ILLINOIS INSTITUTE OF TECHNOLOGY
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ARCHITECTURAL ROBOTICS

SUMMER RESEARCH ORIENTED BY PROFESSOR BRETT BALOGH

Chicago – Illinois
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SUMMARY

1. INTRODUCTION

“Architectural Robotics” is a course oriented by Professor Brett Balogh at Illinois Institute of Technology during the summer 2016. The objective is that each student researches and develops a robotic system over the period of two months, as a prosthesis that augments the built environment and adds some characteristics and behaviors to static structures.

2. ABSTRACT

With the main topic as Light Absorption/Reflection and Color, the objective is to work with relations between interior and exterior colors, economy of energy and light color therapy, with a device that is supposed to make a modification into a building, changing its behavior and giving it personality. Those aspects will be given with a responsive façade that changes its colors according to the outside temperature, in order to economize energy by reflection and absorption of heat. At the same time, the interior is based in principles of Light Color Therapy, with colors that bring the sensation of a warm or cold room.

3. PROJECT’S REFERENCE

As a reference to the project, there is a responsive building called “Prairie House”, it is located in Illinois and designed by ORAMBRA, The Office for Robotic Architectural Media & The Bureau for Responsive Architecture in Chicago.

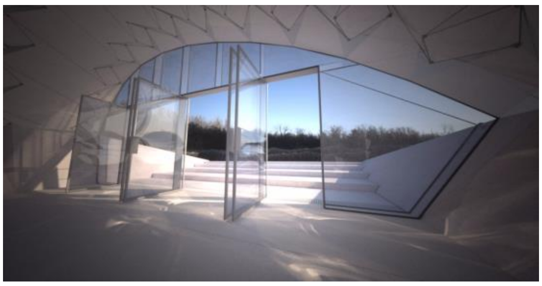
Prairie House uses new tensegrity systems (property of three dimensional structures consisting of members under tension and compression) and cladding technologies, emitting less than half of the carbon of a typical house in Illinois. Characterized as a parametric architecture that flow into the world via physical responses, it uses programming as a form of architectural media that is able to transpose new modes of specialized operation onto standardized building assemblies.

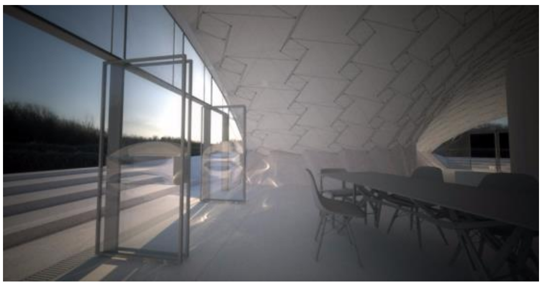
Through the use of the following four characteristics, the building contributes to increase the annual savings of energy up to 23.72%.

Praire House Exteriors

- *Color*: there are skins that change color via thermo-chromatic inks to provide savings. The interior membrane becomes lighter on warmer days, while on colder days it becomes darker. The thermal performance during cold days for example, makes the darker color absorb more heat to the building, decreasing the air conditioning system demand. Annual Savings = 0.45%

- *Openings*: further savings are provided when combining color with permeability. A building with screens that can open or close according to the exterior can save even more energy. The exterior screen opens to let warming sunlight hit the dark interior on cold days, while closing to shade the interior during hot days. Annual Savings = 2.48%





Praire House Interiors

- *Insulation*: levels of insulation can also be controlled. The thickness of insulation is reduced to shed heat in the summer while insulation is increased in thickness during colder periods. Annual Savings = 8.01%

- *Shape and Volume*: structural systems that change shape and volume also contribute. During hot days the building should expand to reduce the impact of internal heat loads and shrink to reduce heating requirements on cold days. Annual Savings = 23.72%

Using this project as an inspiration for the research, the following writes uses responsive architecture as a target to be achieved in the final result. Other references were studied and used, but the focus was mainly at Prairie House.

4. CONCEPT

Using “Prairie House” as an inspiration and reference to the main idea, the project will focus in two aspects. The idea is that the building would change its façade colors according to the outside temperature. At the same time, the interior color would change according to light therapy studies, making the space look warmer or cooler.

- *Exterior Color Changing*: if the color from the exterior changes, it can absorb or reflect the sun light in a more intense way. During cold days the building would be darker in order to absorb more heat, while during harm days, the façade would be lighter in order to reflect more heat. In that way, the building itself will economize energy, as the use of air conditioning systems will be reduced.

- *Interior Color Changing*: if the color from the interior changes, it is possible to bring a better sensation for who is inside. During warm days, the color would be lighter, in order to give the sensation of a colder room. A device would measure the temperature outside and the light inside would be regulated according to it. If the day is cold, the interior would have warm colors (as orange). If the day is warmer, the color inside would be cold (as blue).

The idea about the interior color also brings benefits to our health and it is called Light Therapy. Beyond the sensation of different temperatures, studies already confirmed that stimulations from colors can also help to promote sleep, correct hormonal imbalances, combat depression and SAD (Seasonal Affected Disorder).

5. MATERIALS AND METHODS

To achieve all the objectives intended, the research was divided in two stages. The model itself and the programming code to make the façade's system, with some devices and new technologies.

The model was made to represent in a small scale how the building and its façade would work. It was all done with wood, acrylic and small attachments of metal. With six modular tubes that rotate at the façade, the intention is to show how the system would link all of them. There is a thinner structure inside the tubes that compose the façade and help them to turn through connections at big and small gears that rotate together in order to change façade and interior's colors.

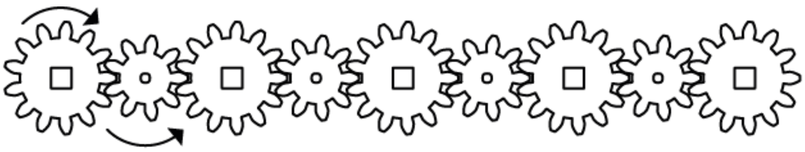
Each side of the square tube is colored with the following inks: black, orange, white and blue. In that way, opposite sides of the tube represent simultaneously the exterior and interior color, as illustrated in the image below.

Colored sides of the tubes

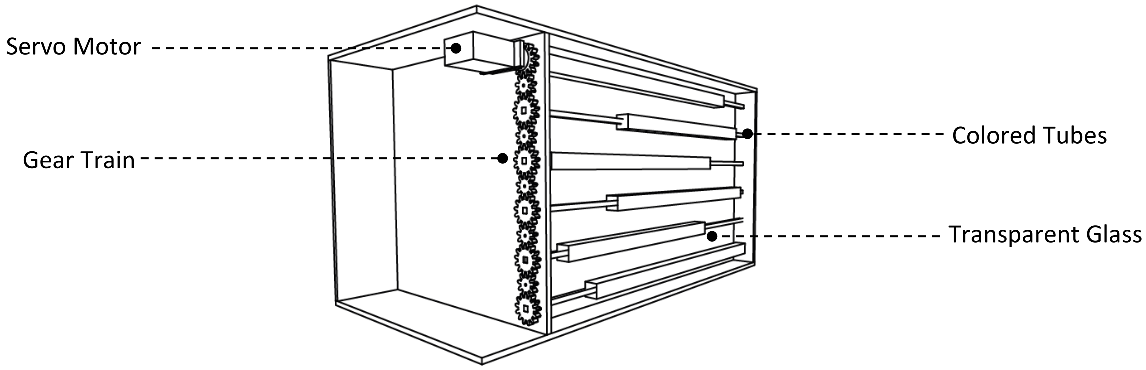
In order to make the tubes turn according to the temperature, comes the second stage of the research, motor and programming. All the tubes turn with a *Servo Motor* that is directly connected to the first tube of the façade. As all the tubes are connected through gears, just one motor is enough to make the other ones turn together.

The tube's rotation needs to be controlled by outside temperature. To achieve it, the code that was written programs a *Particle Photon* to receive the values of temperature with a *Temperature Sensor*.

Each time the sensor detects a temperature higher or lower than a certain value, the Servo Motor is programmed to rotate 90° (positive or negative) degrees. As the Servo Motor is connected just in the first tube - the other tubes are connected by gears - the costs for the whole system are much cheaper than one motor for each tube. The gear system that was used is illustrated in the image below.



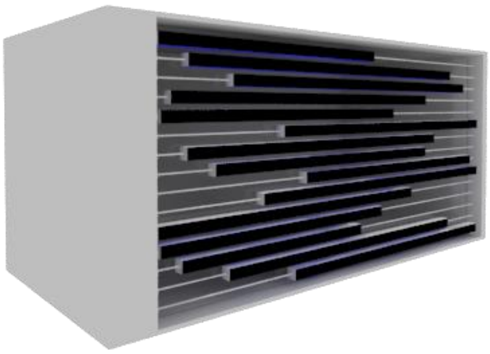
Gears, its connections and directions



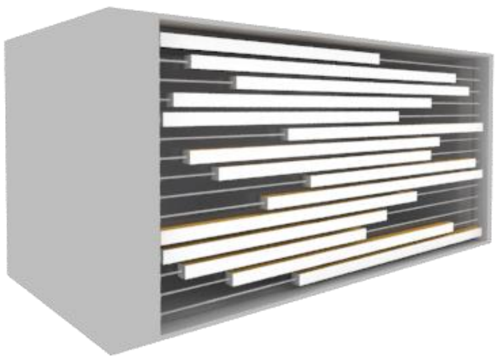
Detailed drawing of the façade's system

The prototype was made exactly how is shown in the image above. There are six tubes connected through eleven gears (six big gears and five small ones). In that way, the model shows enough work at the system that is intended to have.

Below, there are images simulating how the colors of the building would look like during the different periods of the year. The difference between summer and winter is the most contrasting, so it's the one studied.

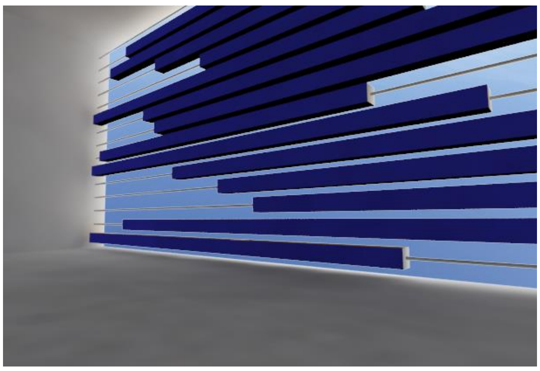


Winter Façade



Summer Façade

Winter Interior

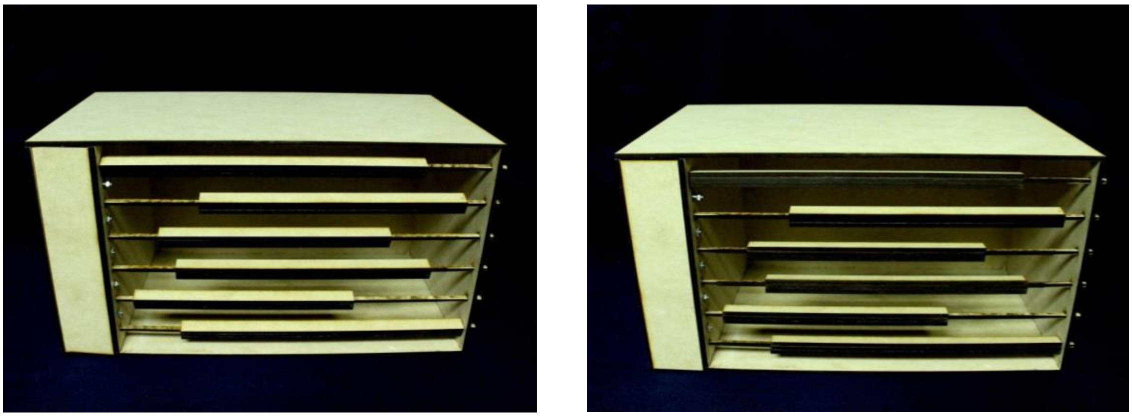


Summer Interior

6. PROTOTYPE IMAGES

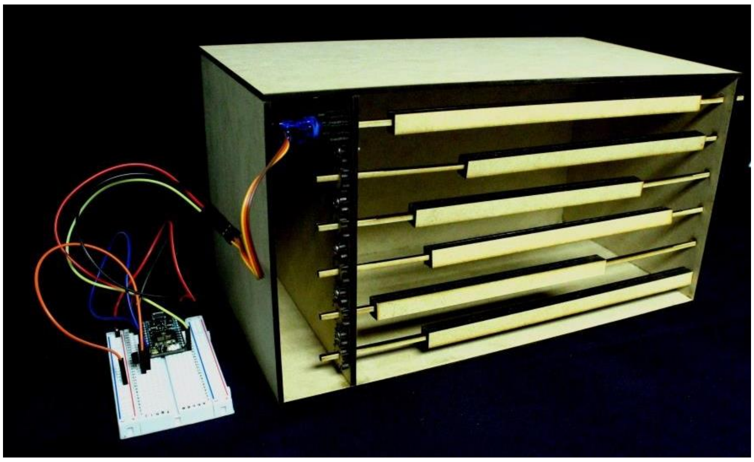
The materials used for the prototype are described below with its name and function during the process for montage:

- Wood: the whole structure was made using wood, as well the tubes and gears
- Photon: the initial point of programing was using the photon
- Cables: connecting different functions and codes
- Temperature Sensor: measurement of the external temperature
- Servo Motor: responsible for the rotation of the tubes



Rotation Process

The images above show the process to turn the sides of the façade, in order to get more or less heat from the sunlight during the day. It represents how the movement would be when the façade needs to get more heat, from white to black.

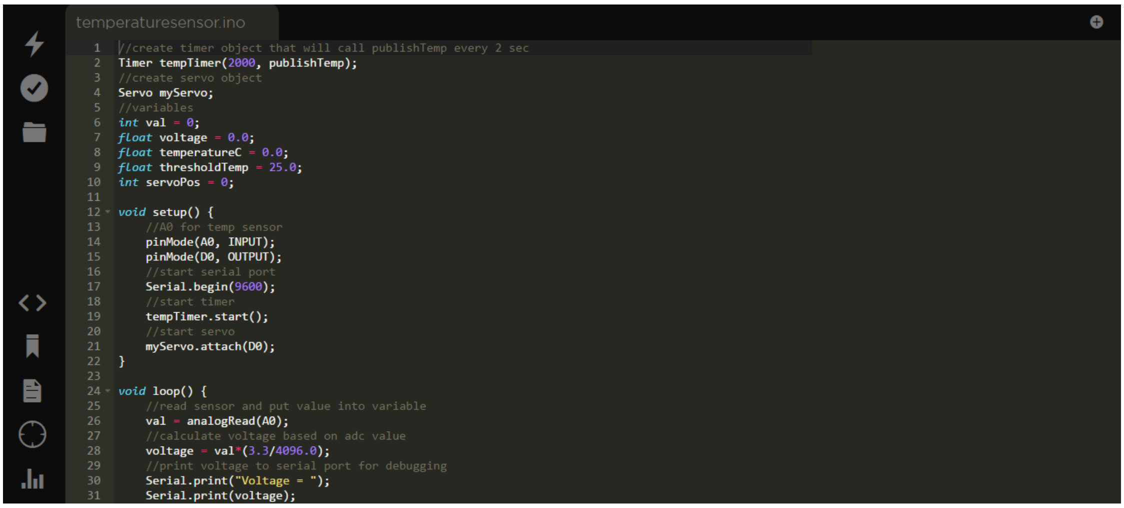


Installation System with the Photon

To get this rotation, the photon was connected in the first gear in a way that the other five main gears would rotate at the same time.

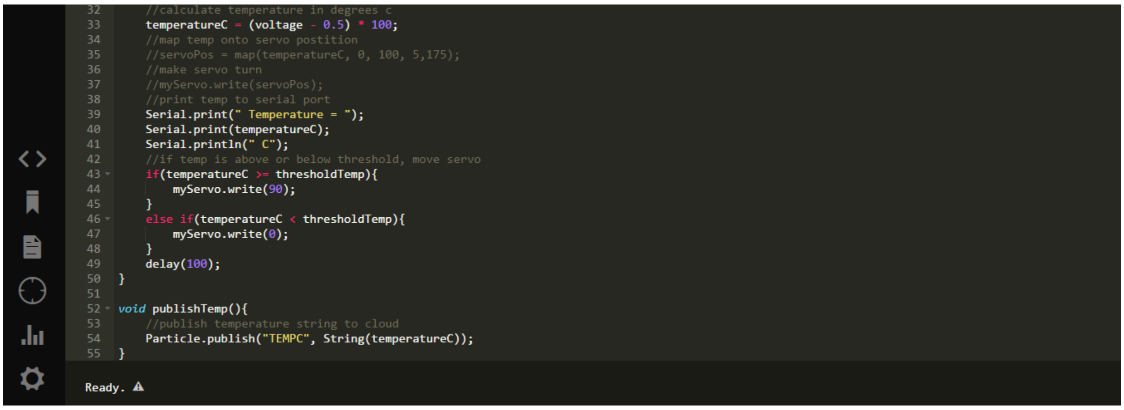
7. PROGRAMMING AND CODE

All the coding received in the Photon was written in Particle (view http://build.particle.io). The following images show the lines 1 to 55 of the coding that was developed to the system.



```
temperaturesensor.ino
1  //create timer object that will call publishTemp every 2 sec
2  Timer tempTimer(2000, publishTemp);
3  //create servo object
4  Servo myServo;
5  //variables
6  int val = 0;
7  float voltage = 0.0;
8  float temperatureC = 0.0;
9  float thresholdTemp = 25.0;
10 int servoPos = 0;
11
12 void setup() {
13     //A0 for temp sensor
14     pinMode(A0, INPUT);
15     pinMode(D0, OUTPUT);
16     //start serial port
17     Serial.begin(9600);
18     //start timer
19     tempTimer.start();
20     //start servo
21     myServo.attach(D0);
22 }
23
24 void loop() {
25     //read sensor and put value into variable
26     val = analogRead(A0);
27     //calculate voltage based on adc value
28     voltage = val*(3.3/4096.0);
29     //print voltage to serial port for debugging
30     Serial.print("Voltage = ");
31     Serial.print(voltage);
```

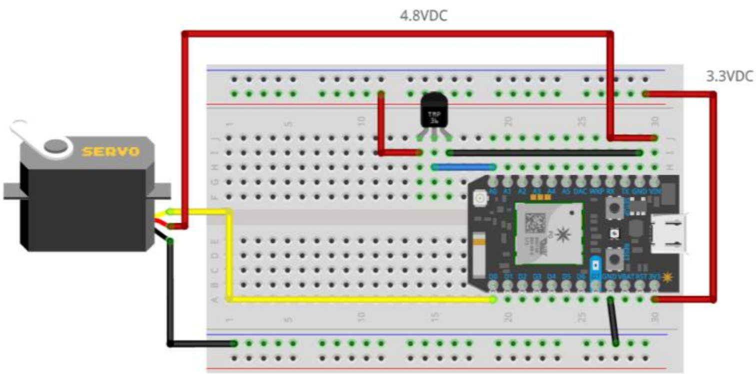
Line 1 to 31 of code



```
32     //calculate temperature in degrees c
33     temperatureC = (voltage - 0.5) * 100;
34     //map temp onto servo postition
35     //servoPos = map(temperatureC, 0, 100, 5,175);
36     //make servo turn
37     //myServo.write(servoPos);
38     //print temp to serial port
39     Serial.print(" Temperature = ");
40     Serial.print(temperatureC);
41     Serial.println(" C");
42     //if temp is above or below threshold, move servo
43     if(temperatureC >= thresholdTemp){
44         myServo.write(90);
45     }
46     else if(temperatureC < thresholdTemp){
47         myServo.write(0);
48     }
49     delay(100);
50 }
51
52 void publishTemp(){
53     //publish temperature string to cloud
54     Particle.publish("TEMPC", String(temperatureC));
55 }
Ready.
```

Line 31 to 55 of code

Using fritzing as a simulator of the Photon, the board was disposed with the cables, temperature sensor and servo motor, as illustrated below.



Fritzing Simulator for the board system

8. OUTCOMES

As the concept expects a responsive façade system, the result was good. The first point was that the model had to be constructed with fewer modules than the desired, once the motor had a small capacity. However, the system represents well how a whole and big façade would work. All the tubes and the gears make the system cheaper than would be if using one motor by each tube.

The coding for the system also works really well. As the temperature increases or decreases near the temperature sensor, it sends a command to the motor that make it rotate exactly 90 degrees right on the time that it needs to be.

9. CONCLUSIONS

The period of this research had a great result in the studies of Robotics in Architecture. Working focused with Responsive Architecture, it was possible to find several solutions for buildings to be sustainable and cheap at the same time. The first intention of the work presented was to use a simple and cheap system that could bring a big benefit to a regular building.

Besides that, the building also interacts with the environment and contributes not only in energy aspects but with people that pass through it. In general, the objective was well achieved with a better result than the expected: a cheap and efficient solution for energy wastes.

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