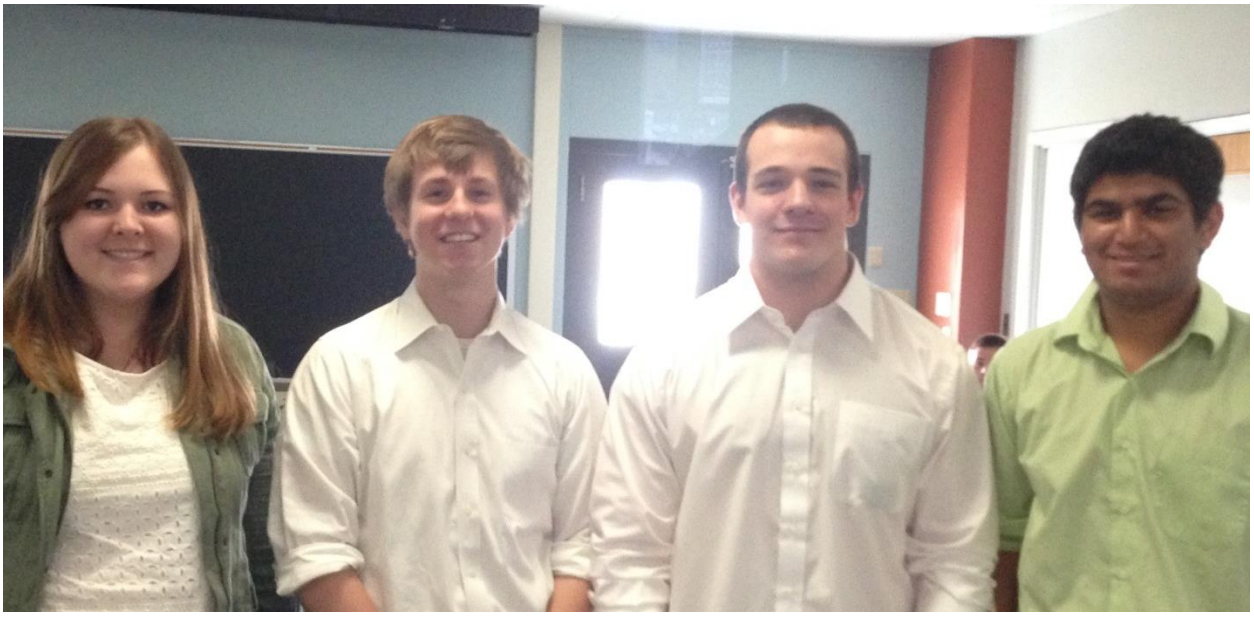
The Master Switch

EDSGN 100 Section 019 Design Team 2

Submitted to Professor Smith 4/30/14



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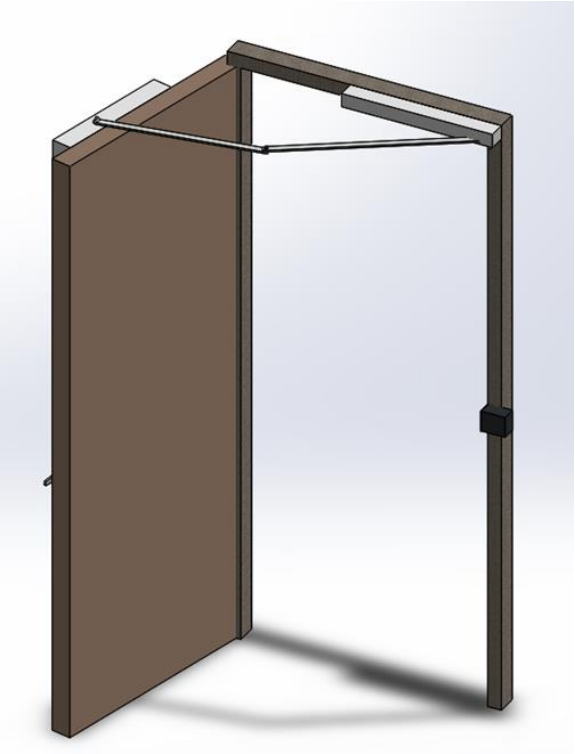
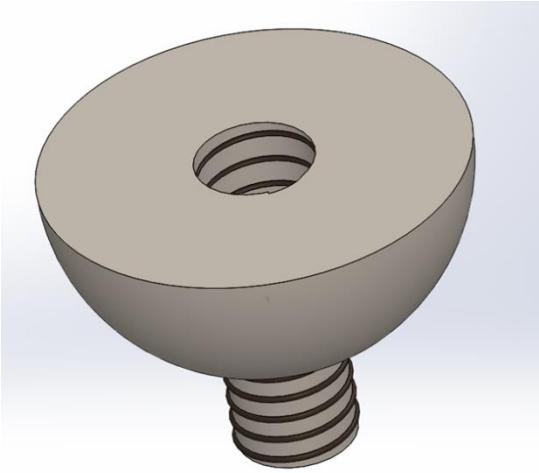
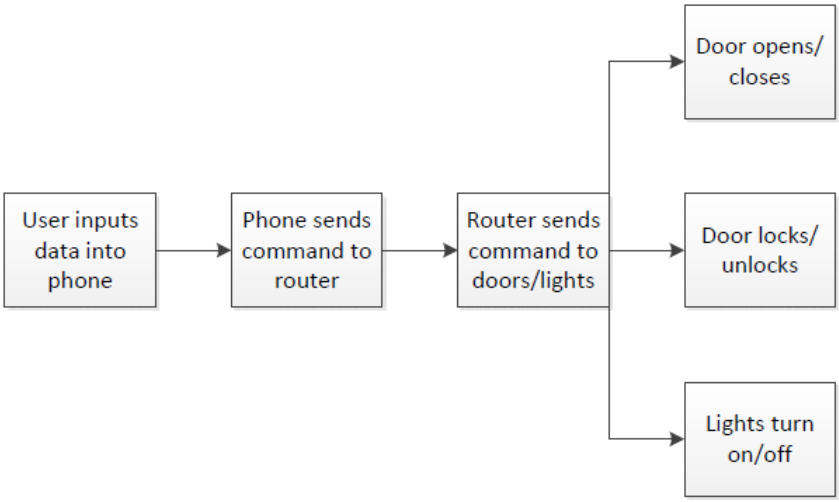




Abstract

In response to the AT&T Statement, which involved creating a design involving the Internet of Things and Machine-to-Machine technology, we were able to identify opportunities that leverage real-time connectivity and new and emerging technologies to collect information that can be used for products and systems that benefit our lives. Through use of the design process our team has developed the *Master Switch* which controls the lights and doors of the user's home through an application on a phone or tablet. The Master Switch would be a useful addition to any home. People are forgetful and sometimes may forget to lock their doors, turn off their lights, and sometimes close their doors.



Introduction

AT&T prompted us to identify opportunities that use connectivity and emerging technologies to collect information that can be used to design a new product that would benefit its customers. The connectivity that is involved includes the Internet of Things and Machine-to-Machine technology. These technologies are becoming a major part of people's lives. With the enhancement of technology in this age, we are transitioning from machine to human communication, to machine to machine communication. Three examples that AT&T presented were digital life (Connected Home), connected car, and wearables (such as google glass). These different aspects communication have the potential to benefit the user's lives. Our team's goal's for this project included finding a topic related to the internet of things that involved machine to machine communication that we could use to design a new technology that is feasible for AT&T. Home connectivity is the aspect our team decided to further develop. Our mission statement was to improve functionality and ease of use of home automation technology.

The team collectively planned to have this project completed by utilizing all steps of the design process. This involved gathering data from customers and external research which we then used to generate concepts to solve our problem. These concepts were evaluated and improved in order to develop our final design, the *Master Switch.* Our final design came out to be a system that is controlled by an application on a user's phone or tablet that is able to turn

lights on/off, lock/unlock doors, and open/close doors. By installing an adapter to the lights, locks, and doors they are able to be connected to the internet which makes long distance control of these household devices possible. An illustration of this process is as follows:

Customer Needs Analysis

In the digital life category, the customers are homeowners and future home owners, as well as AT&T. To determine what the customers wanted, surveys were created that were distributed to potential homeowners. The customer needs survey targeted students who will own a house in the coming years. The survey contained an array of questions concerning automated devices and/or functions in houses they wished to have.

The answers to the surveys varied from closing curtains and windows to being able to control cars, but the most common answer was turning on/off lights and opening/closing/locking/unlocking doors. Another survey was constructed which was directed to more specific details on the results of the initial survey. As a result of the second survey, the average cost that the customers felt comfortable spending on an automated system in their house was clarified as less than 9000$. Moreover, the second survey also revealed the average time for installing the system to be less than a month. As far as user input is concerned, customers have an even split between voice commands and phone app.

Voice commands have many benefits such as opening doors and controlling lights by voice when an individual is already using both hands. The design team was not fully convinced that the voice command would be the best fit for the system, so external research was used to determine positive and negative attributes of phone app and voice command. Customers said there were many reasons as to why an app would be a better choice compared to voice command such as security, privacy, and certainty. An individual can be sure of whether his door is closed or locked with certainty because a phone app can show the status of the door and lights concretely on the phone screen, whereas voice command instrument may not be able to. Finally after doing some external research, the design group decided to use an app on a Smartphone or tablet as the user input method.

After carefully analyzing the data recorded from surveys a needs/metrics matrix chart was created. In the process of developing the chart, metrics were developed and then compared to the customer needs in a needs/metrics matrix chart. This was done to show that all needs had a metric that satisfied them. Figure 1 shows the needs metrics chart. This chart shows the metrics in the vertical components and the needs that satisfies their respective needs. The needs are listed in the order of importance, based upon the number of times the need showed up in the customer research. All metric values were determined based on averages of the data received.

Figure 1: This table shows the customer needs hierarchy and all metrics.

Rank		**Metrics:**	Cost (<9000$)	Time to install system (< 1 month)	Time to configure system (less than an hour)	Method of control (user interface)	Door functionality (subjective)	Light functionality (subjective)
	Needs:							
1st	The system will be cost effective.		X					
2nd	The system can be installed in reasonable time.			X				
3rd	The system can be set up in reasonable time.'				X			
4th	The system can be controlled from a user interface					X		
5th	The system will open/lock doors						X	
6th	The system will turn on/off lights							X

According to the chart in Figure 1, the most important need that customers seemed to have was cost effectiveness. This average cost was around nine thousand dollars. After the cost, the second most important customer need was that the system should be installed in under a month. In the order of importance, the system configuration should be done in under an hour. User interface lies next on the order of importance. As mentioned previously, another survey was conducted which revealed that a smartphone app would be the best fit for the user input device. The next customer need in the order of importance is that they can control their doors first and lights second as the result of installing a system.

Overall, customers considered that automated doors and lights to be the most important functions they would like to have in their houses. Even though they would like to have automated doors and lights, they want the system to be very cost efficient and will not be comfortable spending over nine thousand dollars. Analyzing the customers' needs definitely helped clarify the problem statement which is to design a technology for AT&T that uses internet for communication between two objects.

Benchmarking

Multitasking is a problem almost everyone faces. For example, carrying loads of groceries and trying to open the door to get them into the house or not remembering if you turned

off all the lights in your house before you left. These simple tasks can be made easier without making people lazy. Ordered into a hierarchy, our team generated multiple ideas based on the needs of the customer. Many consumers were looking for easier convenience around the home with carrying large loads, opening doors, and turning on/off lights. With ever evolving technology, companies have begun to experiment with smart technology. Savant Systems LLC has developed a "smart house" that functions similarly to the designs we generated for our products. Their system works in a way that requires implementation of their software systems in order to power specially designed light bulbs. The system receives a signal from an app on a phone transmitted through Wi-Fi. "A user selects a particular depiction of a particular light fixture within a particular virtual room. In response, a state of the particular light fixture within the corresponding physical room is changed" (20120284672). Unfortunately their lighting system involves specialty Savant Systems light bulbs and reworking of electrical systems in the house. It must be installed by room with the minimum being $1,000 per room. Implementing such a system is very expensive and would not satisfy our customer needs.

Our customers also preferred a door system that opened, closed, and locked doors. The company Lockitron invented a unit that attaches to a lock on a door and is controlled by an app on a mobile device. The apparatus can lock and unlock doors but cannot open them. It works through built in Wi-Fi, assuming the customer has a router and other necessities required for internet use. The phone application shows the status of locked/unlocked doors and can lock or unlock them from far away locations ("Keyless Entry…"). Lockitron has licenses for this idea but no patents currently. In comparison with the customer needs, a system that both closes doors and locks doors is preferable.

With our customer needs hierarchy and benchmarking information, we were able to establish some target specifications outlined in Figure 2.

Figure 2: This table highlights important target specifications.

Number	Metric	Unit
1	Cost	<$9000
2	Time to install system	<1 month
3	Time to configure system	Less than one hour
4	Method of control	User interface
5	Door functionality	Subjective
6	Light functionality	Subjective

The highlighted specifications are areas that our group wanted to implement in our designs. These areas are needs that were not met by the competition or in which the competition was lacking.

Concept Generation

In one of the team's biweekly meetings in the Pollock Testing Center, we noticed an automatic handicapped door. This provided the initial idea for improving the daily lives of

homeowners. The door gave us the idea on how to use technology to automatically open doors just by pushing a button on a phone. Not wanting to limit the technology to just doors, it was decided to implement a light system that can also be controlled from a smart phone.

The design team designed multiple door systems in which you would be able to open a door to a house through an application on a mobile device. While we used the following patents for the functionality of the door, we designed most of the wireless technology that opens the door. This automatic door is controlled by a motor which receives radio waves from a router inside the home. A very small computer, onboard the door opening device, connected to wireless adapter translates data received from the phone application into a radio signal and transmits it using an antenna (Brain, Wilson, Johnson).

A wireless router receives the signal and decodes it. The router sends the information to the Internet using a physical, wired Ethernet connection. Then the process works in reverse, with the router receiving information from the Internet, translating it into a radio signal and sending it to the computer's wireless adapter. These signals are then sent through radio waves back to the device attached to the door, controlling the motor, and causing it to open. This wireless connection will be mounted above the door. The application will communicate via the radio waves to the system to open and close the door. The operation of the door will work similar to how handicap doors work. They are controlled by a motor on top of the door and automatically open when activated.

From patent US 6105313 A, this type of door constitutes a bi-directionally swinging door which seals into a doorjamb (US 6105313 A). “An actuator causes the retractable edges to move away from the doorjamb and retract into the door, allowing the door swing either in or out.” From patent US 20040098915 A1 “A fully automatic hinged residential door system is described suitable for quadriplegics, or other persons confined to wheelchairs. A wireless command operated through a hand held or mounted transmitter instigates a series of operations which unlocks the entry way, turns on appropriate lights, opens the door through at least ninety degrees, allows entry or egress, and responds to close commands in manual or automatic mode.” This type of door is fail safe and can be operated automatically during power outages (US 20040098915 A1). A means of manual key or code operation is maintained. The system comprises a low voltage power supply, an opening device comprising electric motors, light controlling apparatus, a locking and unlocking device, force limiting hardware, and a movable door sill. The unit is compatible with all existing hinged door openings and can be retrofitted, or used as part of new construction.

For the lighting system in the house, consumers will be able to use regular store bought light bulbs and buy a designed attachment without needing to buy expensive specialty light bulbs. The team-designed light bulb attachment uses the same wireless signaling process as the automatic door. Signals are wirelessly transmitted to and from the light bulb attachment, turning the lights on and off (Brain, Wilson, Johnson). There is no need for replacing doors or lights; parts are only added. Instead of replacing an entire door and adding a wireless system, the system works with existing doors and only requires for the motor and wireless units to be attached. Also, the lighting system works with existing light bulbs and an easy-to-use wireless attachment rather than reworking the entire electrical work made for specialty light bulbs. The attachment fits on to the light bulb and the unit can be screwed into the socket.

The design team had to come up with a design for customers to be able to control their doors and lights though phone apps. Therefore, a modified version of the 6-3-5 technique using less people

was used to generate concepts. The technique requires every person in the design team to generate a concept that they think is feasible for the problem's solution based on the customer needs. Five minutes were allowed to generate a concept; next the concepts were swapped and other team members edited the concepts so that they could improve the concept. This was done until every member had a chance to edit every other concept. All of the pictorial representations of the concepts be found in Appendix A of this report.

The concepts are as follows:

“High Powered Magnet”

A metal door is installed, and powerful electromagnets are installed in the wall. The magnets activate in order to open, close, and lock the doors. Lights have switches built into the wiring for remote access. These magnets, as well as the lights, are controlled by a wall mounted control panel that sends out infrared signals.

“Radio Motor”

A door opening unit is attached to the frame of the door, and to the door. A motor spins, pulling a cord, which in turn extends two arms to open and close the door. The lock is also operated by a small motor, which spins to extend the locking mechanism. A router sends a signal to the door and locks in order to activate them. The light bulbs also have switches inside them that are activated by Wi-Fi signal.

“Magnet Theory”

The door hinges are replaced with hinges that act as strong capacitors. The door is opened and closed by changing the door hinge charges so they attract or repel. These changes in charge are controlled via Wi-Fi signal. Light bulbs are screwed into an adapter, which in turn screws into the light socket. This adapter responds acts as a light switch that responds to Wi-Fi signals.

“String Theory”

The door is opened and closed by a motor in the wall retracting and extending a string that is attached to the door. This is controlled by a signal from a home router. Lights are controlled the same way as mentioned in the previous design.

Concept Selection

Our concept selection matrix was based on six factors important to the design:

Cost effectiveness: Concepts were judged on the cost relative to each other. This was determined by whether or not the door needed to be replaced, and if the surrounding wall needed to be modified.

Installation time: Amount of time to install the entire system into the home. This was estimated based upon the components of the system that could be installed without modifications of the structure and wiring of the home.

Set up time: Amount of time to configure usage of the system. This was determined by the method of control system used. Designs that used a phone or tablet app were deemed to be faster than those using a wall mounted control panel, because they could be changed on the go.

Control system ease of use: Simplicity of operation

Effectiveness of door control: How efficient the door control mechanism is relative to the other concepts. This was determined based off of which concepts would be convenient to use, and cause minimal interference with other parts of the home.

Effectiveness of light control: How efficient the light control mechanism is relative to the other designs. This was determined based off of which concepts would be convenient to use, and cause minimal interference with other parts of the home.

Our results are summarized in Table A. The "Magnet Hinge" design was the reference design that all other design comparisons were based upon. The 0's represent features that were scored as equal to the reference design feature, the +'s represent features that were scored as greater than the reference design feature, and the -'s represent features that were scored as inferior to the reference design feature. The net sum of the +'s, 0's, and –'s was taken in order to compare the concepts to each other in a qualitative manner.

Table A: Concept Scoring Chart

	High Powered Magnet	Radio/Motor	Magnet Hinge	String Theory
Cost Effectiveness	-	+	0	+
Installation Time	-	-	0	-
Set up time	0	0	0	0
Control system ease of use	-	0	0	0
Effectiveness of door control	-	+	0	+
Effectiveness of light control	+	0	0	0
	-3	1	0	1
	Drop	Combine	Drop	Combine

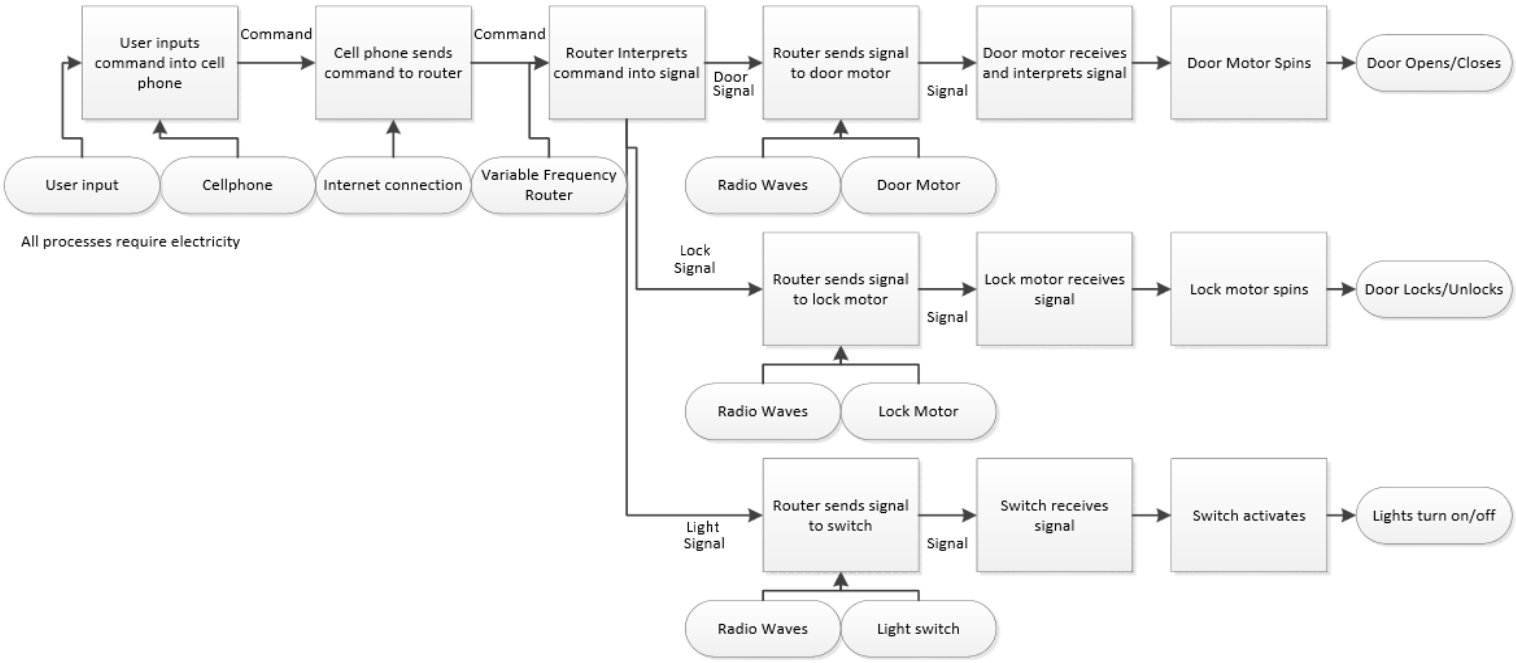
We determined that the Radio/Motor and String theory designs were the best choices of our concepts. After review, we found that the main areas where these designs were superior were the installation time, and the cost effectiveness. This is because these designs do not require a new door or wall, and do not use as much electricity. The door designs were similar with the exception of the door opening/closing mechanism. We realized that we were not trying to reinvent the wheel, so we decided to adapt an already used model into the final design, the Master Switch (US 5881497 A). The Master Switch design is illustrated in the design embodiment section.

The Radio/Motor design has a locking mechanism that worked remotely, just like the door, while the String Theory design used adapters for light control. This light adapter system is similar to the idea of smart light bulbs we researched during our benchmarking phase, but could be used with any light bulb. This increases the cost effectiveness of the system and allows for more user customization.

The final design, the Master Switch, was a system designed to open, close, and lock doors, and to turn lights on and off. The system is operated by receiving varying frequencies from a router in the home.

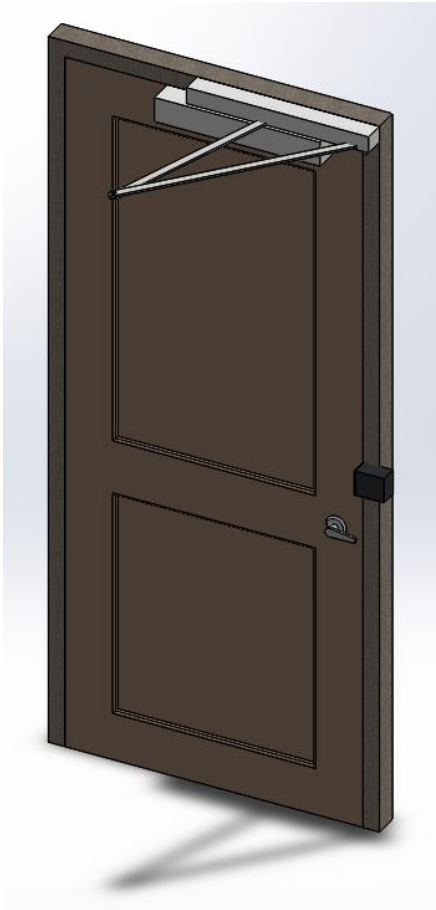
The processes of how this works is illustrated in our systems diagram. The system diagram shows all inputs that enter the system, the processes that lead to the end result, and the outputs that come out at the end.

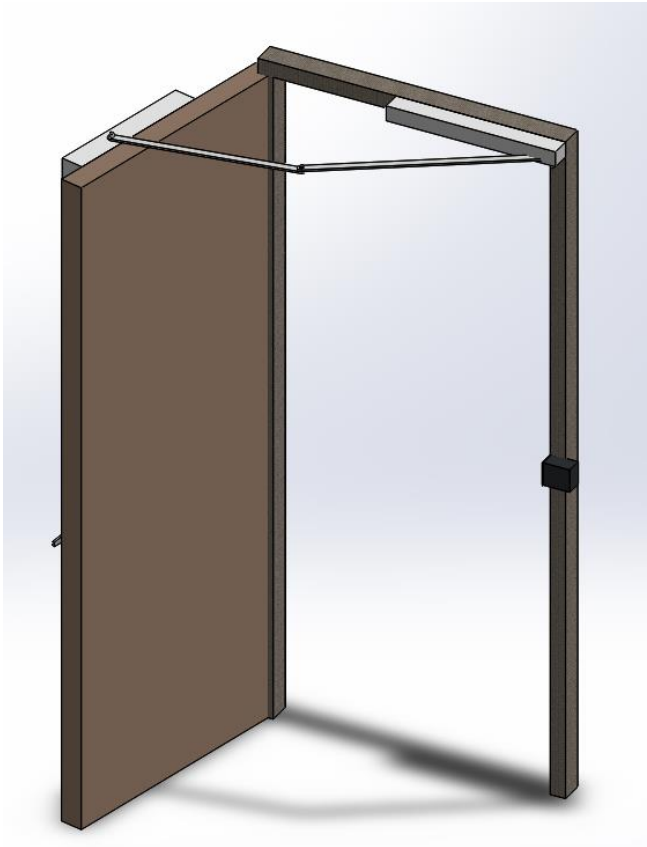
Systems Diagram:



The systems diagram describes the system as a whole. Now it will be broken down part by part.

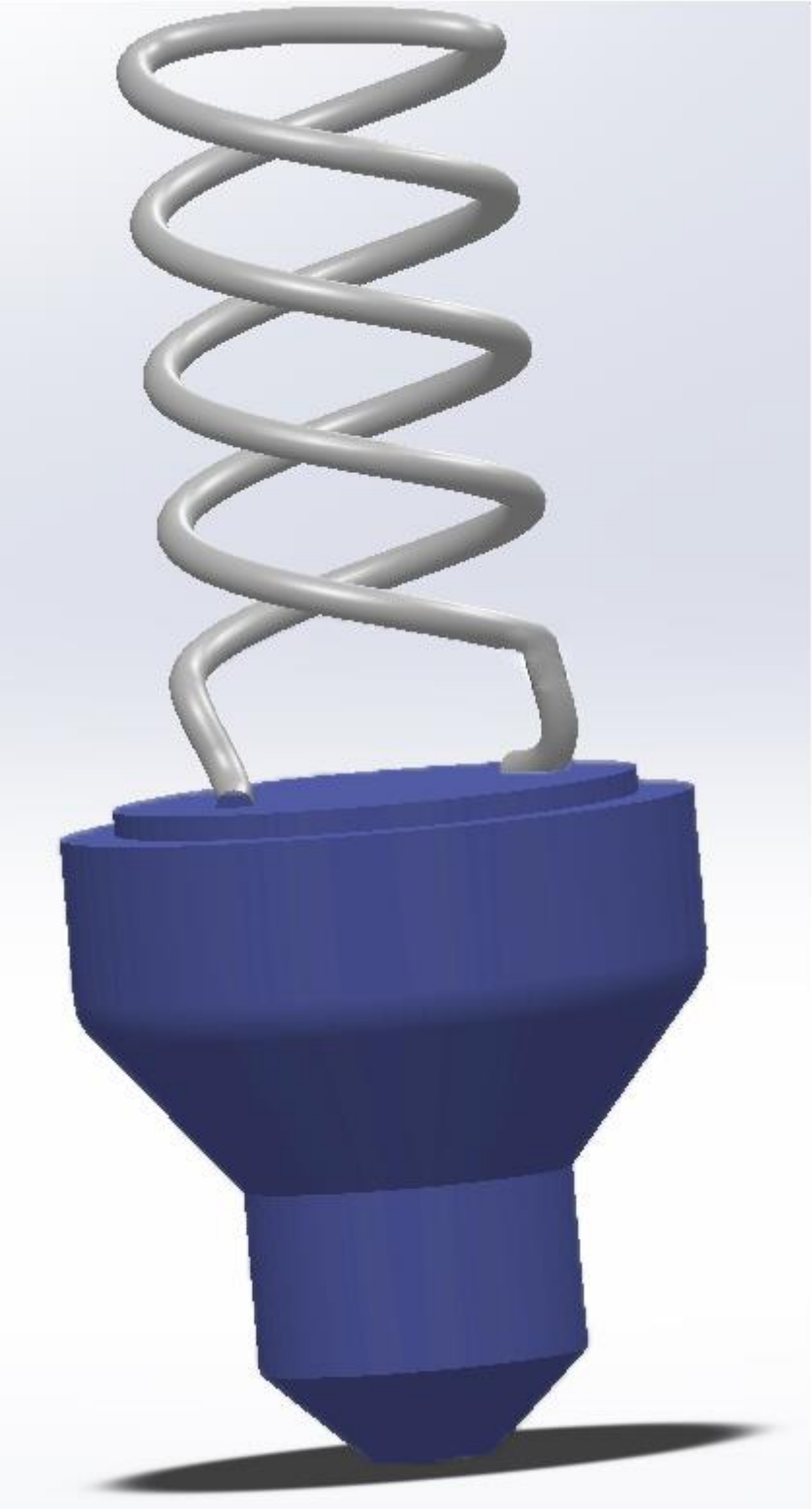
The door uses a mechanical door opener, just like handicap accessible doors. Need to include some additional transition sentences.



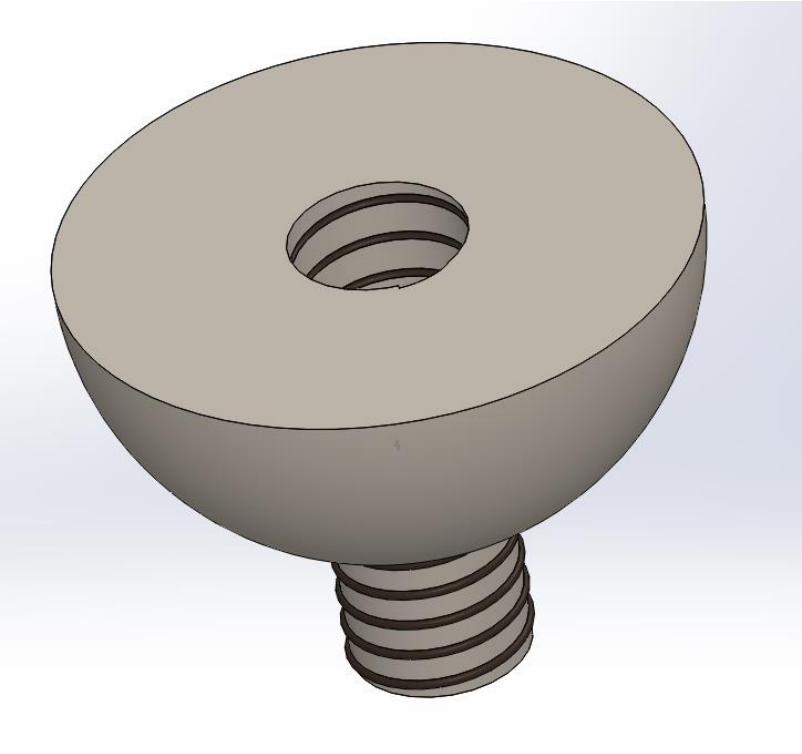


The lock has a motor inside that extends and retracts the locking bar, which is also controlled by frequency via router.

The lights have adapters that the light bulbs screw in to. The adapter has its own switch, which is activated by radio frequency from a router in the home.



The light bulb screws into an adapter which is a radio operated switch. This adapter screws into a light bulb socket, allowing this technology to be used with any light bulb design.



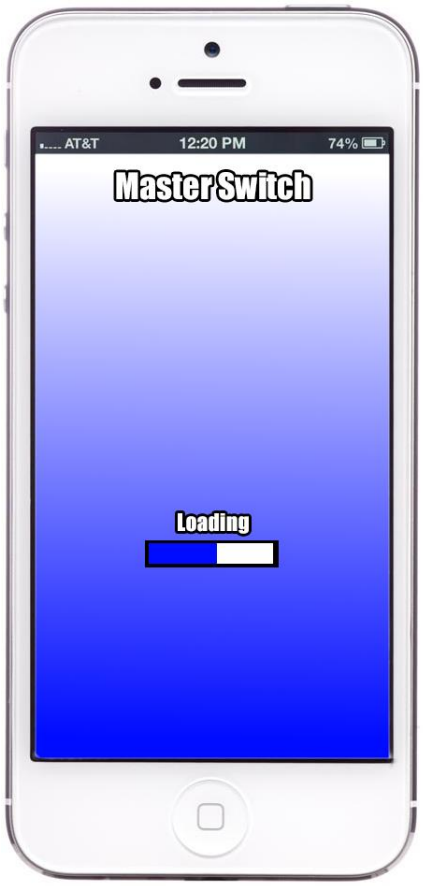
This adapter has a radio switch and is Wi-Fi enabled.

All of these different parts above create this system, but below we show how a user would control the system with a phone or tablet application.

1. User opens app
2. Enter security code
3. Status menu appears
    a. Status of Lights
    b. Status of Doors
    c. Status of Locks

4. Individual menu options
    a. Turn On/Off Lights
        i. Timer
    b. Open/Close Doors
        i. Timer
    c. Lock/Unlock Doors
        i. Timer
    d. Enter security code to finalize changes

Sample screenshots[1] of app menus:



Description:

The user opens the app on their smartphone or tablet and is requested to enter their personal security code to access home control of doors and lights. After properly entering the code, a status menu will appear for your lights, doors, and locks. You will be able to click on one of the options to get more advanced options for said choice. For example if you choose "Status of Doors" you will get to a page with the status of the doors you have programmed which will tell you if they are opened or closed. If you click on a door whose status is open it will give you the option to close it. This would work the same for locks, lights, and closed doors (vice versa for closed doors). After finalizing your settings it will ask for you to enter your security code in order to complete all the actions.

An example of how this device could be useful is when the user buys groceries. The user may have their hands full and not be able to open the door manually when they get home. If the user opens the door with the app and grabs all the groceries, they could easily walk into the home without any extra work.

[1] Images modified from PCMag.com (http://www6.pcmag.com/media/images/301505-apple-iphone-5-at-t.jpg)

Cost Analysis

The *Master Switch* is very cost effective because the user can install it as they see fit. For example, the homeowner can install a door opener and a lock on the front door, but just a lock on the back door. The homeowner can also install as many or as little light bulb adapters as they see fit.

The door opener cost was simple, because many handicap style door openers already exist. For example, an automatic door opener from CareProdx costs $650.00[2]. From this we determined that our door opener would cost the same amount. A door locking system from Lockitron costs $179.00[3], but this costs includes the price of the app, and is a system for the whole home. Our app is free to download, and locks are only installed where the user wants them. Because of this, they are priced individually at $60.00.

The light switch adapter was much more difficult to develop a price estimate for, because it hasn't been developed before. It could not be compared to the Savant Systems LLC, because no change of wiring in the home was needed. The closest equivalent is the Phillips Hue, which requires specialty light bulbs. The price of a Phillips Hue specialty bulb is $60.00[4], but the bulbs are LED's that change color. Since our adapter does not have any color changing, but does have Wi-Fi capabilities, we developed a cost estimate of $35.00.

Conclusion

This project utilized all the steps of the design process outlined throughout this report in order to satisfy the needs of the customer. The needs were initially established through customer surveys obtained by interviews with potential customers. These customer needs taken from the interviews lead us to create several concepts which were modified and refined in order to create the *Master Switch*. This design is a user application on a phone or tablet that allows the user to open/close and lock/unlock doors as well as turn on/off lights. The *Master Switch* satisfies the needs of the customers in the most efficient way.

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[2] http://www.careprodx.com/products/easy-door-latched-door-opener.html
[3] https://lockitron.com/
[4] http://www.amazon.com/Philips-431643-Personal-Wireless-Frustration/dp/B00BSN8DN4/ref=sr_1_1?ie=UTF8&qid=1398775767&sr=8-1&keywords=philips+hue

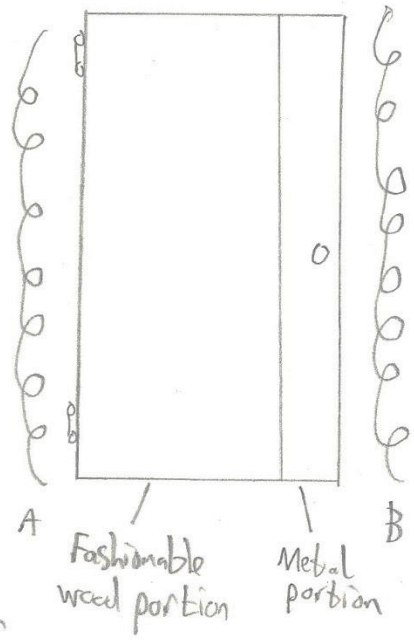
Appendix A

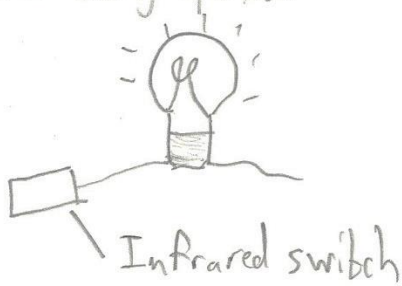
High Powered Magnet:

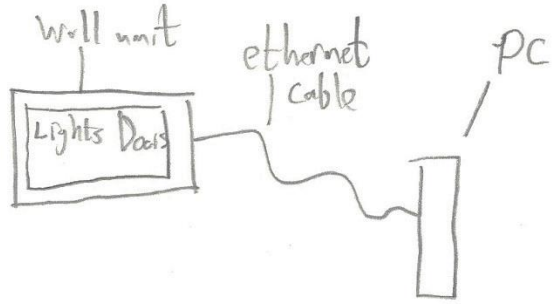
"High Powered Magnet"

Powerful coil electromagnets are embedded in the wall, adjacent to the sides of the door.

To open the door, Magnet "A" is turned on. To close the door, Magnet "B" is turned on. To Lock the door, Magnet "A" is put into maximum overdrive, where so much current is running through that the magnet force prevents the door from being opened.



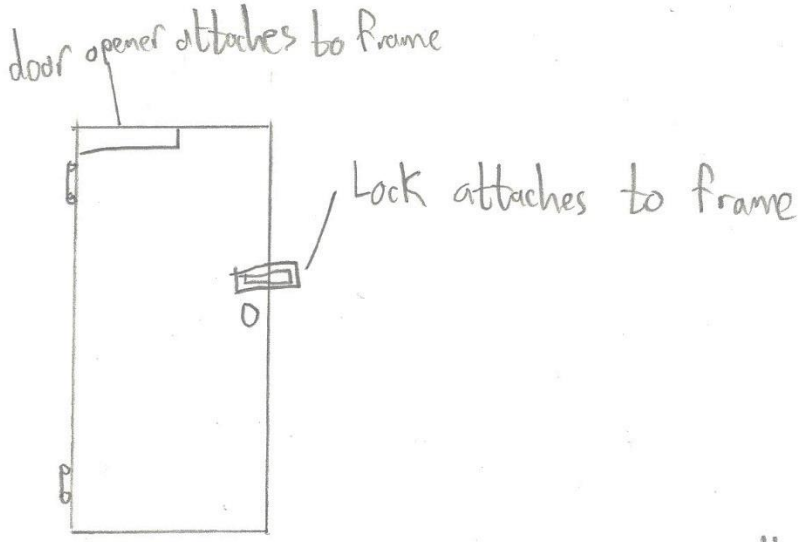




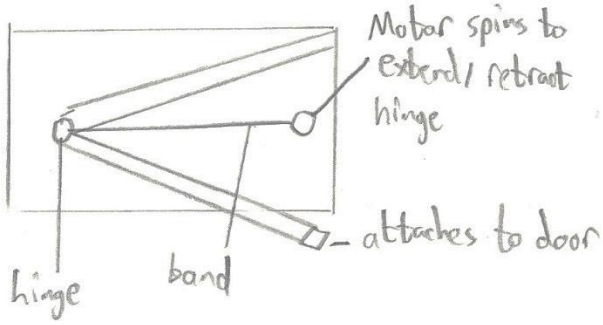
Wall mounted screen sends out infrared signals to switch lights and control doors. Wall unit connects to PC, which can connect to cell phone for remote access

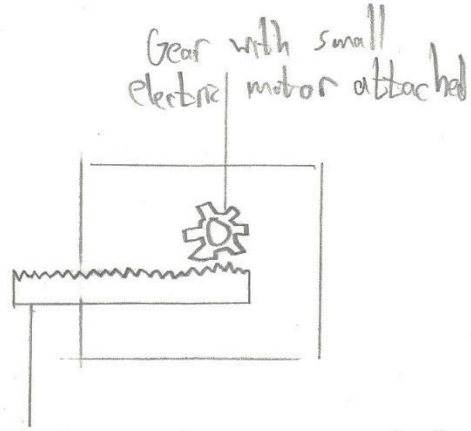
Radio Motor:

"Radio / Motor"



Door opener





Motor spins gear, which extends bar in/out for door lock/unlocking

Both door opener and lock are operated by radio frequency, which is transmitted by a router in the house. Light switches work in the same way.

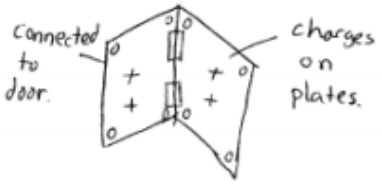
Router inputs can be controlled via phone app.

No new door required.

Magnet Theory:

Magnet Theory.

Hinges of the door



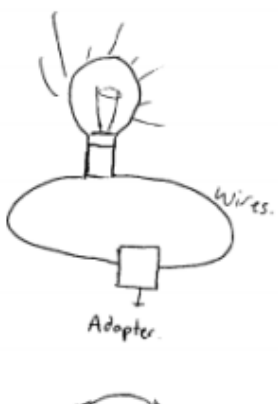
X3 on the door

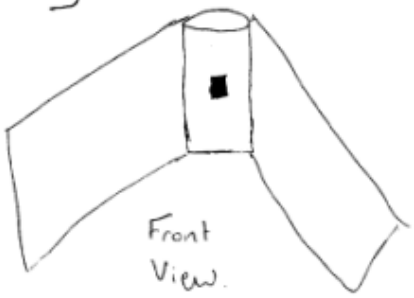
Locks.

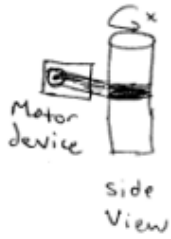
The hinges will have small bars ~~screws~~ going through them, that will keep them from rotating. ~~when~~ The ~~screw~~ small bar can be controlled by a motor bar ~~de~~ system. as described in the picture below.

All hinges are connected to a power supply. and and an adapter that works through ~~using~~ radio frequency. The plates of hinges can turn into capacitor plates charged with the same charge (+ or -) and that will cause the plates to move apart, which will in turn open the door. The charge will be taken ~~of~~ away from the plates when the doors are closed. The hinges ~~can~~ are made so that they can lock themselves by not rotating. ~~This can be done if the hinges are connected~~

Light is also connected to an adapter switch that uses radio frequency to operate. This adapter is connected wirelessly to a Router.



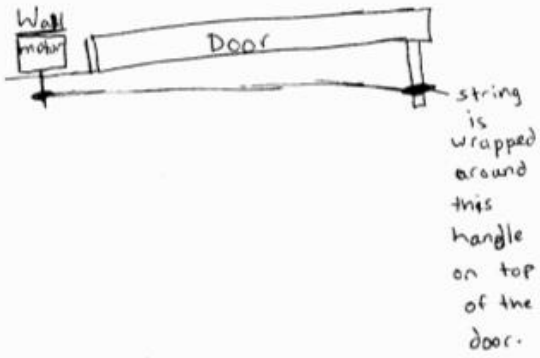


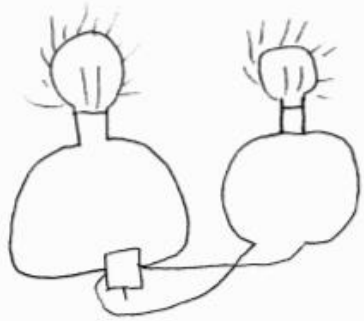


String Theory:

String Theory

Top View of the door





Lights will be connected one device ~~in~~ by wires and that device will act as a switch. The device will be then connected to the internet ~~a~~ and it can be controlled by the internet.

Motor is connected to an adapter switch which is controlled by radio waves sent ~~through~~ by the router. The motor ~~either~~ spins counterclockwise which will retract the string & open the door. Also, the motor would spin clockwise to close the door.

~~To lock the door,~~

To lock / unlock the door, there will be an automated lock system ~~which~~ installed on the door, which will ~~open~~ be operated by charge magnets ~~on~~ between the door and the wall. There will a very strong magnetic force between the door and wall when locked, and ~~no~~ charge will be removed if unlocked. The magnet will be connected to a battery or electric supply.

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