Improving Security: Smart Door

By Gerald Brady, Austin Poch, Hai Le, and Frank Greco
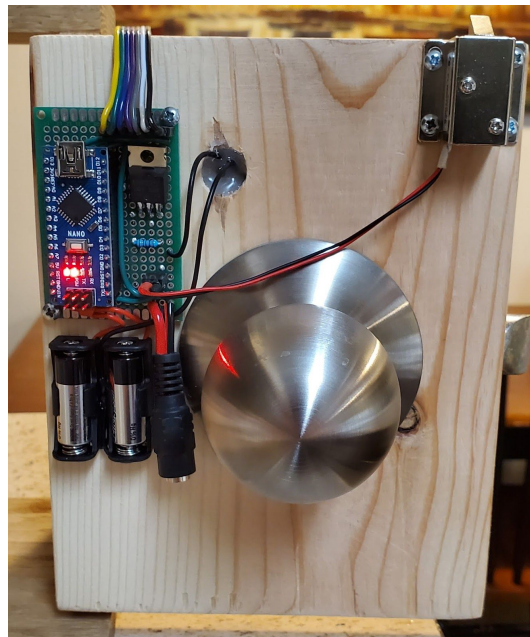
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Abstract

Most people keep their doors locked when they go to sleep at night and when they leave their home to ensure everything inside remains secure. Security isn't just a concern for civilians, many companies will invest in updating both their physical and digital security systems to prevent any and all whom mean to steal from them. Yet, most doors made for places of living still use the incredibly outdated pin and tumbler style lock, which has been utilized for thousands of years. Older locks are easily broken into with simple techniques found by a quick web search or even brute force, especially if it's a well used or older lock.

On an individual basis, the most inconvenient aspect of the standard lock is key management. It takes several seconds to open a locked door, especially if you have additional keys that look similar to the key required for the lock. It also requires quite a bit of accuracy to insert the key into the keyhole, which may be frustrating to anyone who lacks fine motor control such as people suffering from Parkinson's disease or under the influence after a night out.

The advancement of technology allows users to have much more secure locks. Smart Doors are the solution to many traditional lock and key problems. It also provides security and convenience by utilizing radio-frequency identification (RFID) technology. This technology uses radio frequency or electromagnetic fields to communicate between the chip and scanner using a key containing a coil, it's also significantly more convenient than carrying around a keychain to unlock many different locks.

Smart Doors also save time for individuals and companies. Since the system can be centrally controlled, a company could disable any user's key for whichever door(s) they like. It can send alerts when a user or non user attempts to enter. The administrator can set a time frame for accepting building entries, and can lock the doors when closing.

The History of Locks

Many types of locks were invented to increase and ensure security. One of the oldest locks invented was the pin and tumbler lock which dates back to 4000 B.C.(*Strauss*). The early pin tumbler locks were made from wood, and the way this lock works is the lock contains pins of different lengths to prevent a door from opening. When the correct key is inserted, it would force the pins up so that the wooden bolt could slide over to unlock the door. The next significant improved lock was made by the Greeks around 1000 B.C., and consist of a metal key with two notches that would fit inside the door and into two holes on a wooden bolt. By using the

Figure 1: Pin & Tumbler

key, the user could slide the bolt open and unlock the door, and this lock was an early predecessor to the deadbolt lock that we now know today.

The first modern combination lock was invented by Linus Yale Jr. in the 1870s, which was based off of symbol locks that were used by the Romans and Greeks. The design was later improved upon by Joseph Loch, who added rotating number selectors. He focused on making a keyless lock for use in jewelry stores(*Strauss*).

Figure 2:
Combination Lock

The combination lock was a huge advancement from the original lock and key, but as time went on technology gave us a way to become even more secure. In modern society, RFID technology is implemented in many areas to increase convenience and security, but it's not widely used on a consumer level. It's utilized more on a commercial/corporate level. Adoption of new technology can take many years. We are just now beginning to utilize Iot applications making RFID technology more convenient and secure for the masses.

Identifying the Problem

In the United States alone, a home is broken into every 14.6 seconds, of which the front door is the most common way of entry for home invaders (*ADT Home Security*).That shouldn't be a surprise being how volatile most door locks are. Just a few simple tools and it's like the lock isn't even there. Not only are these locks easily picked, but there is a much easier way to break into the lock using a technique known as "bumping". The basic idea of lock bumping is to insert a 'bump key' into the targeted lock and tap the end of the bump key until the lock opens, this is done by taking advantage of how the pins are arranged in the lock itself. The technique is so quick to open locks that it is commonly used by first responders to open doors. Over 95% of home and business locks are vulnerable (*Banks*).

Traditional locks also come with a disadvantage which stems from how they are manufactured. The key itself must be cut with extreme precision to the exact pattern for the lock that it is intended for, or else the key won't even insert into the lock. Locks also have tendencies of seizing up, even if the key can be easily inserted (*Brittain*). A jam can be caused by a number of factors including deadbolt alignment, damaged or well worn pins or keys, mechanisms within the door knob itself, and more.

On top of that, the user must carry many different keys which becomes inconvenient when selecting the correct key. Using keys requires motor skills that not everyone possesses. People suffering from a central nervous system disease, the elderly, intoxicated people, and even people with high stress could have problems opening locks. The amount of time and effort a user must exert to use a traditional lock and key may be minimal but time comes at a high cost in this fast moving world. It's also easy to allow them access in case of emergencies such as a

fire or an earthquake. Automatic locks can help situations such as robberies or shootings. Utilization of RFID technology for a locking mechanism at home is not as widespread and many don't replace the traditional lock and key because in many cases, it is more expensive, and requires change which many don't want when the traditional lock has worked for so long. With the adoption of the Smart Door, individuals and collectives will experience improved convenience, increased security, modularity, and efficiency.

Proposed Solution

A solution to the problem would be to use a digital device to control door locks. This opens up a multitude of possibilities. We will focus specifically on RFID communications which utilize electromagnetic fields to transfer a stored hexadecimal code from a key fob. The key fob can take many different forms. It can be any item that the user wants, as long as it's big enough to store an electric coil. The coils can even fit in a credit card. The hexadecimal code stored on the key fob increases security. Upon placing a key fob on the scanner, the microcontroller will send a signal to unlock the lock. The signal can be used to unlock many different types of electronically controlled locks.

RFID coils can be embedded into small easy to carry objects such as rings, wallets smartphones, or any object the user wants. This will reduce the chance of someone's keys being stolen. With a smart door, it's easy to change keys, and is just a simple change in an app. The scanner pad is always listening for radio frequency signals to unlock the lock, as long as it receives the correct hexadecimal code.

Prototype

Figure 3:
Prototype Front View

Figure 4:
Prototype Back View

Figure 5:
RFID Electric Coil Key

The Smart Door prototype is a small wooden door on a frame. It has an RFID scanner on the front where you scan the key. Scanning the key will unlock the solenoid locking mechanism. The solenoid latch will unlock when a key fob with a correct code is scanned. Right behind the scanner, on the inside of the door, is the main chip containing the arduino nano which runs the code. After the solenoid unlocks it takes 3 seconds to re-lock itself. The Arduino Nano utilizes a mini prototype PCB (printed circuit board pictured in figure 6), because a mosfet (a type of transistor) is used to power the lock itself as it requires more current than the Arduino microcontroller pins are able to provide. Failure to use a transistor or relay would result in frying the Arduino's output pin causing the lock to not function.

Figure 6:
Back View of Prototype PCB

Two 12V batteries running in parallel supply the power. Two batteries are used in order to make the door last longer. The batteries are connected to the button right next to the reading pad, providing the user the function to toggle the power source on and off to potentially save energy and prevent intrusions by means of deciphering the RFID signal. If the Smart Door's 12V batteries are empty, the Smart Door is able to run on an AC power source using a power cable.

The RFID lock requires a key which contains an electrical coil that utilizes radio frequencies to output a certain hexadecimal code which is read by the scanner. The lock will only unlock if the code is an accepted code. The RFID lock fully relies on modern technology, computers, and code to ensure a convenient way to unlock the door. This technology can help us prevent unwanted users from entering by blocking their specific code. The schematic shown in figure 8 uses a mosfet, which acts like an electronically controlled switch, the solenoid, the scanner, and the Arduino Nano.
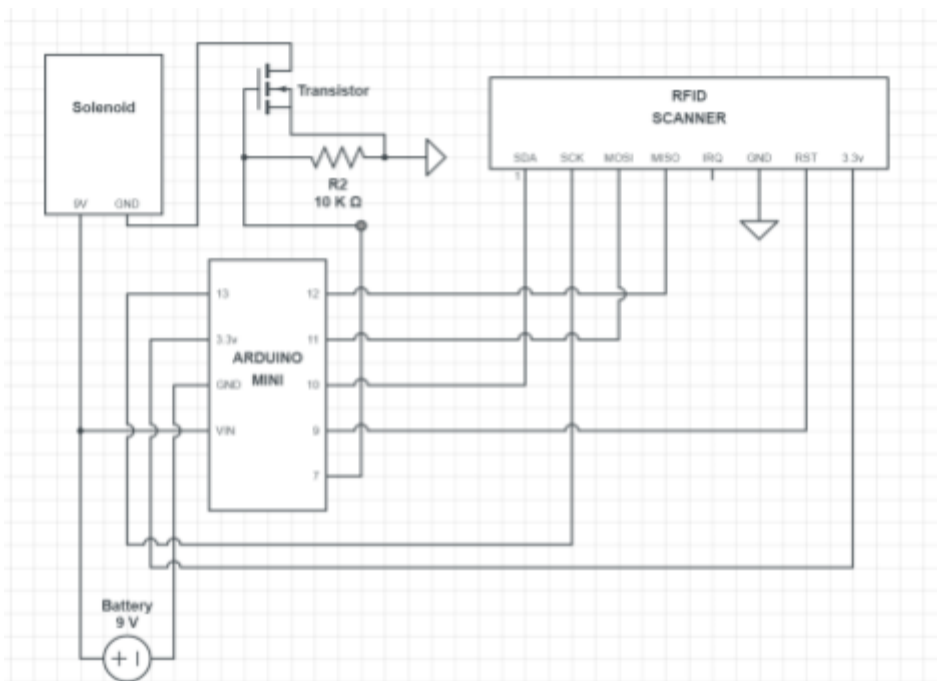

Figure 7: Prototype Schematic Diagram

Future Development

Continuous improvement is the driving engine behind staying relevant. Many companies and ideas that were the mainstay 25 years ago are gone or on life support. As our culture advances and changes, these companies and ideas fall behind due to the rapid advancement of technology. Hence one of the Smart Door's main focuses is being modular. This allows changes within the door to fit the need of any one of its clients whether it be for increased security or ease of access.

The Biometric lock is becoming more common as the cost of these devices drop and become easier to use. Fingerprints, facial and iris recognition technology are the goto biometric devices. They have far better security than RFID at the cost of convenience and durability. Biometrics will most likely be implemented with high security in places such as banks.

Another way to increase security is to use NFC (near-field communication). NFC was derived from and uses relatively the same technology as RFID and as such it fixes most issues that RFID has, such as being far less volatile and easy to hack. This is due to a two way peer-to-peer communication between the coil key and scanner, which means that even the best hacker cannot decipher without catching the communication (*Thrasher*). Of such the only way to catch the communication signal is when it is being used, and without the use of powerful and expensive technology is impossible to get without being a few centimeters away from the scanner and key coil.

The Smart Door can also be custom tailored to fit the exact needs of the client, such as adding a motor to the door to automatically open, close, and lock. As stated above in the proposed solution you can integrate the key coil into almost any object you can think of such as a ring, wallet, or even using the NFC coil already integrated in most phones. This has multiple benefits such as being easier to carry around and less likely to be recognized as a key. Further, access to your Smart Door is as easy as adding or deleting a phone's NFC from the door's registry, which is free, unlike creating a brand new key.

With the creation and implementation of IoT (Internet Of Things) the RFID lock will be utilized more by individuals. As far as costs go, low security RFID can be duplicated and is less expensive, but is more vulnerable to attacks, where as, the high security NFC lock is more expensive and provides more security. There are two ways to increase the security of RFID, one is to have better encryption between the communicating parts, and the other is to decrease the proximity of communication. Both of these methods lower the chances of phishing, the act of hijacking RFID information significantly (*Thoren*).

As technology merges into our lives, life becomes more convenient and streamlined. We now depend on technology to make life more convenient, easy and quick. When inventing and designing new technologies we need to be aware of ever-growing security shortcomings. Hackers are always looking for ways to bypass implemented security, whether it's a physical

device or through coding. We need to be proactive in improving our security rather than be reminded after the fact when new attacks occur.

Conclusion

Since traditional pin and tumbler locks have essentially had their security thwarted due to certain weaknesses we need to focus on finding more secure ways of protecting our belongings. You can see this with a simple web search, it's all but an inevitability that the modern lock will change. The focus of the Smart Door is to grant tighter security while being more user-friendly. The Smart Door will eliminate key management all together. Creating an easier experience to unlock your door while increasing the speed at which it is done to provide convenience. Due to the nature of its technology, the Smart Door can be easily updated to fix any of its shortcomings. For example, if your home gets invaded all that needs to be done is to update your key, which will take only a few minutes at most, compared to changing out the locks entirely. In addition, it's open to modularity, which means there's room to improve depending on the users needs. I.e. Adding a motor to open the door for you if your bringing in groceries.

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