Freshman Design Project Final Report

ENSC 1412 Spring 2019

Houston Baptist University

Brian Davis

Nick Belbas

“The Live-Bolt”

Professor Keith Drake

Team Ghoti

Final Revision: 4/29/2019

Project Description:

According to a study by the Department of Education, 33,883 robberies and burglaries occurred in college residence halls between 2010 and 2012. The studies seem to indicate that most of these are due to "student negligence", being cause by doors left open or unlocked as well as student losing keys or having them duplicated. The switch to RFID or NFC keys has only made it easier as anyone with a recent NFC-enabled phone can easily clone a badge by touching it for less than ¼ of a second. Our idea will eliminate the need to carry around keys or tags that can be duplicated and instead relies on the one thing students will always have with them: their cell phone.

Our door lock uses a custom TOTP code generator algorithm to pull the exact time from a NTP server and generate a 6-digit code that can be used with Google Authenticator. The lock requires only wifi client communication with a remote time server, and deauth attacks or packet sniffing/spoofing would only result in the door remaining locked and will NOT allow unauthenticated users to open the door. Using a hard-coded (but encrypted) secret key, the student's phone and lock will generate the exact same 6-digit codes at the same time, allowing for true offline 2-factor authentication.

Project Summary: https://youtu.be/q4xhElsFcA4
GitHub Repository: https://github.com/nickdrones/The-LiveBolt

Major Components:

- Arduino Mega 2560 r3 as the main microcontroller
- ATWINC1500 WiFi chip for connectivity
- 4x4 matrix keypad
- 12v solenoid with relay in cascading switch
- RGB Led and Buzzer indicator
- 12v external power

Layout of Document:

- Previous versions/road to final revision
- Final Prototype
- Code

Idea Consolidation and Selection - March 21, 2019

Shown below is homework submitted regarding the 6 possible project ideas both lab group members came up with as well as the final option decided upon.

Possible Project Ideas:

1. Autonomous drone control (RPi and Arduino?)
2. Dorm room security
3. Conference room smart camera/whiteboard
4. Gaming peripherals/macros/screens
5. Wireless charging integration
6. Instant photo printer for drone/phone

We would like to try and tackle idea **#2** in the form of a two-factor authentication door lock.

While the autonomous drone control would have been fun, there would not be any use other than as a novelty. Likewise, the conference room smart camera idea would have been easy and useful but only to people who routinely use a conference room with video chat. The remaining three rejected options were deemed to be too difficult to execute within the given time frame, skill level, and budget.

Initial Note to Professor with Idea - March 25, 2019:

To: Professor Drake
From: Brian Davis & Nicholas Belbas
Date: March 25th, 2019
Subject: ENSC 1412 Design Topic - Two Factor Authentication Door Lock

Door locks are one of the first lines of defense against unauthorized intruders in any given space. However, they have many fatal flaws. For example, keys can be copied in clay or by photos, the numbers on keypads can wear out and be easily guessed, and wi-fi "smart" locks can have packets captured and re-transmitted. Our concept uses a single network ping to sync with an NTP time server and use a pseudo-random number generator to create numerical codes in sync with the Google Authenticator app.

Our idea is to design a mechanism that mounts to the standard 2.125 inch hole for door handle mounting in standard interior doors. Our mechanism will hopefully look like Schlage keypad lock and include all mounting points like bolts on the interior side to avoid tampering. On bootup, the knob will connect to the Time.org NTP server and input the time into a pseudo-random number generator seeded with a "secret key" also being used in the Google Authenticator phone app. This allows the exact same numerical code to be generated in both places without the vulnerability of wireless communication while also changing the code every few seconds.

The knob can also include a motion sensor, indicator LED, and a buzzer to alert at incorrect attempts to open the door. If the motion sensor sees a person outside the door and a certain number of incorrect codes are entered, an LED and buzzer on the inside can alert an authorized user once they enter after typing in a correct code.

We may not be able to test this on an actual door in the Hodo because it would require having a door temporarily without a lock as well as the risking damaging a door. However, we should be able to use properly-cut wood to make a mock-up door for our testing purposes.

Signatures of Team Members:

Brian Davis

Brian Davis

Nicholas Belbas

Nicholas Belbas

IDEO Design Process - March 26, 2019

Part 1: Understand the Problem

In this homework assignment, we were required to make a brief few-sentence statement describing the problem we are trying to solve as well as mentioning constraints that help define the problem more clearly.

With any type of door, locks can be picked and keys can be stolen or duplicated. Even if you use a smart keypad lock, wifi signals can be sniffed and duplicated or the combination key can be stolen. We need to create a door locking system incapable of being opened or disabled by an unauthorized user.

Part 2: Observe People in Real Life Situations

In this homework assignment, we were required to:

a. *Discuss why the problem bugged us personally or other people*
b. *List a few people we should take to about our project idea*
c. *List a few specific areas of research needed to complete our design*

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a. This problem bugs me personally because I've been recently learning a lot about lockpicking and it boggles me how outdated lock technology has become.
b. We should discuss our idea with other students living on campus especially in the Hodo as well as faculty with interior-doored offices.
c. We will need to research how the 2-factor authentication protocol works. We will also possibly need to research the Network Time Protocol (NTP) for accurate timing on the lock and a low-power mode to allow it to run longer amounts of time on a battery

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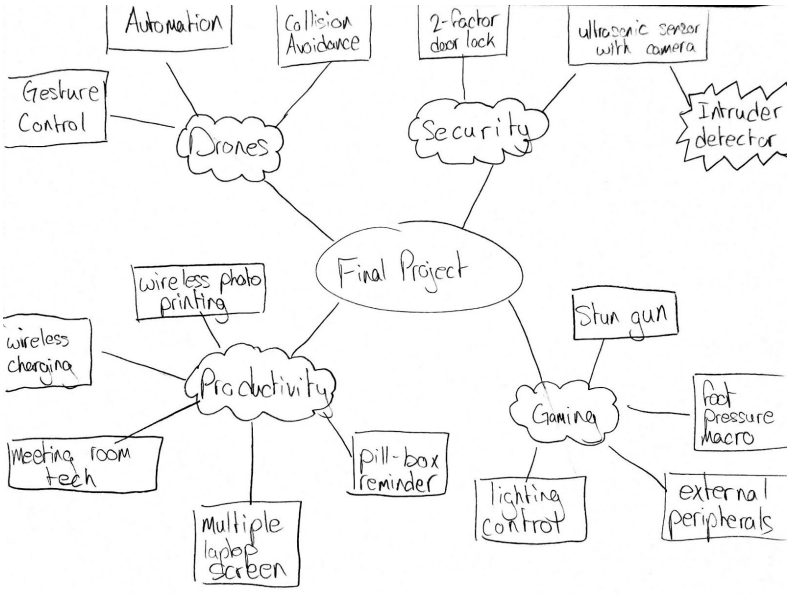
IDEO Design Process (cont) - March 26, 2019

Part 3: Visualize New-to-the-World Solutions

Mind Map of our decision process:

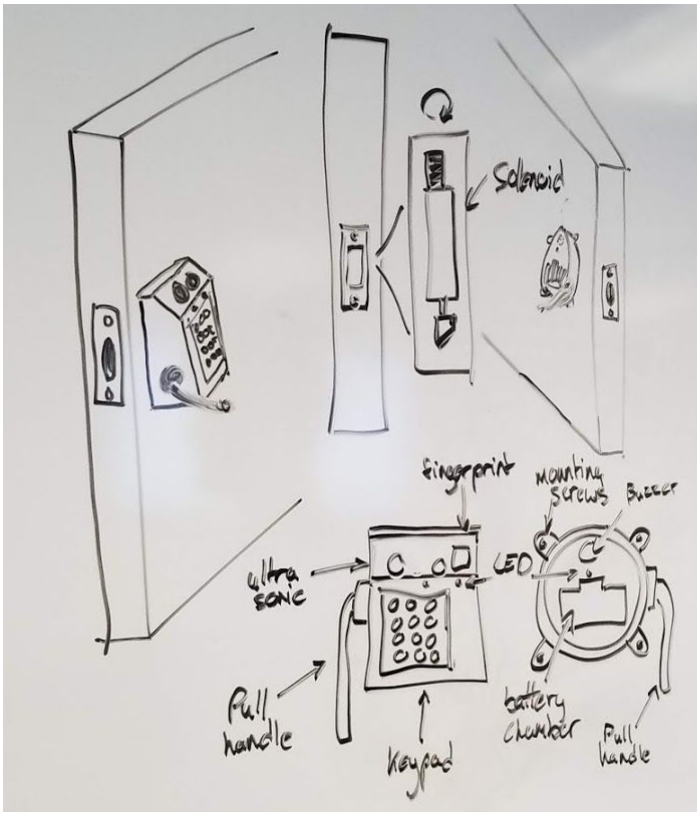


NOTE: When we created this mind map we were unaware that this was the mindmap for ONLY the final decision and not the entire decision-making process.

We only had one main idea for this problem/solution: a **2-factor authentication door lock** that uses the Google Authenticator app to generate codes on the Arduino and on the user's phone.

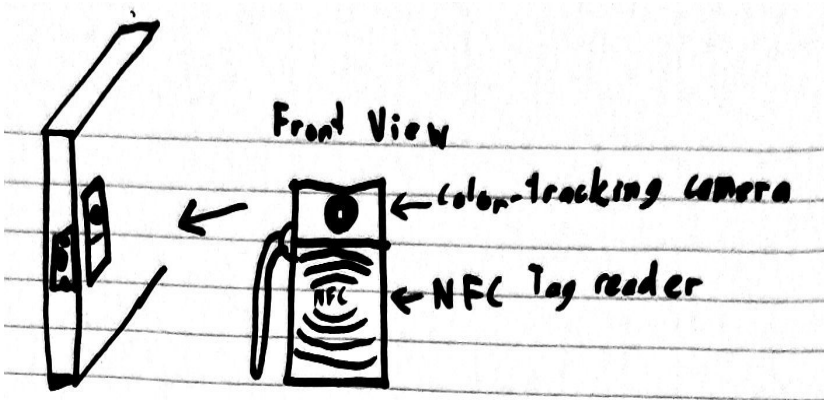
Design Concepts - March 26, 2019

Concept 1:



This design utilizes a keypad on the user's door as well as a wifi-enabled microcontroller, and LED, a piezo buzzer, and a solenoid. The user uses their phone to generate a 6-digit code which is then typed into the keypad, unlocking the door. We also initially planned to have a fingerprint sensor as well as making the entire assembly battery-powered.

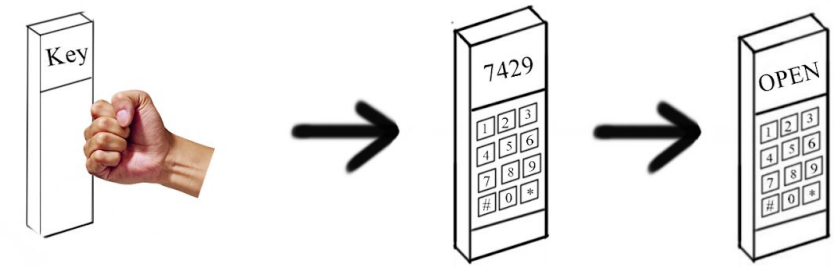
Concept 2:



Door handle that utilizes NFC tags and a color tracking camera to confirm the user. The person walks up to the door wearing a certain color of shirt and has to scan their NFC tag on the lock. Even if someone steals the tag, they will have to be wearing the correct color shirt to open the door.

Design Concepts (cont) - March 26, 2019

Concept 3:



Keypad utilizes an RFID chip that is embedded in the person's hand to activate a switch on the inside. When the switch is activated a panel opens up revealing a keypad. After the keypad is revealed they must still insert the correct keycode and then the door will unlock.

Pugh Matrix Evaluation of Each Concept:

Evaluation	Factor Priority	Concept 1	Concept 2	Concept 3	5=best, 1=worst
Effectiveness	5	5	3	5	
Complexity	4	5	1	1	
Acceptance	3	3	1	1	
Cost to Develop	4	2	2	1	
Cost to Implement	3	3	3	1	
		71	39	39	

Concept 1 was the option chosen to be created by our lab group

Required Parts:

What follows is our initial purchased parts list compiled on April 2, 2019. The purchased parts list as well as the other needed parts list were for our first version of the prototype. Our parts list changed with our different versions of the project, and those changes are reflected in this section. Parts lists are broken down by prototype version.

Prototype Version 1:

Purchased Parts:

Adafruit Feather M0 WiFi - ATSAMD21 + ATWINC1500	$34.95	https://www.adafruit.com/product/3010	Adafruit	Small Arduino IDE - compatible board that has wifi and a built-in lipo balance charger and UPS circuit
Lithium Ion Battery - 3.7v 2000mAh	$12.50	https://www.adafruit.com/product/2011	Adafruit	Small but decent capacity 3.7v lipo with the connector to plug directly into the Feather board
Mini Push-Pull Solenoid - 5V	$4.95	https://www.adafruit.com/product/2776	Adafruit	This is a small solenoid that runs on 5V and when unpowered is in the extended position, so ideal for a locking mechanism

Other Needed Parts:

Piezo Buzzer	Price NA (already have)	Personal Components	This is a buzzer to indicate when an incorrect code is entered into the keypad
RGB LED	Price NA (already have)	Programming Kit	The LED blinks red while the lock is activated and will turn green when the door is unlocked
Ultrasonic Sensor	Price NA (already have)	Programming Kit	This sensor measures when someone walks in front of the door. This allows us to run in low-power mode until someone walks to the door to unlock it
Toggle switch	Price NA (already have)	Programming Kit	This is a manual power switch for the inside of the door so at times where no one else should enter the room the door can be completely deadbolted
Momentary Switch	Price NA (already have)	Programming Kit	This button releases the solenoid from the inside so the door can be opened from the inside

Required Parts (cont):

Prototype Version 2:

Purchased Parts:

Adafruit Feather M0 WiFi - ATSAMD21 + ATWINC1500	$34.95	https://www.adafruit.com/product/3010	Adafruit	Small Arduino IDE - compatible board that has wifi and a built-in lipo balance charger and UPS circuit
Arduino UNO Rev3	$22.00	https://store.arduino.cc/usa/arduino-uno-rev3	Arduino	Arduino board for controlling various electrical components in the project.
Mini Push-Pull Solenoid - 5V	$4.95	https://www.adafruit.com/product/2776	Adafruit	This is a small solenoid that runs on 5V and when unpowered is in the extended position, so ideal for a locking mechanism

Other Needed Parts:

Piezo Buzzer	Price NA (already have)	Personal Components	This is a buzzer to indicate when an incorrect code is entered into the keypad
RGB LED	Price NA (already have)	Programming Kit	The LED blinks red while the lock is activated and will turn green when the door is unlocked
USB Power Bank	Price NA (already have)	Personal Components	This replaces the small 3.7V lipo from Prototype 1 and gives 5V,1A and also includes the charging circuit as well as has a protective case around the battery
Toggle switch	Price NA (already have)	Programming Kit	This is a manual power switch for the inside of the door so at times where no one else should enter the room the door can be completely deadbolted
Momentary Switch	Price NA (already have)	Programming Kit	This button releases the solenoid from the inside so the door can be opened from the inside

Required Parts (cont):

Prototype Version 3:

Purchased Parts:

Adafruit ATWINC1500 WiFi Breakout	$24.95	https://www.adafruit.com/product/2999	Adafruit	Wifi breakout board used by Arduino to connect to wifi infrastructure
Inland Arduino Mega 2560	$9.99	https://www.microcenter.com/product/486545/inland-arduino-mega-2560	Microcenter	Arduino board for controlling various electrical components in the project.
Mini Push-Pull Solenoid - 12V	$7.50	https://www.adafruit.com/product/412	Adafruit	This is a small solenoid that runs on 12V and when unpowered is in the extended position, so ideal for a locking mechanism

Other Needed Parts:

Ultrasonic Sensor	Price NA (already have)	Lab Kit	This sensor allows us to open the door from the inside without grabbing anything or pressing any buttons
Miniature OLED	Price NA (already have)	Lab Kit	This Display shows the status of the door: locked or unlocked
Piezo Buzzer	Price NA (already have)	Personal Components	This is a buzzer to indicate when an incorrect code is entered into the keypad
RGB LED	Price NA (already have)	Programming Kit	The LED blinks red while the lock is activated and will turn green when the door is unlocked
12V Power Supply	Price NA (already have)	Personal Components	This replaces the small 3.7V lipo from Prototype 1 and the USB power bank from prototype 2. This means the door must be plugged in but also means we do not have to worry about dead batteries.
Toggle switch	Price NA (already have)	Programming Kit	This is a manual power switch for the inside of the door so at times where no one else should enter the room the door can be completely deadbolted
Momentary Switch	Price NA (already have)	Programming Kit	This button releases the solenoid from the inside so the door can be opened from the inside
Door/Frame	Price NA (scrap wood and door)	Personal Components	This will be the base onto which all the electronics will be mounted in the final version

Progress Update - Homework from April 4, 2019

For our second prototype since we do not have any of our ordered parts, we are working on parts separately before we combine them together in the final version.

We currently have code running on an Adafruit Feather board that syncs with a remote NTP server and encodes the timestamp into an sha1 hash. This is what allows the door lock and phone to always generate the same code.

We also have code running on an Arduino UNO board utilizing the keypad library to read each button press from the 4x4 keypad and display the presses in serial.

Listed below is the components used in our project as well as a current status of each with regards to how far it is integrated into the final prototype using the following formatting:

a. Implementation not started for this sensor /device
b. Sensor / device implemented separately
c. Sensor / device implemented with other sensors and/or output devices
d. Sensor / device fully integrated into prototype

Sensor/Device	**Status**	**Comments**
Keypad	c	Keypad returns value properly, just needs to be implemented into final version of prototype
Time Sync	d	Fully Working and implemented
RGB LED	c	Works as an indicator of current lock status
Buzzer	a	Need to implement ASAP with LED
Solenoid	c	Working separately, needs to be triggered by keypad
Ultrasonic Sensor	b	Working on other Arduino, needs to trigger keypad listener

Progress Update - Homework from April 18, 2019

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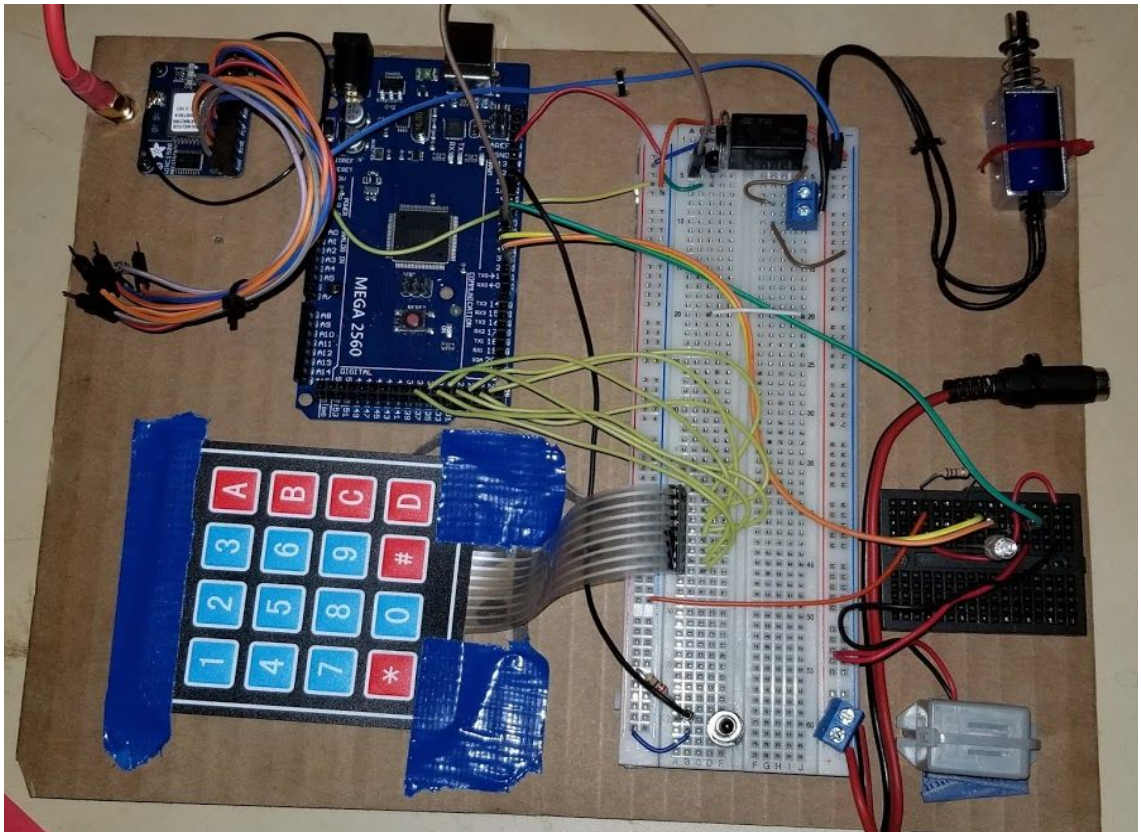
*We have all of the components working in this final version except for the wifi antenna. The keypad allows the user to enter a 6 digit code and return the final buffer by pressing the * key. If the input buffer matches the hashed key, the LED will blink green, and the solenoid will compress, allowing the door to be opened. If the incorrect key is entered, a buzzer will alert the user and the LED with blink red.*

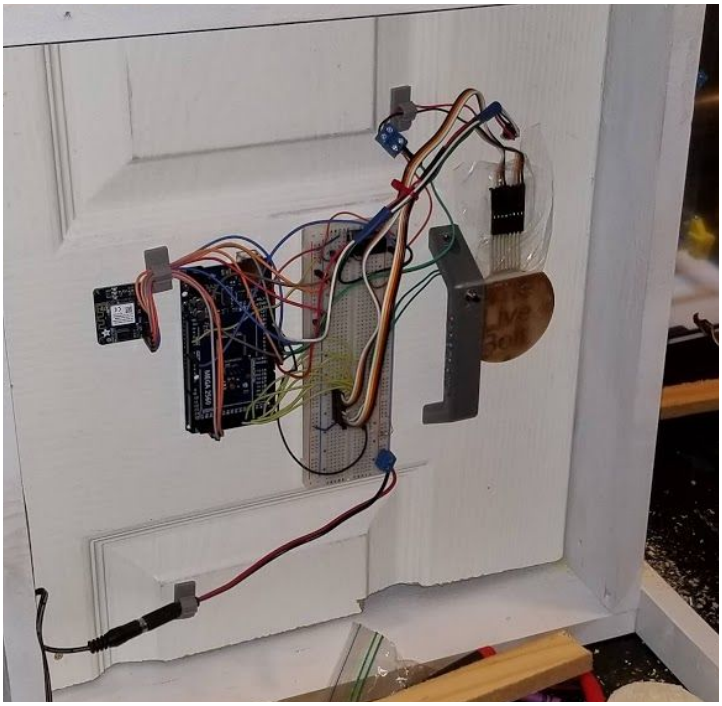


Future plans:

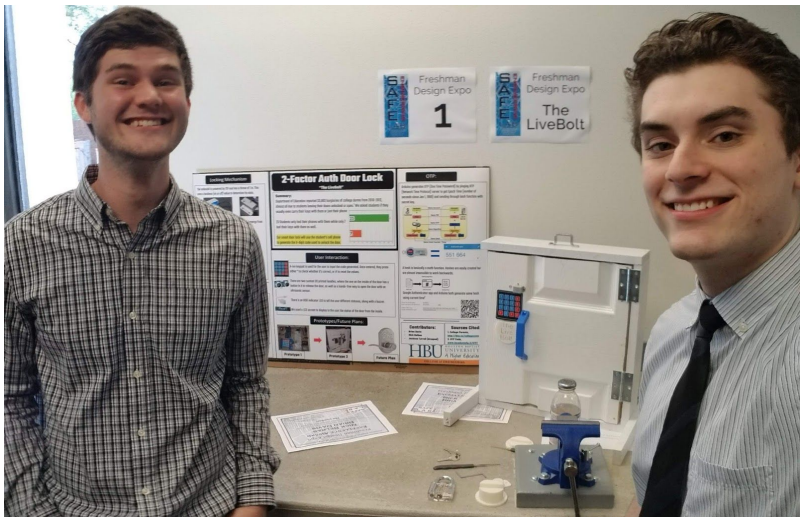
- *New wifi board has been ordered because current one is dead. Once new antenna arrives, I will add ~7 lines of code to generate the hashes from the secret key and time.*
- *We need to mount all of the components to a door and prepare the prototype for the final presentation.*

Progress Update - April 25, 2019 - FINAL PROTOTYPE

We have our final prototype completed and completely functional. I got a door from someone in my neighborhood for free, cut it down, and mounted it in a frame built out of scrap wood. The solenoid to unlock the door is held in place by a small 3D printed bracket mounted in the door. We also implemented the ultrasonic sensor for hands-free opening and a mini status display.



We presented our final prototype at the Freshman Design Expo on April 25th, 2019 in the class lab and received an award for our project and presentation. According to our grade on Blackboard, the average score we received from the judges was ~89.92%.



We created a poster to have all the data needed for our presentation and the high-resolution version of this poster is included in our GitHub repository.

Code/Libraries

Our code has been finalized and been put onto Github for anyone to download and use. Our repository also includes a high-resolution photo of our poster as well as pictures of our final prototype. Our GitHub is linked here: https://github.com/nickdrones/The-LiveBolt

Since our code uses a good number of third-party libraries (and even a semi-custom written one), we have included all the needed libraries in the repository as well. The TOTP library was created by an Telecommunications Engineering graduate from Italy whose website is linked here: http://www.lucadentella.it/ . However, since his website is slightly confusing and not in English, I have copied the latest version of his library to my repository.

To set up the Arduino with a new TOTP generator, you can use this website to generate the hex array: http://nickbelbas.servehttp.com/TOTP.html . This website is directly copied from another source but since the original site is currently down, my duplicate is the only accessible version. In case my website goes down, anyone can run the webpage on their own computer since I have included the HTML code for the page on the GitHub page as well.

You simply select a name that will be displayed in the Google Authenticator app and a 10-digit secret key. The webpage creates a HEX array that needs to be copied into the Arduino code in the proper place. The QR code can be scanned by your smartphone using the Google Authenticator app and will begin generating the codes as well. An example is shown below.

Future Plans

We do not intend to patent the design and instead we want to make it open source. That means that anyone can use our code and concept for free as long as they do not make any money off of it.

We want to add an internal RTC capacitor. That way the doorknob needs access to wifi for only 5 seconds on boot to sync with the time server. After that point, the clock being referenced is the internal battery. This also would allow the knob to work after a few power outages without wifi.

We also want to add some kind of battery to the lock so that it isn't constantly plugged in. Not only is this more efficient but it will also be able to run in power outages.

Finally, we want to make this lock smaller and more aesthetically pleasing, more like an actual product that you might see at a home improvement store.