DEX LOCK

A Project Report

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ABSTRACT

"Each year it is estimated that there are two and a half million burglaries across the United States. These burglaries cost homeowners $3.1 billion in the U.S. This concludes that the average loss per burglary is around $1,700," statement found in an article, American physicist and Professor of Physics at Yale University, by David Demille. Therefore, in all times security has become an important factor in our lives. In addition, security is established to protect anything valuable or that one feels necessary to secure and protect. As a result, security in your home's property is essential to keeping your family safe and protecting your valuables.

Most households use a standard door lock to secure or gain access to his or her home. A standard door knob and deadbolt door are good, but in any way, provide resistance to an intruder. The main aspect of protection but without another form of home security is the problem. For example, if the persons lost a key and found in someone else's possession, it would grant him or her access to the person's home. Therefore, we propose to apply a facial recognition system to provide support to standard locks that would grant access to residents of the home. In addition, the facial recognition would be able to identify and verify a person's unique identity, whereas an unknown person with or without a key would not be allowed into the home and would be denied access to a person's home.

Advances in Facial Recognition has reached a high standard in security within the last few years. Therefore, by unlocking the technology of identity and verifying the person's identity has created various opportunities into different fields that we may apply a facial recognition system into. For instance, access/security, criminal identification, and healthcare are just a few fields that will benefit greatly from advances in facial recognition. Facial recognition provides a unique high security system that grants access to users or allowed persons in the settings. Also, one of the most common uses of facial recognition is to gain access to a cellular device. However, the usage can be implemented to simplify the mechanics of different gadgets, home appliances, and security systems.

In the advent of the internet, the world has become more interconnected. By that being said, this interconnected spans all aspects of modern life. The multiple ways of being interconnected are phones and their ability to interact with the world's computers. Therefore, by the advances in technology the best logical next step is to include this in our product. Therefore, by applying an additional method to unlocking or locking a door lock can be via a mobile application. Having the option to unlock and lock a door lock via a mobile application can be convenient to homeowners, because it reduces the usage of keys and allows the homeowner to not wonder if they forgot to lock the door. Going back to if one loses their key, they won't have access to enter their homes, but having the application can allow the user to enter their home at any moment. This wireless communication pairs well with the modern world, so it can be applied to anyone who has internet installed in their home.

This smart lock hopes to solve a home security problem by reducing lost or stolen keys. There are other systems of security locks out in the market. However, most of these systems tend to be either prohibitively expensive, going as far as costing a couple of hundred dollars, or cheaper, but missing features such as the facial recognition. This is where Dex Lock solves these problems by being relatively cheap, having facial recognition tech, and connecting to a mobile device to get the job done.

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1.Introduction

1.1 Problem Definition

DEX manufactures a DEXlock model aimed at the people. The reason for the DEXlock is that it can be used on any front door after installments. Studies from Safehome.org state that "1 in 5 people leave their doors unlocked, meaning that 80% of Americans lock their front door." The DEX community wants to provide a convenient package deal that comes with a facial recognition camera, keypad, and a personal app for locking and unlocking the door. For such effect to properly take place, the device has to be user friendly and convenient in all possible ways. The DEX community's purpose is to impose a mechanism to help all homeowners. The project team will come and put together all documentation to produce the DEXlock. The DEX company will build all locks on sight in the manufacturing stockroom and will not be outsourced.

1.2 Project Specifications

Interface Controller:

The Raspberry Pi 3 (RP3) is used to be the main interface controller. It is designed in this way for the interface of the system, because the raspberry pi can act as a mini computer and can handle multiple request given to it in python. Therefore, the raspberry pi can have a keypad attached to it. Additionally, the raspberry pi can intercept the signal from the keypad and choose the appropriate action. Also, RP3 can send an output signal to the LCD screen to properly inform the user of their options. The block diagram input and outputs will be connected to the RP3 GPIO pins but will be pre configured and hidden from the user for ease of use. These pins will send and receive the inputs and outputs of the system.

Keypad:

The keypad is the main onboard device used to interact with the system. The keypad uses 8 pins to send the signal to the raspberry pi. The raspberry pi then deciphers the signal sent to read the proper output of the keypad. The output signal determines the way the mRPi controller responds. The input of the device comes from the user and the output goes to the raspberry pi. Here is a schematic diagram for the keypad which contains 8 inputs, 4 for rows and 4 for columns, and can be program in different ways (Appendix A.D for more info)

Camera:

The LG Webcam is used for facial recognition and is used in conjunction with the open source software (OpenCv) to do facial recognition. The camera takes succession of 1920 by 1080 resolution photos, and sends them to the Raspberry Pi system. The OpenCv Library will receive pictures taken from the camera, and compares them to an existing picture database to determine if there is a match. If the taken picture is a match, then the program will trigger a signal. For setting up the camera, it can be connected to any of the Raspberry Pi's USB ports. As for the webcam, it only takes photos as a means to minimize any performance issues instead of a live video feed.

LCD:

The LCD screen, with an operating voltage of 3.3-5V, can display many characters over the span of four lines. There's a potentiometer to adjust the resistance leading to a change in the backlight of the LCD, although this option will be hidden from the user. The LCD will get information from the keypad and display the appropriate menu depending on the selection. And by default, the LCD will always be on to show the main menu to the user. Here is a schematic diagram and pin description for the LCD screen which is the same for different LCD sizes. (Appendix A.C for more info)

Door Lock Controller:

The door lock controller will be made up of an Arduino, Bluetooth module, Servo motor, and a UltraSonic Sensor. The controller will take an input signal sent by the bluetooth from the front panel microprocessor (Raspberry Pi) and control the door accordingly. The Ultrasonic sensor will also send a signal to the controller to indicate if the door is closed after opening and opened after closed. It will also give the user an LED indication for the status of the door (Green - Open, Red -Closed).

Servo Motor

The servo motor is a Lobot LD 27 MG and has a torque force of 20 KG per centimeter, which is powered fully at a voltage range of 6V to 7V. When the servo motor receives the PWM signal, which is triggered by the door lock controller (Arduino), it starts the rotation of the motor, and it controls the movement of the deadbolt. When booting for the first time, the servo motor moves at 0 degrees (Unlock state) and changes depending on the two inputs (Bluetooth receiver or Door status identifier). It will rotate 90 degrees when it is triggered by any of the inputs only if the door status is close.

Bluetooth:

The bluetooth, HC-05 module, aspect is a great feature because it allows connection from the raspberry pi to connect to bluetooth toggles that will be implemented into the arduino. The purpose of having the bluetooth connection is to have the power split separately, so that the Raspberry pi is not having to pull all the power into the camera, LCD, keypad and servo motor. In addition, the idea is that depending in the user's input on the keypad, the raspberry pi can send a signal via bluetooth to the arduino to control the servo and be able to unlock the door. The schematic and pin diagram below, is a description of the HC-05 bluetooth module. (Appendix A.EAppendix A.C for more info) for more info)

Arduino Board:

The arduino board will be used for the rear side of the device. It is responsible for triggering signals to the LED, Servo and Ultrasonic sensor and receive incoming signals from the HC-05 Bluetooth. The LEDs will be use as a status indicator to prompt the user if the door is locked or open. The Ultrasonic sensor will be our distance tracker to indicate if the door is open and closed. This device will have a mountable block that will be placed next to the door for the ultrasonic sensor to sense for checking the status of the door. If the door is closed, then the distance from the sensor to the block is a fixed distance and if opened, the distance is larger. As for the servo, the Arduino will trigger it based on the incoming

signal from the bluetooth module. It is responsible to turn the servo 0 or 90 degrees depending on the incoming signal and state of the door.

System Analysis:

The design has a few issues.One design issue was the fact that any intensive calculations done by the RPi for the facial recognition was too performance intensive.This would lead to power issues in the rest of the system .This could be as severe as a complete shutdown of the RPi system to and at best severe slowdown while the system was processing the live video feed.To remedy this we changed the large portions of the code to not run video at all .Instead we have it so the camera and face recognition software use is kept to a minimum.We have it so it's only used when the user chooses the appropriate option and we also removed most instances of a live care feed and had the camera take a series of pictures.Changing it into pictures and having the camera be off until the user requests it means that the camera would need time to boot up.In this boot up time the camera would take black pictures so we had to add in an initial buffer of about 30 frames to allow the camera to boot up, any pictures taken in the initial boot up time buffer would be discarded and then after the buffer the final images would be taken and used for face recognition.These modifications were to lower the performance cost of the face recognition which would in turn provide the rest of the system with enough power to run

Android Application:

The android phone application is another way to be able to unlock the door via bluetooth communication with the arduino. The app interface consists of a button that when pressed, the app will send a signal to the bluetooth module in the arduino that will get the servo to turn to unlock the door. The app interface also consists of a status display to demonstrate whether the door is unlock already or not.

1.3 Hardware Specification

1.3.1 Interface Controller ++

Device: Raspberry Pi 3 B+
Microprocessor: Broadcom BCM2837B0, Cortex-A53 64-bit SoC @ 1.4GHz Quad-Core
Ram: 1GB LPDDR2 SDRAM
Storage: 32GB
WIFI: Dual-band 802.11ac wireless LAN (2.4 GHz and 5 GHz) and Bluetooth 4.2
USB: 4 USB 2.0 Ports
GPIO: 40 GPIO Pins
Power: 5V / 2.5A DC
Video and Audio: Yes (HDMI)
Operation System: Linux [1]
Dimensions: 3.35 x 2.20 inches [2]

1.3.2 LCD Display

Physical Specification: 20x4 LCD display
Color: White/Blue
Backlight: Yes
Dimensions: 3.9 x 2.35 inches
Display View Size: 3 x 1.02 inches [3]

1.3.3 Keypad

Key Dimensions: 4x4
Dimensions keypad: 2.71 x 3 inches
Dimensions Cable: 0.787 x 3.46 inches [4]

1.3.4 Camera

Brand: Logitech
Camera: Laptop Camera
Max Resolution: 1080p/30fps - 720p/30fps
Cable Length: 3ft [5]

1.3.5 Deadlock-Turning-Mechanism ++

Device: Arduino Mega 2560
Microcontroller: ATmega2560
Clock Speed: 16Mhz
Memory: 256KB flash Memory
Operation Voltage: 5V DC [6]

1.3.5 Bluetooth Modules

Device: HC-05
Frequency: 2.4GHz [7]

1.3.6 Rotate Device

Device: LD-20MG Servo

1.3.7 Door Status Detector

Device: HC-SR04 Ultrasonic Sensor

1.3.8 LED Status Indicator

Device: Generic LED w/ 250Ω resistor (Green & Red)[1]

[1] ++ Refer to appendix A for more information

1.4 Software Specification

1.4.1 User Interface

Language: Python 3
Library: OpenCV
Functionality: Facial Recognition
User Options and User Interaction
Cross Communication: Yes via Bluetooth

1.4.2 Deadlock Program **

Language: Arduino IDE
Library: servo.h
Functionality: Uart Communication via Bluetooth,
Deadlock rotation via servo
LED Controller
Cross Communication: Yes via Bluetooth

1.4.3 DexLock App

Language: Java
Library: Android Studio Standard Library
Functionality: Uart Communication via Bluetooth
Cross Communication: Yes via Bluetooth

[2]

[2] ** Refer to appendix B for more information

2. Related Works

2.1 Existing System

There are a few similar products on the market such as The Nest x Lock and the August Smart Lock. The following demonstrates these two products:

Nest x Lock

- Goes over deadbolt lock and controls locking mechanisms
- Additional keypad that allows user to open door
- Connects to home wifi and allow users to open the door through the app and allows the homeowner to send temporary keys to other app users to allow them inside
- Schedulable period of entry for designated guests
- Google home integration to check lock status
- Price point of $400
- Activity Log

August Smart Lock

- Schedulable period of entry for designated guests

- Activity Log
- Connects to home wifi and allow users to open the door through the app and allows the homeowner to send temporary keys to other app users to allow them inside
- Remote access through their proprietary Nest app
- App allows for automatic opening and locking of the lock by mere proximity
- Price point of $150

2.2 Proposed System

The proposed system we have design shares many of the features as the related works but has a few key difference.Communication within the device is done by bluetooth.This allows for the device to be more easily control through an app.The proposed system has a variety of method to enter a house.One method is by using the built in keypad to navigate the simple to use interface.ONe method is by password input from the keypad,Another method is to use the built in facial recognition system to allow entry.This is a key feature of the device .The system will also allow for password change and additional entry in the face database.This all in conjunction with the app which will allow a third method of entry into a household. This variety is what sets the DexLock system apart from others which tend to focus on one specific area.

3. System Design and Evaluation

3.1 Requirement Specification

Principle of Operation:

The initial step in using the Dex Lock is to install the device to all doors the user wishes. Following the successful installation of the device on the door, the user needs to download the DexLock app from the Google Play to their Android device(phone is recommended). After installation on both devices, one more step is required. To begin using the device, the devices are to turn on the bluetooth communications for the android device can connect to the DexLock system. After pairing phone with bluetooth, the user will be greeted by the app interface to control the devices.

In the app interface the user can control the lock in a number of ways. For example, in the app the user will be provided with option to open the door lock and close it as well. Therefore, to have access to

the door lock the user will always have to connect to the bluetooth from their phone to be able to control the door lock. There will be additional methods to control the door lock aside from phone application. In addition a keypad will be included in the entrance of the door with a mounted LCD screen on the outer door device which will present options to the user. On this menu, the user can decide their action depending on the key selection. The selections include; unlock door via password, modify password, face recognition, and add face to the database. To open the door through the keypad, choose the appropriate option on the menu, and enter a password for entry. Also, to open the door with face recognition the user will again choose appropriate option and use the camera to take an image and again allow entry. The previously mentioned app will not interfere with these hardware controls but work in conjunction with them. The multiple options of entry will allow the user flexibility depending on the circumstances

User Interface:

The DexLock system will have two methods of interaction with the device. There is the built in hardware interface. This interface is made up of a keypad along with an LCD screen.Therefore, on the LCD screen, the user will be presented with a menu. The first option is to enter a password to unlock the door lock. The second option is to modify the password. The third option is to use the built-in face recognition to unlock the door. The last option is to take a picture to add face to the database.

The second user interface for the device is the phone application interface. This application interface is held on an Android app that will be available on the Google Play store. When opening the app, it will initially ask user to connect to DexLock system via bluetooth. After connecting user's device with bluetooth communication to the door lock, the main interface will become present. The interface will have the options to open and close the lock with a button.

Input :

The system will have various inputs. One is the keypad input into the system which controls the hardware menu. Another input is the capture of an image by the DexLock camera, which is used for the facial recognition system. Another input is the output selection fo the app that is sent through bluetooth communication and received by the hardware interface.

Output:

The outputs of the DexLock includes the servo motor,LCD Screen, app bluetooth signal . The servo motors will be activated by the inputs from either the keypad input ,facial recognition, or the app. Once the servo is activated then the door will open or close. The Lcd screen upon boot up will display a menu .This menu also changes depending on which option is chosen. Then it will ask for a password and upon a succesful password entry, a message showing approval will be displayed followed by the door opening.It will also display a message when access is denied. The last output signal is the bluetooth communication of the app to control the servo motor as well.

User Manual:

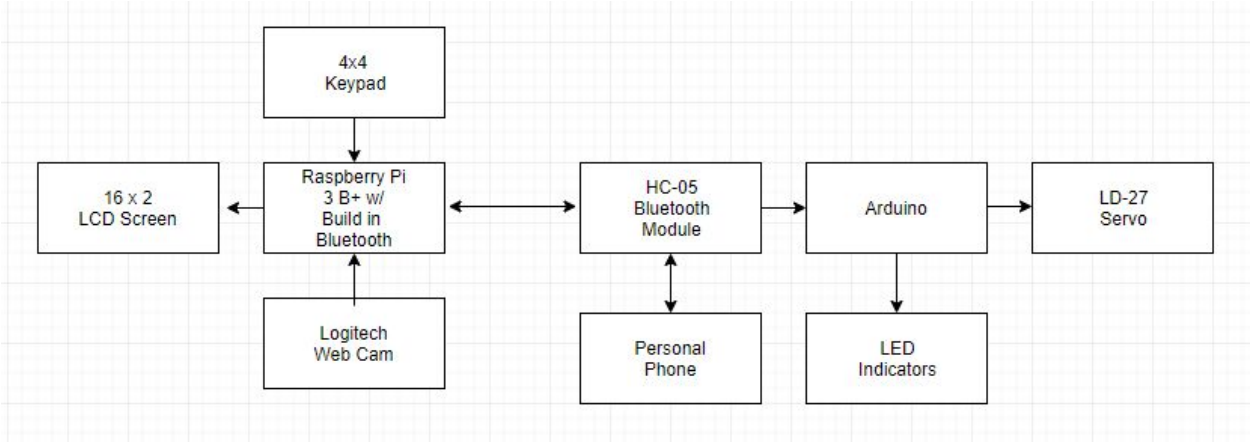
The DexLock is made with ease of use in mind. Therefore, to get DexLock up and running is relatively an easy process. The DexLock provides the user with all information required for proper usage. This information can all be accessed from the hardware interface of the Android app.

App

- First make sure to be in bluetooth range of the device
- Once in range ,connect to the device by entering the correct bluetooth pin password provided
- The app menu should pop up
- Click on open button to open the door lock.If not working check bluetooth connection and if problem persist check on the hardware itself

Physical Device

- To begin use of the device ,choose one of the options displayed on the LCD screen
- Press the appropriate button for your desired action.
- Press 1 to enter open the door which will prompt the use to enter the door passcode
- Press 2 to change the password .This will ask to user to enter passcode then upon successful passcode input will allowing for the new passcode to be inputted
- Press 3 to open the door through facial recognition.To properly use the facial recognition the user need to align themselves directly in front on the onboard camera for the optimal picture quality.If lighting conditions do not allow for proper use of camera use another method entry
- Press 4 to train a face for facial recognition .Repeat the process described above to take optimal photo



Pros	**Weight**	**Cons**	**Weight**
Improved Security	4	Camera angle	3
High Accuracy	5	Data Storage	4
Fully Automated	3	Major Appearance Difference	3
Low Maintenance Costs	5	Lighting	2

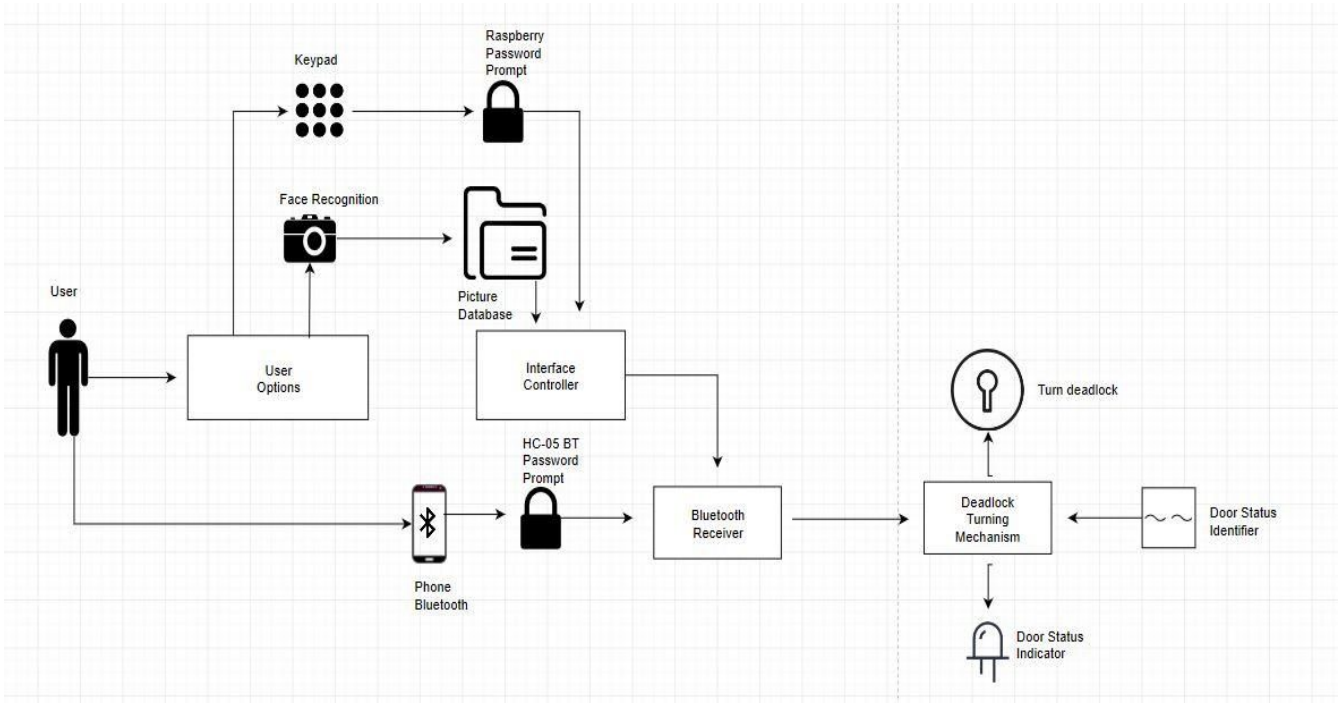
Total	17		12

Design Deliverables:

- Schematic Diagram of the device
- A working prototype of the “Smart Lock “ device that is demonstrable
- Required parts list
- Device Documentation

3.2 System Design

3.2.1 Block Diagram



3.3 Detailed Design

3.3.1

The Dex Lock consists of a communication interface, a local processing and decision unit that will apply its embedded functions to complete the task of the Dex Lock.

- Low power
- Low Cost

- A prediction rate higher than 60%
- Opencv library to accomplish face recognition
- Built in PWM GPIO pins on the Raspberry pi
- Keypad working in conjunction with the camera to increase security

3.4 Testing and Evaluation

A test plan is for the Dex Lock is provided below. The scope of this documents includes all software and hardware activities that are used by the Dex Lock. Resourcesces , features to be tested, the testing environment are listed in this document. All formal testing for the software/product is provided below.

- **Scope of Testing:**
  The goal in testing the Dext Lock will include quality to make sure the system meets the specified requirements and meets the users needs and expectations. Also, the usability of the Dex Lock will be tested to make sure the "user experience" is an easy to use product that the user may use without any hassle., reliability and performance of the device in functionality and business requirements. Also verify Software requirements are complete and accurate.

- **Resources:**
  Hardware required for testing include: Raspberry Pi 3 B+, Logitech HD camera, LD-27 MG Servo Motor, Adafruit Keypad, Kwikset 660 Deadbolt,Android device,bluetooth device. Smart Lock device will be tested in an outdoor environment. Device will be installed on door entry which will allow for real life applications.

- **Testing Tools:**
  Reusable Cable Ties 8"
  Gorilla Glue (Polyurethane) 4oz Bottle
  Craftsman Phillips Screwdriver
  3M Utility Duct Tape (silver)
  4 - #8x ⅜ Black Coated Phillips Wood Screws

- **Test Strategy:**
  Facial Recognition under varying lighting conditions. Adjust the effect of lighting on human faces.

  Case 1:
  Well illuminated environment. An illuminated environment would be used to test the facial recognition system. Testing during daylight or artificial light, when present, will meet these requirements.

  Case 2:

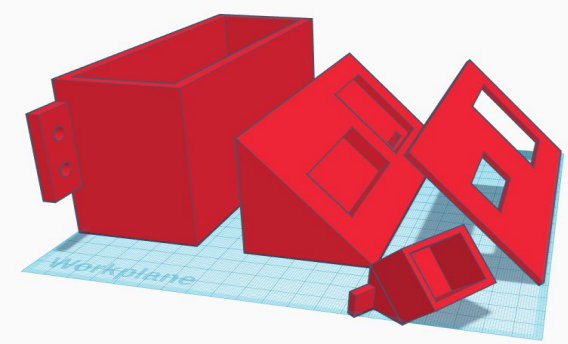
Semi-illuminated environment. A semi-illuminated environment includes when light is present, but also when shadows are present.

Case 3:
Non-illuminated environment. A non-illuminated environment is when no form of light is present.App testing under different conditions

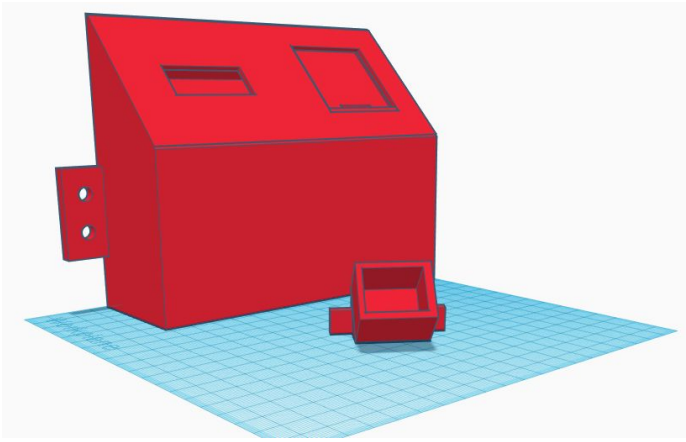
- Test sending the app signal in high frequency interface areas
- Test in areas with low interference
- Test the signal properly sends

- **Test Planning:**
  Document test cases by recording through video and recording data outputs. Keep track of the various fields of the test cases through the trails of facial recognition and android app successes and efficiency of the unlocking process. Testing to validate functionality has not been affected by changes of environment. The goal in testing the Smart Lock device is to validate the quality, usability, and performance of the device.

- **<u>3D-Case Design Testing:</u>**
  Case in 3 separate pieces:



Case all together:



- **Test Results:**

  The variation of lighting has a significant effect on the Dex Lock. In a well illuminated area the Dex Lock has a 60% succession rate. While in a semi-illuminated lighting area the Dex Lock has a succession rate of 40%. In the case of a non-illuminated lighting are the Dex Lock has a very low succession rate of about 25%. As the the test results show the lighting of an environment has a significant effect on the Dex Lock.

Results/Demo

User interface: keypad, LCD screen to display options to unlock the door, and camera for face recognition usage.

LCD screen options for the user:

Conclusions/Recommendations

In the end the product was a success.The overall functions of the device worked.Even though all desired functionality worked within the confines of the system design.Once fully implemented certain aspects of the design were limiting.So a recommendation would be to change the method of communication of the system and the app.Having multiple bluetooth devices create unforeseen problems.It is recommended to change the communication from bluetooth to a simple server to store the the info received from the phone before it was sent back to the device .Another recommendation to the current design is to improve on the app functionality.An increased feature set would improve the user friendliness and usefulness.Overall the system works well within its set design.It complete all its intended functionality and meets it design goal of being simply and easy to use.

References

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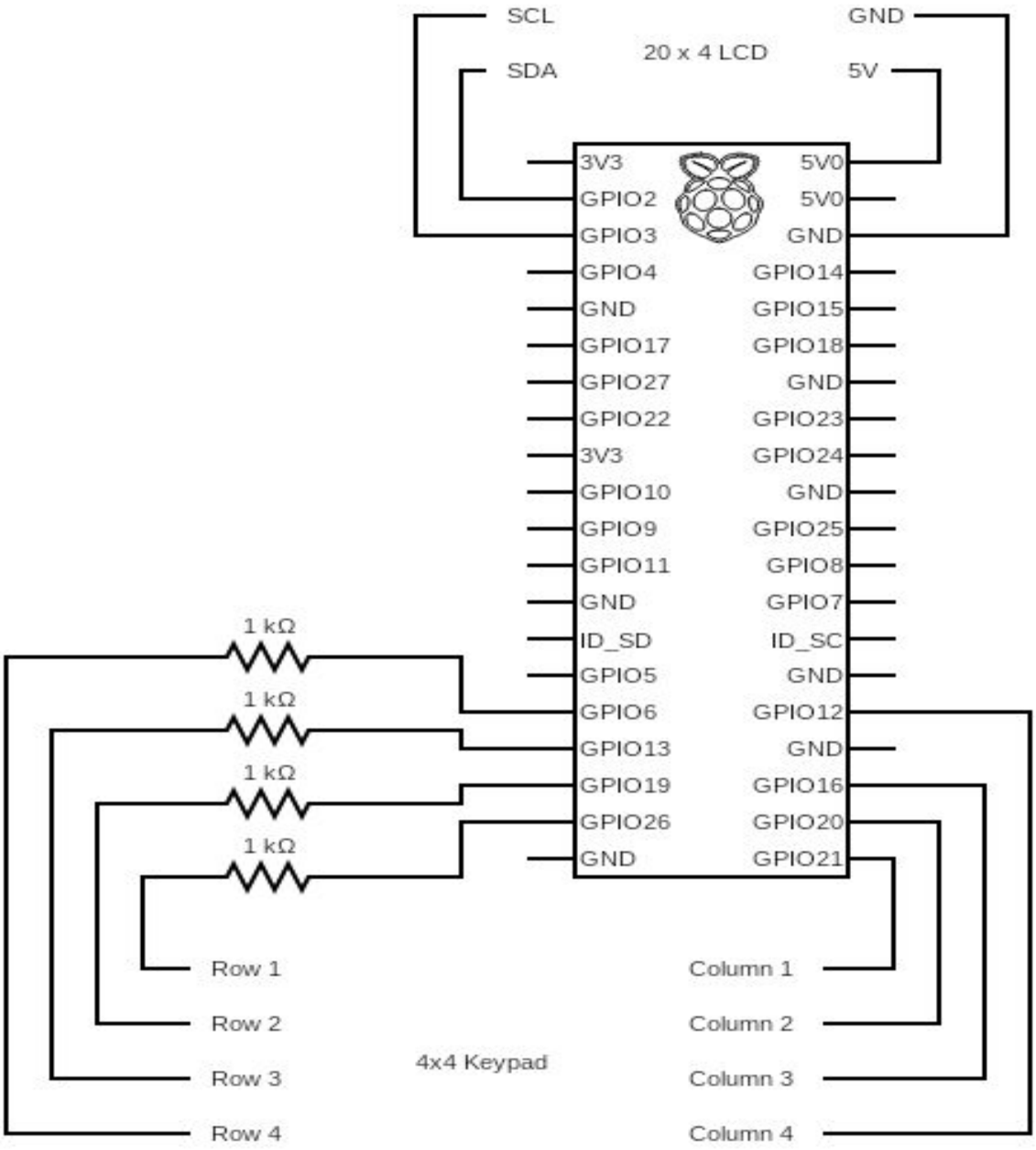
[7] ITead Studio (2019, June 3). *HC-05* . Retrieved from http://www.electronicaestudio.com/docs/istd016A.pdf

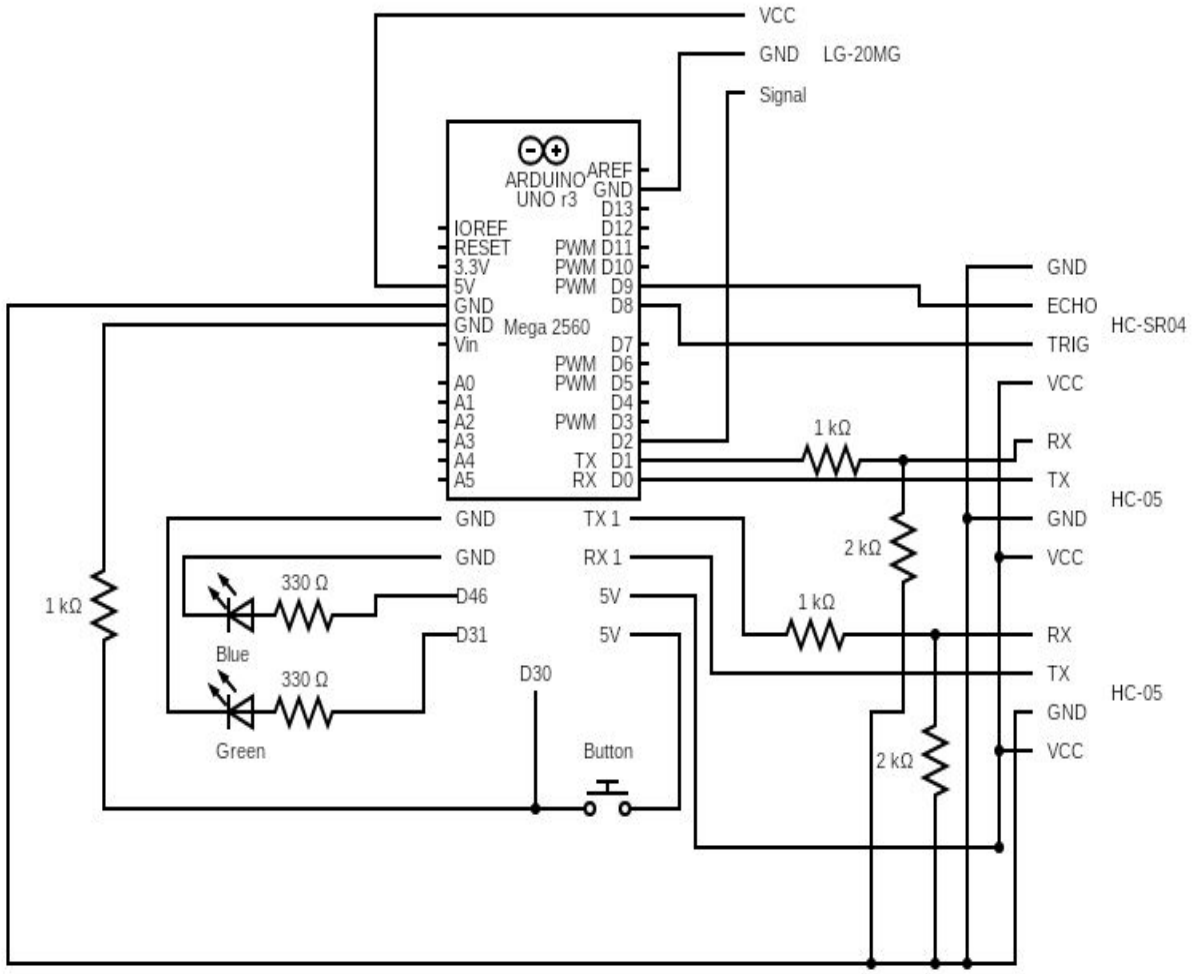
Appendices

Appendix A: Hardware Aspect

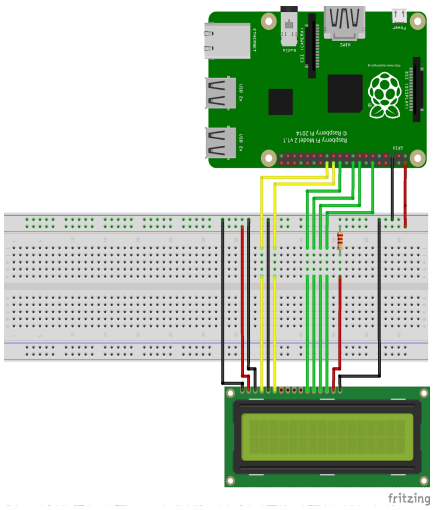
A.) Interface Controller Circuit Diagram

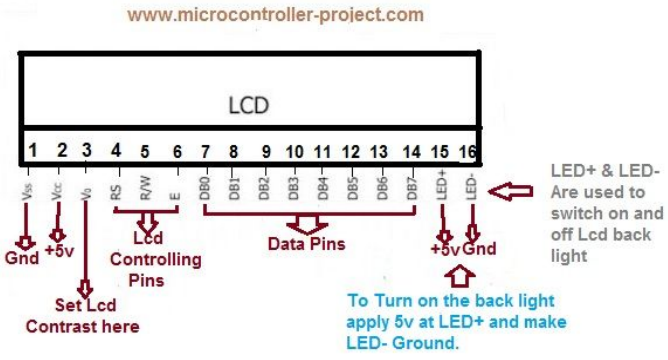


B.) Deadlock Turning Mechanism Circuit Diagram



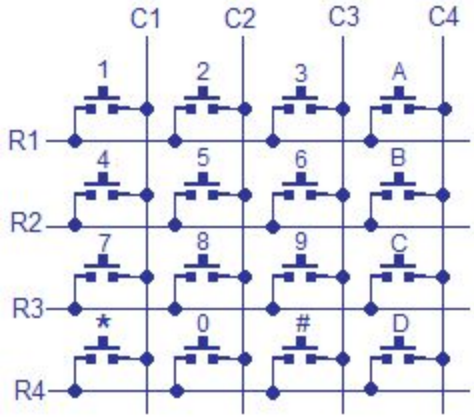
C.) LCD





All the Character lcds 8x1, 8x2, 8x4, 20x1, 20x2, 20x4, 24x1, 24x2, 24x4, 32x1, 32x2, 40x1, 40x2 are of same Pinout Given above.

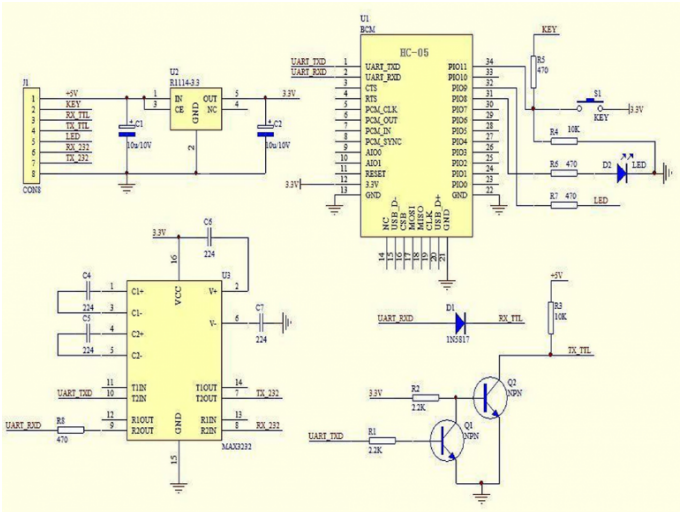
D.) KeyPad



Hex keypad www.circuitstoday.com

E.) Bluetooth

Pin	Definition	Description
1	TXD	Example
2	RXD	Example
11	Reset	put it NC, connect to low for reset
12	3.3V	VCC
13	GND	GND
31	module status	1hz flashing (when power on)- at command mode 2hz fast flashing = pairing mode 2hz slow flashing - communication mode
32	Pairing status	Output low TTL before pairing, and vice verse
34	Mode selection	High TTL for AT commands mode Low TTL for pairing and communication mode



Appendix B: Software Aspect

A.) Servo.h

```
// Setting to Lock when door is shut
if(distance < 2 and islock == false)
{
  delay(50);
  while(distance < 2 )
  {
    delay(1000);
    counter++;
    if(counter >= 5)
    {
      //Turn Red LED for Lock
      setLED(redLED,0);
      setLED(greenLED,0);

      myServo.write(83);
      delay(300);
      setLED(redLED,1);
      setLED(greenLED,0);
      lock = true;
      counter = 0;
      break;
    }
  }
}
```

This is an example of a Arduino IDE program for the Dex Lock. The myServo will be our Servo object in our program.

B.) LED

```
void setLED(int LED, int onOff)
{
  digitalWrite(LED,onOff);
}
```

This is another example of a Arduino IDE program for the Dex Lock.This will implement our LED indicator to fluctuate from on to off.