3rd May 2016

Smart IOT Home

Introduction

Home automation lets you control devices in your home from a smartphone over the internet from anywhere in the world. A smart IOT home will have a central hub which interfaces with lights, fans, air conditioners and other appliances in it, and decide their state (On or Off) based on a sensor network which monitors the temperature, humidity, luminosity and the presence/absence of humans. Most of the companies which offer home automation solutions will require going behind the switchboard to add a component. We are trying a different approach.

Project Scope

- Device to be mounted on top of switchboard, without any interference to the original circuitry behind the board.
- Automation to realized mechanically instead of electrically.
- Power using batteries, use low power devices to ensure longer battery life.
- Modular design
- A fully functional sensor network.
- A fully functional android app.

Demo

1. Connect smartphone to central hub via internet (connects to a web server).
2. Demonstrate the working of switching mechanism.
3. Demonstrate the working of sensor network.
4. Demonstrate the fluid interaction between sensor network, switching mechanism and Android app by activate switching mechanism when-
   - A hardware manual override button is pushed.
   - A soft button on the android app is pressed.
   - Sensor values triggers some logic in the central hub. (for example heat rises above a given threshold)

Team members and responsibilities

Siddharth Sundar - Communication - Bluetooth and Rest server
Shashwat Chaudhary - Switching mechanism, sensor network and blog
Luv Sharma - Switching mechansim and sensor network
Hasan Kamal - Android app

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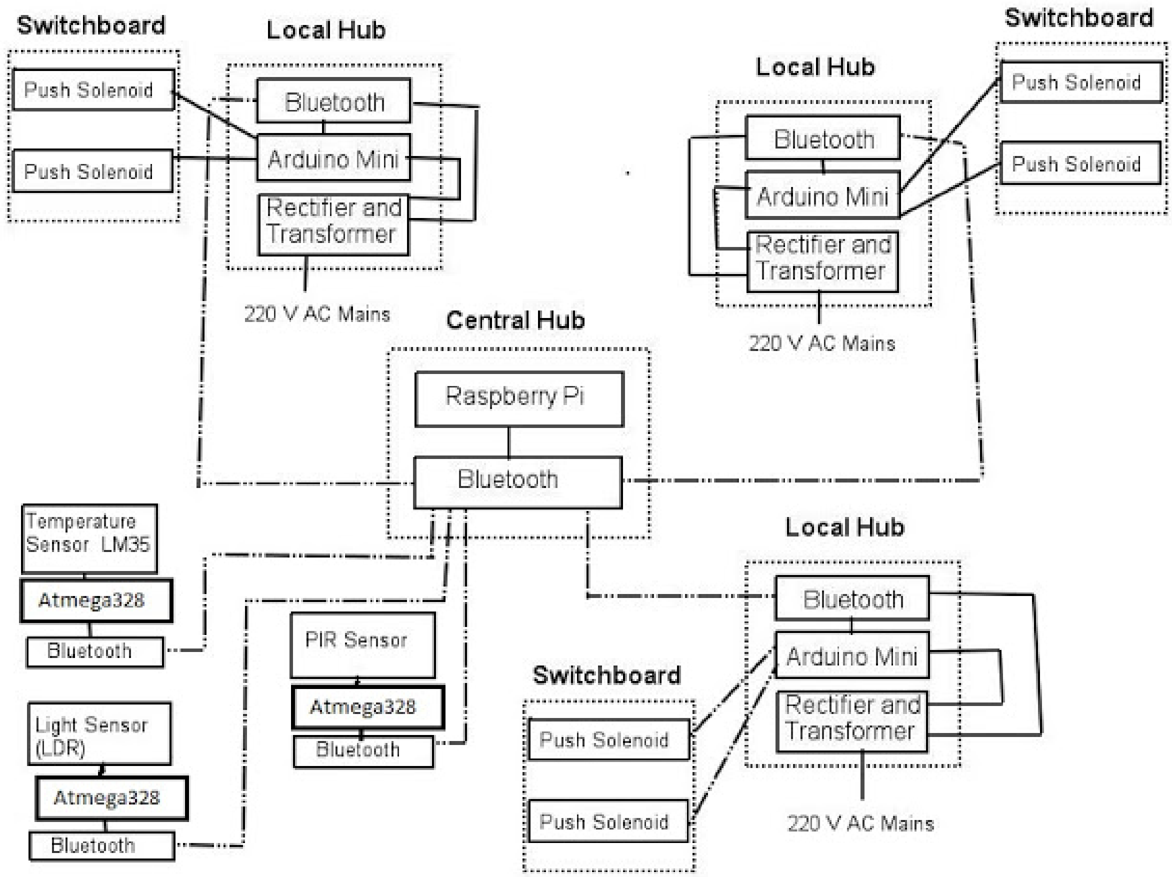
Mentor and Instructor - Dr. Jyoti Sinha

Block Diagram



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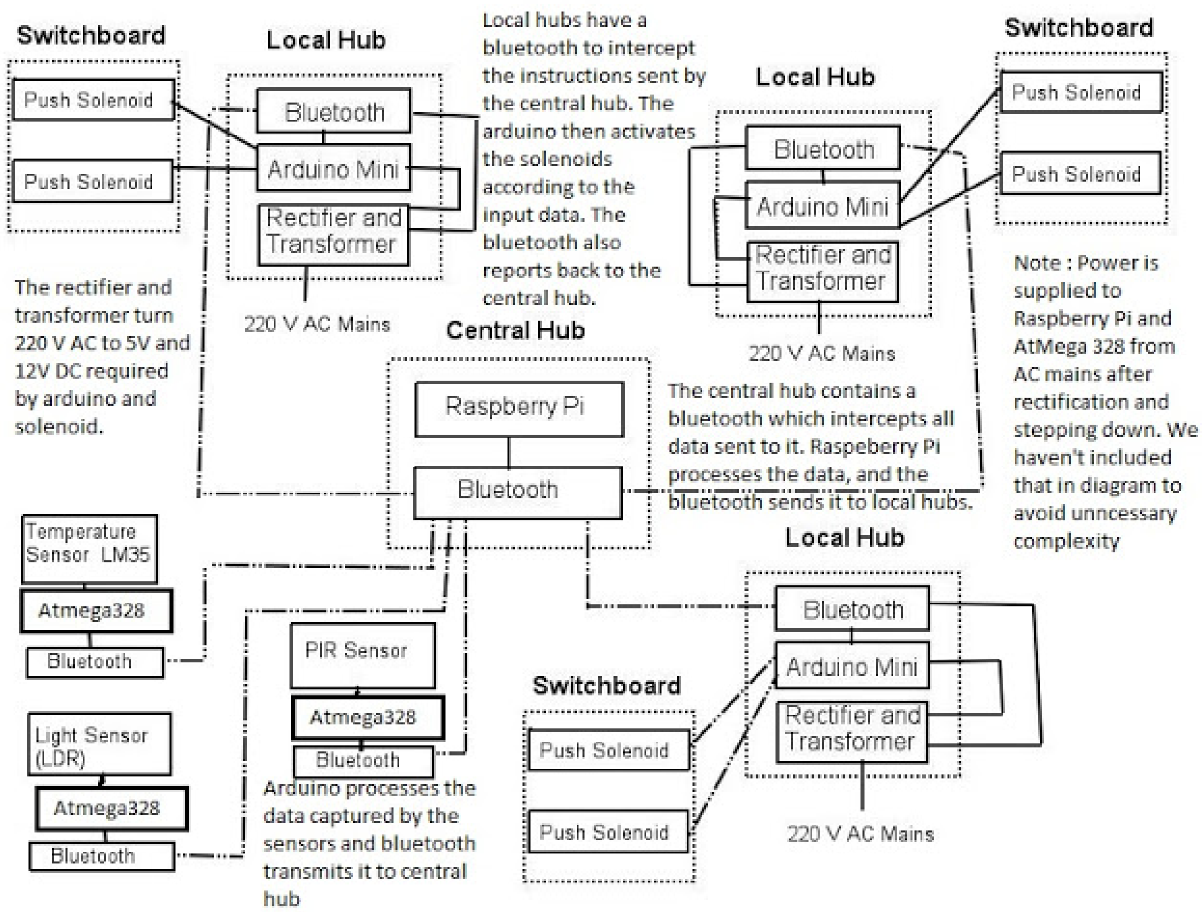
This is the original block diagram we made when we started making this project. However, now we are using servo motors instead of push solenoids, and 4 AA batteries (since they are readily available in the market) instead of 220V mains.

Functional Diagram



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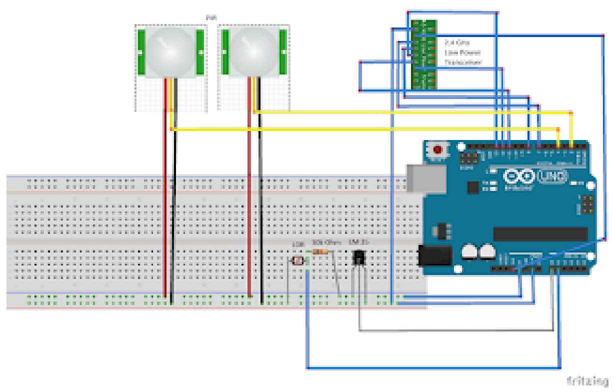
This is the original functional diagram we made when we started making this project.

Pin Diagram



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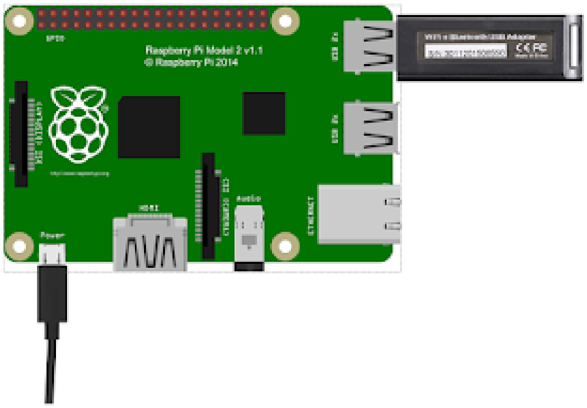
Sensor network. We are additionally using infrared LED and infrared receiver.



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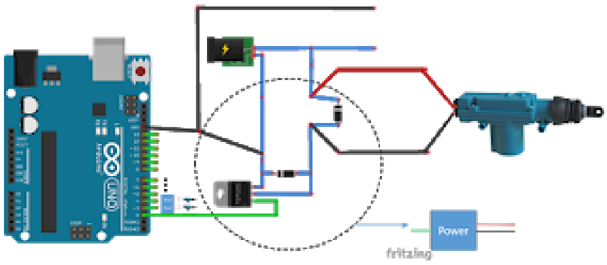
Raspberry Pi



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We planned to use Push Pull solenoids, however, instead we are using servo motors now. Also we are using arduino pro mini and push buttons too.

List of Components and their sources

We used:-

Component	Quantity	Source
Raspberry Pi	1	Provided by instructor
Arduino Uno	1	Arduino Set
Arduino Pro Mini	2	Amazon
HC05	2	Amazon
Low power Bluetooth	1	Amazon
Servo Motor	4	Lajpat Rai Market
HC-SR501	2	Lajpat Rai Market
IR LED	2	Arduino Set

IR receiver	2	Arduino Set
DHT11	1	Lajpat Rai Market
WiFi Adapter	1	Amazon
Bluetooth USB Adapter	1	Lajpat Rai Market
LDR	1	Arduino Set
Push Pull Solenoid	2	Lajpat Rai Market
DC Motor	2	Lajpat Rai Market
Metal Rods	10	Automobile Repair Shop

References

https://www.arduino.cc/
http://playground.arduino.cc/
https://www.adafruit.com/

Tools/software used

Software:

- Android Studio
- Arduino IDE
- Python interpreter
- Tinkercad
- Slic3r

Initial approach

> When we approached the problem we were dealing with, the most daunting question was how to realize the switching mechanism. There were many ways we could have gone about doing that. There was the mechanical possibility, and the electrical possibility. The latter, though relatively simpler for us, meant that the installation of our home automation system would be hard for the end user. Pure mechanics and no interaction with the switch board implied that we use batteries, which caused many problems. Finally we settled for a mid-way solution. We would use mechanics and only open the switchboard once to withdraw power.

This paragraph that we wrote in the initial understanding section of the first project submission around 2 months ago is the best way for us to describe our initial approach towards the project. A lot changed in the coming months, and we solved most of the problems linked with batteries (the biggest one being the solenoid, which drains power very fast). While a lot has changed, we stayed true to our initial goal of minimizing interface with circuitry behind the switchboard, and instead of taking a mid-way solution, we took the one we wanted all along, to use batteries for power. Also, initially we were looking at solenoid for getting linear motion, as it was the smallest implementation we could think of to get linear motion. We also looked at ways to get linear motion from motors, but none of them were suitable for our needs. More details in the next section.

Journey to complete the project

Short Version

If I had to sum up our journey, I would describe it as a series of choices that we had to make as we went along making the project. As soon as we started we faced the first question of how to achieve automation
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Automation technique
-> Electrical V/S Mechanical
-> Modularity V/S Ease of use

Then after that, we had to decide how to actually push the switches.

For Mechanical Motion
-> Linear motion using motor vs solenoid
-> Linear motion V/S circular motion
-> Space V/S Complexity

Then when we had figured out a way how to push the switches, then the challenge was how to make the mechanism modular, and how to design a system for a variable sized switchboard, not just for a single switch.

For overall Design
-> Modularity V/S Cost
-> Battery V/S power supply
-> Aesthetic appeal V/S complexity

And if there is anything we learnt from this project, it was that **Simplicity occupies the least space!**

This was the short version, now the long version.

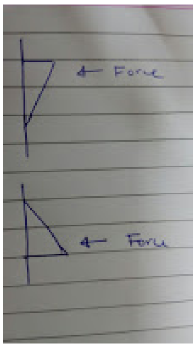
Long Version

Let's look at the journey as a series of choices and the challenges that these choices lead to.

Choices

1. We chose not to touch the circuitry behind the switchboard.
2. We chose to make our switch pushing mechanism as modular as possible.
3. We chose to make our home automation system easy to use.

Our second and third choices would often be at odds with each other. More modular components meant that they will work for every switchboard. However, modular components meant more assembly time for the end user, since the more number of factors we considered as variable, the more variables would the end user need to set to a their required value to get the components working in their case. In the end, the bargain was somewhat like this, our setup was modular, and installation was very easy but not very instantaneous (it would take some time to install our system, but it would be easy for anyone to do, and won't require the end user to take professional help).



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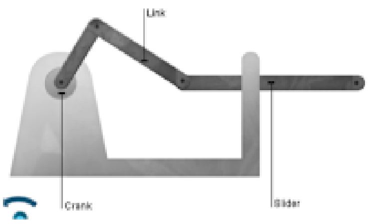
The First Challenge

The first choice meant we needed to mechanically push the switches. The task itself was fairly straightforward, a linear push at two points, dictated by an arduino. However, we had space constraints as well as power constraints. More than that, making this project made us realize that pressing switches takes a considerable amount of force, considering their size.Speaking of size, we had to ensure that our pushing mechanism is not wider than 2 cm. Any larger than that, and we have borrowed space from the adjacent switches, which need space for their own pushing mechanism.

So, now we were looking at various mechanisms which helped us convert rotatory motion provided by a motor into circular motion with high efficiency (we needed to deliver high force and couldn't afford to lose too much energy to frictional loss).



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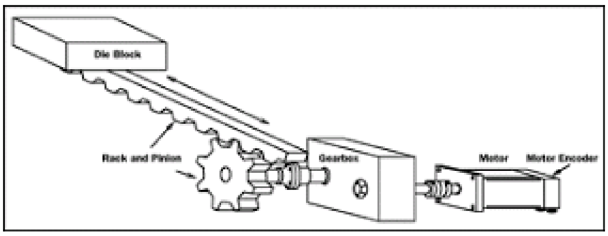

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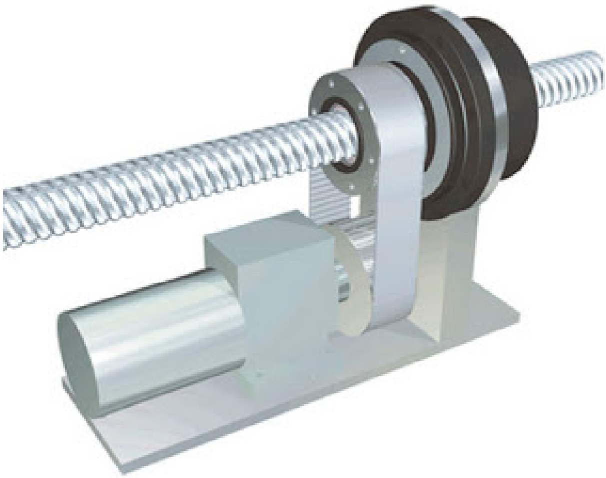

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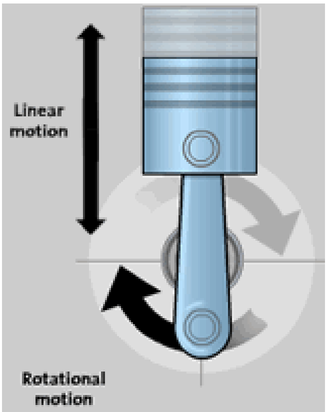

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We soon realized that there was no way to fit a motor, along with a system to convert the motor's motion to linear, in such a constrained space. Most of the motors themselves were either small but too weak (not high enough torque) or strong but too large. Small but high torque motors were expensive, and we needed 2 motors per switch, making expensive motors unfeasible.

Then we start looking for ways to directly convert electrical energy to linear motion (instead of converting electrical energy into rotatory motion and then to linear motion, wasting space and energy). We found push pull solenoids as well as a linear actuation device used in car doors (locking/unlocking).

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However, while the linear actuation device gave enough force to push any button (when operating at 12V), it was way too large for our purposes, and we couldn't think of any way to minimize it's size. The push pull solenoid gave a force which was incomparable to what we needed. We did find models with higher voltage ratings and power outputs, but they were again, too expensive. We needed to make a model which could scale. Knowing that the force output of the solenoid was nowehere close to what we needed, we had given up hope in the solenoid solution. However, we did half heartedly try to make a solenoid ourselves and see what kind of force we could harness. Unfortunately, we failed miserably.

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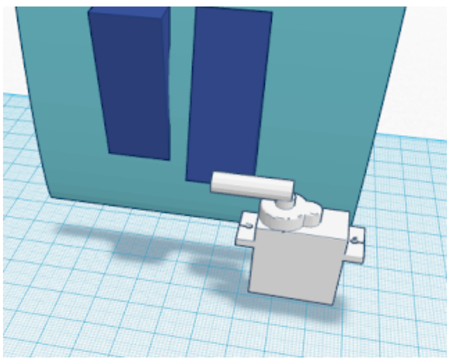
Finally, we tried to think outside the box, and tried playing with servo motors. Tower pro SG90 was a very small sized yet quite powerful servo motor that we had encountered, and we were hoping we could somehow harness it's torque to push a switch. That was when we had our first success. With proper positioning and at the right angle, we could use the rotatory motion directly. We had hit a breakthrough.

This is what our initial position for pushing button using servo motor looked like.



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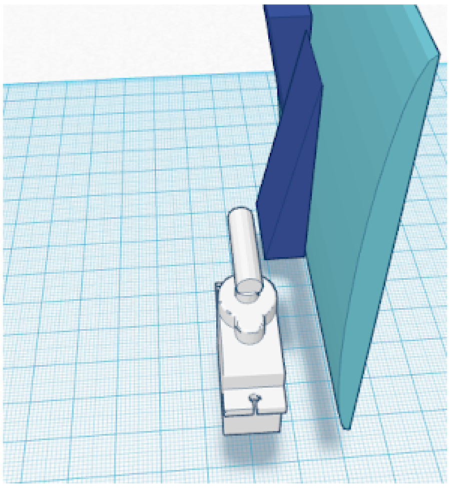

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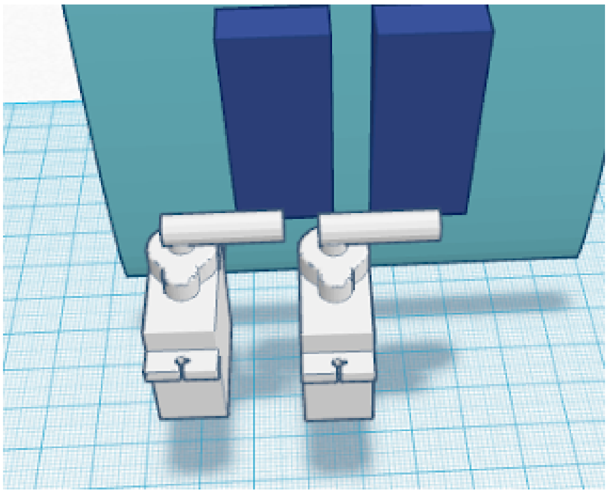
There was just a little problem. Even this little motor was a bit too wide. After our young eager minds had thought of every single way in which we could remove the 'unncessary' parts to make the servo smaller (for example, we wanted to get rid of the plastic cover, and large parts of the gear chain), we arrived at a much simpler solution. We simply changed the orientation of the motor. While it may seem very obvious now, arriving at this simple solution took a lot of efforts. After we finally got this working, I had this Eureka moment, and said to myself, 'simplicity takes the least space'. After all the efforts we had made, we ended up using a servo motor, a very common one at that.



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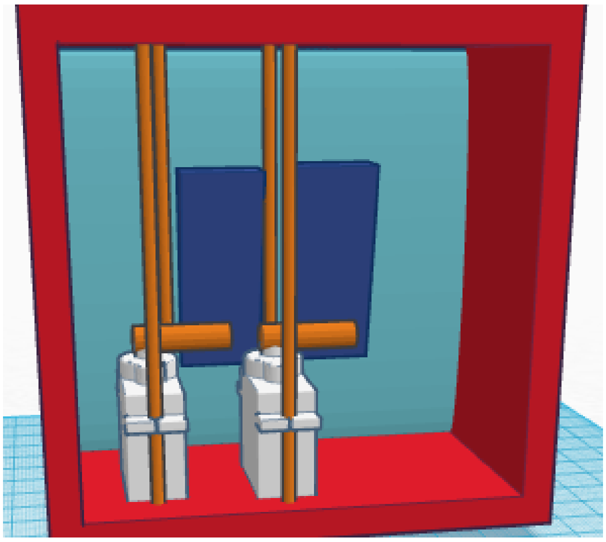
The Second Challenge

Now we had to come up with a modular design for our switchboard mount. Before doing that, we had to address the problem of keeping the servos in place, in front of their respective switches. We decided to solve the problem for the switchboard in our room, before thinking about modular options. We came up with this design. The plastic covering that we were so eager to get rid of (to minimize size of the servo) came in handy. We used the holes provided in it to hold the servos in place.



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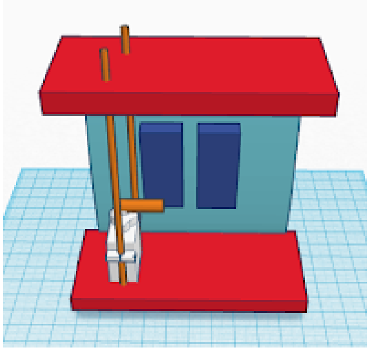
Now we had to make the design modular. The first design we came up with was this. Basically, we could cascade multiple units of this kind, and then have 2 pieces which come in from the sides. The side pieces were no necessary, and were present for completeness.



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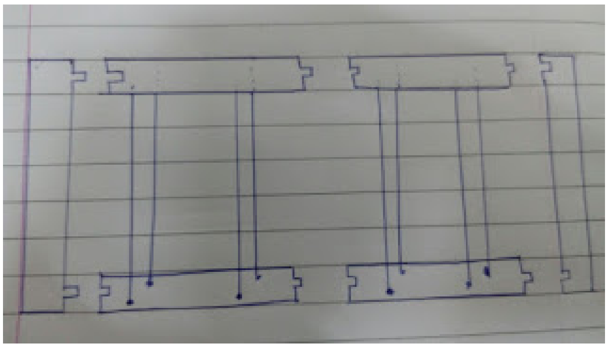

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This design had the limitation that it would needs to assume the position of the switches on the board, which varies accross boards. To solve that, we introduced a 4 switch wide pivot (note that while the positions of the switches may vary, the combined width of 4 switches is fixed). This is the pivot.

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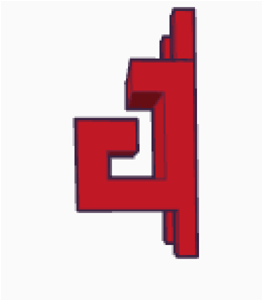

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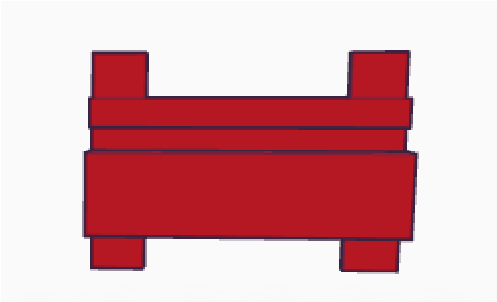

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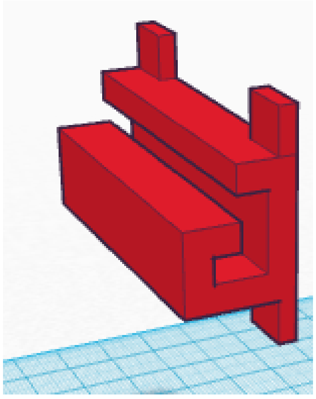

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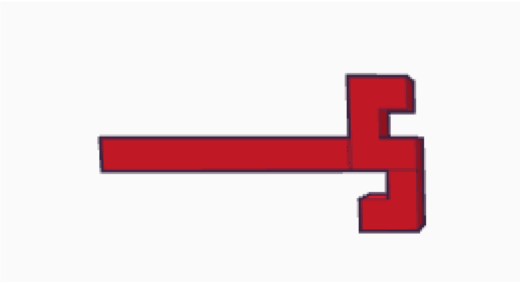
We now have an object which can be slide into the required position on the pivot. This is the object that will move on the pivot.



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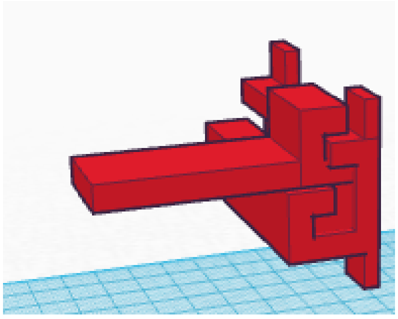
This is how it will fit on the pivot.



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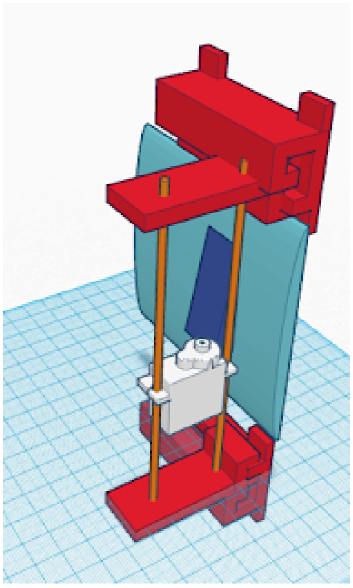
This is how the setup looks like (The pivot would be longer than this)-



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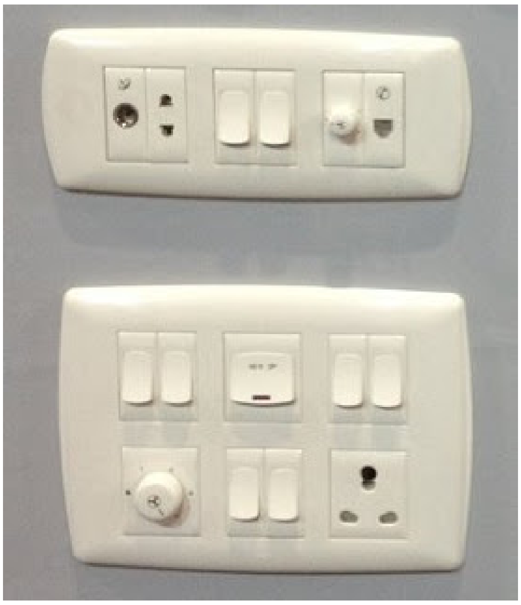
Now the only variable that remains is the height of the switchboard. The solution to that is the bars will also cascade. Also, we will now address the question of how will the servo stay fixed on the bars (along z-axis), and not slide down.



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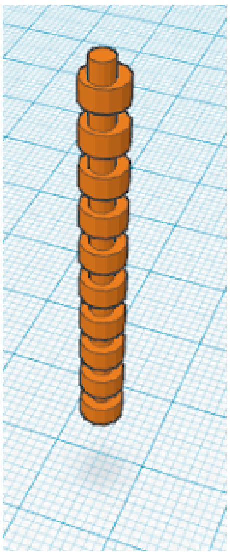
This is what our bars look like-



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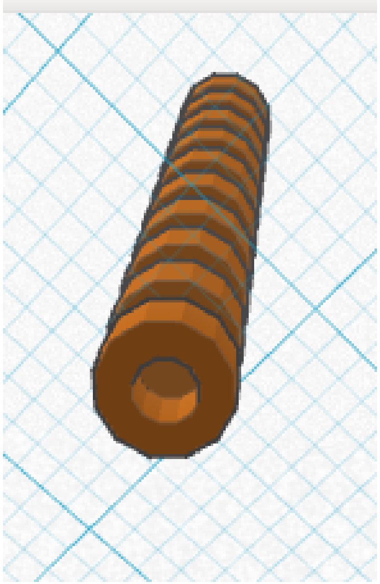

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As you can see, the servo will not slide down, and even the rods can be cascaded. Thus finally, our model is fully modular. However, as mentioned earlier, this modular nature invariably results in added effort on the part of end user in assembling the components to fit their needs. Note that we could not find a way to implement this bar/rod design in metal and hence are not demonstrating using this design, and would use a simple rod instead.

Challenge 3

[https://1.bp.blogspot.com/-mIuYovsd1FA/VyfEc-lFCUI/AAAAAAAAAls/VQQs38nK2Vojnq8DPrOJxAs-LULr3ONiACLcB/s1600/PIR.jpg]

This project also required a lot of effort in the software side of things. As far as arduino codes were concerned, most were readily available. We encountered a roadblock in PIR sensors, which had too large a delay (around 7-8 seconds), which made them useless. We could get them to figure out the number of people in the room if everyone entered one at a time and with around 10 seconds time interval. However, when a group of people entered a room, we detected only one, and if one of them left the room, we would conclude that the room is now empty (since we believed there was only one person in the room). Also, we could have made the assumption that people would enter in gaps for more than 10 seconds, but that is a bad assumption, and people frequently enter in groups.

[https://4.bp.blogspot.com/-iiEu_j-LOV0/VyfEcxVwXmI/AAAAAAAAAlo/GQAe6OR179cRwhIse9plKN9_osooMUHUACLcB/s1600/ir.jpg]

We solved that problem by using IR sensors instead. While it took a lot of trial and error to arrive at a working code, we did succeed finally.

Challenge 4 - Communication

One problem with the available Linux bluetooth stack 'Bluez' is that it has absolutely no documentation. Although a community documentation exists, it is extremely outdated (last updated in 2008) and so much has changed in the world of Bluetooth. Thus, we had to search a lot to get Bluetooth working with the Arduino flawlessly.

We found the Bluetooth communication between RPi and Android to be unreliable. Although it worked really well on some phones, on other phones, it would not respond at all. Thus, we decided to communicate between RPi and Android only via wifi. For this purpose, we use a server incorporating REST design principles.

Communication between the RPi and app is via the web service, which also serves as a cloud backup, while communication between the central hub and the devices is via Bluetooth.

All communication is encrypted. The REST service is encypted using a simple HTTP authentication whose details are known by the app and the central hub alone.

New methods used/ Invented

Very creative model to mechanically trigger switches. Some innovation with IR sensing.

Posted 3rd May 2016 by Siddharth Sundar

Labels: Home automation, IOT

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