Auxiliary Combination Lock Based on Door Knocks and Door Knob Turns

ECE 445 Project Proposal

Team 77:
Jack Kelly (jacktk2), Vishal Rajesh (vrajesh2), Adam Frerichs (adamdf2)

TA: Vishal Dayalan

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1 Introduction

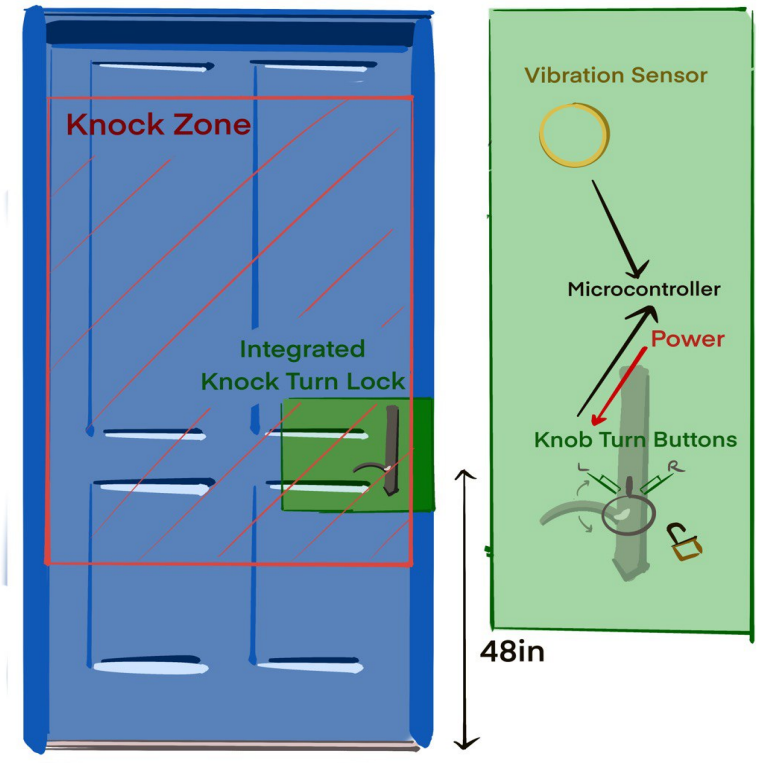
1.1 Problem:

Getting locked out of one's apartment or house happens frequently, especially when living alone. Many large apartment buildings have security at the entrance, meaning people often do not feel the need to lock their apartment door, and as such do not carry a key. The number of high-rises continues to grow [1] and as such, the number of buildings with entrance security will grow. In order to combat this problem, many people hide a spare key or install a keypad lock. Hiding a spare key is a security risk, as it can easily be found by somebody trying to gain entry, while keypad locks are often large and unsightly, and obviously convey a second path of entry.

1.2 Solution:

We propose an auxiliary lock based on a combination of knocks and door knob turns, that can be reprogrammed in case the combination gets spread. This would be hidden from the outside, in order to not show a secondary path of entry. From an outsider perspective, it would simply appear as if somebody was let in by a roommate.

1.3 Visual Aid:



1.4 High-Level Requirements:

1.4.1 Consistency:

The combination must be able to be input consistently by an authorized user when input correctly. This would avoid situations where the existence of the combination becomes apparent due to repeated knock and turn combinations from outsiders.

1.4.2 Discreteness:

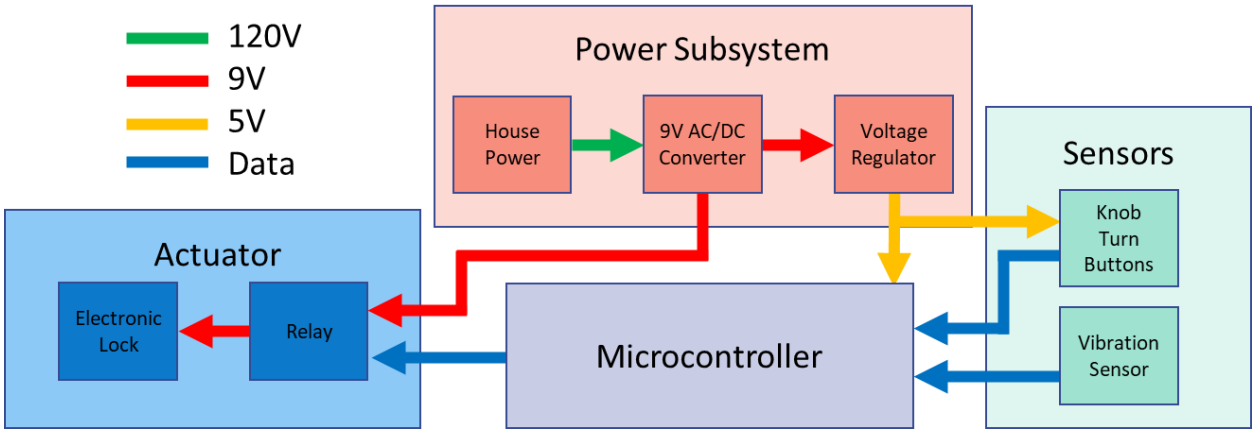
One of the advantages of not having a keypad or RFID reader is strangers are unable to tell there is a way to enter other than having a key, and as such are unable to figure out a way to bypass it. The entire design should be able to fit inside of a door in order to avoid this outward display of a second entry point, as well as potential unsightly electronics.

1.4.3 User Programmability / Security:

The lock should have a user-friendly interface for programming and changing the combination. This would allow the user to customize the combination to their preferred sequence of knocks and turns, and also change the combination in case it is shared or spread. Changing the combination should be a simple and intuitive process. Additionally, the lock should allow for multiple combinations to be programmed for different users for potential HIPPAA compliance. Finally and obviously, the programming interface should be secure and prevent unauthorized access.

2 Design

2.1 Block Diagram:



2.2 Subsystem Overview:

2.2.1 Power:

House Power (Simulated):

This device will be wired directly to the house power supply, which will be simulated using a wall plug.

Requirement 1: The wall plug accurately simulates direct wiring by supplying at least 2A of 60 Hz, 120V single-phase power.

9V AC/DC Converter:

This device will take the AC power from the house wiring and convert it into 9 Volts of DC power, which is required to run the motor.

Requirement 1: The AC/DC converter will output at least 1.5A of 9±0.1V power when supplied with 120V AC power.

Voltage Regulator:

This device will take the 9V of power from the AC/DC converter and output 5V which is required for the microcontroller.

Requirement 1: The voltage regulator will output 500 mA of 5±0.1V power when supplied with 9±0.1V of power

2.2.2 Sensors:

Knob Turn Buttons:

These buttons will make contact when the door knob is turned left or right. These buttons will be connected to the microcontroller input pins with a pull up resistor.
Requirement 1: The buttons must be able to detect quick knob turns.
Requirement 2: The buttons must not be audible so as to prevent outsiders from knowing there is a combination lock.

Vibration Sensor:

This will be a piezo sensor that generates a voltage when there is a force applied to detect knocks. The voltage generated will be connected to a microcontroller input pin.
Requirement 1: The sensor must pick up knocks that are as quiet as 60dB, which is about as loud as normal speech, in order to avoid banging on the door.
Requirement 2: Turning the door knob must not be picked up as a knock by the vibration sensor.
Requirement 3: The sensor must be able to detect knocks in quick succession, as little as 0.2 seconds apart.

2.2.3 Microcontroller:

The microcontroller will collect data from the sensors and make decisions whether to unlock the door based on the current combination programmed into the lock.
Requirement 1: The microcontroller will need 3 I/O lines for communication between the sensors and the relay.
Requirement 2: The microcontroller will need enough memory to store a simple program that determines if a sequence of inputs is the correct combination.
Requirement 3: The microcontroller will need enough processing power to analyze inputs at human speeds.

2.2.4 Actuators:

Relay:

The relay will take the control signal from the microcontroller output and pass the 9V power from the AC/DC converter to the lock in order to allow it to unlock once the combination has been reached.
Requirement 1: The 9V power passes through within 1 second of receiving the unlock signal from the microcontroller.

Electronic Lock:

The lock will be locked whenever it receives 9V from the relay.
Requirement 1: The lock closes within 1 second after it receives 9 Volts.
Requirement 2: The lock draws little enough power to not turn off the microcontroller when it activates (<1A, 9W)

2.3 Tolerance Analysis:

Vibration Sensor Thresholds

In order to make the combination not obvious, all knocks must be done at a reasonable volume, which means around 60 decibels. However, these vibrations will not be much stronger than vibrations in the door due to the door knob turning. If the vibration sensor cannot differentiate between the two, it would mean that any combination without distinct sections of knocking and turning (ie. knock once, turn left, turn right, knock again), would read multiple knocks and keep the person locked out. Further, differing door types, background noise and other local factors must also be considered to avoid this outcome, violating the high-level requirement of being able to consistently unlock the door upon first attempt.

Preliminary investigations indicate that an amplitude high-pass filter would be the most effective filter for this use case. Unintentional inputs, from the door knob or the environment would be ignored, given the signal amplitude does not reach the set threshold value. This must be tested in order to determine the precise numeric threshold which correctly interpretes sensor outputs as knocks/noise – exact figures can not be provided until then.

If no sensitivity threshold can correctly differentiate knocks and noise, then physical deafening to the vibration created from turning the door knob may be necessary.

3 Ethics and Safety

Given our position as computing professionals, our actions and the resultant products of our intellectual property have the potential to change the world, in both positive and negative ways. As such, a careful analysis of all the ways in which our work could be used is warranted. What follows is a thorough overview of the Knock Turn Lock in its relation to the ethical standards proposed by the IEEE and ACM. While both codes differ in their minutiae, the overarching themes are largely congruent, and all the main themes relevant to the Knock Turn Lock will be covered.

With regards to IEEE, the main relevant code is “to uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities,” specifically “to hold paramount the safety, health, and welfare of the public, to strive to comply with ethical

design and sustainable development practices, to protect the privacy of others." ACM emphasizes that we must " design and implement systems that are robustly and usably secure" and "use care when modifying or retiring systems."

Our product being a novel lock that aims to replace existing tried and tested systems, we must abide by this ethos in a very literal sense. Through rigorous testing, we shall ensure that our lock is robustly prepared to handle the actions of bad actors whilst also allowing easy access to authorized users. Beyond this, before our product comes to market we will apply for ANSI/BHMA commercial hardware certification, ensuring without a doubt that any consumer of our product is properly informed of the security grade of the Knock Turn Lock.

In addition to the Knock Turn Lock abiding by the relevant ethical standards as proposed by IEEE / ACM, it is equally important for the product to abide by the safety standards put into place by the relevant regulatory authorities[2]. Given that the Knock Turn Lock is designed for residential, not commercial use, we could sidestep many regulations aimed exclusively at the latter, especially given that residential door lock regulations are largely non-existent. However, since we aim to allow the Knock Turn Lock to be used in as many places as possible, its design will attempt to follow commercial regulations as well, whether or not we officially advertise this compliance. What follows is a thorough overview of the Knock Turn Lock in its relation to the safety standards outlined by the ADA and HIPAA. While all commercial locks must abide by the ADA, HIPAA applies to specific industries where patient privacy is in question. Again, since the Knock Turn Lock aims to be used in as many places as possible, all efforts will be made in this pilot product to satisfy as many regulations as possible, and official compliance can be established by a later version.

Regulations exist for both doors and locks. Our product will be assumed to be installed on a compliant door. Thus this discussion will be limited to the scope of lock regulations. The ADA requires:

- All locks and handles attached to your doors must be operable with one hand and not require any extreme grasping or twisting
- Any lock or handle hardware must be mounted no more than 48 inches above a finished floor; this ensures that those in wheelchairs are able to reach door locks as needed.

The Knock Turn Lock will use a lever handle, and allow knocks from below 48in of height. Easy egress will also be implemented automatically by the lever handle. The additional stipulation placed by HIPAA is an access control system. We could abide by this through the use of different combinations for each user.

4 References

[1] N. Routley, “There is a global race to build even taller skyscrapers”, *World Economic Forum,* 3, January, 2018. [Online]. Available: https://www.weforum.org/agenda/2018/01/theres-a-global-rush-to-build-ever-higher-skyscrapers#:~:text=Cities%20are%20growing%20up&text=Global%20skyscraper%20construction%20has%20increased%20a%20whopping%20402%25%20since%202000. [Accessed 9, February, 2023]

[2] S. Chris, “Door Lock Compliance: What Business Owners Need to Know”, *Great Valley Lockshop,* 22, January 2019. [Online]. Available: https://www.gvlock.com/blog/door-lock-compliance/#Specific_ADA_Requirements_for_Commercial_Door_Locks. [Accessed 9, February, 2023]