with the air temperature, in a way that cold water vapor holds less vapor and worm or hot water vapor holds more water vapor before it becomes saturated at a point. The humidity is expressed in terms of a percentage of the density of water vapor and the density of water vapor at saturation, as shown in Equation (1) below:

$$\text{Relative Humidity} = \left(\delta w / \delta s\right) * 100\% \quad (1)$$

δw : *Density of water vapor*;

δs : *Density of water vapor at saturation*.

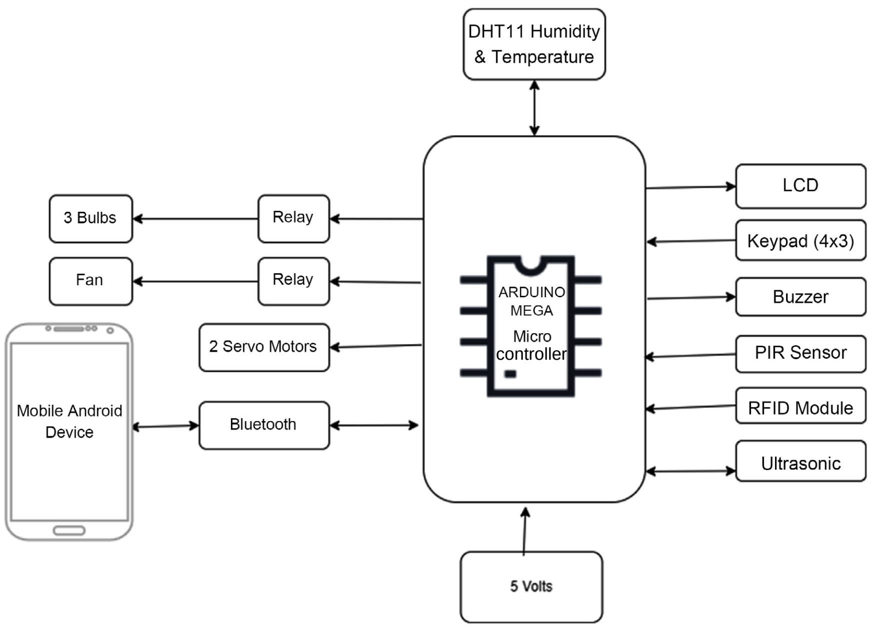

Figure 3. Set up of the connected components to the Arduino Mega of the Smart Office framework.

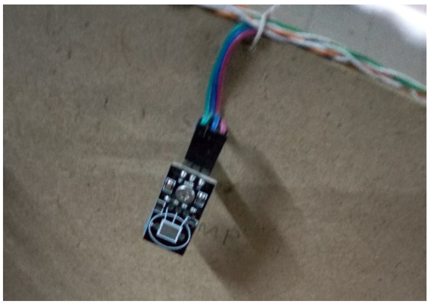

Figure 4. A temperature sensor attached to the main smart office wall.

It also measures the temperature using a surface-mounted thermistor or a negative temperature coefficient (NTC) temperature sensor embedded into the unit and composed of variable resistors whose resistance decreases with the increase in temperature. NTC is composed of a group of semiconducting materials that contain charge carriers. Only high temperatures may lead to the issue of more charge carriers. Since we are using the thermistor, it can only measure voltage. Then, we can obtain the resistance converted from the voltage using the Steinhart –Hart equation, as shown in Equation (2), to obtain the temperature reading in degrees Celsius.

$$\frac{1}{T} = A + BInR + C\left(InR\right)^3 \qquad \text{(ii)}$$

- R is the resistance at T (in Ohms);
- T is the temperature in (Kelvins) but subtracts 273.15 so that the values obtained are in degrees Celsius;
- A, B and C are the Steinhart-Hart coefficients that vary depending on the thermistor type.

When the temperatures elevate beyond the set 26˚C, the fan automatically is triggered to maintain a good temperature in the environment. And on the other side, when temperatures decline beyond the set 26˚C, the fan is automatically triggered off. All these values are read from the LCD placed inside the main Office.

3.5. Hardware/Software Integration

In our work, different hardware components were integrated to develop this prototype when coming up with this low-cost design flame work.

3.5.1. The 4 × 3 Keypad

The 4 × 3 keypad is a hardware input device that enables users to input data into a microcontroller, as shown in Figure 5. This device consists of twelve buttons arranged in a matrix of four rows and three columns. This device was placed at the outer door of our project. It has seven pins connected to the Arduino UNO. Column zero was connected to Pin8, Column one to Pin7, and Column two to Pin6 of the Arduino UNO. Row zero was connected to Pin5. Row one was connected to Pin4, row two to Pin3, and row three to Pin2.

Figure 5. A 4 × 3 keypad for the outer door.

3.5.2. The 2 × 16 LCD (Liquid Crystal Display)

A Sixteen-pin LCD (Liquid Crystal Display) is used on the outer door. The power supply pins, the Gnd, and the Vcc are connected on the negative row of the breadboard and the Vcc on the +5 v of Arduino's, respectively. The contrast pin of the LCD is connected to the 10k middle pin of the potentiometer, which can help us to adjust the contrast of our characters. Register select (RS) pin of the LCD is connected to pin13 of the Arduino, A Read/Write (R/W) pin is connected to the ground (GND), an Enable pin is connected to pin12, the backlight (−) of the LCD is connected to the GND and the 220-ohm resistor is connected from backlight (+) of the LCD to the positive row of the breadboard, pin14 of the LCD (D7) connected to the digital pin11 of the Arduino, pin13 of the LCD (D6) connected to the digital pin10 of the Arduino, pin12 of the LCD (D5) connected to the digital pin9 of the Arduino, pin11 of the LCD (D4) connected to the digital pin8 of the Arduino, the other two pins of the potentiometer are connected one at the +5 volts and other one to the GND of the breadboard.

3.5.3. The TowerPro SG90 Servo Motor

A servo motor is an electrical device that can rotate an object from 0˚ to 180˚ degrees. In our project simulation, we used two servo motors to open the two specific doors (see **Figure 6**). On the first door, the servo motor pairs up with the keypad for position feedback of opening the door at an angle of 120˚ once the pin pressed into the keypad is correct. After a delay, the servo motor rotates back to 0˚, closing the door, and the control wire communicates these angle rotations.

It has three leads, and each lead has a specific color code. The brown wire of the Servo is connected to the GND pin of the Arduino, the red wire is connected to the +5 v of the Arduino, and the orange wire from the SG90 servo is connected to a digital pin10 on the Arduino.

3.5.4. Buzzer/Piezo Speaker

We also installed an alarm system called a buzzer to give an alarm sound with attempts to access an office by authorized personnel. It has two leads (positive and negative) that we connected on the breadboard; one positive lead was connected to the Arduino digital, the other was connected to the 100-ohm resistor, and then to the GND.

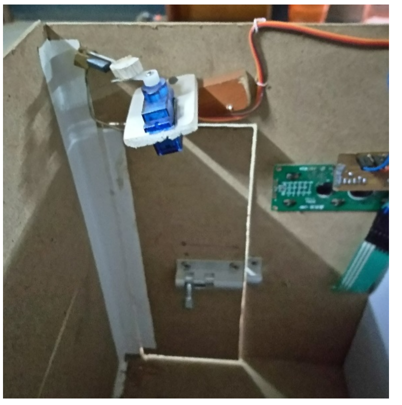

Figure 6. TowerPro SG90 Servo Motor that opens the outer door.

3.5.5. Ultra-Sonic Sensor HC-SR04

We used this device to be alerted about someone coming in to access the Office (see Figure 7). It has 4 pins and uses sonar to determine the distance of an object. We connected the Ground pin to the GND of the Arduino mega, the Vcc to the +5 volts of the Arduino, and the trig and echo pin connected to the digital I/O pin3 and pin4 respectively on the Arduino mega. Whenever someone enters through the first door and starts to move closer to the second door, their distance will be calculated by the ultrasonic sensor and then outputted on the LCD in the Office of the academic registrar. We set that whenever someone comes close to the door by 4 cm, the single beep of the alarm is triggered. We used the Servo.h library in the Arduino for communication.

3.5.6. Radio-Frequency Identification RFID-RC522 Module

This module has two RFID tags, uses electromagnetic fields to transfer data, and uses a frequency 13.56 MHz plus an input voltage of 3.3 V. This module also comprises a two-way radio transmitter and receiver that sends a signal to the tag and reads its immediate response. For the RFID reader to read the RFID tags, they must trail the same frequency, and each RFID tag has a unique identification number that identifies it. Suppose the unique ID of the tag placed close to the reader equals the predefined value stored in the Arduino's memory. In that case, the door will be unlocked, and if the unique ID of the tag is not equal to the predefined value stored in the Arduino's memory, then the door will remain locked.

Each RFID tag has a small chip inside, and this chip doesn't have a battery to get power, but it receives power from the RFID reader. The RFID can read our RFID tag from a distance of 20 mm, It has 8pins, but seven were used, the 3.3 V pin of the reader is connected to the 3.3 V pin of the Arduino mega, the RST pin is connected to the pin5, GND pin is connected to the GND of the Arduino mega, Master In Slave Out (MISO) pin is connected to digital pin50, Master Out Slave Out (MOSI) pin is connected to digital pin51, Serial Data Line (SDA) pin is connected to digital pin53, Serial Clock (SCK) is connected to digital pin52.

Figure 7. An ultra-sonic sensor HC-SR04 attached in the corridor.

We used the MFRC522.h library for communication with Arduino. In **Figure 8** below, the first image on the left-hand side is the RFID reader that reads the RFID tags.

The middle image is the RFID key chain tag, a wrong tag that cannot enable the user to access the smart Office. The last image on the right is the RFID electromagnetic card (valid card) meant to be owned by an authorized user to access the Office. Just above the right-hand image is a green LED bulb, indicating to the user that he has been granted access to the Office, and after a few microseconds, the door opened (see **Figure 8**).

3.5.7. HC-SR501 PIR Sensor Module (Passive Infrared Sensor)

This module consists of a pyroelectric sensor that generates Energy when exposed to heat and several Fresnel lenses that focus the infrared Energy onto the pyroelectric sensor. This means when a human gets in range of the sensor, it will detect the movement because the human body emits heat energy through infrared radiation (see **Figure 9**).

The Passive Infrared (PIR) sensor doesn't use any energy for detecting purposes but works by detecting other objects' Energy. PIR sensor has three pins, the GND that powers the module is connected to the GND pin of the Arduino, the out pin, which gives high logic level when an object is detected, is connected to the digital pin8 and the Vcc pin is connected to the five volts of the Arduino.

It also has two potentiometers, a sensitivity potentiometer that regulates the sensor's sensitivity, *i.e.*, the distance it covers that can be expanded to over seven meters, and a delay time adjustment potentiometer that helps to adjust the time the output stays high.

When the motion is detected, which can be adjusted from 0.3 seconds to 5 minutes, there is also a jumper that has two positions, H, which denotes a repeatable trigger that keeps the output high all the time when the detected object is present in the detected range. L denotes a non-repeatable trigger when the sensor output is high and the delay time is over, the output will automatically change to low hence switching off the lights in the room, but for our case, we moved the jumper to the H position.

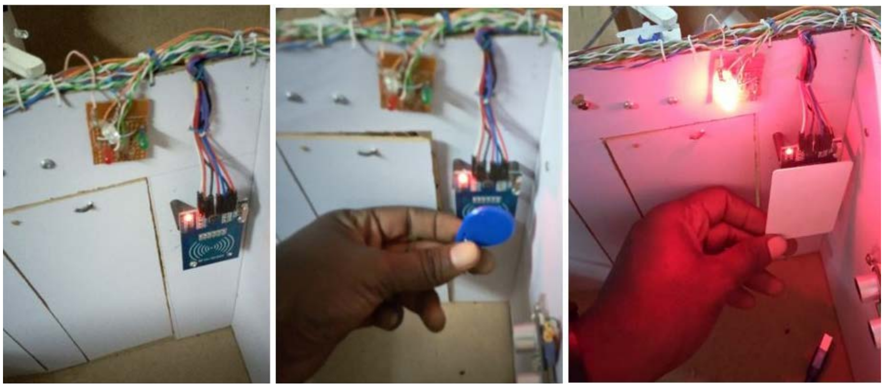

Figure 8. Radio-frequency identification RFID-RC522 module attached just opposite the inner door.

Figure 9. A HC-SR501 PIR sensor attached to the walls of the smart office system.

3.5.8. The I2C LCD Screen Module

We required a display screen to read the output values of the ultrasonic sensor, DHT11 temperature humidity sensor, and RFID module notifications (see Figure 10). We used the **LiquidCrystal.h** library in the Arduino.

3.5.9. DHT11 Temperature and Humidity Sensor

This was an independent module. Its humidity range is 20% - 90%, and its temperature ranges from 0˚C - 50˚C and operates on a voltage of 3 V to 5.5 V (see Figure 10).

It has three pins, the signal pin that we connected to digital pin 48 on the Arduino mega, the Vcc connected to the +5 V, and the GND connected to the GND of the Arduino mega. Here we used the **DHT.h** library to upload our code for Arduino communication, as discussed earlier in this module.

3.5.10. The Fan

When the temperature exceeds 26˚C or falls below 26˚C, the Arduino is programmed to trigger the relay to turn on or off the fun respectively (see Figure 11). Our fan is attached to the walls inside the main Office of the academic registrar.

Figure 10. The temperature and humidity values displayed on the LCD screen.

Figure 11. A fan attached to the walls of the smart office system.

3.5.11. The HC-05 Bluetooth Module

In this module, we control some actions of the Arduino mega microprocessor using an Android smartphone via Bluetooth wireless technology (see **Figure 12** & **Figure 13**). This wireless technology exchanges short-distance data using short-wavelength Ultra High-Frequency radio waves.

The HC-05 Bluetooth has six pins. The enable pin is used to switch between the data mode and the AT mode, and by default, the module is in the data mode before it is powered on.

The state pin helps to show whether the Bluetooth is working perfectly and its connection to the onboard Light Emitting Diode (LED). The Vcc powers up the module, and it's connected to the +5 V Supply voltage to the Arduino mega microcontroller.

The GND is also connected to the GND of the microcontroller. The Receiver (RX) pin (receive a pin, supporting only 3.3 Volt) and the Transmitter(TX) pin (transmit pin with 5 volt output) are communication pins.

We defined the TX and RX pins as pins 39 and 40, respectively, on the Arduino mega microcontroller and also defined the 3 LED bulbs as LED1, LED2, and LED3, then attached them to pins 41, 14, and 43, respectively, of the Arduino mega microcontroller and set to low. Software serial future function, we used it to define the TX and RX pins that aid the communication process between the output LED bulbs and the Android mobile smartphone. We used the SoftwareSerial.h library for the serial communication when uploading our code because the pins TX and RX use it for the serial communication.

We then connected our Arduino smartphone to the Bluetooth module of the Arduino and paired the devices using a default password of 1234. We made our application that controls Arduino using MIT App Inventor online application.

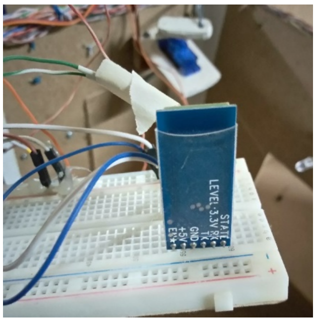

Figure 12. A HC-05 Bluetooth attached to the breadboard.

Figure 13. Illustrates how an Android phone is connected to Bluetooth and the 3 LED bulbs.

3.5.12. Android Smartphone

After pairing the Bluetooth module with the smartphone using the connect button. Our Android application has three sliders that the user could slightly slide to the right to either switch on the LED bulb to increase or decrease its contrast.

3.5.13. The SRD-05VDC-SL-C 5V Relay

Electronic devices like light bulbs and fun use a higher voltage (120 - 240 V), and Arduino operates at 5 V it cannot control these devices. Hence we required this device to control these devices and the Arduino to control this device.

It has three low-level voltage pins, a Signal pin, a GND pin, the Vcc pin that connects to the microcontroller, plus three high-level voltage terminals that connect to a specific electronic device, Common terminal C, Normally open terminal NO, Normally closed terminal NC. In our work, we connected the relay to the fan, and three bulbs connected it to different office locations.

3.5.14. Arduino ATmega2560 and Arduino Uno Microcontrollers

This microcontroller has 54 digital Input/output pins and 16 analog input pins. Most modules were attached to this Arduino AT mega microcontroller because it has many digital output pins compared to the Arduino UNO. After writing our program, we uploaded the programs on respective Arduino.

3.5.15. Arduino Uno

This microcontroller has 14 digital input/output pins and six analog inputs. We used this microcontroller at the entrance to the big room of the smart Office. After writing our program, we uploaded it to this microcontroller. This is shown clearly in Figure 14, and a complete structure of our simulated smart office framework in Figure 15.

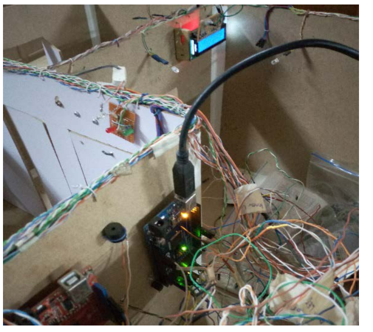

Figure 14. An overview structure of the two microcontrollers.

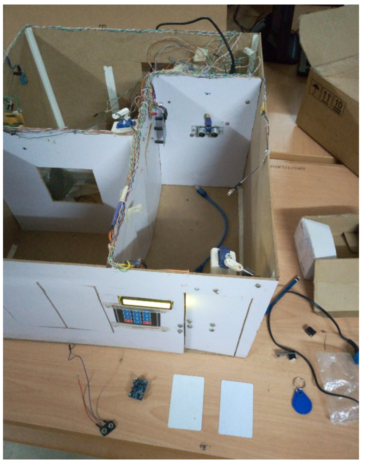

Figure 15. An overview structure of our simulated smart office design framework.

4. Software Integration

To come up with this work, we used some software. We used Android Studio to create the GUIs for our mobile application with nice-looking user interfaces.

Android Studio is the official integrated development environment (IDE) developed by Google for creating Android applications [20]. Android Studio IDE is the most widely used and recommended for developing Android APKs. However, there are several other options such as Eclipse, IntelliJ IDEA, Visual Studio through using the Xamarin platform to write Android apps using C# and the .NET framework, NetBeans, and AppCode developed by JetBrains, which is designed for iOS and macOS app development. Our research used the Android platform to develop the entire project and Java language with an Android software development kit (SDK) to develop and implement the Smart Office automation mobile application.

4.1. Arduino IDE (Arduino 1.8.7)

We used this open-source software to write codes and upload them to two Arduino microcontrollers. This software application was used to write and upload code to the two Arduino boards. We used this application for our project because it is an open-source platform initially designed to simplify life for beginners with embedded electronics and operating system programming.

4.2. Server-Side Scripting

We used MySql for database creation and Hypertext Preprocessor (PHP) for creating Application Programming Interfaces (APIs) that linked Android interfaces to our locally hosted database. Additionally, we used XAMPP to host our local database. XAMPP is also a free and open-source software package that provides us with an easy way to install and configure the Apache web server, MySQL database server, and PHP on our local computer.

5. Results from Deployment Test

We tested our prototype to verify the performance of our simulated smart office system prototype. Three users were given a chance to work through our simulated prototype, given a pin code 1234 (is the wrong pin) and 4664 (is the correct pin). Additionally, given RFID tags (a key chain tag (wrong tag) and an electromagnetic card (correct tag)). A User moved on to open the first door of our smart Office and inputted a pin 1234 on the keypad. The smart short piezoelectric alarm shown was triggered two times, and a message was displayed on the LCD screen, "wrong pin access denied" The notification message on the LCD screen also included the number of attempts left. And when the user went on further inputting a wrong pin and the number of attempts exceeded three times, a long piezoelectric alarm was triggered to notify the surrounding about an intruder trying to access our smart Office. When the user inputted the correct pin code of 4664, the TowerPro SG90 Servo Motor opened the door, and after a small delay of about five seconds, the door was locked again.

As the user moved through the corridor to the main Office, the HC-SR501 PIR sensor module detected some movements the SRD-05VDC-SL-C 5 V Relay triggered ON the light of the corridor. As the user moved closer to the Office, his distance was seen on I2C LCD Screen Module as he came close to less than 4cm, and a smart short piezoelectric alarm automatically triggered ON one beep. The distance was measured by the Ultra-sonic sensor HC-SR04.

On the second door, the user uses a key chain tag. The red LED bulb just above the door is meant to notify the user that he has been denied access to the Office due to the wrong card being presented. When the user tries more than three times, a long piezoelectric alarm is triggered to notify the surrounding about an intruder trying to access the Office. When the user presents the other electromagnetic card, the green LED bulb just above the door flashes to notify the user that he has been granted access and the door is opened for a while for the user to pass through. After a few seconds, the door is locked. Inside the main Office is a temperature and humidity sensor DHT11, which operates on a voltage of 3.3 V to 5 V with a measuring range of 20% - 90% relative humidity and an accuracy of ±5%, and a temperature range of 0˚C - 50˚C with an accuracy of

±2˚C. DHT11 provides an easy way to monitor the temperature and humidity of our project and then sends the values to the microcontroller. And so, when the temperature goes beyond the threshold (26˚C), the fan is automatically triggered ON, and when it falls below 26˚C, it is automatically turned OFF. Figure 16 elaborates on the workflow of the state of the fan and temperature variations until the final state of how they are stored in the MySQL database and accessed on the smartphone by the user.

Another way can be done manually by registering, as illustrated in Figure 17, and login see Figure 18. Then the user can control the Office using the smart Android phone (see Figure 19). The user can switch the lights on and off using the Arduino smartphone connected to the smart Office using the Bluetooth module. Still, the temperature and humidity variations are outputted on our 12C LCD screen. On the dashboard, the user can control the lights (see Figure 20). All lights are ON state (see Figure 21), the main door is opened, and the office door is closed (see Figure 22), the fan is OFF (see Figure 23), the fan is ON (see Figure 24), all doors are Opened (see Figure 25) and also be able to observe the temperature variations and the state of the fan (Figure 26).

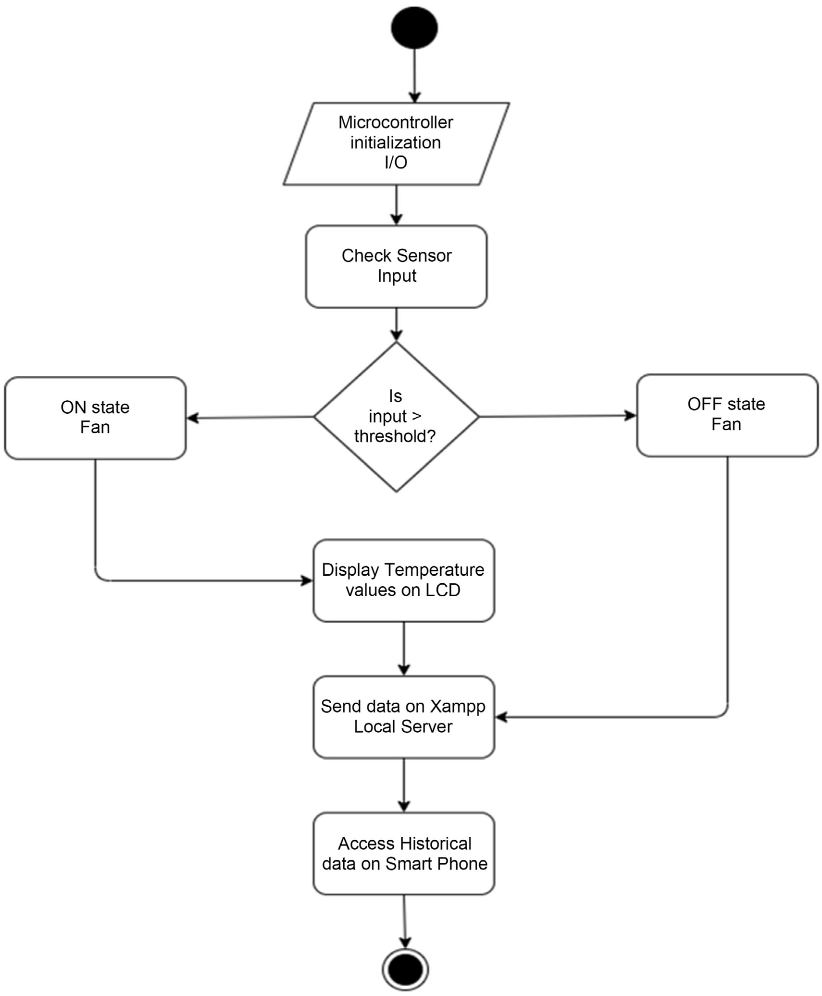

Figure 16. Flowchart of data acquisition from the DHT11 temperature sensor.

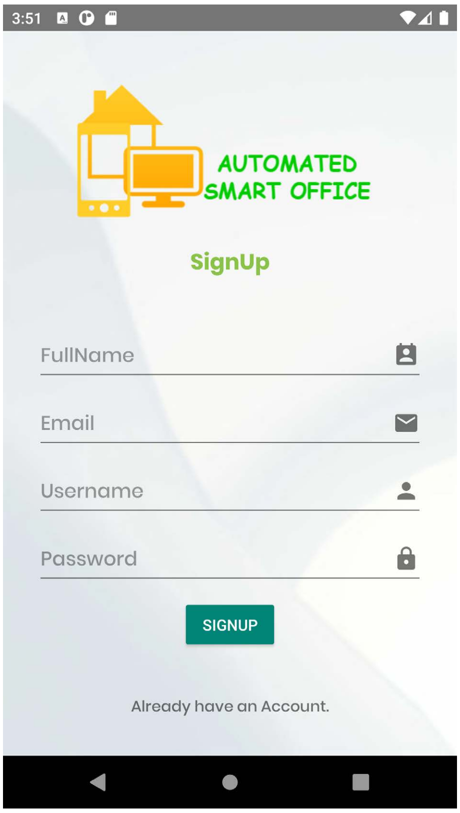

Figure 17. Registration interface.

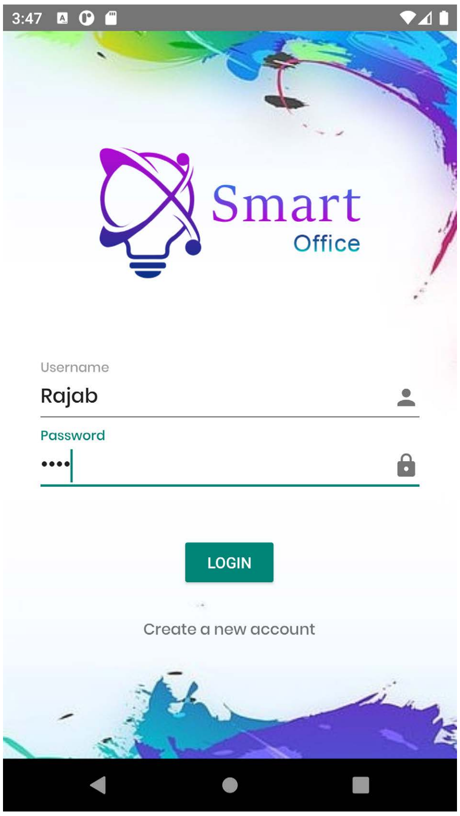

Figure 18. Login interface.

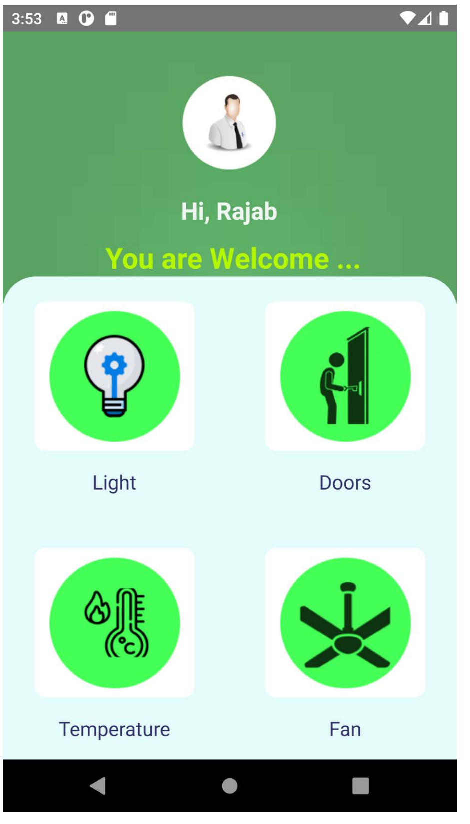

Figure 19. Dashboard interface.

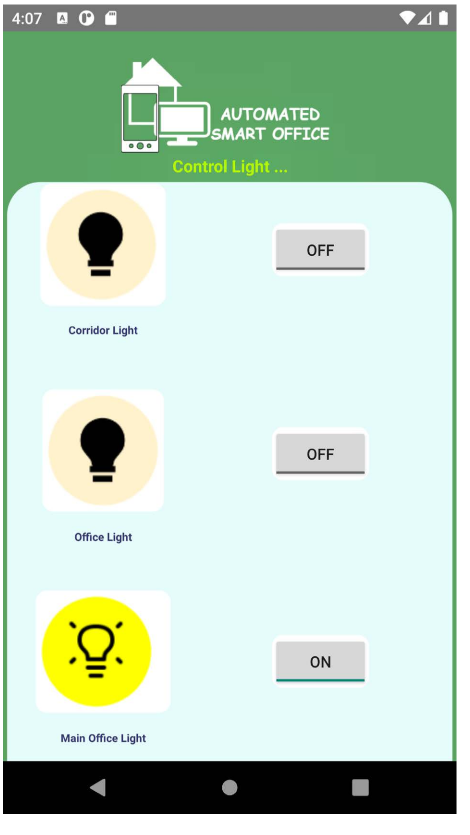

Figure 20. Light management interface.

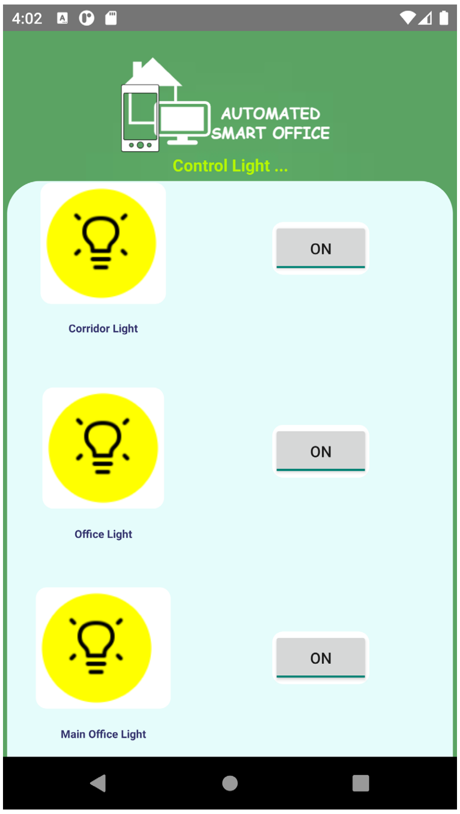

Figure 21. State when all lights are on.

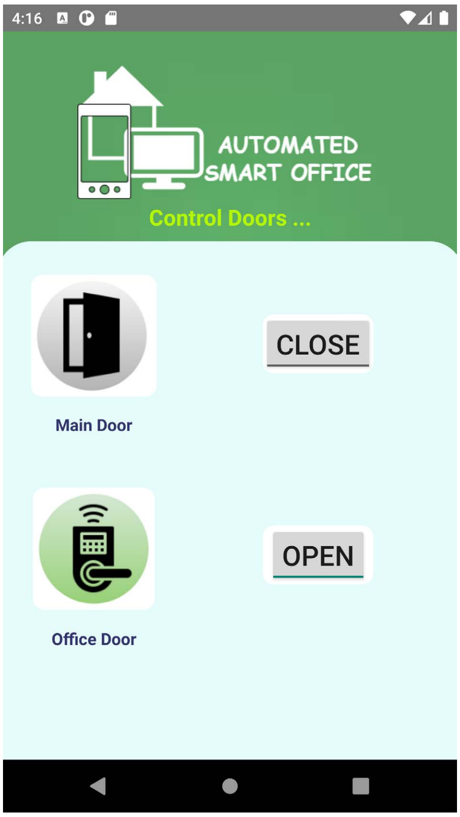

Figure 22. Door management interface.

Figure 23. Off state of the fan.

Figure 24. On state of the fan.

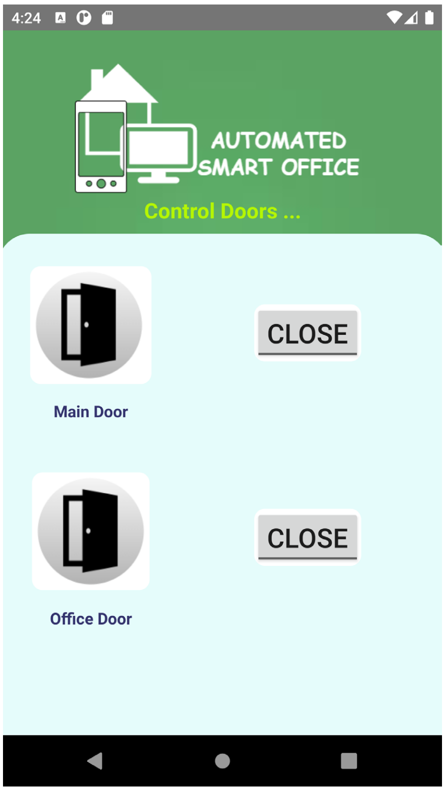

Figure 25. Both the main and office doors in open state.

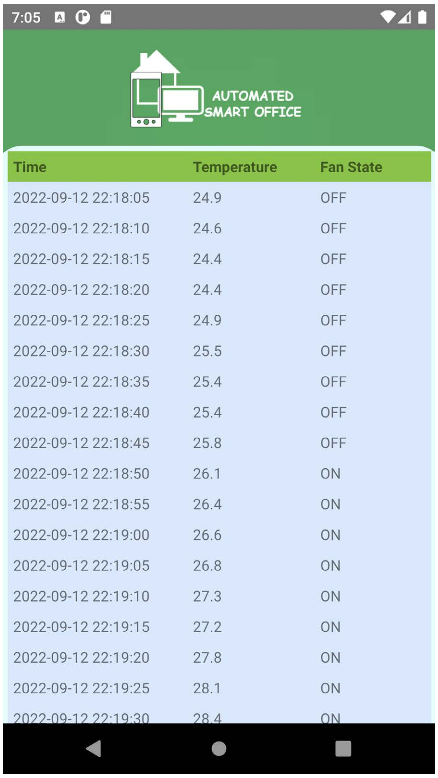

Figure 26. Stored data of varying time, temperature, and the state of the fan.

All these can be done during the manual state using a smart android phone by the user first registering and filling all fields. Then the user can log in using the correct username and password. If any provided login credentials are wrong, the user will receive a message alert shown in Figure 27 "wrong username or password." He will proceed to the smart office application dashboard if the credentials are correct.

6. Discussion and Future Directions

Our simulated smart office design system framework works properly, and it's an improvement and a combination of many modules that were done before, as initially discussed in our related work.

In the environment that we live in, technology is quickly changing and advancing every day. RFID cards get stolen, get swapped, identity theft becomes a common practice due to the above situations, and passwords and pin codes are inconvenient and easier to forget. Due to these factors, the security system to access our smart Office will be vulnerable to intruders.

Our security system would be upgraded to a biometric fingerprint sensor and also include solenoid locks and relays to conveniently and solitary allow authorized users to unlock the doors. To remotely control our smart Office at different locations, we see it in the future to upgrade our system to SIM900 GSM GPRS Shield (Global system for mobile communication and General packet Radio Service) so that we can connect our smart Office to the Internet over the GPRS

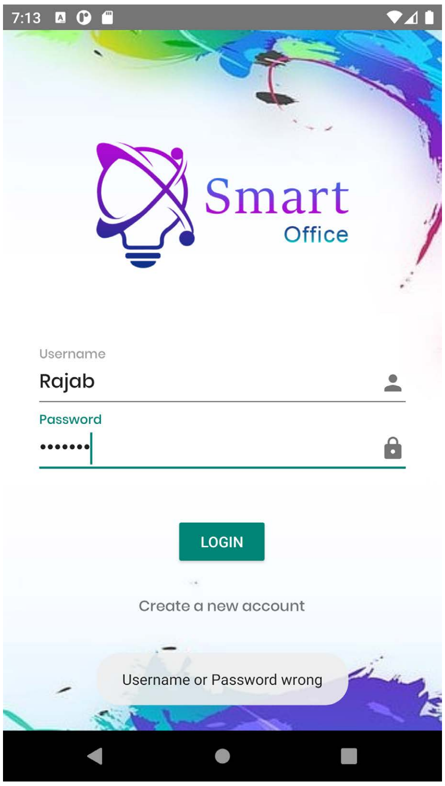

Figure 27. Security authentication.

network and remotely control it, send and receive SMS plus calls since our Bluetooth module without obstacles communicates approximately in a range of 10meters. The MQ-2 Gas Sensor, inductive proximity sensor, and light sensor fully optimize light energy bills.

7. Conclusion

Our research first describes the cost-effectiveness of our smart office design system framework, and then provides efficient performance to the users by combining different modules like the security module, lighting module, and the ventilation or temperature and humidity module into a single module. Our research is successful due to the promising results and system consistency when implemented in the physical world.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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