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Towards secure smart cities: design and implementation of smart home digital communication system

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ABSTRACT

Home and building security are major concern in our daily life and digital smart door lock (DSDL) have become an essential part of these systems. In this paper, a secure DSDL which can grant access to home with a fingerprint is designed and implemented. An Arduino Nano microcontroller board, finger print sensor and servo motor have been utilized for lock/unlock door based on finger print. The DSDL is an automatic authenticate and validate the user for secure access. The implemented system aims to develop a cost effective DSDL based on low cost components compared to the systems already on the domestic market. The ease of use and cost effectiveness makes the DSDL a strong competitor to the digital security system on the domestic market and outperforms it and suitable for security–based home automation systems.

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1. INTRODUCTION

Home automation system (HAS) is the fastest emerging technology that contains many smart home appliances for the convenience of the homeowner. HAS includes home security, e.g. access control systems, control appliances, climate and lighting [1, 2]. Embedded systems, smart sensors and wireless technology with the recent developments in interactive applications have improved the quality of human life in various areas including HAS, smart healthcare and smart cars [3]. Smart home appliances based built in sensors have improved the home live through many home appliances that include refrigerators, sewing machines, washing machines, television, etc. As a consequence, security of property and life requires serious attention, particularly with the advent of the era of 5G and internet of things (IoT) [4-7].

Home security is essential. A major component of home security is the increasing number of criminal activities worldwide. DSDLs put an obstacle to criminal acts. DSDLs will definitely be a favorite for every homeowner. They provide identical level of safety as traditional door locks, with aset of alternatives to the traditional key [8-10]. Previously, there was only one authentication method available for door locks the mechanical key. However, the keys are usually misplaced, left at home or lost. DSDLs offer a variety of authentication techniques to choose from suitable for user specific needs and offer total peace of mind [11, 12].

2. LITERATURE SURVEY

Many DSDL systems was developed recently and commonly used in commercials homes and buildings [13-20]. Based on RFID (radio frequency identification) technology, low cost technology. P. Tripathi proposed a technique to realize DSDL system [13]. The user is first registered in the security system and his data is copied into the RFID tag. When the user comes to the entry/exit point and places the RFID tag in the reader, the security system checks if a user is registered or not. If registered, the door will open and close immediately after a fixed time period. Otherwise, user does not pass. B. Saraladevi has designed and implemented a password based security lock system. If the entered password is correct, the door will be opened by an actuator which is utilized to rotate the door lock handle [16]. In [14], Kamelia et al. have purposed a secure HAS using Bluetooth technology. The purposed HAS is relies on Android platform. Y. T. Park had purposed a digital door lock based HAS which exploits the full advantage of ZigBee technology based wireless sensor networks [15]. We found through the survey, some of the pervious implemented DSDL systems are expensive. Others do not provide multi level functionalities.

3. HARDWARE COMPONENTS

3.1. Actuator

Actuator or servo motor (DS04–NFC), is a cheap, high–torque and 3600 rotation motor which can rotate continually with forward/reverse direction [21]. DS04–NFC is capable of lock/unlock the door in real–time. In the implemented system, DS04–NFC is activated via fingerprint reader. Some of the main features of the DS04–NFC motor we used are listed below [22]

a) Operating voltage: 4.8 – 6v.
b) Current:< 1000mA.
c) Dimensions: 39.5 x 40.8 x 20mm.
d) Operating temperature: 0 – 600C.

3.2. Grove - fingerprint sensor

One of the most common devices in use which acts as a data entry device is the fingerprint sensor. Fingerprint sensor, is an optical sensor that will allow adding fingerprint identification and verification [23]. The sensor can record up to 200 fingerprints, and each recorded fingerprint appoints an ID from 0 to 199. This sensor comes with four wires in different colors as depicted in Table 1 [24].

Table 1. Finger print sensor wires function description [24]

Pin number	Color	Function description
1	Red	+ 5V Power supply input
2	Yellow	Tx wire for TTL sensor
3	White	Rx wire for TTL sensor
4	black	GND

3.3. Arduino nano board

Arduino Nano is a breadboard–friendly micro–controller which communicates with DS04–NFC servo motor and triggers a door based on the command received from fingerprint sensor [25]. It contains USB connection, crystal oscillator, eight analogs (I/O), twelve digitals (I/O), and a reset button. Its operating voltage is 5v [26, 27].

4. DSDL SYSTEM IMPLEMENTATION

As shown in Figure 1, authorized users should be first registered with the system. Registration is done through finger print sensor. Fingerprints will be saved on different IDs in the Arduino Nano microcontroller. When a user comes to access the door, the system examines if it is registered user or pretender. If the entered ID is matched the saved, the user is trusted, the lock is open, if not, the access is not allowed.

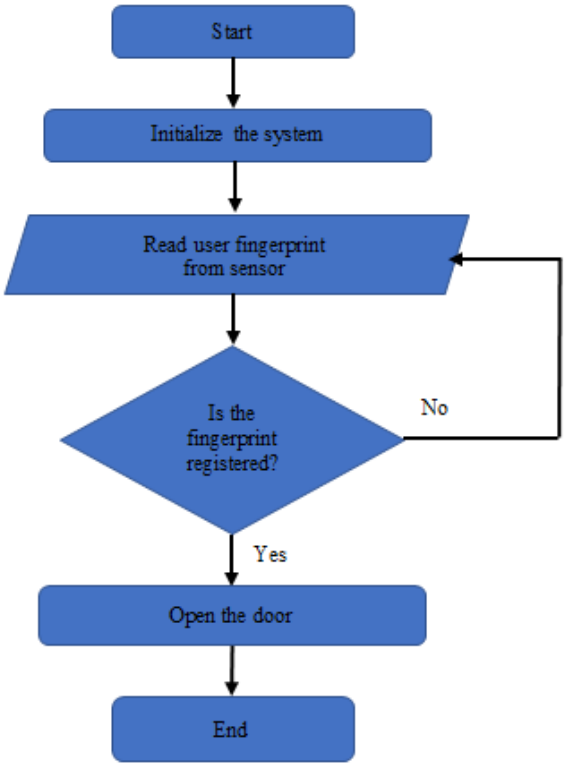


Figure 1. Block diagram of the DSDL system

4.1. Practical design of the DSDL system

Figure 2 depicts the circuit diagram and practical design of the DSDL system. The following steps explain the circuit diagram of the fingerprint DSDL.

1) Connect Arduino Nano via a USB–Type B port.
2) Connect the yellow terminal of servo motor to the pin D9 of Arduino Nano board.
3) Connect red terminals of both fingerprint sensor and the servo motor with the 5v of Arduino Nano board.
4) Connect black terminals of both fingerprint sensor and servo motor with the GND.
5) Connect the yellow terminal of fingerprint sensor into the pin D3 of Arduino Nano board.
6) Connect the green terminal of fingerprint sensor into the pin D2 of Arduino Nano board.
7) Connect one end of both the opening and closing buttons to the GND.
8) Connect the Open lock button from inside with pin D6 of Arduino Nano board.
9) Connect Lock Buttons from Inside and outside with pin D5 of Arduino Nano board.
10) Connect short terminals of the LEDs and positive terminals of the resistors1K–Ohm with the GND port.
11) Connect red LEDs with pin D12 and green LEDs with pin D11 of Arduino Nano board.

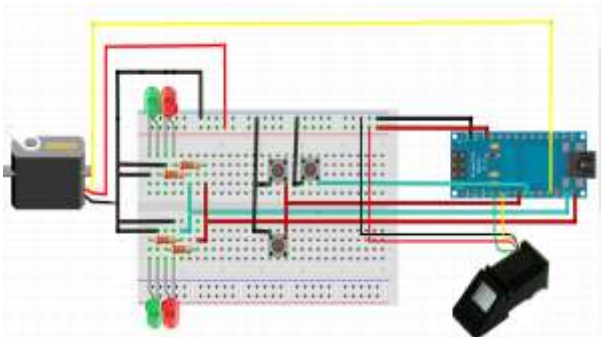


Figure 2. Circuit diagram of the DSDL

4.2. Working of the DSDL system

4.2.1. Fingerprint registration

The following steps are undertaken to record a new fingerprint [28].

a) Arduino IDE, run → File → Examples → Sensor Library → Enroll Fingerprint.
b) Upload Arduino code, then initiate COM4 at 9600 baud–rate.
c) At the **top left corner,** you must enter the fingerprint ID to be stored. At the **top right corner** click send.
d) On the Grove-fingerprint sensor, put your finger, then follow the procedures on COM4 screen, as shown Figure 3, you will be prompted to put identical finger two times. If the fingerprint similar your fingerprint recorded successfully.

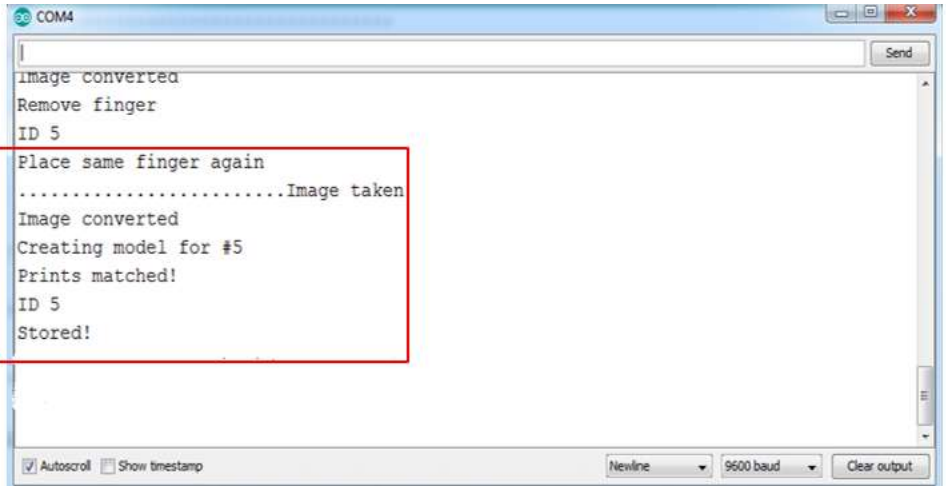


Figure 3. Register a fingerprint

4.2.2. Fingerprint matching

Multiple fingerprints have been recorded with different identifiers (IDs). The following steps are excuted to find similarity with the sensor fingerprint [29].

a) Arduino IDE, File → Examples → Sensor Library → Fingerprint.
b) Upload Arduino code.
c) Initiate the serial COM4 with 9600 baud–rate.
d) Place the finger to be recognized on the scan. COM4 screen, reveals that the ID matches the saved, as depicated in Figure 4.

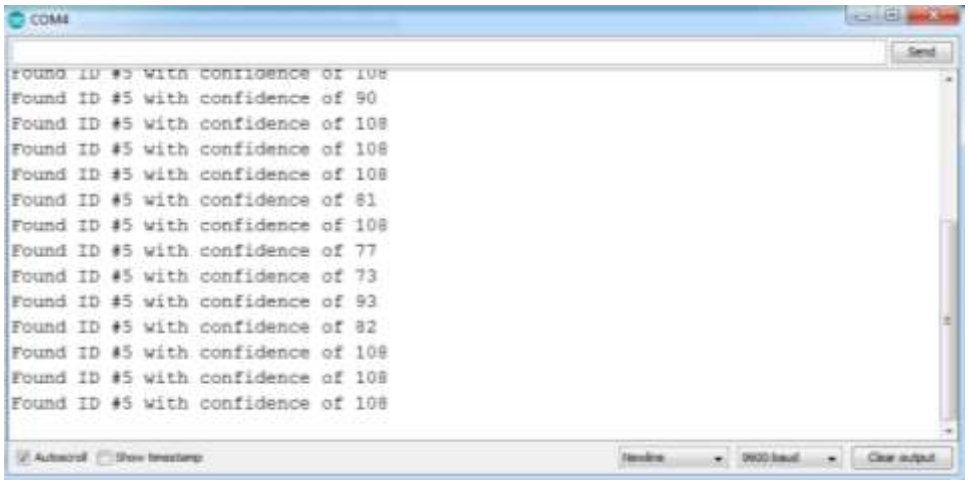


Figure 4. Fingerprint matching

4.2.3. Working of the DSDL system (outside door)

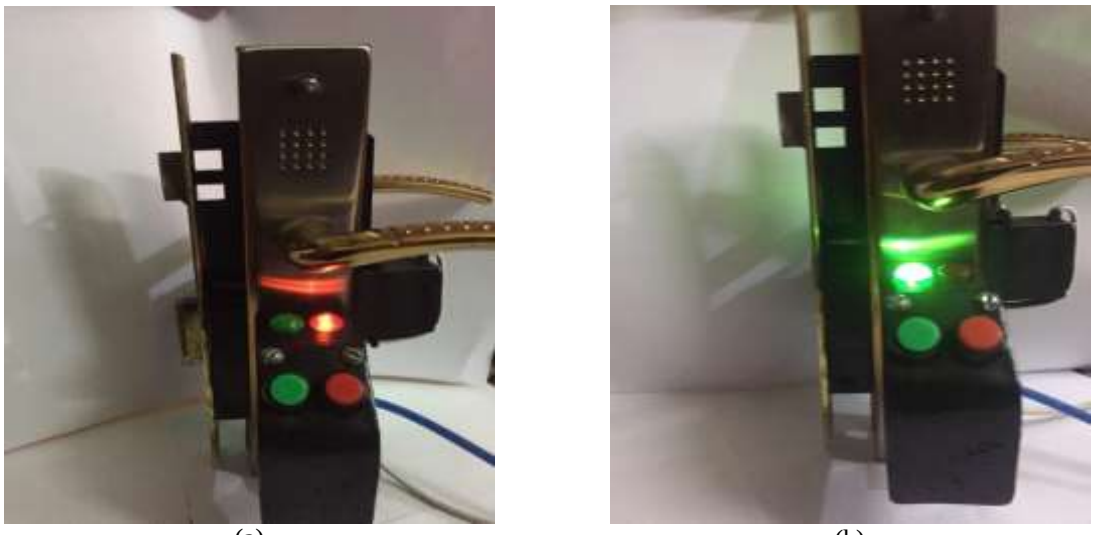
Pressing the red push-button will lock the door from the outside. When the lock is activated, the red light will turn on to indicate that the door is locked as shown in Figure 5(a). The DSDL opens from the outside with only the mateched fingerprint ID, allows authorized persons to access the door, then the green light will activate to indicate that the door is open as shown in Figure 5(b).

(a) (b)

Figure 5. (a) Outside door (locking), (b) Outside door (opening)

4.2.4. Working of the DSDL system (inside door)

Locking the door from the inside pressing is done by pressing the red button. When the lock is activated the red light will be turned on to indicate that the door is locked as depicted in Figure 6(a). The door opens from the inside by pressing the green button. When the lock is open, the red light will be turned on to indicate that the door is opened as depicted in Figure 6(b).



(a) (b)

Figure 6. (a) Inside door (locking), (b) Inside door (opening)

5. SMART DOOR LOCK SYSTEM PROGRAM DESIGN

C–language code used to configure hardware−based Arduino DSDL system is listed below:

```
#include <Adafruit_Fingerprint.h>
#include<Servo.h>
#include <SoftwareSerial.h>
#define sw1_pin 5
#define sw2_pin 6
Servo myservo;
volatile boolean sw1 = false;
volatile boolean sw2 = false;

uint8_t sw1ButtonState = 0;
uint8_t sw2ButtonState = 0;

uint8_t lastsw1ButtonState = 0;
uint8_t lastsw2ButtonState = 0;
int getFingerprintIDez ();

SoftwareSerial mySerial (2, 3);
Adafruit_Fingerprint finger = Adafruit_Fingerprint(&mySerial);

void setup ()
{
  Serial.begin (9600);
 pinMode (sw1_pin, INPUT_PULLUP);
 pinMode (sw2_pin, INPUT_PULLUP);
  Serial.begin (9600);
 finger. begin (57600);
 myservo. attach (9);
 pinMode (12, OUTPUT);
 pinMode (11, OUTPUT);
}
void loop ()
{
 getFingerprintIDez ();

   checkIfSw1ButtonIsPressed ();
   checkIfSw2ButtonIsPressed ();

   if (sw1) {
    Serial.println ("sw1");
     sw1 = false;
     myservo. write (20);
     delay (7000);
      myservo. write (90);
digitalWrite (12, HIGH);
digitalWrite (11, LOW);
    }
   else if (sw2) {
    Serial.println ("sw2");
     sw2 = false;
     myservo. write (170);
     delay (7000);
    myservo. write (90);
digitalWrite (11, HIGH);
digitalWrite (12, LOW);
    }
}
```

6. CONCLUSION

In this paper, a secure and fully–automated DSDL is designed and implemented using Arduino Nano. An Arduino Nano based on Atmega328 microcontroller has been utilized for lock/unlock the door of home or building based on user's finger print so that only authorized users will grant access. The DSDL system is an automatic authentication and authorization system that can be installed at the bilidings or home to grant access to authorized people. The main objective of designing and implementing this system is to compare the cost with the existing DSDL systems. The cost of the whole implemented (prototype) system is only about 75$ which is cheap compared with existing secure access systems which cost about 150$–300$.

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