BeatLock

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Abstract**—** BeatLock is a dance alternative to traditional door-locking mechanisms such as keypads and physical keys. The Beatlock system comprises a dance pad doormat, a two-factor authentication app, and a wireless door lock with a speaker and a backup keypad. The motivation behind BeatLock was to create a more secure home locking system that doesn't rely on remembering a physical key while creating a fun and engaging experience in a usually mundane activity. Compared to the current market, Beatlock is more secure than a traditional six-digit code, utilizing two-factor authentication and time-dependent dance moves, and is guaranteed fun with song and dance customization.

Index Terms**—Design, Bluetooth connectivity, Budget, Door lock, Doormat, Force-sensitive resistors, Functionality testing, PIN pads, Reliability testing, Risk mitigation, Security, Speaker system, Structural design, Two-factor authentication, Usability testing, Weather-resistant materials**

I. Introduction

BeatLock was conceptualized as a fun and lighthearted alternative to a regular key, keypad, or card swipe door access, recognizing the growing concerns around mental health within the younger generations. The users of this product will be young people looking for improved security and a fun experience to add to their home environment. This device would also provide customizable access and improved security compared to the more traditional methods mentioned. The intended use case for the system is in indoor doorways, such as the entry to an apartment or a bedroom in a house, though the design will consider weather-resistant materials to potentially allow for use in outdoor doorways as well.

Unfortunately, the security of the previously mentioned traditional locks pose many problems. With the key or keycard system, losing the only way to enter the home is a very real possibility as well as accidental lockouts. With PIN pads, the complexity of codes tend to be questionable and easily copied by an outside user.

The BeatLock doormat mitigates these issues. The system itself employs a two-factor authentication process with the user's smartphone to begin the dance. This system prevents the challenge of maintaining a key or keycard, with a backup PIN pad in the off chance that the user has lost their phone. Once the user has been verified and the song selected, a unique dance of ten or more steps is completed on the door mat, creating much more complexity than the traditional PIN pad in addition to adding an active element to process requiring further understanding of the system from any perpetrators. Once the dance is completed the door lock opens with the entire process taking as little as five seconds.

II. Use-Case Requirements

The following is a list of requirements according to our use case described in the introduction, broken down into three groups: security, hardware and software, and manufacturing.

Security

- The backup pin must be at least six digits long to match the security of existing door lock keypad options. Six digits provide 10^6 possible pins.
- The dance routine must be at least ten dance steps in duration. Ten steps, without considering timing, provide between 4^{10} and 12^{10} possible combinations, depending on if the user dances with one foot or both per dance move. A minimum of ten dance steps should allow for door entry in 15 seconds.
- The mat must work for at least one song for MVP and should work for a small selection of songs to simultaneously add security and customization.

Hardware and Software

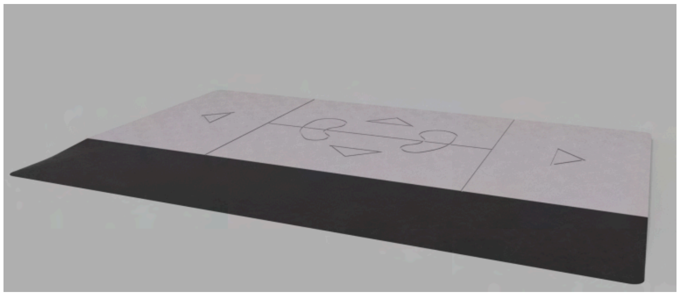
- The app, acting as a two-factor authentication method, must communicate with the mat and door lock via Bluetooth. Connecting to the mat and lock should take under five seconds.
- The dance mat must have a failure rate of 1% for correct dance moves, where failure is defined as not detecting a dance step.
- The song playing from the speaker in the door lock must begin at the same time in relation to detecting dance routines on the mat. Timing differences cannot be greater than 100 milliseconds.
- The speaker must operate within 100Hz and 15kHz to capture most of every song and must output songs at around 70 dB and no greater than 85 dB for audio safety [1].
- The batteries in the lock and mat must be exchangeable and should last at least one month. Battery duration will be tested and assigned a more accurate value once the power consumption of a complete use of the system is measured and extrapolated.

Manufacturing

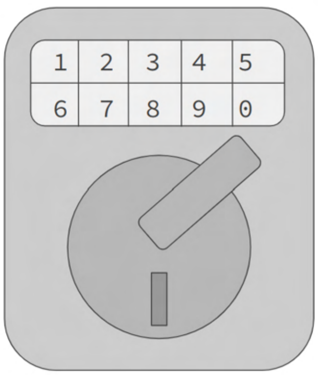
- Materials and structural design must be able withstand up to 300 lbs standing force, the 95th percentile of American males [2].
- The dance mat must have at least 36 in^2 of a traditional rough door mat material (six by six inches), for users to clean their shoe soles with.
- The dance mat must have a bright visual if thicker than a quarter inch, constituting the minimum height of a tripping hazard [3].
- The mat materials and design should reach an IPx3 water resistance rating, described as withstanding

spraying water [4]. The dance mat should only be placed on covered patios or in indoor hallways.

III. Architecture and/or Principle of Operation



(a)



(b)

Fig. 1. A depiction of the doormat rendered using Fusion 360 and a drawing of the assembled lock design. (a) This render shows the design of the mat and the planned thinness of it and ergonomics. The mat should be around the thickness of an everyday doormat, so thin sensors and electronics are used. The darker portion of the mat is designed to function like a traditional doormat and clean off dirty shoes before stepping on the front portion of the mat for dancing. The design also keeps the pads in positions that are easy to access so the user does not require a handle bar found in dance pads in arcade systems. (b) The door lock will implement a capacitive touch pad for the buttons allowing for a modern look and design. This also allows for the system to keep the number pad hidden with a bump to indicate the locations of numbers if the user wants to keep the backup system more secure and out of sight.

The BeatLock system begins with the user activating the system using the mobile application on their smartphone. Their they select the song they plan to use which also verifies that the user is a legitamate user. This creates a secure two-factor system that also enables unique systems for multiple users of the same device. In the case where a phone is not available, a backup PIN pad is present on the door lock to allow the user to bypass the phone application step in emergencies. From there the user can step on the doormat, music is played, and the dancing can begin.

The uniqueness of the BeatLock system comes from the implementation of a dance pad system in an entryway doormat. The doormat has four "arrow" pads that activate using force sensitive resistors at each corner of them. When a change in force is detected that indicates a step, the microcontroller can track the timing and order of the step and verify that this was done correctly internally. Once this is done correctly the door lock will unlock for the user and it can be promptly locked again by pressing on the keypad, similar to other smart lock systems.

The entire system is designed with simplicity from the perspective of the user. This is to maintain a quick and justifiable usage of the doormat. As a result, the three parts of the BeatLock system: the phone application, door lock, and doormat will all communicate wirelessly with the hardware running off of built-in rechargable batteries. Additionally, the minimum step count will be ten steps. If the user wants quick entry, this ten step minimum remains secure yet can be done in around five second assuming they can step at 120 beats per minute. This should result in very short and acheivable dance codes that are highly secure.

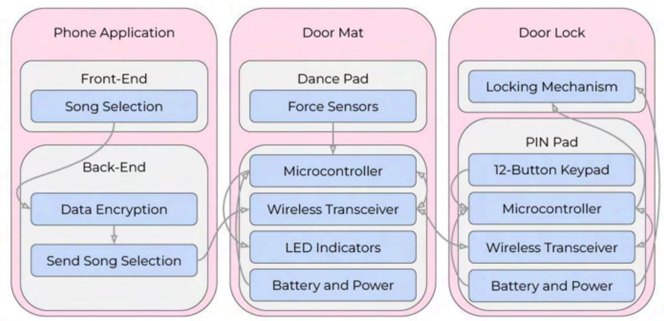


Fig. 2. This is the block diagram showing the overall process of the entire three part system. The phone application encrypts and sends the song selection to the doormat wirelessly. Afterwards, the doormat follows the users input pattern to verify correctness. Once that is done it is then wirelessly sent to the door lock that the user has input the correct dance in and the system unlocks. THis also keeps in mind the case where the application is not used and the keypad on the door lock is used instead.

IV. Design Requirements

The following is a list of design requirements according to our use-case requirements, broken down into three groups: security, hardware and software, and manufacturing.

Security

- The backup pin must be at least six digits long. The keypad should have twelve possible digits to maximize the number of passcode combinations.
- The mat must work for at least one song for MVP and more than one song post-MVP. So, the mobile app must provide a function to choose between songs. Furthermore, an SD card should be added to take into account the memory requirements of audio recordings.

Hardware and Software

- Bluetooth support must be added to the mobile app, the mat module, and the lock module. This will involve an additional component to connect to the Seeed XIAO microcontroller.
- The weight sensors must detect the existence vs. non-existence of dance steps with 99% accuracy.

- The song playing from the speaker in the door lock must begin within 100 milliseconds in relation to detecting dance routines on the mat.
- The speaker must operate within 100Hz and 15kHz to capture most of every song and must output songs at around 70 dB and no greater than 85 dB for audio safety.
- The batteries in the lock and mat must be exchangeable and should last at least one month. Replacement batteries must be easy to source, or the battery could be rechargeable.

Manufacturing

- Materials and structural design must be able withstand up to 300 lbs standing force, the 95th percentile of American males.
- Extra space on the mat (at least 36 in^2) will be made of a traditional rough door mat material, for users to clean their shoe soles with.
- The dance mat must have a bright visual if thicker than a quarter inch, constituting the minimum height of a tripping hazard. Components like foot pads will be made with 3D printed materials in bright colors like pink and yellow.
- The mat materials and design should reach an IPx3 water resistance rating, described as withstanding spraying water.

V. Design Trade Studies

The following is a list of design specifications to meet use case requirements and their accompanying discussion of design tradeoffs.

A. Design of Foot Pad Placement

Through acting out the use of the Beatlock mat, two concerns arose that impacted our design of the mat layout: the starting foot placement before beginning the dance and the size of the overall mat. This tradeoff correlates with the requirement of successful step detection, as the user standing before the dance should not be considered a dance step. We opted to have the user stand in the middle of the mat partially on both the front and back arrow foot pads, signaled by the outline of two feet in the middle of the mat; This will place a greater emphasis on ensuring the timing of the beginning of the dance detection and differentiating between the user standing and dancing. As a tradeoff, the mat will be much slimmer than a design with a neutral middle to stand on, allowing for more room for a rough sole cleaning material while keeping within reasonable door mat dimensions. Fig. 1 demonstrates the sizing and foot pad placement tradeoff.

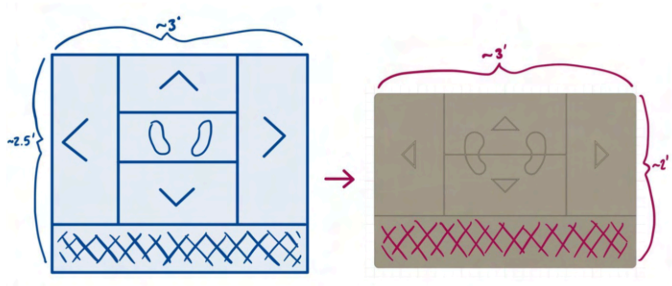


Figure 1. Foot Pad Placement and Mat Sizing Tradeoff

B. Placement of Speaker

Another tradeoff concerning the dance mat is the placement of the speaker. Originally, we were going to place it within the mat; however, this raised two concerns: the increased thickness of the mat, resulting in a greater chance of users tripping, and the vulnerability of the speaker, as it would be subjected to the force of users stomping on it. The tradeoff here was centralized sound from the mat versus speaker integrity. As suggested to us by Professor Gary Fedder, we are moving forward with a design where the speaker is located in the door lock housing; this forfeits centralized sound, but protects the speaker, and will potentially allow us to lower the volume as the speaker will be much closer to the user's ears, which could make achieving audio requirements defined by our use case easier to attain.

C. Primary Security

Our team met with Dr. Lorrie Cranor at the beginning of the semester to discuss security measures and possible holes in our design. From this, we discovered a tradeoff between security and entry time. While the user would like to gain entry to their home within fifteen seconds, the BeatLock system must have secure enough measures and backup measures to attain or better the market standard. Using the Apple iPhone facial recognition as an example, our mat is similar to facial recognition in being the most secure and primary option; just as facial recognition is not always a viable way to unlock the iPhone, there will be times the user cannot use the dance mat due to a dead phone, a dead mat, or even personal injury preventing the ability to dance. Therefore, just as Apple's backup to facial recognition is the four or six-digit pin that most of society deems acceptable security, we have opted for the six-digit keypad as our system's backup, recognizing that the keypad is a less secure, but still secure, option.

D. Back-Up Entry Options

There were four backup entry options that we considered, each with pros and cons. This tradeoff is concerned primarily with the security requirements of our use case. These options and their comparison are as follows.

The first option was to put a backup pin option in the two-factor authentication phone app. The main issue with this solution is that there is a reliance on the phone having a charge; one of the main reasons anticipated for needing a backup entry option is the user's phone having a dead battery and is therefore unable to communicate with the dance mat.

As such, using the phone as a backup would not be a reliable option.

Similarly, the second option, using the phone's digital wallet, would not be a viable option for the same reason as the app. Although this would be an appealing selling point, having a digital ID loaded into the user's digital wallet still relies on the user's phone being charged at the end of the day.

The third option we considered was having a keypad raised in a corner of the dance mat. Although this moves us away from reliance on the user's phone, it would be in a rather awkward location, requiring the user to crouch down to enter their pin.

The fourth option we came up with was to include a keypad in the door lock, as in traditional door locks. This makes the most logical sense, though we were concerned about possible security issues, such as an onlooker watching and recording the pin sequence. Because of this concern, we believe that to make this the most viable option, a flat, capacitive touch keypad could be implemented with a piece of opaque acrylic or similar material thinly covering the keypad to conceal the numbers.

E. Force Sensitive Resistors

The tradeoff we found to exist for the force-sensitive resistors used for step detection in the foot pads was assembly time and accuracy. This directly impacts the step detection requirement defined by our use case. More FSRs provide more sensitivity to weight distribution changes but include more wiring and circuitry, whereas fewer FSRs mean a decreased ability to detect weight distribution changes but also a decreased amount of wiring and circuitry. While we decided on kits of four FSRs with a breakout board, another option we considered was using force-sensitive resistive sheets, which would have been much cheaper but also much more difficult to fine-tune.

F. Locking Mechanism

A tradeoff we discovered recently after having purchased the first round of parts for the BeatLock system was with the battery life versus the solenoid lock in the door lock sub-system. After purchasing a solenoid door lock, we realized that the solenoid must be constantly powered when the door is unlocked, posing an issue to the longevity of the battery powering the door lock. As we would like the door lock battery to last at least a month before needing to be swapped, constantly powering the solenoid is not a viable option due to its high power consumption. For testing, we may continue with the solenoid, however, the final iteration of the design should consider this power tradeoff through the use of a stepper motor or something similar, that can be controlled with lock and unlock buttons on the keypad. A further tradeoff with this new approach will involve the door lock sizing; a stepper motor will consume less power, but sizing may become an issue depending on which stepper motor the team decides on.

G. Wireless Connectivity

The final tradeoff we are concerned with is the method used for wirelessly connecting the phone app, dance mat, and door lock. The two options available are wifi and Bluetooth. The tradeoff that exists here deals with our team's current knowledge and skills in implementing either of the two options and what the user is likely to prefer. With wifi, our team has experience implementing this method of connection, however, the user is likely less inclined to want this, as it requires that a stable internet connection be provided, which cannot be the case in a power outage. With Bluetooth, our team has minimal experience implementing this technology and will require more time researching, assembling, and testing the system; however, Bluetooth is a much more reliable option, relying only on user proximity to the mat and lock.

VI. System Implementation

The BeatLock system is broken down into three subsystems: the phone application, the dance mat, and the door lock. These subsystems communicate wirelessly with each other. This section is devoted to going into detail about how each subsystem will be implemented.

A. Two-Factor Authentication App

The two-factor authentication app will be a React Native app built with Expo. The app will be available to test on the Expo Go app on iOS or Android. It will be tested on an iOS device during development. The app will have a song selection screen with titles and images for each song. When the user clicks on a song, they will be redirected to another page, which will transmit via Bluetooth the song choice to the doormat. Focus will be placed on a sleek and usable user interface.

B. Dance Mat

The doormat is comprised of a microcontroller, dance pads, sound system, antenna, and power system. The details for each component are as follows:

- The microcontroller chosen was a Seed Studio Xiao ESP32S3. This was chosen for the compact size, low-power settings, multiple ports for the many connections required, and an IIS system for audio capabilities that many microcontrollers lack.
- The dance pads consist of a loop of four generic load cells with a total weight measurment capability of 200 kilograms for each pad. To digitize and amplify the output of these loops, an HX711 Amplifier is used as this is a popular affordable option with sufficient frequencies for the application.
- The sound system is currently planned to use a DFPLayer Pro MP3 Player and Storage as this is small and capable of storing well over fifty songs with the built in storage. It will also use a surface transducer to take advantage of the mat to output audio. It should be noted this sound system may be removed if a sufficient design is completed to implement the speaker within the lock to keep the mat thickness down.
- The power system will simply use a 3.7V battery with a high capacity to last a long time that will be rechargeable.
- The antenna will be the integrated antenna extension available with the Xiao ESP32S3.

The mat will use rubber, 3D printed plastic, and metal for the construction. This will keep the durability of the device at a maximum with metal supports and make sure it is immune to environmental factors if the rubber encloses the entire system. (See extra figure at end for further detail.)

C. Door Lock

The door lock currently comprises a capacitive touch keypad, a Seeed Studio Xiao microcontroller, a solenoid door lock, a wireless antenna, a battery, a speaker, and a 3D printed exterior to house the electrical parts. The block diagram for the connection of these components is found in Fig. 2. Specifically, the parts that our team has decided to move forward with are as follows:

- The capacitive touch keypad chosen is an MPR121 Proximity Capacitive Touch Sensor Controller.
- The microcontroller currently decided on is the Seeed Studio Xiao ESP32S3 due to its small size and wireless connectivity capabilities.
- The door lock mechanism we have chosen is a solenoid door lock, JF-S1040DL Pull Push Type with Mount Board and 10mm Stroke, operating on a 12V power supply. However, as previously mentioned in Section V on design trade studies, this solenoid will likely be swapped for a stepper motor in the final iteration of the design.
- The wireless antenna chosen was an additional component that already comes with the Seeed Studio microcontroller.
- The battery hasn't been chosen yet due to the likely change from solenoid lock to stepper motor. This change will determine the voltage level needed for the battery.
- The speaker hasn't been chosen yet due to additional research needed, given the recent change of the speaker location from being in the doormat to being in the door lock.
- The 3D-printed housing, as seen in Fig. 3, was constructed on Fusion 360, based on the sizing of the current components to be used in the door lock. Because a few components will likely change, the housing will not be printed until components and their respective sizing have been solidified.

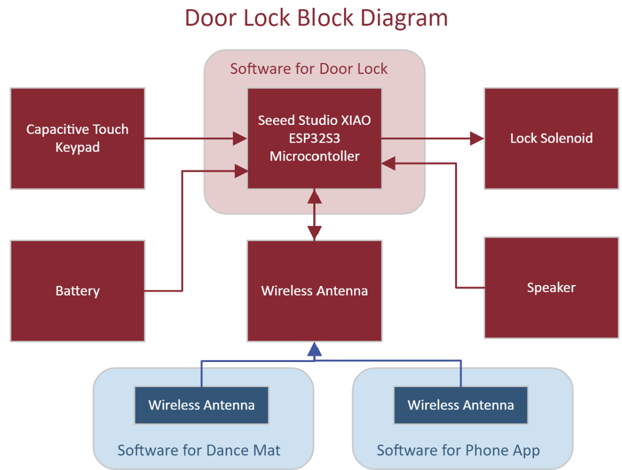
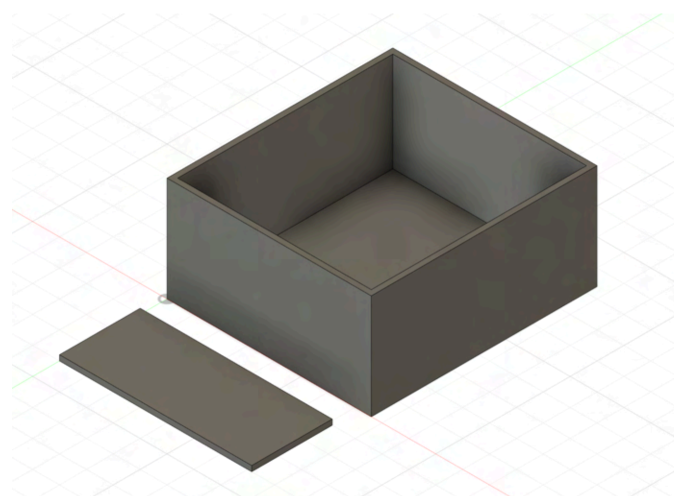


Figure 2. Door Lock Block Diagram

The battery will be connected to the 3.3V and GND pins of the microcontroller to power the keypad. The speaker and solenoid will likely be connected to digital I/O pins, once the solenoid is swapped for a stepper motor. The wireless antenna has a specific connection spot on the microcontroller.

Receiving a wireless signal from the app with the song selection, the microcontroller will send the signal to the speaker. Once the dance routine is completed correctly, a signal will be received from the dance mat and sent through the microcontroller to the solenoid/stepper motor. In the event that the user needs to utilize the backup option to unlock their door, they will input their pin, which is sent to the microcontroller and then to the solenoid/stepper upon inputting the correct pin.

Figure 3. Door Lock Housing with Divider



This section can use 1.5-3.5 pages. Most groups will use between 2 and 3 pages.

VII. Test, Verification and Validation

We will test our product in three major areas: functionality, usability, and reliability. Functionality testing ensures that the user of the product experiences the correct functionality from the product. Usability testing evaluates the usability and user experience of the product. Reliability testing ensures that the product remains functional after consistent use. In the following section, testing and verification plans for major use-case and design specifications will be discussed.

A. Tests for Use-Case Specification A

The backup pin must be at least six digits long to match the security of existing door lock keypad options. In testing, the door lock should open upon providing the correct six-digit pin 100% of the time. Reliability testing will be performed to ensure that using the backup pin always opens the door and never causes any errors. The keypad will be used to open the door 100 times, and the test will be considered a success if the door opens 100 times without any errors.

B. Tests for Use-Case Specification B

The song audio must begin at the same time relative to the dance step detection on the mat. Functional testing will involve starting the system multiple times using the same song and dance routine combination and measuring the timing via software. If the timing is off by more than 100 milliseconds, the difference may be noticeable to the user, so changes must be made to decrease the timing difference.

C. Tests for Use-Case Specification C

The speaker must operate within 100Hz and 15kHz and must output songs around 70 dB (no greater than 85 dB) for audio safety. Functional testing will involve, for all current songs, using a sensor to detect the dB levels. If the dB levels are too high for any songs, the volume will be turned down in software.

D. Tests for Use-Case Specification D

Materials and structural design must be able withstand up to 300 lbs standing force, the 95th percentile of American males. Testing will involve stress testing the FSRs and mat construction. 300 lbs standing force will be applied to the mat components for 200 trials, with 15 dance moves per trial. Assuming the average person unlocks their door twice a day, this amounts to 100 days of usage. The sensitivity of the weight sensors will be measured before and after this test in software to see whether the test affects the quality of the sensors. In addition, the product will be examined for any external damage.

E. Tests for Use-Case Specification E

The dance mat must have at least 36 in^2 of a traditional rough door mat material for users to clean their shoe soles with. Usability testing will involve having multiple users try and clean their shoes using our mat and asking about their experience with our mat, compared to their past experiences with other doormats. The goal of our product is to provide an equivalent experience to other doormats.

F. Tests for Use-Case Specification F

The mat materials and design should reach an IPx3 water resistance rating, described as withstanding spraying water. Reliability testing will be conducted on the mat after manufacturing. 30 trials will be conducted, each trial involving getting the mat wet with water from a spray bottle and drying the mat with paper towels and an electric hair dryer. After the trials, we will check the integrity of the housed electronics using visual inspection and continuity testing. If there is any water visible in the electronics, or there are closed circuits between parts that should not be connected, the test will fail.

VIII. Project Management

A. Schedule

See Gantt Chart in Figure 4, appended at the end of this document.

B. Team Member Responsibilities

Each member of the team has distinct responsibilities that build on their strengths and backgrounds. The software for the mat and the mobile application is being developed by Zoe, because she has a background in software development and embedded systems. Brooke and Jada have similar backgrounds in circuits and hardware development, so they are splitting work in these areas by the module. Brooke is working on the circuitry and hardware in the mat, and will be developing the PCB for the mat. Jada will be working on the circuitry and hardware in the mat, and will be assisting Brooke when necessary. All members of the team will work together to integrate systems together, and each team member has a testing area that they will focus on once the product has been developed to MVP – Jada will focus on functional testing, Zoe will focus on usability testing, and Brooke will focus on reliability testing.

C. Bill of Materials and Budget

The current Bill of Materials for our project is located in Table II on page 9. Items that we decided not to buy are marked by strikethrough. Some materials have not yet been sourced, and will be listed here instead: DAC/AMP, SD card holder, lock battery, pad battery, PCB board, miscellaneous wires, and 3D printer plastic. Other materials may be added if required. We do not anticipate having problems working within our budget.

D. Risk Mitigation Plans

There are several potential risks we have identified that we could encounter during the completion of the project.

One possible risk is that different software and hardware components will not be able to effectively and consistently communicate. We have three different modules that must wirelessly communicate with each other: the app, the mat, and the lock. Furthermore, the mat and lock modules consist of several components that must work together to perform their tasks. Without good communication, the product will not work as intended. To mitigate this risk, we plan on conducting thorough testing of our communication protocols early on in our assembly process, so that we can identify problems early enough that we have enough time to debug.

Another potential risk lies within the design and method of manufacturing of the dance mat itself. The mat has to be thin, but it must also be strong, and it must fit the required electronics. If the design or manufacturing process is done poorly, these requirements may not be met. Although the CAD model looks sufficient to meet our requirements, translating this model to be a real product may pose some challenges. To mitigate these risks, we plan to conduct all manufacturing carefully, and to make sure our components match what they are on CAD. We also will leave room to fix potential sizing problems we may run into.

Additionally, there are several risks associated with ordering and testing components. If there are shipping delays after we order parts, it will set us back in terms of testing components and manufacturing. This risk can be mitigated by ordering components early, and by splitting up work so that there is always work to be done that is not dependent on incoming components. In addition, testing components might be more difficult than anticipated, if the code or method to use the components is difficult to understand or if none of us have used a similar component in the past. To mitigate this issue, we are buying highly rated parts when possible, because these are often simpler and are likely to work as intended. We have also given ourselves a lot of time to do component testing, given that it can sometimes take a while to figure out how to get a component to work.

IX. Related Work

The inspiration for our doormat is the Dance Dance Revolution dance mat. The most well-known arcade dance mat is a type of hard mat, which is usually made of metal due to its strength and durability [5].

In 2008, Google introduced Android lock patterns – a password system in which 9 nodes are presented to the user in a 3 x 3 grid, and the password is a continuous pathway between the nodes. It has been in use for 15 years by millions of people worldwide. There are 140,704 combinations of patterns to be used as passwords. However, according to Marte Løge of the Norwegian University of Science and Technology, this system of pattern-based passwords is not very secure. 44% of passwords start in the top-left corner, and 77% start in one of four corners. A significant number of patterns used only connected 4 nodes, which reduced the number of potential combinations to 1,624 [6]. While Android lock patterns might be secure if used as intended, the human tendency to choose the same patterns and limit the length of the patterns reduces the security of the system.

Gait-based biometric systems for user identification and security have been proposed for various applications. These involve analyzing a user's unique foot shape and kinesiological movements to identify the user, similar to fingerprint and facial recognition. These gait-based biometric systems propose a promising alternative to current security measures, given the variability and uniqueness of individual behavior and movement patterns [7].

While there are many related projects, no other security system has used a dance mat doormat and lock interface.

X. Summary

BeatLock introduces a novel approach to door-locking mechanisms by integrating dance elements into its system. It consists of a dance pad doormat, a two-factor authentication app, and a wireless door lock with a speaker and a backup keypad. The system aims to enhance security while providing an engaging and enjoyable experience for users, particularly catering to younger generations concerned about mental health issues. Compared to traditional methods, BeatLock offers improved security through two-factor authentication and time-dependent dance moves, along with customizable access options. The system targets indoor doorways initially but considers weather-resistant materials for potential outdoor use. The design incorporates various trade-offs and considerations regarding security, hardware, software, manufacturing, and user experience. Testing and validation procedures ensure functionality, usability, and reliability. BeatLock represents a unique fusion of security and entertainment, setting it apart from traditional door-locking systems and existing alternatives.

Glossary of Acronyms

MQTT – Message Queuing Telemetry Transport
OBD – On-Board Diagnostics
RPi – Raspberry Pi

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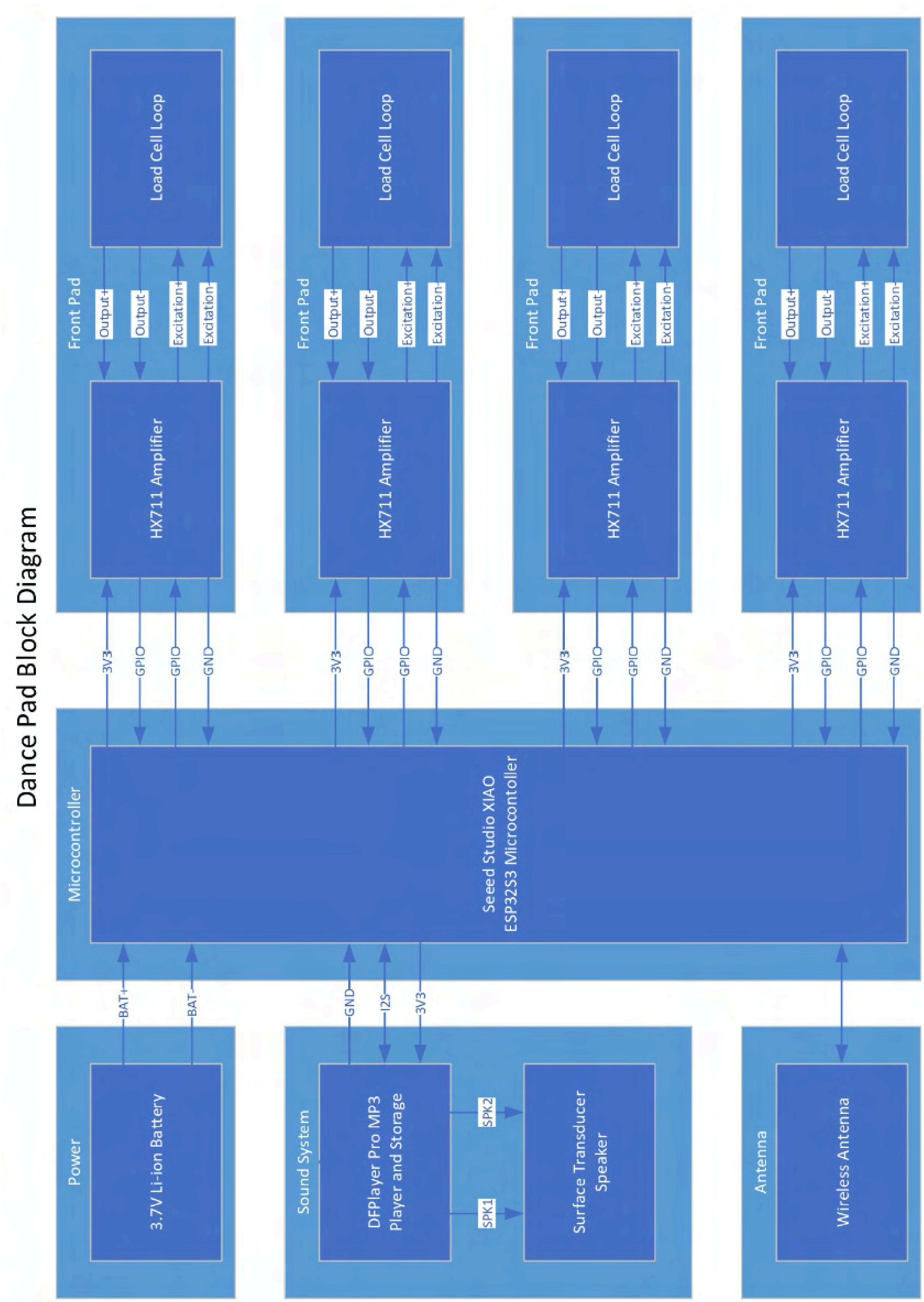
Dance Pad Block Diagram
Front Pad
Load Cell Loop
Output+
Output-
Excitation+
Excitation-
HX711 Amplifier
3V3
GPIO
GPIO
GND
Microcontroller
Seeed Studio XIAO
ESP32S3 Microcontoller
BAT+
BAT-
Power
3.7V Li-ion Battery
GND
I2S
3V3
Sound System
DFPlayer Pro MP3
Player and Storage
SPK2
SPK1
Surface Transducer
Speaker
Antenna
Wireless Antenna

Part	Amount	Cost	After Tax	Manufacturer	Model	Name	Description
~~Lock Solenoid~~	~~1~~	~~$16.00~~	~~$16.96~~	~~YXQ~~	CYJ0905A7		
Lock Solenoid	1	$10.00	$10.60	YXQ	CYJ0905		Lock/unlock door
Touch Pad for Lock	2	$18.00	$19.08	Hyuduo	MPR121	Capacitive 12 digit Touch Pad	
~~Force Sensors and Amplifier~~	~~4~~	~~$35.96~~	~~$38.12~~	~~NEXTION~~		~~4pcs 50kg Load Cell Half Bridge Strain Gauge Human Body Scale Weight Sensor + 1pcs HX711 Amplifier AD Module for Arduino~~	~~Each pad will use four load cells with an amplifier that converts to digital signals to measure the weight applied to each dance pad and send to the controller.~~
Force Sensors and Amplifier Two Pack	3	$32.94	$34.92	DIYmalls	HX711	DIYmalls 8pcs Load Cell 50kg Weight Sensor Half Bridge Strain Gauge Human Body Digital Scale + 2pcs HX711 Amplifier AD Module for Arduino	Each pad will use four load cells with an amplifier that converts to digital signals to measure the weight applied to each dance pad and send to the controller.
Microcontroller for Lock	1	$16.99	$18.01	Seeed Studio	ESP32S3	Seeed Studio XIAO ESP32S3-2.4GHz Wi-Fi, BLE 5.0, Dual-core, Battery Charge Supported, Power Efficiency and Rich Interface, Ideal for Smart Homes, IoT, Wearable Devices, Robotics	BLE 5.0 + WiFi compatible microcontroller on ESP32 chip. Very small
Speaker	1	$25.00	$26.50	sparkfun	COM-19102	Surface Transducer	
	1	$7.00	$7.44	sparkfun	COM-18379	Cheap speaker	

TABLE II. BILL OF MATERIALS

Display week: 4

TASK	ASSIGNED TO	PROGRESS	START	END
Planning and design				
Finish proposal presentation		100%	1/29/2024	2/4/2024
Compile materials list		100%	2/4/2024	2/18/2024
Sensor testing	Jada	80%	2/18/2024	2/25/2024
Flowcharts		100%	2/11/2024	2/18/2024
PCB Schematic	Brooke	0%	3/25/2024	3/28/2024
MVP				
PCB Design	Jada & Brooke	0%	3/28/2024	4/1/2024
Firmware	Zoe	0%	2/18/2024	3/10/2024
CAD for mat and lock	Jada & Brooke	0%	2/18/2024	3/3/2024
3D print parts	Brooke	0%	3/10/2024	3/17/2024
Assemble mat electronics	Brooke	0%	3/17/2024	3/24/2024
Assemble lock electronics	Jada	0%	3/17/2024	3/24/2024
Create mobile app	Zoe	30%	2/11/2024	3/10/2024
Final product development				
Add songs	Zoe	0%	3/10/2024	3/17/2024
Finish mat	Brooke	0%	3/24/2024	3/31/2024
Add security	Zoe	0%	3/24/2024	3/31/2024
Build lock	Jada	0%	3/24/2024	3/31/2024
Slack		0%	4/7/2024	4/21/2024
Testing and verification				
Functional testing	Jada	0%	3/31/2024	4/7/2024
Usability testing	Zoe	0%	3/31/2024	4/7/2024
Reliability testing	Brooke	0%	3/31/2024	4/7/2024

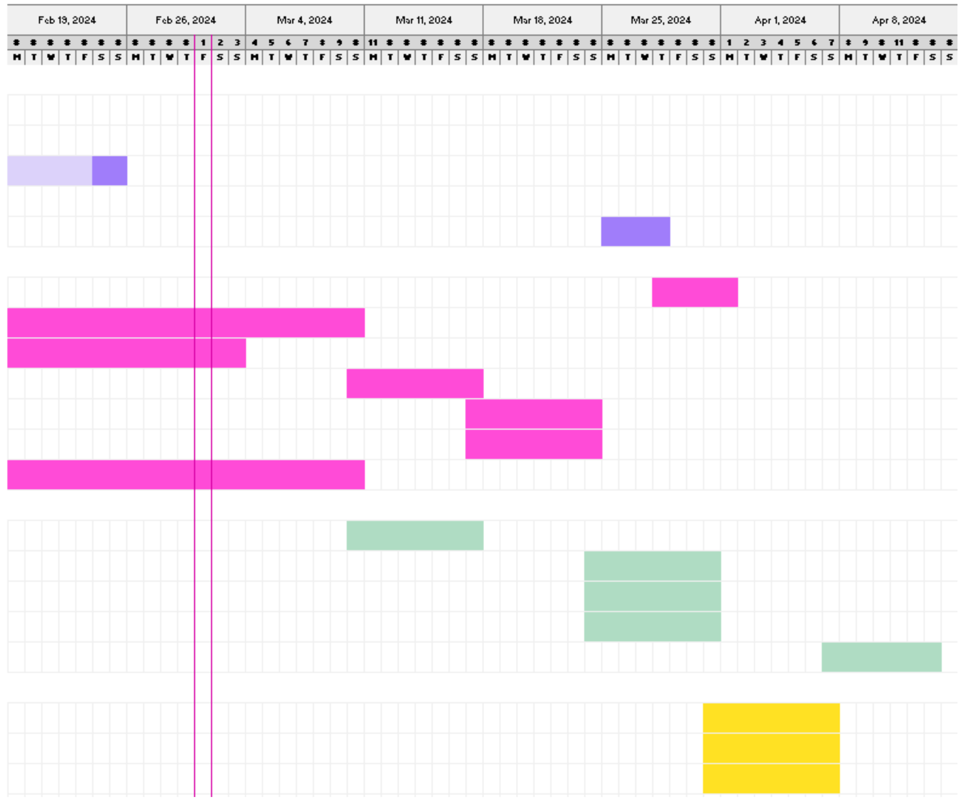

Figure 4. Gantt Chart for Task Management