ILLINOIS INSTITUTE OF TECHNOLOGY

FINAL ASSIGNMENT

RESEARCH IN ARCHITECTURAL ROBOTICS

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ABSTRACT

Robotics is an increasing issue of the technological society that exists today and it is present in almost all sections of industry, one of them is the construction industry, not only with robots that are architectural or in other words automated machines that help with the construction of a building, like putting bricks together, but the building by itself can be robotic. This type of architecture can be defined as adaptive, responsible, dynamic or iterative. To the architecture to be interactive, it needs to be capable of analyze the internal or the external environment conditions and respond to it. This process is possible because buildings are equipped with sensors, actuators and controllers, enabling them to collect information, process and act on it autonomously.

Branko Kolaveric said that “over the past decade we have seen an increasing interest in exploring the capacity of built spaces to change, to respond dynamically”, showing that the use of robotics in architecture have been increasing and becoming an important factor of the contemporary buildings nowadays.

Some well succeeded examples of robotics in architecture are the Institut du Monde Arabe, designed by Jean Nouvel, the Bahr Towers, in abu Dhabi by AHR and the tessellate adaptive facade system designed by ABI in collaboration with A. Zahner Company. These buildings use a responsible system to the light, the facades changes according to the sun, allowing the building to have as much natural light as possible or to block the sun when it is not desired. A different example of interaction in architecture is the Light Creature, designed by Studio Guto Requena where the building facade lights up with different colors, in response to the noise in the surrounding, the air quality and a mobile phone application that allows anyone to directly interact with the facade by voice or by finger taps.

Robotics can also be present in a minor scale of the building like in lamps, furniture and infrastructure equipment. Some very simple examples of responsible objects that sometimes we even do not perceive are automated doors, water tap and lights. But the furniture industry is going further and creating iterative furniture. For example, Adam Lassy created a project called Ikea where he designed automated furniture that respond to people with a behavior similar to the animals according to the furniture’s mood.

Although the number of experiments with furniture are much smaller than with facades inside the architecture field, it can be very interesting and bring a completely different experience inside the building. That is one reason for the idea for my project in this research: a responsible piece of furniture.

The initial idea for the project is to make a responsible chair that opens with the presence of people, inviting them to seat. It will use a photon to store and read the codes, a motion sensor and a motor that will allow the chair to open by itself. The project aims that people not only appropriate the building but also perceive and use the furniture.

CONCEPT

The idea for this project was to create an object that could embrace robotics, architecture and furniture. For that some question had to be answered: what is a robot? What is architecture? How can a robot be architectural? How can architecture be robotic? What is the relationship between architecture and furniture? How robotics, architecture and furniture can work together?

What is a robot? Robot a system that contains sensors, control systems, manipulators, power supplies and software all working together to perform a task, according to Galileo website. It has four essential characteristics: sensing, movement, energy and intelligence. In other words, the robot needs to perceive the surrounding through sensors like light, touch and pressure, chemical or sonar sensors. The robot also needs to move, be able to power itself and be “smart”. The smart of one robot can be acquired with a programming.

What is architecture? In fact, the term Architecture is very complex, embracing and difficult to be described. Many historicists and theorists tried to explain architecture through their point of view. For the ancient Greek culture, architecture was all about beauty through proportion, module and the Golden number. Vitruvius Pollio (c. 90 - c. 20 BCE), a Roman engineer and architect, who wrote “*De architectura”* (on architecture) defined architecture as the union of three concepts: *firmitas*, *utilitas* and *Venustas*, which means firmness, commodity and delight. For Le Corbusier, a very important architect from the international style, architecture should have five aspects: pilotis, free plan, free facade, long windows and roof garden. Many other architects and theorists tried to explain the them architecture. For me, architecture is the study and realization of space and its relationship with the environment and people. It changes with the society that it is designed for. Nowadays the society is becoming completely technological and so is architecture.

How can a robot be architectural? Robots can have many functions in different fields of study, one of these fields is architecture. A robot that is architectural is programed to help the fabrication in architecture. It can move bricks and construct a wall, for example.

How can architecture be robotic? Day by day buildings are getting more technological and intelligent. Everywhere you can see doors that open with movement sensors, stairs that moves, lights that turn on by themselves. All those elements collaborate to architecture to be a robot. One great example is the Institut du Monde Arabe, in Paris, France, designed by Jean Nouvel. A main feature and innovative element of the building is the advanced responsive metallic brise soleil on the south facade. The system incorporates several hundred light sensitive diaphragms that regulate the amount of light that is allowed to enter the building. During the various phases of the lens, a shifting geometric pattern is formed and showcased as both light and void. Squares, circles, and octagonal shapes are produced in a fluid motion as light is modulated in parallel. Interior spaces are dramatically modified, along with the exterior appearance.

Architecture is not only about the building and its structural components like walls, doors and windows. Architecture is also about the empty space between those components and how it is occupied. With that thinking, furniture is an important complement of architecture, it occupies and defines how the space will be organized and used. One way that furniture can influence the architecture is being interactive through robots. One example of how furniture can change the scapace are the Roombots, a project funded by the Swiss NCCR in robotics. According to the description on their website, “the Roombots explore the design and control of modular robots to be used as building blocks for furniture that moves, self-assembles, and self-reconfigures. Modular robots are robots made of multiple simple robotic modules that can attach and detach. The type of scenario that they envision is a group of Roombots that autonomously connect to each other to form different types of furniture”.

(a) (b) (c)

Fig. 1: Roombots: (a) Roombots as table (b) Roombots conection and (c) Rombots moving a furniture.

After all those questions answered, some simple examples of robotics in architecture also inspired the idea for the project, such as automated doors and water taps that work with motion sensors. In other words, something simple that reacts to the people in its surroundings. With that in mind, the idea for the project was to design and build a chair that opens by itself when there is someone near it, as it was inviting people to seat on it. This proposal aims to make people to use and perceive the furniture in the space they use.

For the design, some collapsible chair designs were taken as inspiration, such as the Folding Bamboo Chair by Snow Peak, the Folding Chair by Mogens Koch and the Flapps Folding Chair by Malte Grieb.

(a) (b) (c)

Fig. 2: Examples of collapsible chair designs: (a) Folding Bamboo Chair by Snow Peak (b) Folding Chair by Mogens Koch and (c) Flapps Folding Chair by Malte Grieb.

Some of the design proposals for the chair were first, a chair with a moving seat, it would have a fix structure similar to a regular chair but with a sit that could move down when someone was next to it, second, a chair with lateral opening, similar to the folding chair by Mogens Koch and third, a chair with crossed legs that would have a pivot point and a seat made of fabric.

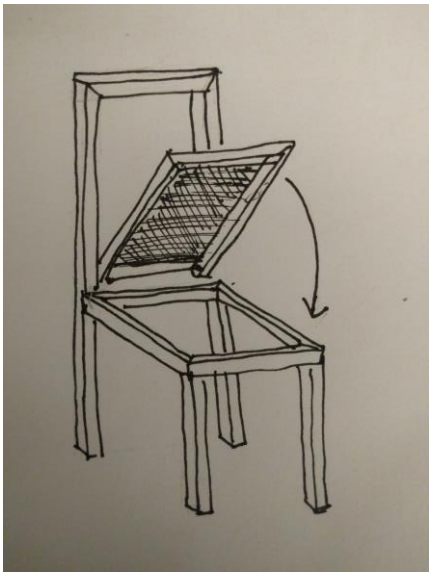


Fig 3: Fist idea and concept for the chair.

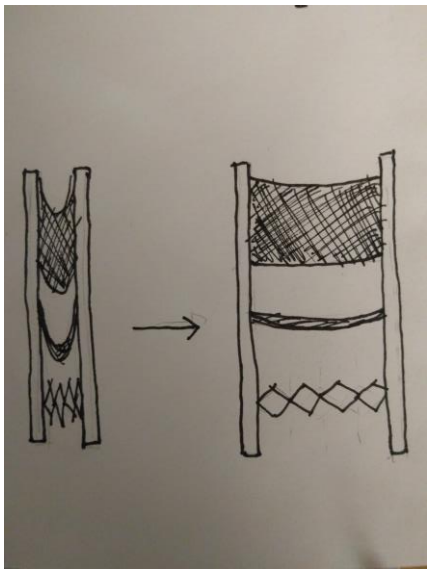


Fig 4: Second idea and concept for the chair.

Fig 5: Third idea and concept for the chair, used for the built final project.

MATERIALS AND METHODS

The craft of the chair was the most complicated part of this project: think about the best design for an easy opening mechanism, how the pieces would fit to each other, build and program it.

The materials used for chair were wood for the structure, screws, threaded rods, nuts, fabric for the seat, photon for the code, a step motor driver, an Arduino, a motor, a 12 voltage battery, a motion sensor and wires. For the fabrication, it was used some machines and tools such as planer, table saw, band saw, drill and laser cutter.

The first, it was done a prototype to see how the pieces would fit to each other and where the electronic parts would be placed.

The final model had to have two transversals pieces that could not only help with the structure and the stability of the chair but also would have to rotate and support the motor and the threaded rod to allow the opening and closing mechanism. Also, it had to have a piece of wood to support the battery and the photon, it was located in the same pivot point as the crossed legs, in a way that the piece could rotate, so the force caused by the weight of the battery would be always directed down. In addition, some precise pieces were cut on the laser cutter one to fit a nut where the threaded rod should fit and one to support the battery and the Arduino. The final step of the fabrication was to glue the fabric for the seat.

The electronic parts: the photon was used to code, the Arduino to convert the voltage of the battery to the right voltage necessary to the photon, the battery gives power to the motor and to the photon, the motor is the responsible of the motion of the chair, the PIR sensor reads the environment telling to the photon if there is motion or not on its surroundings, the step motor driver adjusts the current to the motor.

The programing was done at the Particle website. The code means that if the PIR sensor reads any motion on its surroundings and if the chair is closed, the photon will receive an information to open the chair, the motor needs to rotate 130 times to completely open the chair. If there is no motion for 60 seconds, and the chair is open, the chair will close.

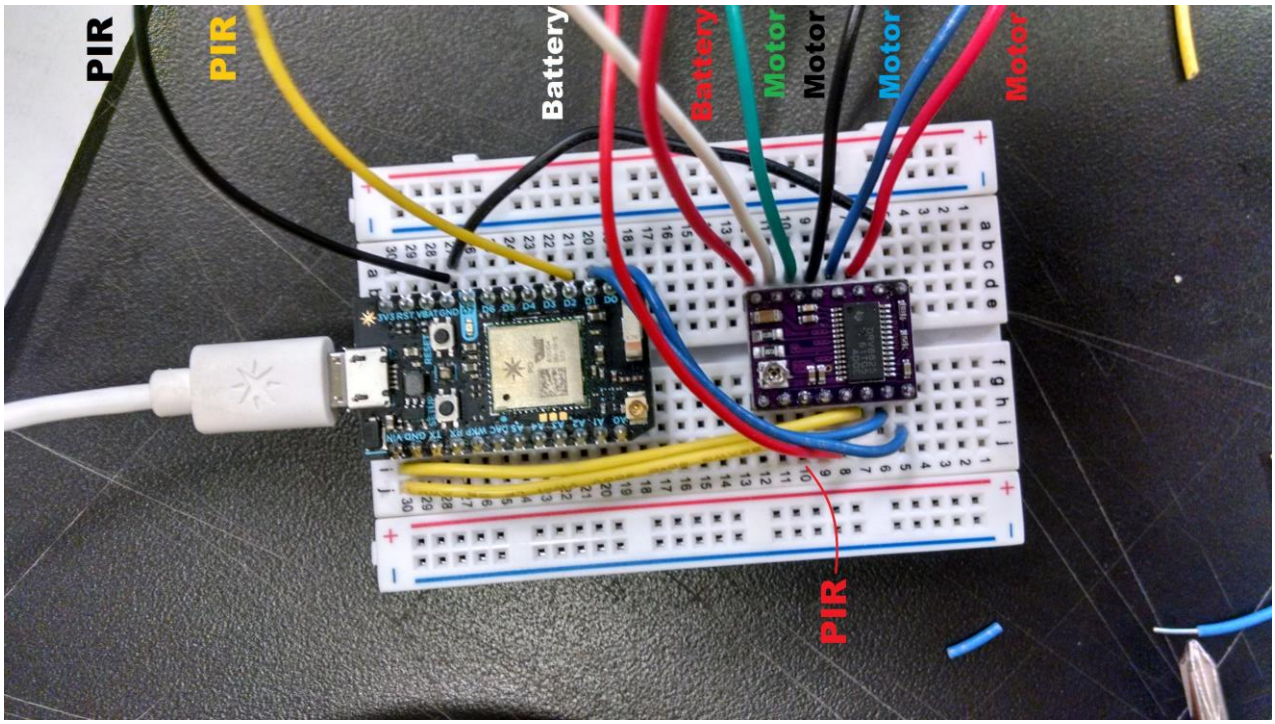


Fig 6: Schematics wires and connections.

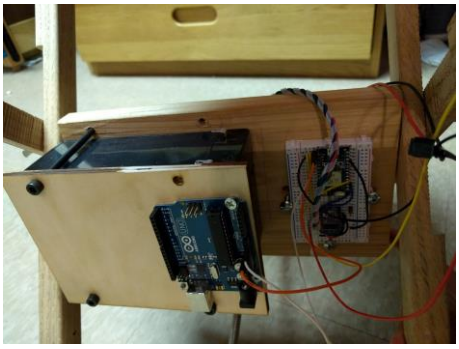
Code:

```
int pir = 0;
int stepPin = 0;
int dirPin = 1;
int open = 1;
int close = 0;
int totalRotations = 130;
int stepsPerRev = 200;
bool triggered = false;
bool closed = true;
Timer closeTimer(60000, closeTimerHandler);
void setup() {
    pinMode(0, OUTPUT);
    pinMode(1, OUTPUT);
    pinMode(2, INPUT);
    pinMode(7, OUTPUT);
}
```

```
void loop() {
    pir = digitalRead(2);
    if(pir && !triggered && closed){
        openChair();
    }
}
void openChair(){
     triggered = true;
     step(totalRotations*stepsPerRev, open);
     closeTimer.start();
     closed = false;
     triggered = false;
}
void closeChair(){
     triggered = true;
     step(totalRotations*stepsPerRev, close);
     closed = true;
     triggered = false;
}
void closeTimerHandler(){
    closeChair();
}
void step(int steps, int dir){
    digitalWrite(dirPin, dir);
    for(int i = 0; i < steps; i++){
        digitalWrite(stepPin, HIGH);
        digitalWrite(7, HIGH);
        delay(1);
        digitalWrite(stepPin, LOW);
        digitalWrite(7, LOW);
        delay(1);
    }
}
```

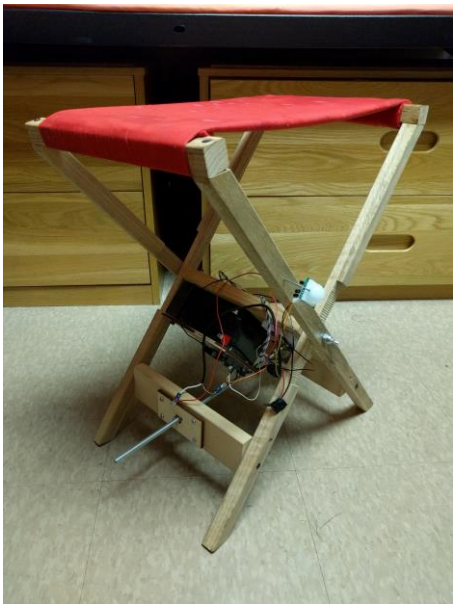
OUTCOMES

The prototype helped to see what complementary pieces the chair should have to support the electronic parts, see appropriate dimensions and the resistance of the chair. The wood used for the prototype was soft maple and it was not strong enough to support the weight of one person. Also it got bigger than the desired proportions. The final chair was made of oak and it got much more resistant compared to the prototype. In overall the chair was successful.

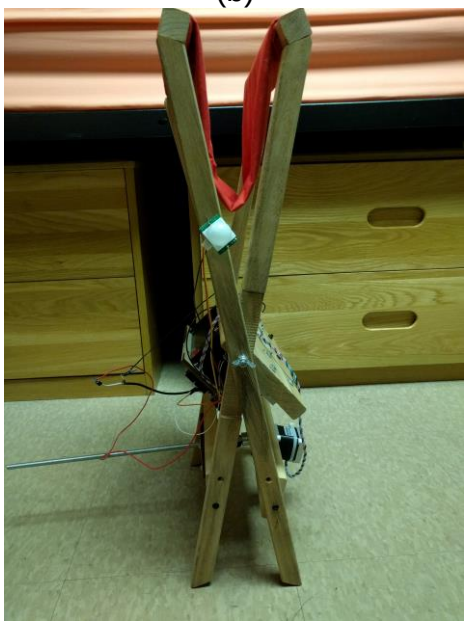


(a)

(b)



(c)



(d)

Fig 7: Result of the built chair: (a) battery, Arduino and photon located on the chair (b) motor and threaded rod on the rotational pieces of wood (c) Chair opened (d) chair closed.

CONCLUSIONS

The concept and the result were very close. The chair opens when there is movement on its surrounding and closes if there is not. The appearance and proportions were satisfactory. But the chair takes longer than desired to open and it got heavy due to the battery. Some improvements could be done to the chair to make the opening and closing mechanism easier. The transversal woods where the motor and the threaded rod are located need to have a looser pivot point so it would rotate more easily and the motor would have to make less effort. Also, in the same wood it would be good to have two additional threaded rods on the sides that would help to maintain the woods in a parallel position. For the code, it could help to have a switch button that would stop the motor when the chair is completely open or closed, instead of rotating for 130 times.

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