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A microcontroller-based combinational lock system

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ABSTRACT

From time memorial, insecurity has been a global challenge hence the need for increased measures on individual goods and properties to combat intruder's efforts. This research presents a design and implementation of a microcontroller based electronic door access system for modern buildings with an improved security system. It includes a dual use of keypad system and the Global System for Mobile Communications (GSM) module for securing entries. Three major methodical processes were employed including the system software design, modular circuit de and hardware implementation. The Arduino microcontroller was programmed using C++ with the Arduino Integrated Development Environment (IDE). The entire circuitry of the system was designed with the electronic design automation (EDA) software. Each module is interfaced on the Arduino board and the entire implementation was mounted on the door frame with proper connection to the door latch to create a fully functional prototype. Adequate testing of the final prototype depicts that the system can alert security personnel and property owners of any attempted breach through the use of an alarm and SMS notification system. The device notifies its user when the door is unlocked as well as a potential brute force attack.

***Keywords*:** Security, SMS Notification, Microcontroller, Arduino, GSM

1. BACKGROUND OF STUDY

Insecurity and lack of an efficient and effective protective system are some of the biggest problems in any society in recent times [1]. A door lock system is a mechanical or electronic

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system comprising a lock and a key, used for fastening or closing the entrance such that it is inaccessible until a piece of secret information is provided. This information can be in form of a card, number permutation, password, facial recognition, or even a key [2]. Door locking refers to the mechanism or method for providing access, controlling access, and providing security that relies on a hidden knowledge of mechanics [3]. This is implying that the main purpose of having a door lock system is to restrict and control access majorly for security reasons by implementing a coded mechanism or method to achieve such a system. In the past, humans have sought to secure themselves and their valuables in a different way even till date [4]. One salient way of securing entrances is by preventing intruders, through the use of door lock systems. Security requirements have led to the invention and improvement of the door locking mechanism to prevent access to properties and valuables [2-3]. In the pre-industrial age, humans used simple knots made from rope to secure homes. With the advent of crude technologies, around 4000 years ago, the first set of locks were invented by the Egyptians. Since then, man has always looked for ways to improve the lock system which led to the industrial revolution, a period where various inventors and researchers came up with several solutions to improve the system. The digital age has brought about improvements in technology including electronically driven mechanisms [1]. Doors can now be unlocked without the use of physical keys because computer technology has brought about the use of other digital resources.

It is therefore noticeable how Man has always been trying to secure himself through the use of locking technologies. This importance have been replicated beyond homes to commercial infrastructures such as banks, corporate offices, and several other organizations. [5] revealed that burglar related cases were the highest number of criminal acts (having a total number of 465,761 reported criminal cases) after assault based on their findings. Most of these burglary activities involve the forceful opening of doors [6], especially doors with a traditional locking system. This work focusses on improving the security of homes and other organisations by adding an intelligent control mechanism with real time SMS notification as the entry and exits with the use of PIN codes. The implemented security system is universal in nature and compatible with common door types, it is versatile and modular in structure. The economic consequence is relatively affordable. Integrated Short Message Service (SMS) notification as well as a buzzer alarm system for potential illegal entry are part of the designed system.

In 21st century, Microcontroller-based digital lock system is very essential for security. The significance of this work goes beyond doors of homes only, due to its versatility, it could also be applied to vaults in financial institutions, car doors, modern houses and gates etc. The output of this work is applicable to every structure with a door or an opening addressing the challenges of security by preventing unauthorized access into buildings. Generally, the deployment will be useful for both wooden and metallic doors as well as new and existing doors, meaning anyone can easily install the door locks on their existing doors without having to change the entire door. This study would serve as a foundation for future cost-effective digital lock systems. The overall goal is to strengthen and increase security of life and property. This research work will guide future researchers by increasing the chances of the system detecting potential crimes by intruders even before interference.

1. 1. Significance, Merits and Downsides of Digital Lock System

The use of digital lock system comes with the convenience of having a keyless system which helps in eliminating the issue of searching for a misplaced key as well as changing keys

or need for extra keys [7]. Owners of buildings, properties and other related secured entities are only required to take note of their passwords and entry to their buildings which is easier. The digital lock system provides better security for buildings and homes as it offers a safer way to protect homes and buildings against burglars and intruders. The flexibility of a digital lock system to change password code as at, when necessary, makes it even more secure than the traditional mechanical lock-and-key systems. Lots of Burglars and thieves can easily break the normal mechanical lock system; this risk is reduced when using the digital lock system [8]. Digital lock systems offer a very flexible and easy way for installation. on any type of door and door frame. It can as well be installed on existing doors, which means house owners do not need to change the entire door and door frames to adopt digitalization [2]. A digital lock system can be integrated with an access control system. This will allow building and house owners to manage and control access of people by restricting their access to a certain part of the building for a particular time frame. [10]. The traditional lock-and-key system wears out after a while thereby making opening and closing of doors more difficult, this is also abolished with the use of digital locks.

Albeit there is no guarantee of a hundred percent security but continuous optimization of the digital lock system is required to reduce the dangers attached theft to a minimal level. Although the use of PIN is more secure, it does not eliminate the fact that it can be forgotten. PIN codes can be easily forgotten especially when it is changed and set under an unfavourable condition like during the rain or while rushing the authorization process. Furthermore, the risk of exposing PIN codes strangers who can in turn seize the chance to intrude into the particular building [8]. When a particular PIN code has been used for a long time, the number on the button could start rubbing off due to frequent input attempts of PIN codes using fingers. This may however give an intruder or a burglar an idea of the PIN combination(s), which means the door lock must be properly maintained in such a manner that PIN should be changed frequently. In countries or communities where the daily electricity access is limited to few hours [11]. The use of an electricity-powered (grid) digital lock system would be inhibited. Nonetheless, the digital lock is primarily for improving the security of homes and buildings by using PIN combinations, the fact that there are hackers who can hack and break the system cannot be overlooked.

1. 2. Working Principles

The traditional key lock system utilizes *the pin and tumbler* method whereby a line of miniature pins holds the lock cylinder in place [8-9]. Each of the pins consists of the upper and lower half. The uneven serrated edges of the key move the pin to a particular distance whenever the key is inserted and turned. When every of the metal pins is moved to a certain distance enough to conveniently create a straight separation between the upper and the lower halves of the pins then it opens [12]. A similar approach or principle is applied for the electronic door lock which implements the use of *actuators* instead of the normal conventional pins. These actuators connect the cylinder or bolt to the motor which is inbuilt within the door or the door frame. There are various ways to trigger the electric motor using an electrical impulse including the use of a keypad, electronic card reader, wireless remote sensor, or even Radio Frequency Identification (RFID) tags. The electronic door lock has been programmed and configured in such a way that the motor-driven actuator begins operation once the correct electronic input has been received [12]. The digital lock system comprises the hardware system as well as the software sub-systems.

The software system runs on the hardware, it is written in different programming languages related to the hardware platform. The software controls the functionalities and mode of operation of the hardware. The hardware system utilizes a microcontroller that interprets data and sends information to other hardware sub-systems which in turn perform the necessary operations as given by the software [12- 13]. This research project will be using an Arduino UNO microcontroller with a significant improvement on previously implemented working principles of digital lock system.

2. EMPIRICAL REVIEW

This section provides insights into the achievements and gaps in the studies conducted by several exceptional researchers on locking system and how it has helped secure life and properties over the years. It is on this basis the current study stands to improve the gaps towards addressing identified problems with current narratives. In the old days, ancestors used simple knots made from rope to secure their homes and the first set of locks was created by the Egyptians [14]. They were pin tumbler locks created entirely from wood. Due to the wooden material, it was easy for the lock to be broken which then leads to the improvement of the lock system by the Romans. Romans made the lock entirely from iron, thereby improving the lock's quality [7]. Due to modernization and advancements new methods emerged to bypass these locks which made the locks more obsolete and led to the invention of deceiving locks around 100AD [14-15]. During the period of the industrial revolution, which was a period of rapid innovation and technological advancement, there were a lot of improvements and innovations in the door locking system during this era. Some of the most significant door lock system inventions were led by the following scientist identified in literature [15]. First is Robert Barronin in 1778 who created the double-acting tumbler lock, followed by Joseph Bramah (Bramah Lock) in 1784, Jeremiah Chubb (Detector Lock) in 1818, Linus Yale, Sr. (Pin Tumbler Lock) in 1848, James Sargent (first combinational lock and first-time lock mechanism) in 1857 and 1873 respectively, Samuel Segal (first jemmy-proof lock) in 1916 and Harry Soref (first padlock) in 1924.[16]. In the digital age, technology has so much improved on the door lock system. Doors can now be unlocked without the use of physical keys because computer technology has brought about the use of biometric scanners, face recognition, pin combination, digital cards etc. In this section, a conceptual overview of previous research was carried out based on their design and construction of various digital and manual lock systems.

Authors in [1], and [17] both proposed an Internet of things (IOT) algorithm for door lock systems. They used simple interfaces and Radio Frequency Identification (RFID) tags and Arduino limited to selected entrances and the door system do not have the to react to possible vandalization. [18] explored the approach of creating a digital lock system using the Android mobile operating system. The system proposed by the authors operated on two different modes which are; the normal mode (which allows only a single user to use the system) and the multiuser mode (which allows more than one user to use the system). Similarly, [16] pointed out the flexibility of creating an automatic door locking system using passwords. The paper proposed a two-way security measure by ensuring the user enters a password before connecting to Bluetooth and then also entering passwords to unlock the door system through the application on the mobile phone. However, these systems utilize a Bluetooth module that requires users to have in their possession a Bluetooth-enabled smartphone to use these systems.

In the work of [15] a step was taken further by including features related to security notification and password modification into the digital lock system in case of security breaching. Also in their findings, they stated the flexibility in the work architecture as the password can be set and reset without the use of any external devices. The authors also stated the ability of the system to go into a lock state at every wrong password attempt and report to security personnel. However, this paper does not explicitly state the approach by which the security personnel is contacted.

Comparably, in the research done by [19], an explanation of the possibility of achieving home security for advanced homes using an app-controlled smart locking system was highlighted. In the work, it was stated that the system is a robust digital door lock system that utilizes the internet of things (IoT) giving users the opportunity to control the operation of opening and locking the door remotely from any location. It was also stated that the application has an additional feature of taking pictures as well as video coverage of all activities going on in front of the door. Additional feature includes a fire alert system that alerts the fire brigade of a potential fire incident is built on the system with no implementation record. Also, [22-23] illustrated a similar approach. They inferred that their approach isn't as robust as one done by Basak *et al* even though they added a feature of SMS messaging. This is because Basak *et al* implemented the use of a robust smart mobile application for remotely controlling the door lock system, and all security notifications are being sent to the user's mobile application [19]. This feature was not implemented as security notifications are only gotten through email and SMS messaging [1], [21].

In a research work conducted by [22], they proposed a digital lock system that uses an 8-bit microcontroller ATmega328P and a push keypad. They explored the possibility of creating this security system with only an alarm system that gives sound in case of potential burglary activity. However, it can be deduced that the security features stated in their output are not enough to guarantee maximum security. This is the same as the prototype proposed by [23]. [24], proposed a different approach for implementing a digital lock system by using a removable (plug-in) electronic password-based door lock. The approach implemented a framework that utilizes security consisting of two levels and sections. First is a section acting like a key comprising of a microcontroller, Light Emitting Diode (LED), and the matrix keypad which is then plugged into the second stationery which is mounted on the door. The stationary section powers the mobile section and through this interconnection the operation of closing and opening the door is done. However, this solution does not solve the problem of achieving a keyless system as a mobile device is needed to be carried around.

The possibility of adopting a smart biometric lock among the South Asian Association for Regional Cooperation (SAARC) nation was reconnoitered by [25]. In the study, the authors investigated the possibility of creating a cost-effective biometric lock solution for the SAARC nation. The study was targeted at providing a cost-effective smart biometric lock system for the average class populace of the SAARC nations. Similarly, Dahe [26] implemented a conceptual design of biometrics technology in the door lock system. The paper was able to solve the fundamental problem of electronic door locks by using a biometric lock that grants access to users using fingerprints. However, the author did not specify how to grant access to unregistered recognized users, thereby limiting the flexibility of the system. Furthermore, [27], proposed a novel system for access monitoring and control on a digital door lock that uses Bluetooth technology. The work argued that since a whole lot of devices is Bluetooth enabled, the proposed approach should offer a more convenient and safe system.

The addition of a motion detector capable of monitoring anyone at the door was considered. Since this solution implements the use of an external device, it might be difficult to provide considerable user experience. Related design approach was implemented by [28].

A robust approach whose working principle was based on speech recognition was implemented by [29]. The authors developed a prototype by training the system to use Mel-Frequency Cepstral Coefficients (MFCC) feature extraction and Vector Quantization using the LBG algorithm (VQLBG) to recognize a speaker. They added the use of Euclidean distance for the calculation of parametric representation of individual speech signals. With their approach an accuracy of 75% was obtained based on word error rate. However, this system is limited to voice commands and might not perform optimally in all situations, for example when users lose their voice. In another study is a focus on security provision for the bank vault system, authors proposed that password selection should be more flexible, rather than using the conventional digit PIN combination [30]. The study also proposed the implementation of a password system that allows users to choose alphabet combinations rather than digits as a review of existing works.

Bamisaye and Adeoye [31], proposed a prototype design that comprises four operational modules namely; the mobile communication, the decoding mode, the switching mode, and the controlling. This prototype was designed in such a way that the opening and closing operation of the door is controlled through SMS messaging on the mobile phone where the users can simply enter their PIN through SMS messaging. Similar work was conducted by [32], however, the prototype is not as robust as one done by Bamisaye and Adeoye since the study does not state the provision for operational modules for converting signals into binary codes. [33], presented the design and construction of an automatic security system of a door using RFID technology. The paper justified the use of Radio Frequency Identification (RFID) technology because of its low cost, ease of use properties as well as the ability to identify animate and inanimate objects through radio waves. [34], presented a detection scheme that uses SMS messaging and Dual tone multi-frequency (DTMF) technology, with a fingerprint sensor module to allow access to owners as well as to serve as the doorbell system. However, the paper did not explicitly present how their system is meant to identify known visitors which can be dangerous as doors can be opened for strangers remotely which can then lead to property theft. [35] shared the possibility of using three (3) different modes for the design and implementation of a digital lock system. In the study, the authors stated the three modes to be keypad, Bluetooth, and GSM modules. The design also implemented two password systems for the keypad module, one for closing the door and the other for opening the door. The shortcoming of such design is that users need to keep to memory, two password codes of which can be forgotten easily. The result of the design shows that of all three modules the GSM module is the best as a user can open and close the door through SMS messaging remotely. In the work of [36], a review of intelligence to outline some of the literature written on intelligent lock systems was carried out. The authors outlined the pros and cons of the previous research works. Also, the research work was divided into two categories namely; single protocol system (single security feature) and multiple protocol system (multiple security features) with some level of complexity.

From the empirical review so far, it is crystal clear that the relevance of digital lock technology is continuous and open for improvement. A clear glance at previous research efforts revealed that a whole lot of effort had been invested into providing a reliable security system for buildings however, it is crystal clear that prototypes of efficient and comfortable security system is lacking from most of the design efforts. The few prototype designs require an external

device to work with the door lock system (e.g., Bluetooth/Wi-Fi connections). The novelty of the work understudy is the design and implementation of a prototype that does not require an internet connection or Bluetooth. This is to eliminate the necessity of carrying mobile devices around before users can efficiently secure their assets. In addition to the aforementioned, reviewed literatures require physical presence of the user and RFID tags to operate the door lock system. This research addressed these setbacks by employing a solution that does not require an internet connection or compulsory physical presence of the user, as the door operation can be performed remotely using a combination of Short Message Service (SMS) and other offline measures without completely discarding the online measures integration. This work further explores the possibility of detecting probable vandalism of doors by intruders and burglars thereby raising an alarm to alert the house owner or security personnel.

3. METHODOLOGY

To create an efficient solution in line with the identified problem. A tripartite methodology with three (3) major stages is implemented including the prototype design, system design and integration, and control system design flow. The prototype stage involves the design of the outer framework of the project. This is demonstrated as a working model created in form of a mini door to show how the system will work in real-life situation. This feat demonstrated is a unique approach not seen from previous related work. The prototype design is in form of a wooden door frame modeled in the form of a house with a door of dimensions not greater than $60cm \times 30cm \times 65cm$ $(L \times B \times H)$. A system design with integration features of digital lock divided into two major sections (hardware and software) was carried out.

3. 1. Hardware Sub-System

The digital lock hardware system consists of the keypad module, SIM800L GSM Module, and the motor driver which are then interfaced with the Arduino ATMEGA 328 microcontroller. The SIM800L GSM Module is used for mobile communication. During testing, it achieved communication between the mobile device and the Arduino platform majorly involved with sending and receiving SMS. The connection between the Arduino board and the SMS module are done serially as depicted in figure 3.1. The SMS module consists of two major pins which are the Transmitter (Tx) and Receiver (Rx). This set of pins are correctly connected to the digital pins of the Arduino board which are Pulse Width Modulation (PWM) enabled. Pins 9 and 10 are both PWM with Pin 9 connected to Tx and pin 10 connected to Rx. This method is implemented through the use of the Arduino software serial library; this is responsible for serial communication. The diagrammatic illustration for the connection is shown in Figure 3.1.

The Keypad module is as a form of input device for entering the PIN combination codes into the system. A keypad wired as an X – Y switch matrix is used. The implementation used a Pin combination of 12 pads wired in 3 columns by 4 rows. The columns namely C1, C2, C3 are connected to pins 3, 1, 5 of the keypad modules respectively, and the rows namely R1, R2, R3, R4 are connected to the pins 2, 7, 6, 4 of the pin flexible cable of the keypad module respectively. The interface works with the Arduino subsection connected to the keypad pins 1, 2, 3, 4, 5, 6, and the Arduino digital pins are connected to 3, 5, 2, 8, 4, 7, and 6 respectively.

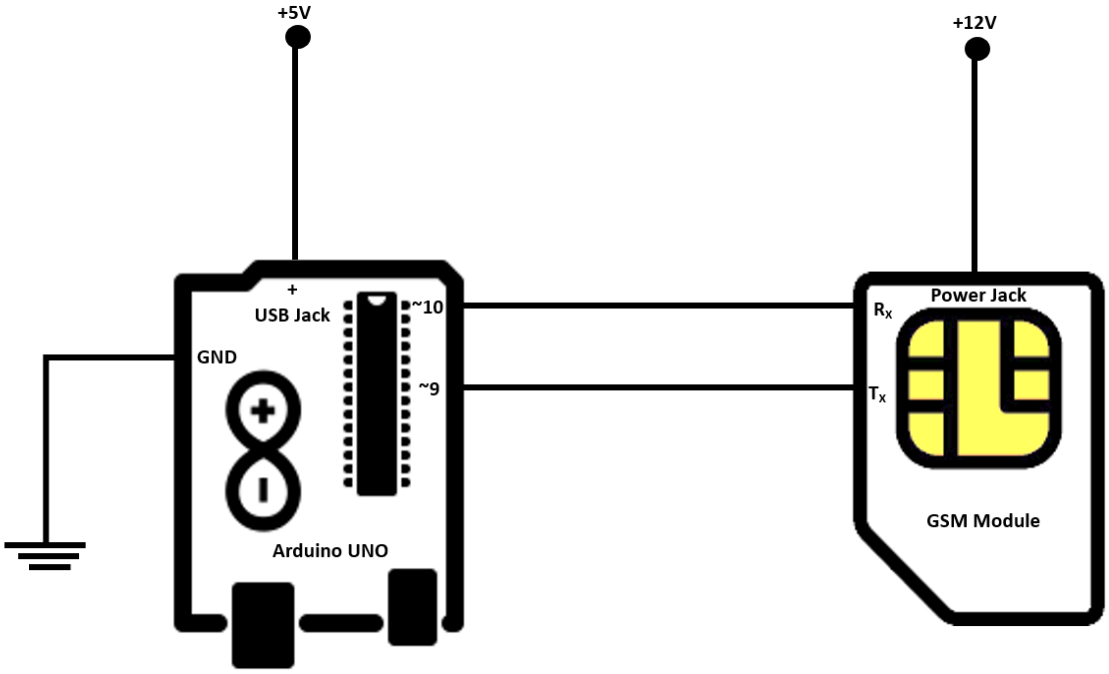

Figure 3.1. Arduino UNO connection with the GSM module

It is important to note that the SIM800L GSM module can also be solely used for locking and unlocking doors through text messages. The GSM module is not only used for sending and receiving SMS alerts only, it can also be used for door lock operations. The module contains a total number of 12 pins that is connected to the Arduino board and other components. A NET pin is interfaced with the inbuilt helical antenna. The Common Collector Voltage (VCC) Pin is responsible for supplying power to the module (Adebisi et al., 2021). The reset (RST) pin is used for hard reset, this is done by inserting the pin in a low state for 100ms. The Rx and Tx are accountable for serial communication with the Arduino, connected to the digital pins of the Arduino board. The other Pins on the module include the GND, RING, DTR, MIC, and SPK pins. For proper integration with the Arduino platform, the helical antenna is soldered to the pin as stated earlier, and an activated micro-SIM card is inserted into the module socket. The Tx pin and the Rx pin are then connected to the digital pins of the Arduino board.

For the opening and closing of doors, the action of a motor and a motor driver is required. This is achieved with motor rotation in specific direction to either close or open the door system. A connection is established to connect the Arduino to the motor; the logic pins IN1 and IN2 of the motor connected correctly to the digital pins D7 and D8 of the Arduino board. The summary of the methodology used for connection and interfacing of the various modules of the design to the Arduino UNO board is presented in Table 3.1

Additional components are connected to the system to ensure the digital lock system works properly. The block diagram showing the connection of the major device modules to the Arduino UNO platform is presented in Figure 3.2. Arduino is an open-source electronics platform primarily based on easy-to-use hardware and software approach [38]. Arduino boards have the capability of interpreting input commands and giving out outputs as results.

Table 3.1. The connection of the major device modules to the Arduino UNO board.

Device Module	Device Pin	Arduino UNO pins
Keypad Module	Pin 1	D3
	Pin 2	D5
	Pin 3	D2
	Pin 4	D8
	Pin 5	D4
	Pin 6	D7
	Pin 7	D6
	VCC	5V
	GND	GND
GSM Module	Tx	Pin 9
	Rx	Pin 10
	VCC	5V
	GND	GND
	GND	GND
Motor Driver	IN1	D7
	IN2	D8
	GND	GND

The example of the input commands can be ‘light on a sensor’, ‘turn on a Light Emitting Diode (LED), ‘change switching states’, ‘finger on a button’, while the output results can be LED turned ON, activation of motor, etc. The Arduino board is instructed through sets of instructions for precise activities in line with the microcontroller on the Arduino board (Adebisi and Abdulsalam, 2021; Drymonitis & Drymonitis, 2015; Smith, 2011). These instructions are programmed using the C/C++ language which is then processed on the Arduino Integrated Development Environment (IDE). The Arduino Platform is less costly compared to other microcontroller platforms like the raspberry pi. Assembly is handy, and support cross-platform integration. With these unique features, Arduino software can run on various operating systems like Windows, macOS, and Linux operating systems.

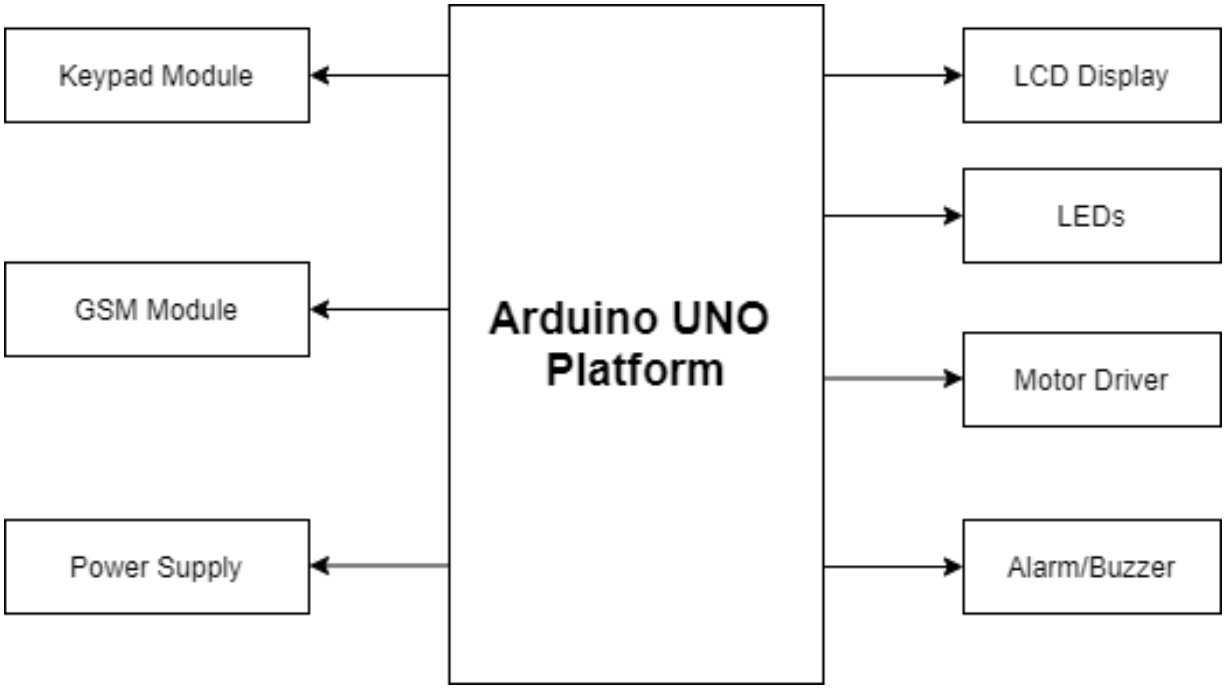

Figure 3.2. Block Diagram of the door lock system

3. 2. Software Sub-System

For the software section of the project, used for the Arduino platform as an IDE. Codes were written and uploaded to the hardware using C++. This works hand in hand with the hardware sub-system as illustrated in Figure 3.3.

The digital lock. Keypad, SIM800L GSM Module, and the motor driver are all interfaced with the Arduino UNO board to operate closing and locking of doors as shown in the flow diagram (Figure 3.3). The inbuilt/default PIN code of 1234 is set on the prototype after which the users are allowed an option to reset the PIN to preferred Code. During each operation, the microcontroller checks if the PIN matches the code on database.

If the PIN matches, the database the door opens otherwise Liquid Crystal Display (LCD) displays Incorrect Entry and return to home screen. In case a user enters an incorrect PIN too many times, the buzzer sounds send SMS the user (owner) through a registered mobile number as well as the nearest security personnel for proper awareness on a possible security breach. After a few seconds, the alarm stops sounding and the system refreshes. If an intruder or burglar results in banging the door, the system can detect possible door vandalization and an alert sent for possible vandalization of properties.

The door lock system also allows users to be able to open or close doors remotely through SMS messaging by making use of the SIM 800L GSM module. When the user sends a Pin as a text message, it is being received by the GSM module. The Arduino ATmega microprocessor which had been initially programmed with the GSM module receives the message and interprets the message. If the message contains the correct pin code, the door opens, otherwise, the message would be ignored and the door remains unlocked.

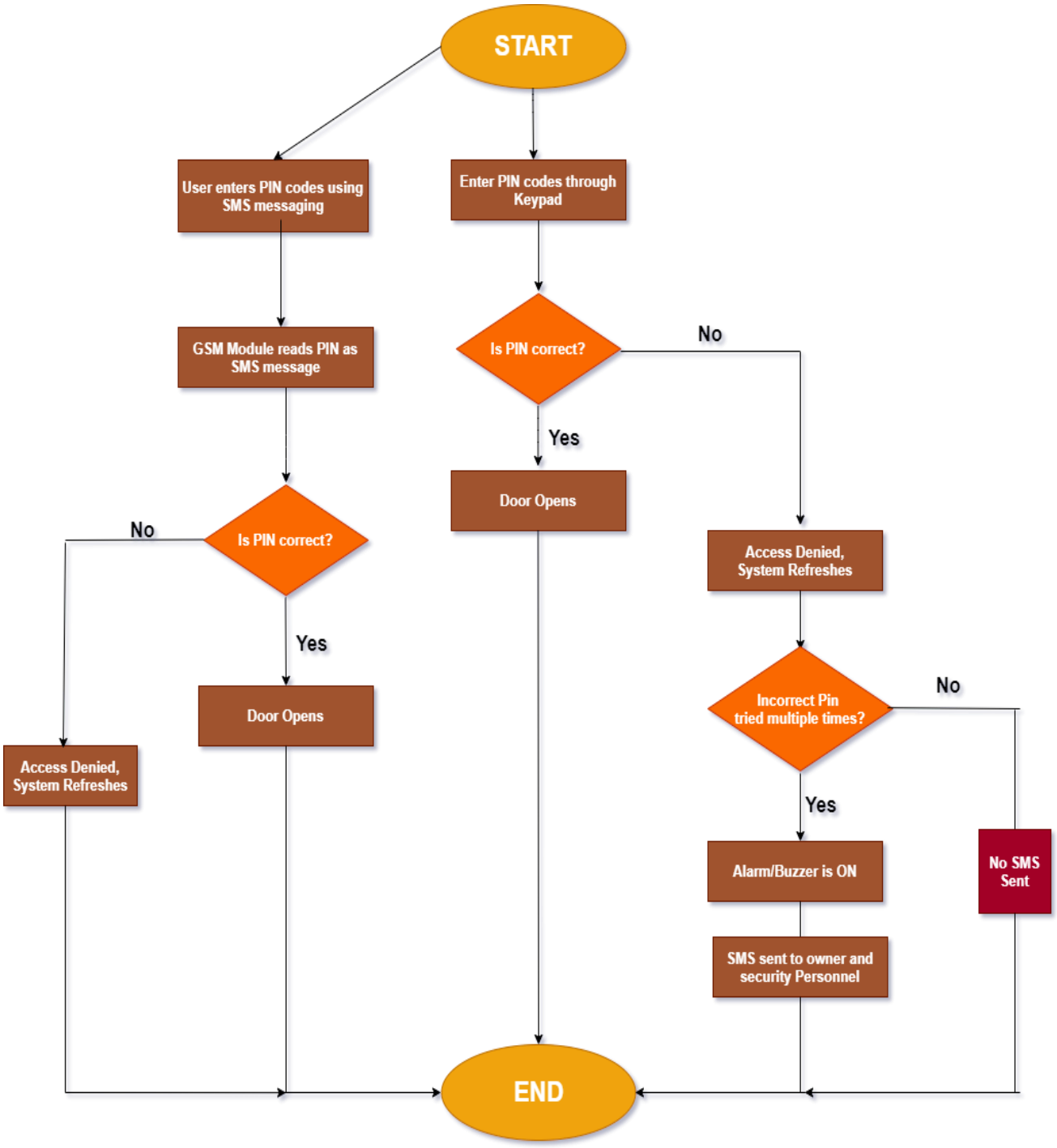

Figure 3.3. Flow diagram for the digital lock system

3. 3. Power System Requirement

The power system requirement of each component cannot be overemphasized in this work, it is calculated using mathematical formulations from the components power ratings. The operating voltage of Arduino is rated at 5V and a 40 mA Direct Current (DC). A DC of 50 mA

is required for 3.3V pin while the requirement for the keypads are 5V, 50 mA respectively. Details breakdown of the power requirements are shown in Table 3.2.

Table 3.2. List of major components and their power ratings

COMPONENTS	Operating Voltage	Current
Arduino UNO Board	5V	50 mA
Keypad Module	5V	50 mA
GSM SIM 800L	5V	2A
Relay Module	5V	100 mA
Buzzer	5V	100 mA
LCD display	5V	50 mA

From the above power specifications in Table 3.2, it is clear that the components are connected in parallel as they all have the common voltage of 5V. The total current requirement for this system is as given in eq (1):

$$Itotal = 50mA + 50mA + 2A + 100mA + 100mA + 50mA$$
$$= (50 \times 10 - 3)A + (50 \times 10 - 3)A + 2A + (100 \times 10 - 3)A$$
$$+ (100 \times 10 - 3)A + (50 \times 10 - 3)A = 2.8A$$

Eq (1)

The total current required by the system is 2.8A which is approximately 3A. A value twice the calculated current is recommended in real deployment to mitigate additional conditions that may draw power, this is important to avoid power drop below the required value. Therefore at least a 9V DC supply would be required for effectiveness. A standard 12V DC supply is considered for testing this implementation for long lasting period.

4. IMPLEMENTATION RESULT

Following a successful design of a distinctive schematic modular circuit diagram for the door lock system using EasyEDA, the entire system was connected to the breadboard based on the design. The system was tested on a breadboard as shown in Figure 4.1 with all functionalities working in line with the objectives of this study. The components were soldered on the Printed Circuit Board (PCB), after which the servo motor was connected to the door lock. The entire door lock system was mounted on the ready-made wooden frame designed using AutoCAD (height of 300 mm, a width of 450 mm, and a thickness of 10mm) for complete prototyping.

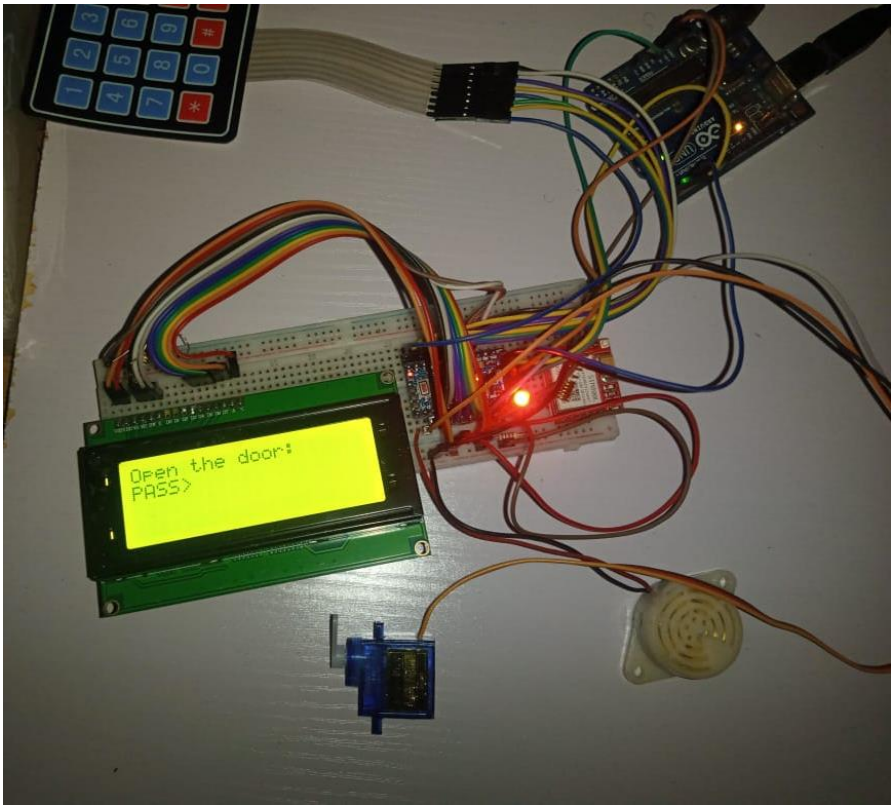

Figure 4.1. Breadboard connection of the lock system

(a) **(b)**

Figure 4.2. (a) Unlock Password interface and **(b)** Key B press for sending password via SMS

The entire code for the system was carried out in Arduino IDE using the C++ programming language, the program was then loaded into the Arduino microcontroller (ATMEGA 328) for operational purpose.

Adequate testing of the system with random users using default 4 digits password at the initial boot/reset of the device and use of Key B for SMS activation as indicated in Figures 4.2 (a) and (b) respectively.

The sample of SMS received on mobile is shown in Figure 4.3.

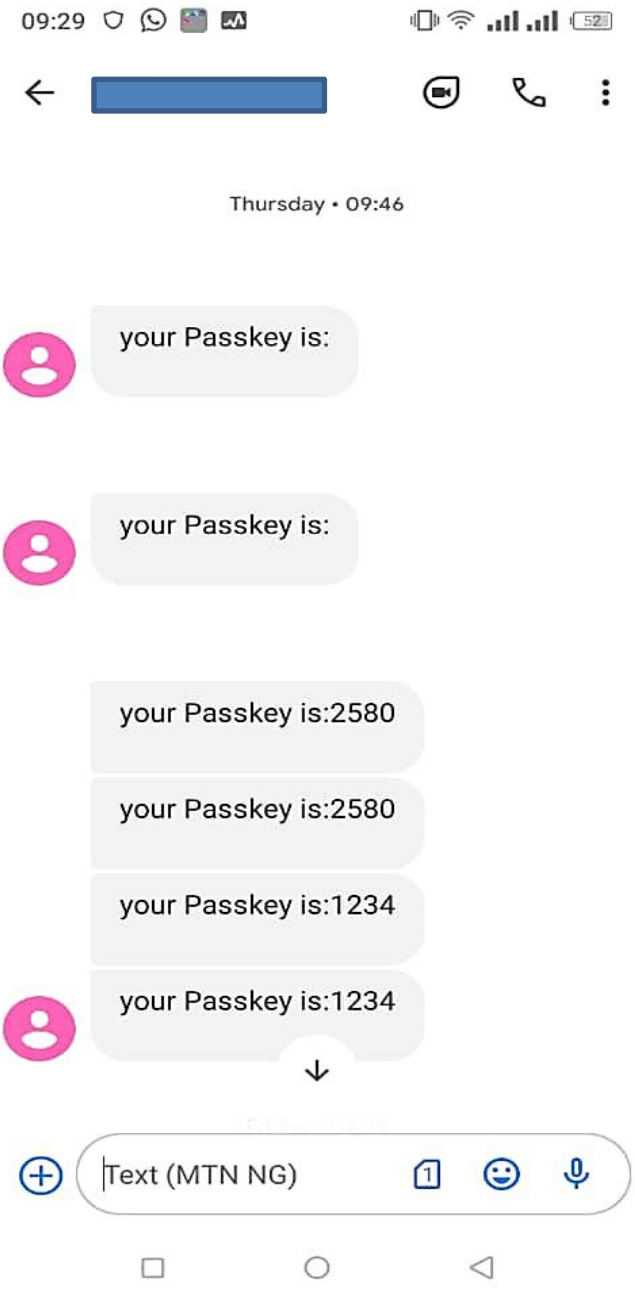

Figure 4.3. Text message of Passcode received by user

The received password is used on the device to unlock through the **key *** on the keypad (Figure 4.4). The device then sends a message to the user alerting users that their door has been unlocked. This is a security feature is a unique blend and wholistic in nature to address security problem ensuring the user knows the state of their door in case the password is bypassed by an intruder.

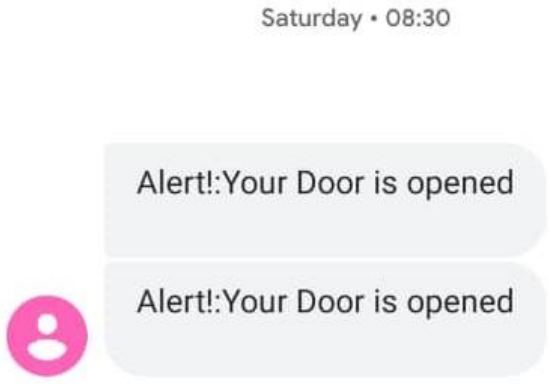

Figure 4.4. SMS message alerting user their door is opened

From the implementation, Automatic lock is possible after 10 seconds of being unlocked (Figure 4.5). This is a special security feature to ensure the door is always locked at all times even when users left the door open unconsciously.

Figure 4.5. Automatic Door Lock after 10 seconds

The implementation of this work allows password reset at any point in time especially when it is suspected that there is a breach of security. It is recommended that users change their

password at any time. This unique feature is available on the press of **key A**, current password is required twice (Figure 4.6 a and b) followed by a press on key *, new password is allowed (Figure 4.6c). All passcodes are limited to 4 digits.

(a) **(b)** **(c)**

Figures 4.6. (a and b) Entering existing password. (c): setting new password

In addition is a 2-way security notification system through the use of SMS and Alarm system. In case of 3 consecutive wrong password attempts (Figures 4.7 a and b) after the first attempt by a possible intruder, The Alarm system turns ON to alert security personnel in the locality, also an SMS message is sent to the owner to alert them of the presence of a potential intruder (Figure 4.7c) and the system will be completely disabled by being locked out.

(a) (b)

Figure 4.7. (a) Wrong Password attempt warning, **(b)** Locked out, Alarm Light ON

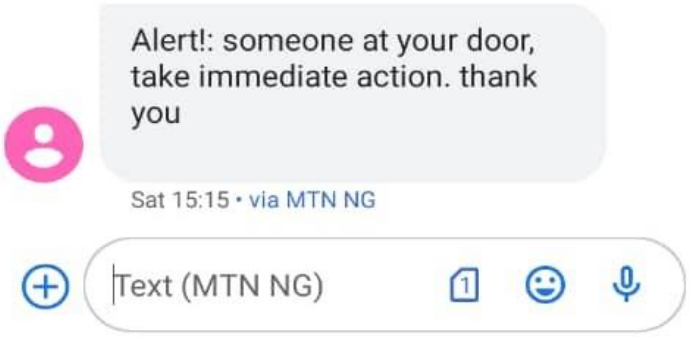

Figure 4.7. (c) SMS Alert Sample to User on intruder attempt

It is important to note that, users can select their PIN combination from the digits on the keypad, except for keys A, B, and C which are the control keys of the device with various specific functions. Key A is used for resetting the device password while key B is for sending the user password as a text message to the user in case the user forgets their password. Key C and D is reserved for future control functions. Figure 4.8 is a complete prototype of the output of this research in perfect condition.

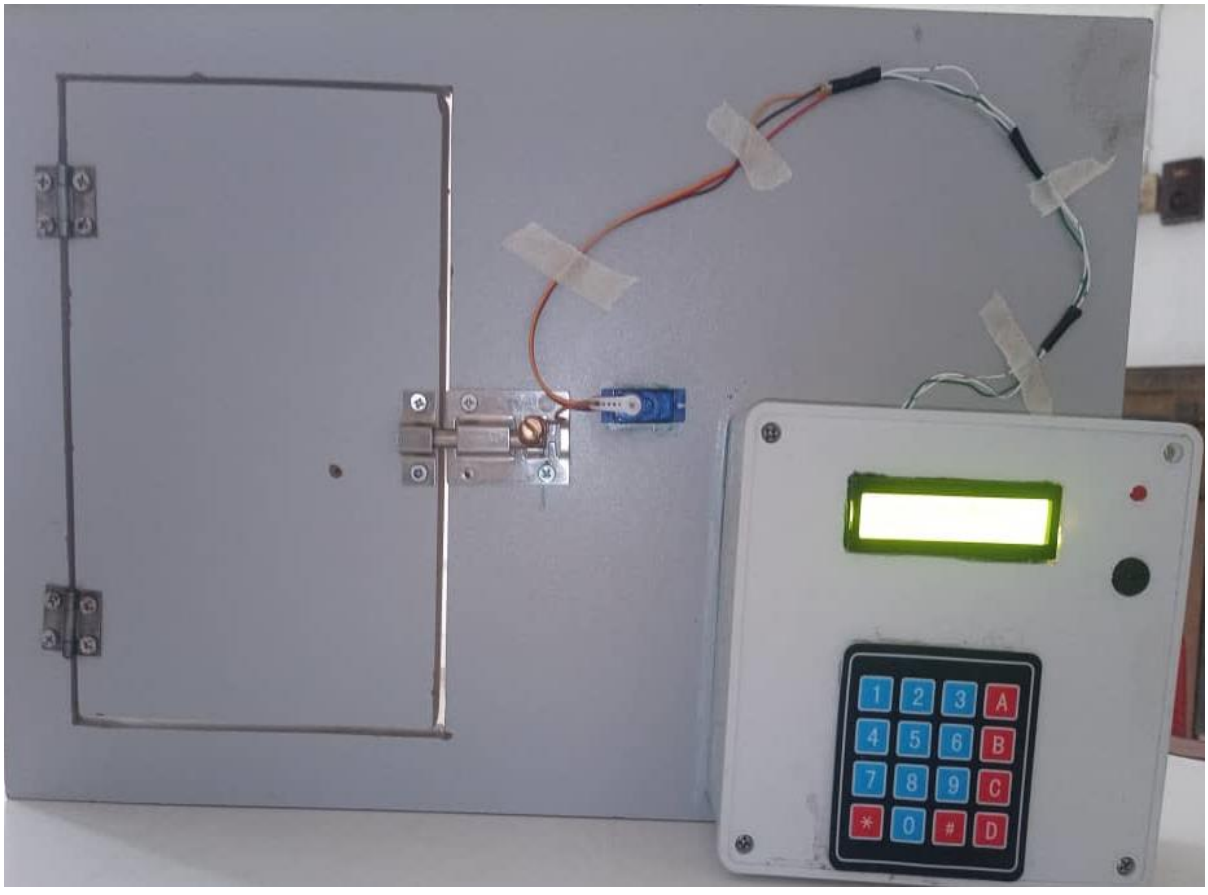

Figure 4.8. Prototype of the Microcontroller-Based combinational Lock-System

5. CONCLUSION

Over the years, researchers have worked on various ways of securing entries including the use of personal identification number, Radio Frequency Identification (RFID) tags, Bluetooth-enabled devices, etc. This work carried out an extensive survey of many research being carried out to improve the security system of door access in buildings. Beyond the extensive review of literature, this study designed and implemented a digital security electronic device for a door lock system that is capable of denying access to intruders. It implemented a unique combination of password/pin lock system and a security alert feature. The output of this work is capable of alerting security personnel and house/property owners of any potential intruder. The final build of the project is a cost-effective and fully-functional working prototype. The device helps to solve the problem of insecurity, especially for homes. It is a 2-way security alert notification through the use of alarm and SMS messaging helps to monitor and curtail illegal access to users' homes and properties. This work has contributed to knowledge in the area of security attentiveness. It is a system with 360 degrees feature based security system with password input, door unlocking SMS alert, automatic door lock after 10 seconds, and password reset. In future, rechargeable power source could be considered as a backup supply to prevent frequent battery replacement, this would help cut the cost of running the device. In addition, a password entering system that can integrate seamlessly from the SMS alert to mitigate the case of a faulty keypad can be considered.

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