Spring 2022 Senior Design 1

Live Bolt Smart Lock

Department of Engineering and Computer Science

University of Central Florida

Initial Project and Group Identification - Divide and Conquer

Group 22

Linda Anyosa - Electrical Engineering

Mohamed Faizel - Computer Engineering

Andrew O'Reilly - Electrical Engineering

Joel Shaw - Computer Engineering

Project Motivation

It's every homeowner's dream to discover an all-in-one security system. While the world is becoming increasingly more digital, most home locks have not. A majority of homes still operate on the traditional deadbolt lock, which can easily be picked by anyone with a simple kit. Live Bolt is a comprehensive system that integrates security home monitoring and access entrance at the convenience of the consumer. This product offers a variety of methods of unlocking through an iOS/ android application or at front door convenience. This includes facial recognition, 4 to 6 PIN digit code, RFID, voice recognition, or GPS proximity. Furthermore, the supply includes outdoor monitoring with a security camera and motion sensing notification through the application. Live Bolt will include the flexibility to have single-use access code for guest entrances and delivery workers. The lock will be battery powered and use a rechargeable battery. This will be convenient for the user as they will not have to replace the battery each time it runs out. Never again will you have to call a locksmith to get back into your own home or worry about your package to be refunded because it was stolen off your porch. All of these ideas were motivated by the different companies discussed further in our research of our product.

Ring Doorbell

After surveying the landscape of existing products similar to Live Bolt, the most competitive smart home security on the market is the Ring Video Doorbell, shown in **Fig 1**. It is a doorbell monitoring system that has some of the features we plan to implement, like motion-sensing and application availability. Live Bolt differs from Ring in that it includes access control into a home rather than just a home monitoring system. Furthermore, all features in the Live Bolt system will be accessible to consumers with no subscription plan. This will allow users to be able to use a cheaper yet safer alternative to the Ring Video Doorbell.

Fig. 1: *Ring Doorbell*

Google Nest Doorbell

Another product similar to Live Bolt is the Google Nest Doorbell; Google's attempt at a home security monitoring system. It has many features such as a camera, doorbell, sound detection and familiar face detection. Moreover, the set up is wired to configure with an existing doorbell system or can run wirelessly. Google has made it possible to integrate the doorbell with the rest of the Google Nest environment. Features the Nest Doorbell that Live Bolt will include is the camera monitoring system, face detection, and app integration. However, unlike the Nest Doorbell, Live Bolt allows for multiple unlock methods and gives the user an unlock log report through the application interface. It additionally differs in that it is a door locking security system compared to Nest Doorbell which only offers video and audio monitoring. Through this comparison between the two systems, we can see clearly that Live Bolt is the more cost-effective option than the Nest Doorbell. The Nest Doorbell only offers Doorbell monitoring of your existing system while Live Bolt steps up the security of your system.

Yale Lock Integration

The Google Nest Doorbell has the capability to interface with the Yale electronic door lock. The Yale lock is a keyless smart lock, similar to Live Bolt, that incorporates a digital keypad. Yale allows for a passcode you can give to people you trust, that you can disable at any time. It also offers self-locking features, and the ability to lock/unlock through a phone application. With Live Bolt, we will combine features from both the Nest Doorbell and Yale Lock to enhance safety and security in a single product. Both products can be seen working together in **Fig 2**.

Fig. 2: *Nest Doorbell interfaced with Yale Electronic Lock*

August Smart Lock

The August Lock is a Smart Lock system like many of the others we researched which integrates directly onto an existing deadbolt system. It does require some unscrewing to integrate however August does include videos to guide users through the process. One benefit is that the August lock doesn't prevent you from using your traditional key so that option is still available to use. It includes an Auto Lock and Auto Unlock feature which allows for geofencing to be used to determine if the user is leaving or heading toward the home. It also allows for the ability to use a smartwatch to lock and unlock the door without having to bring out your phone. The lock has a mobile app which allows many features including controlling multiple locks, inviting other people to manage the locks, temporary guest keys, an activity timeline, and additional security with the option of mobile bio authentication through the smartphone. These are useful features and many of which we are including in our Live Bolt system to strengthen it's security and usability. The August Lock Mobile Application is shown in **Fig. 4**. Additionally the August Lock does have multiple models to choose allowing customers to choose what locking system works best for them. The pricing of their most costly locking system, the Wi-Fi Smart Lock, comes to 229 USD which is comparable to the wired version of the Google Nest Doorbell. Additionally if customers end up getting a cheaper model and want to add the August Wi-Fi Bridge to get all the features the total cost is the same as or less than the cost of the Wi-Fi Smart Lock. A visual of the Wi-Fi Smart Lock in use is shown in **Fig. 3**.

Fig. 3: *August Wi-Fi Smart Lock*

There are downsides to August's Smart Locks. For one the newest generation released by August, although smaller and less bulky then the previous generation, has a smaller battery life. The 3rd generation had a battery life ranging from 6 to 12 months where the current 4th

generation has a battery life from 3 to 6 months. Additionally the batteries for the 4th generation are not the standard AAA or AA batteries and are instead CR123A batteries. These batteries are both more difficult to find and expensive to purchase than normal replaceable batteries. A drawback from August lock comes to auto unlocking connectivity. Auto lock works well for when the lock is able to connect to bluetooth easily. However, it doesn't work as well when it fails to connect before the User reaches the door making them wait. Another issue can happen when the door unlocks but the user takes too long to open it. If the user lives in an area where they must climb stairs or use an elevator the door can unlock and then relock before the user reaches. This also becomes a convenience issue for the user as it could force them to use their key or have to unlock the lock again from their phone. Another issue with the August lock and most other smart locks is the lack of RFID and Near-Field Communication (NFC). The August Lock already supports smartwatch integration and allowing for NFC unlocking would be a useful feature. It would eliminate the need to take out your phone or open the app allowing for the user's device to be held close to the lock to open. With Live Bolt we plan on incorporating both RFID and NFC to give users more options to unlock the system and ease of access.

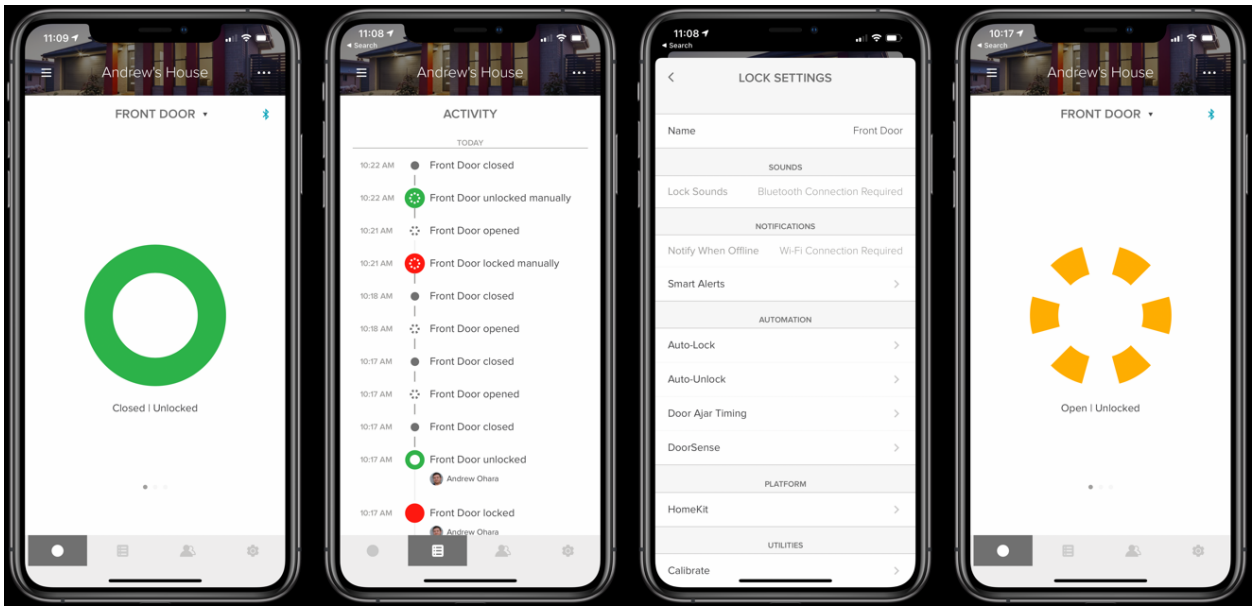

Fig. 4: *August Lock Mobile Application*

Nuki Smart Lock

The Nuki Smart Lock is another product that caught our attention as we were researching for our project. It is a smart lock system that directly integrates onto an existing locking system. A visual overview of the Nuki Smart Lock is shown in **Fig. 5**. There is no need for screwdrivers or other tools to install the system as it uses a physical key to lock and unlock the door as if a person was turning the lock themselves. This way of integrating the system allows for it to be compatible with many door locks. Nuki has recently revamped their product line with the 3.0 series offering a normal and pro model. Both share many of the same features aside from the pro having a Wi-Fi module in addition to its bluetooth module, and a rechargeable battery where the

normal uses 4 AA batteries. In our Live Bolt system we will be providing only one product so users will not have to worry about product trade offs like with Nuki's products. Nuki also provides a smartwatch integration in addition to their mobile app allowing for you to unlock your door from your smartwatch. They also allow the ability to create and assign digital keys to family and friends which is similar to a feature we will include in the Live Bolt system.

Fig. 5: *Nuki Smart Lock 3.0*

We did see downsides to the Nuki Smart Lock 3.0 series which we have taken note of in designing the Live Bolt system. The first is that not all locks work with Nuki's system so customers will need to check their compatibility guide before purchasing a lock. Another is that for the normal lock model any Wi-Fi actions the user wants to do will need the Nuki Bridge, one of Nuki's many accessories. The Nuki Bridge has a Wi-Fi module allowing for the base model lock to connect to Wi-Fi. The Pro model comes with this feature in the box. Without the Wi-Fi module in the Pro or Nuki Bridge with the base model users lose out on features like Smart assistants, and Remote management. This significantly limits the users experience and these are features we plan to implement into Live Bolt without the need for accessories. Another downside of the Nuki is cost. The base model is 149 € which is 169 USD and the Pro is 249 € which is 305 USD. This is already a high cost for the system and it doesn't take into account the price of the many accessories Nuki offers to enhance the Smart Lock experience. Some accessories that Nuki provides are shown in **Fig. 6**. From a Keypad to open your door with a code to the Door Sensor which enhances the sensing of the system, Nuki offers many accessories which can feel vital to a better experience. Lastly, the Nuki system does not include a camera for both models. Lacking this feature makes seeing who is at your door impossible however Nuki does include an activity report in the app for monitoring. This is limited however to Nuki products that can connect to

Wi-Fi. The Live Bolt system will have a camera for viewing activity outside the door allowing for the user to know what is happening at all times.

Fig. 6: *From left to right: Nuki Fob, Nuki Bridge, Nuki Smart Lock 3.0, Nuki Keypad*

Our goal is to create a reliable low-cost security system with multiple methods of home/ package safety for the consumers of tomorrow. We want to challenge the current security market by creating a new set up with an app and hardware systems interface. In doing so, we would keep the system as user-friendly as possible while keeping it as secure as possible. We will achieve these goals by creating a lightweight security system that can be placed in desired monitoring areas (e.g home, shed, garage), distributing power to electronic hardware, and establishing a connection between the lock and phone application. It is also a goal for us to keep costs of hardware low while maintaining quality in order to make this product accessible to low-income families. How we'll achieve these goals and requirements will be further elaborated in the requirement specification sections within **Tables 1, 2, 3, and 4**.

Requirement Specifications

For the design of our Live Bolt product, we'd like to incorporate a mixture of all of the following research we've conducted on these home security devices. The list below in **Tables 1, 2, 3, and 4** will include requirement specifications on hardware and software execution of our senior design project.

Table. 1 *Requirement specifications for Security System Features*

SECTION	REQUIREMENT	SOLUTION	VERIFICATION
Security System (SS)			
SS.1	Notifying motion sense to consume	Controlled through an Arduino Uno (IR motion detector)	Integrate sensors to application
SS.2	Home monitoring	5 Megapixel, 2592 x 1944 image resolution, 1080p video resolution	Viewable video stream sent from camera
SS.3	Time stamp unlock attempts	Sensing	Send message to user when attempts are made
SS.4	Single use PIN numbers for guests/ delivery workers	Application interface for one-use code	Send a text message to guest with one-use code
SS.5	Alarm system	Integrate LEDs and buzzers trigger when multiple attempts are failed in succession	Send message to app when alarm system is triggered

Table. 2 *Requirement specifications for Access Control Features*

SECTION	REQUIREMENT	SOLUTION	VERIFICATION
Access Control (AC)			
AC.1	Accessibility to consumer with ease	Android/iOS application	Publish to App Store/Google Play Store
AC.2	Application unlocking system	4 to 6 digit PIN number, unlock remotely via mobile application, face detection through application, NFC	Notification sent when door is locked/unlocked
AC.3	Hardware unlocking system	Voice recognition, PIN code access	Door is able to be opened without interference

Table. 3 *Requirement specifications for Application Features*

SECTION	REQUIREMENT	SOLUTION	VERIFICATION
Application (A)			
A.1	Simple and user-friendly UI/design	Adhere to commonly held design standards for usability	Use a variety of methods to test code, including end-to-end tests
A.2	Live Bolt must be always-online to mobile application	Use a React API to monitor internet connection	Display message to user if connection is lost
A.3	Accessibility	Tools like VoiceOver or TalkBack	Integrate TTS in user interface

Table. 4 *Requirement specifications for Design Features*

SECTION	REQUIREMENT	SOLUTION	VERIFICATION
Design (D)			
D.1	Locking door system	High torque servo to turn lock, 10 kg*cm with about 170 degrees range of motion. 3D Printed cover for dead-bolt turn knob	Servo is successfully able to turn the knob cover enough to lock/unlock door every time
D.2	Weather-proof casing	Housing made of weather-proof material like plastic or metal	Product able to withstand varying states of weather while maintaining functionality
D.3	Long battery life	Implement low power mode to conserve battery when not in use. Allow for easy swapping of battery packs. Implement battery monitoring system (BMS)	Device can withstand weeks to months of use on a single charge

House of Quality

To ensure the highest possible quality, our product must achieve a balance between our engineering requirements and marketing requirements. The House of quality matrix, shown below in **Table 5**, allows us to identify the level of importance and devise a strategy on how to achieve our requirements. In addition to our matrix, a legend is provided to indicate correlation, relationship, and direction of improvement for the product.

Table. 5 *House of Quality for Live Bolt*

Category	Weight	Customer Requirements (Explicit and Implicit) / Engineering Requirements		Size	Power Usage	Security Protection	Cost	Sensors	Microcontroller
				-	-	+	-	+	+
Quality of Product	6	Good User Experience	+	○	▽	●	○	●	▽
	5	Robustness	+	○	○	●	○	○	▽
	5	Multiple Options	+	●	●	●	●	●	▽
User Preferences	9	Cost	-	○	●	○	●	●	●
	6	Smart Phone Application	+	▽	▽	▽	▽	○	●
	8	User Interface	-	▽	▽	▽	▽	▽	▽
	7	Intallation Ease	+	●	▽	▽	▽	○	○

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

Block Diagrams and Design Sketch

Hardware:

A better representation for how all the hardware communicates and relay information is better expressed through a block diagram. Using two microcontrollers, they will dictate information input and reaction output. We discussed as a team that outputs will be primarily security based to indicate break-in or unlocking functionality. **Fig 7** outlines the inputs and outputs of the hardware, and their relationship to the microcontrollers and application.

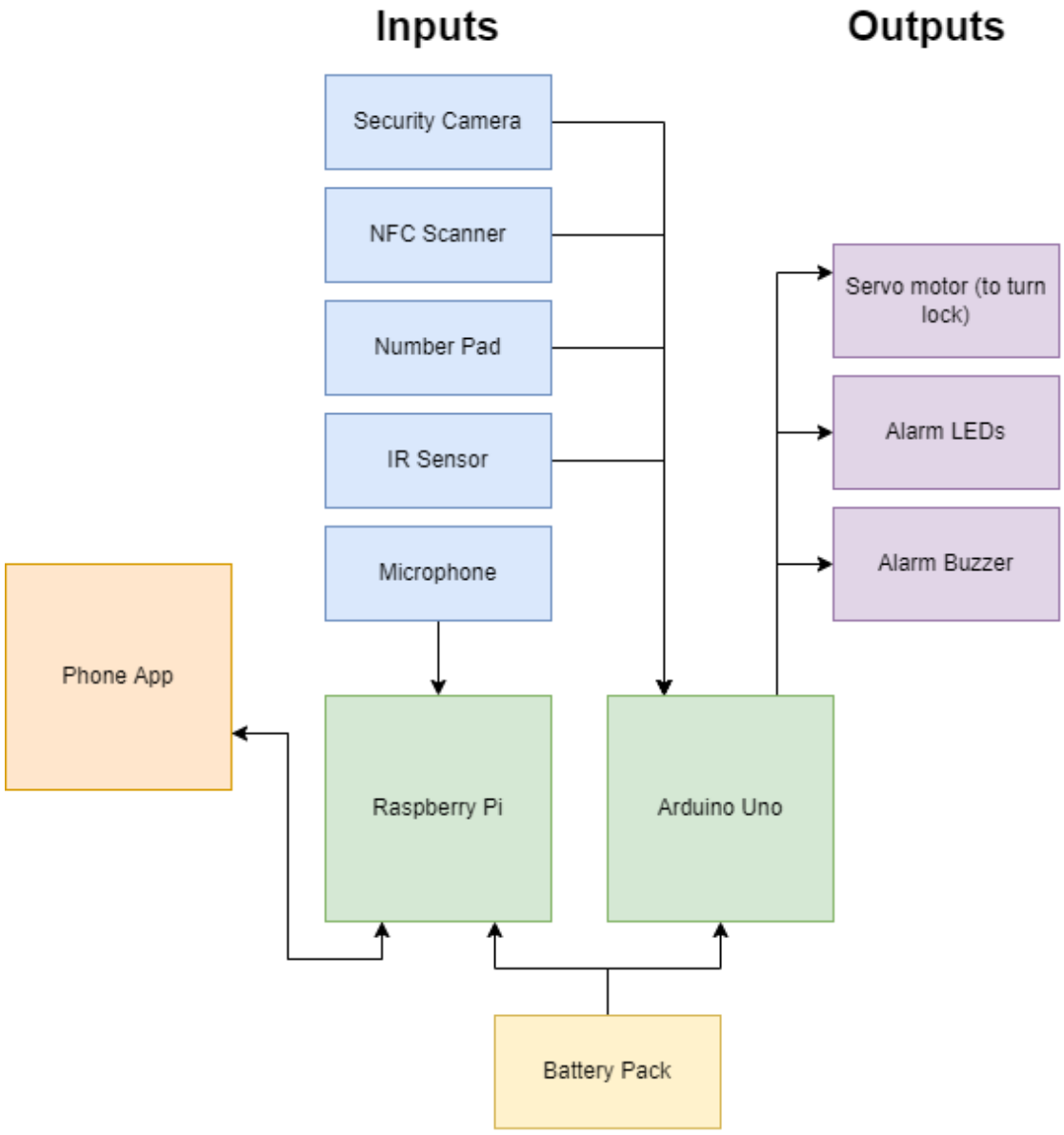

Fig. 7: *Relationship Between Hardware Components*

Mobile Application:

The accompanying mobile app of this device is to be compatible with both Android and iOS devices and to be developed using the React Native software platform. The app will take advantage of the built-in facial recognition present in newer iPhone models to further increase the number of ways to interact with Live Bolt. **Fig. 8** below details the planned logic of the application.

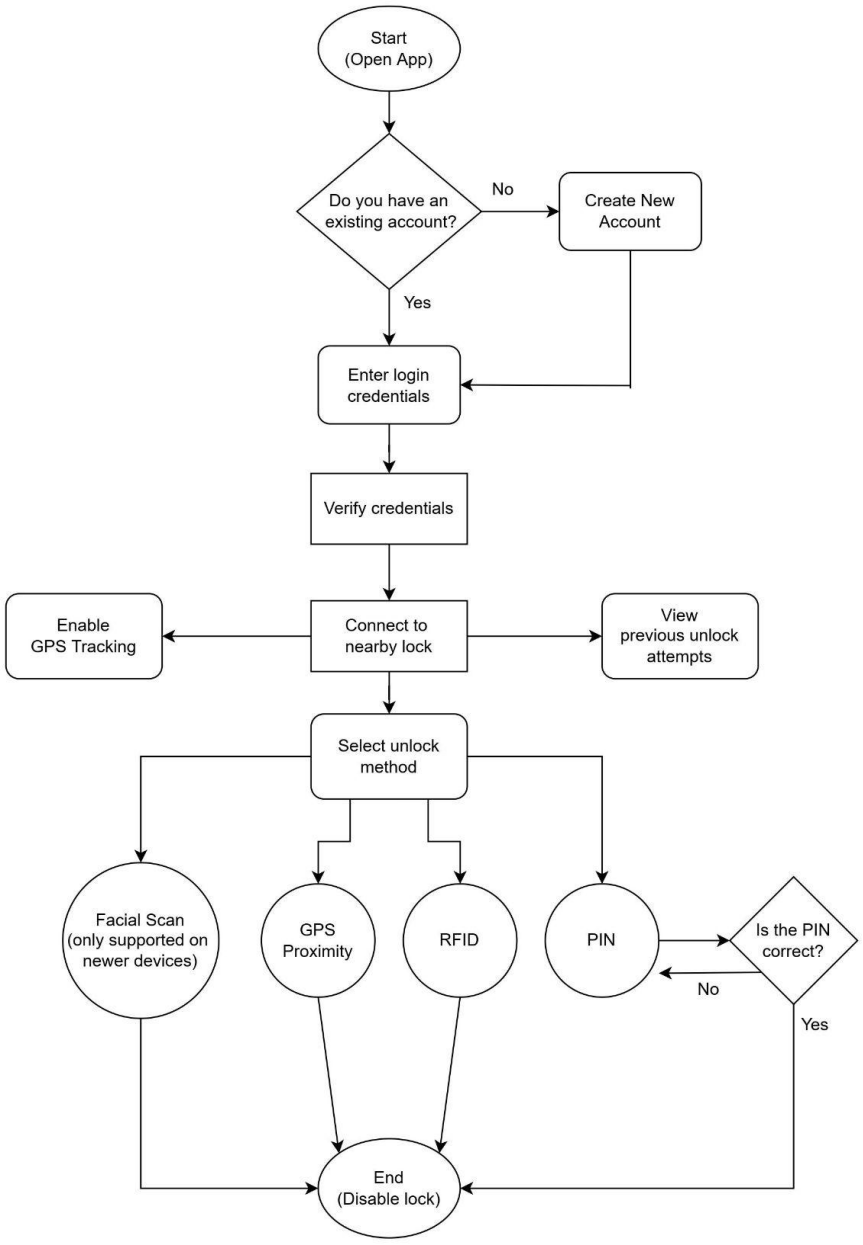

Fig. 8: *Software Flow Graph for Mobile Application*

Design Sketches:

The doorknob cover component of the Live Bolt will be 3D-printed with a design that allows it to be placed on most types of doorknobs. The covering will fit over the dead-bolt turn knob and also house the servo motor. This eliminates the need to unscrew the door knob and make modifications to it. **Fig. 9** below shows a preliminary concept of the design on a door. **Fig. 10** shows a close up view of the cover. **Fig. 11** is a mockup of the mobile application the Live Bolt Smart Lock will use.

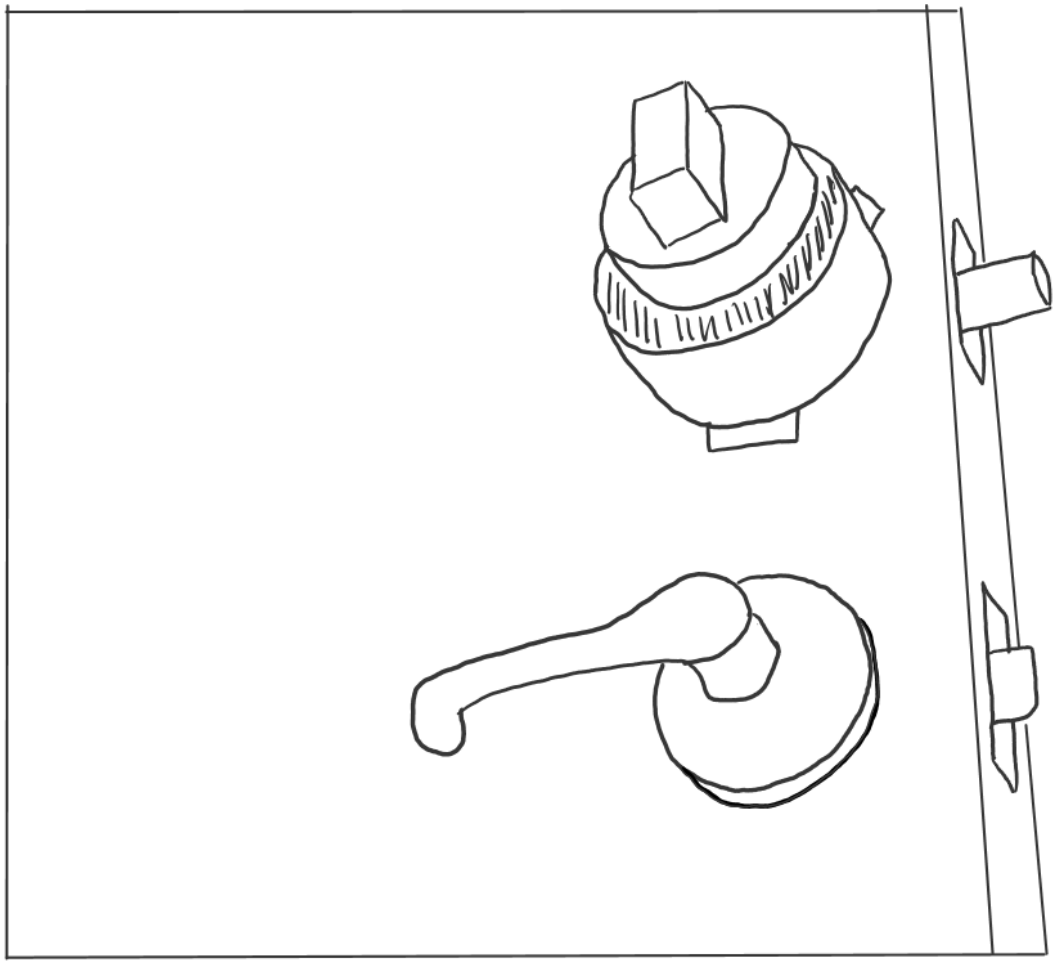

Fig. 9: *Dead-bolt door knob cover, fitted onto a door lock*

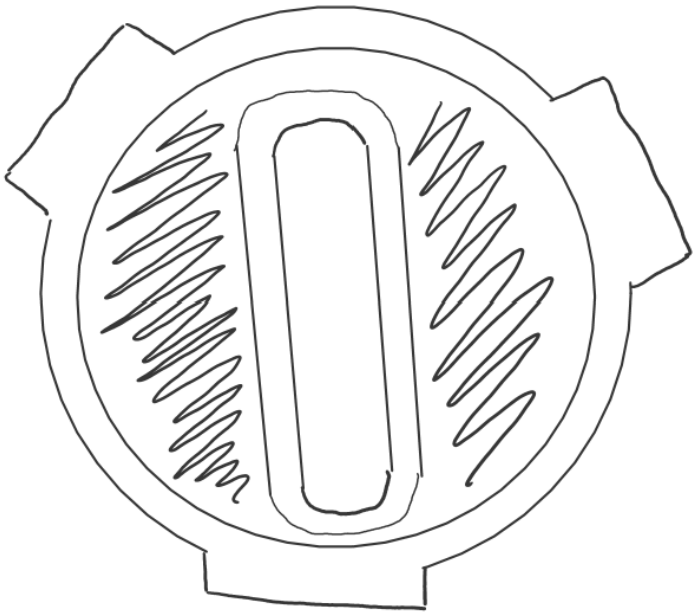

Fig. 10: Frontal view of the Door Knob Cover

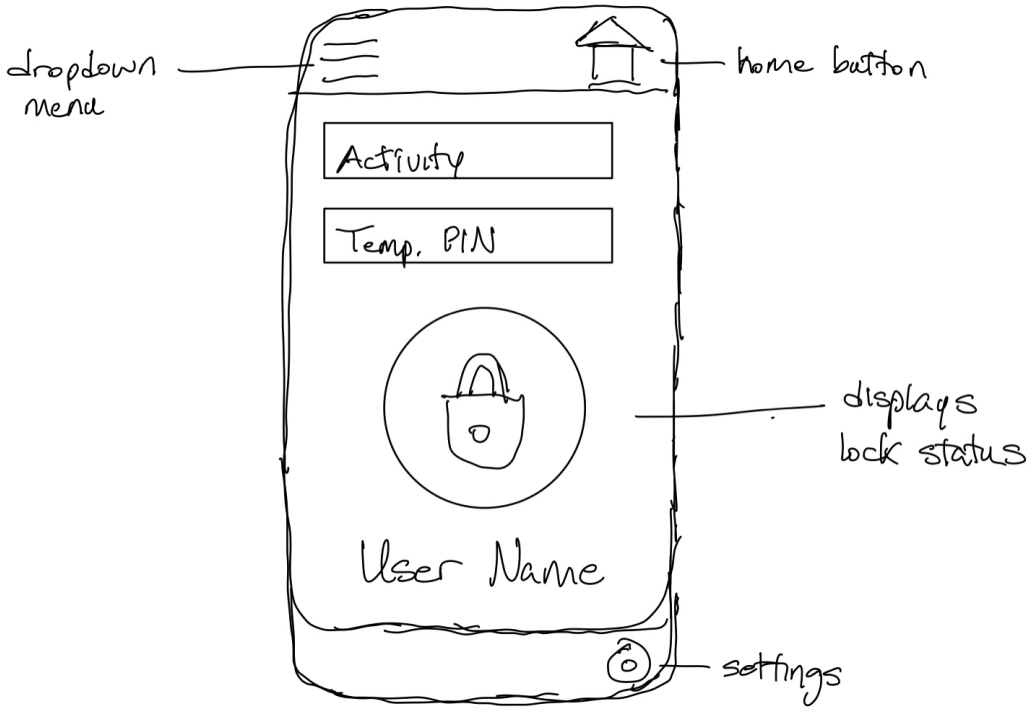

Fig. 11: Application Main Interface

Budget and Financing

A goal is to make Live Bolt as cost-effective as possible while maintaining quality in the build and design. **Table 5** outlines the parts we have identified for the product and their costs. Most items are marked as 2 needed, so there will be backup components in case any malfunction. The price per single unit and total price are both listed. Items marked as $0 indicate that the team already has them, so there is no need to include those costs in the final price. **Table 6** provides the total cost of all components and the amount of money each member of the group will contribute.

Table 5. *Assortment of Parts and Prices*

Part Description	**Qty Needed**	**Price/Unit**	**Estimated Total Price**
Raspberry Pi 4	2	$40	$80
Assorted Wires, LEDs, Buzzer, and other electrical components	-	$0	$0
Camera	2	$15	$30
Pin Pad	2	$0	$0
NFC Reader	2	$9	$18
IR Motion Sensor	2	$8	$16
Raspberry Pi Microphone Array	2	$29	$58
Arduino Uno	1	$0	$0
High Torque Servo	2	$20	$40

Table 6. *Self-funding cost*

Total Cost	**Number of Team Members**	**Amount Funded per member**
$242	4	$60.50

Project Milestones

In **Tables 7 and 8** shown below detail our plans of researching and completing our senior design project. **Table 7** focuses on our milestones we will be working on in Senior Design I while **Table 8** lists our milestones for Senior Design 2. The milestones column lists the tasks we are trying to accomplish during each semester. The duration column lists the number of weeks we will devote to each milestone. The dates column lists the deadlines we must complete the milestone by in order to keep on track. Some of the dates in **Table 8** are tentative as we do not know the exact dates we will need to complete milestones that far into the future. As we continue working on and researching our project we plan to revisit these milestones frequently.

Table 7. *Senior Design I Milestones*

Milestone	**Duration**	**Dates**
Brainstorm	1 Week	January 14
Select Project	1 Week	January 21
Divide and Conquer	2 Weeks	February 4
Research	4 Weeks	March 4
Table of Contents	1 Week	March 11
60 Pages Due	2 Weeks	March 25
Edit Draft	3 Weeks	April 15
Finalize Report	1 Week	April 22
Submit Final Report	1 Week	April 29

Table 8. *Senior Design II Milestones*

Milestone	**Duration**	**Dates**
Source Remaining Parts	2 Weeks	September 2
Build Prototype	4 Weeks	September 30
Test and Troubleshoot	3 Weeks	October 21
Finalize Prototype	3 Weeks	November 11 (Tentative)
Final Report	2 Weeks	November 25 (Tentative)
Final Presentation	1 Weeks	December 2 (Tentative)