University of Colorado Boulder

Illuminating Horizons: Flatirons Light Sculpture

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GEEN 1400: Engineering Projects

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17 September 2025

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ABSTRACT

Today, there is a continuously growing crime rate in Boulder. According to the Boulder Reporting Lab, the Boulder Police Department in 2021 received 377 reports of violent crimes, a 63% increase from 2010. (Herrick) Previous research proves that increased visibility at night results in the feeling of safety and reduces the number of concealed locations. (Giménez) One primary solution is to introduce light sculptures into commonly gathered spaces. According to Rutgers Center for Green Building, light sculptures reduce their contributions to light pollution by saving energy and projecting less light through LED lighting and ultrasonic sensors. (Rutgers) Ultrasonic sensors ensure that the LED lights, which reduce heat emissions and use less energy than traditional lighting, only operate when there is motion from citizens. These elements ensure that the artificial light produced from the sculpture will not intrude into residential backyards and disrupt the local ecosystem.

BACKGROUND

The project goal was to create a light sculpture prototype for a public location in Boulder, Colorado. The prototype had to include an input for interactivity and convey motion while remaining energy conscious. Parts of the sculpture had to be manufactured, laser cut, and 3D printed. Additionally, the sculpture must use an Arduino to control the lighting and interactivity. To meet these goals, the sculpture was designed to be placed in Harlow Platts Community Park where the hypothetical sculpture is ten times the prototype size. The park needs more lighting to contribute to a sense of safety for children playing at night, and to engage the community, the sculpture would have interactivity. The sculpture is a model of the Flatirons to reflect local scenery and provide coercion between the statue and the environment.

DESIGN PROCESS AND FINAL DESIGN

The model must be designed to consider power usage, overall energy efficiency, and the specific location chosen in Boulder. The main constraints for the sculpture were lack of time to design and prototype the model, money, and the miniature model size. Since the prototype is scaled down ten times, there is no opportunity to add extremely intricate detail.

With these considerations in mind, multiple designs were reviewed. Most of the designs incorporated a nature theme either through local flowers, mountains, or animals. After reviewing each idea, the sketch of the flatirons, as shown in Figure 1, seemed most realistic for this project and fit best for the chosen location.

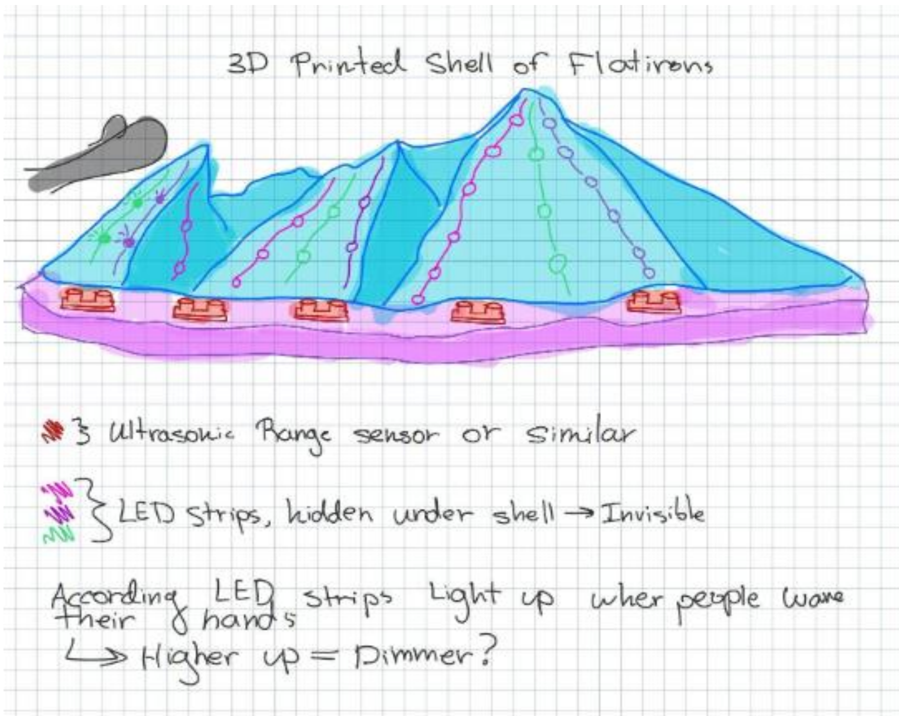

Figure 1. The original sketch for the light sculpture prototype.

While deciding how to create the prototype, the model structure was debated briefly. A hollow base was chosen so it could hold the Arduino. In the manufacturing center, the base was quick and easy to build. Though there was some debate on how to fabricate the flatirons, using a 3D printer would create the most precise replica. The sculpture needed more nature elements, so laser cutting decorative pieces, like the trees and bench, accomplished this goal.

The final design includes a wooden, hollow box that stores the Arduino with a 3D printed model of the Flatirons on top. Surrounding the mountains, there are laser-cut trees that have been painted green, a bench, and actual rocks. The user interface of the sculpture is designed through Arduino. Around the Flatirons sculpture, there are ultrasonic sensors, which detect motion near a certain part of the Flatirons sculpture. Once motion is detected, LEDs inside of the mountain light up. Additionally, rocks and grass clippings have been added to the mountains and the base to reinforce the nature theme.

The process of reaching this conclusion was difficult as there were some steep learning curves. Manufacturing the box was challenging since precise measurements were not made beforehand. The sides of the box were initially too long, so there were additional cuts to trim the sides down. There were some issues with laser cutting the trees as the software CorelDRAW did not allow the bitmap to be edited in order to convert the tree image into a clipart design. However, this was later fixed by copying a blank Christmas tree cut out from the internet, pasting it into CorelDRAW, and converting the bitmap into clipart. Successfully, the trees were laser cut from a wooden board and painted green with acrylic paint.

Creating the circuit and program for the Arduino took time in both researching how the motions sensors worked and in executing how to create the circuit and program. The team had to learn how the sensor emitted sound waves, which reflect off an object for them to be received by the sensor. By considering the sound wave's return time, the Arduino could be programmed to calculate the object's distance. Once the sensor worked, the circuit could be built. At first, creating the circuit and code for the Arduino was relatively simple, however, once more components were added, the circuit and code became increasingly complex. The main challenge was arranging the sensors, so they could remain connected to the Arduino without having to be plugged into the breadboard. Using female cables to attach the sensor to the Arduino solved this issue, allowing the motion sensor freedom to move in the design.

After designing the Flatirons using CAD, as shown in figure 2, the process to 3D print was difficult. The printer failed several times due to the uneven base of the model, which disrupted the layering when attempting to print. Additionally, there was hollow geometry which contributed to the failing prints. The final redesigned model originally had a solid base but is now hollow in certain areas in order for the LED strip lights to fit into the Flatirons model.

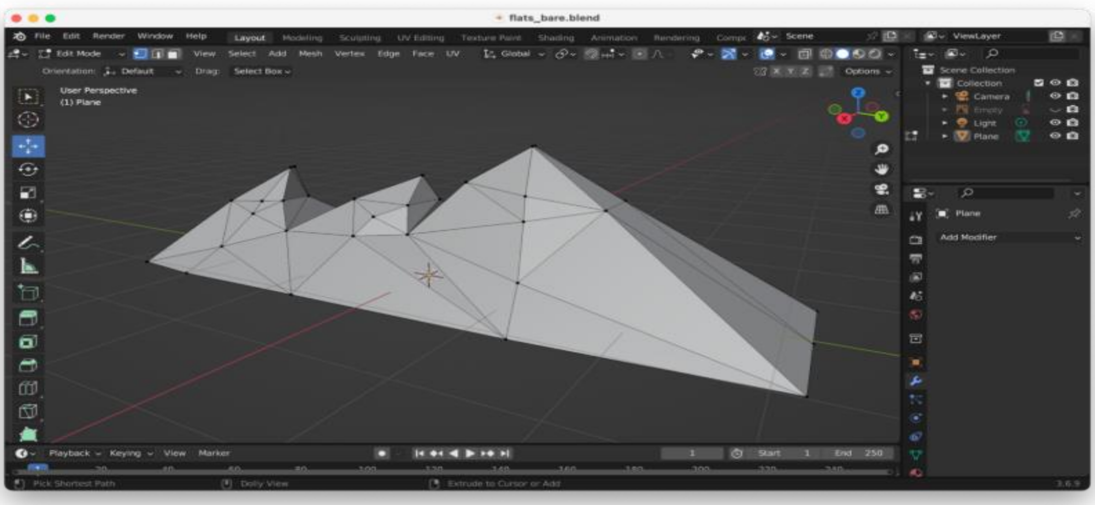

Figure 2. The CAD sketch of the Flatirons.

POWER & ENVIRONMENTAL ANALYSIS

Initially, the team was deciding between a light sculpture that serves to illuminate the outside of Fiske planetarium, such as a small-scale model of a telescope, and one that lights up a public park. Ultimately, the Harlow Platts Community Park would best display the light sculpture as it lacks light at night, thus providing a safety hazard as seen in Figure 3, and would become an interactive sculpture for kids. To reduce environmental impact, eco-friendly powder coatings found in transparent paint could decorate an authentic Flatirons light sculpture while not releasing volatile organic compounds (VOCs). LED lights brighten the sculpture since they are more durable and use less energy, reducing greenhouse gas emissions. Fiber optic cables are incorporated to transmit data through light, opposed to electrical signals, which lower energy consumption, reducing the need for replacement cables. The light pollution at Harlow Platts Community Park is 1.08 mcd/m^2, in comparison a non-light polluted sky is around 0.25 mcd/m^2. . According to the Bortle Dark Sky Scale, this puts the park at level 5–equivalent to that of a typical suburban sky. The power for the model scale is approximately 2.6 watts. During low traffic hours and certain times of night, the sculpture lighting will be off unless someone initiates the motion sensors. This feature will ultimately lead to less light pollution compared to other sculptures and artificial light that interrupts the ecosystem.

CONCLUSION

Although there were learning curves in all processes of making this sculpture, time was used effectively and efficiently to maximize the ability to revise and edit the light sculpture engineering design process. Initially, the box measurements were imprecise, and the plan needed to consider the depth of each piece. In the future, it would be best to build the box all from one wood type to keep dimensions aligned and to nail the box together instead of using screws. To allow for more freedom in designing the light sculpture, the sensors are attached to the Arduino by female and male cables to allow them to not be connected to the breadboard. When 3D printing, the initial model's base was uneven, which caused a floating second layer. The hollow geometry originally in the CAD model caused the printer to begin printing a very thin wall. Both of these issues caused stringing and several print failures. For future designs, the CAD model could be developed with more intricate detail, and the wires connected to the breadboard could be more organized.

APPENDIX

Figure 3. Picture of hypothetical location in Harlow Platts Community Park.

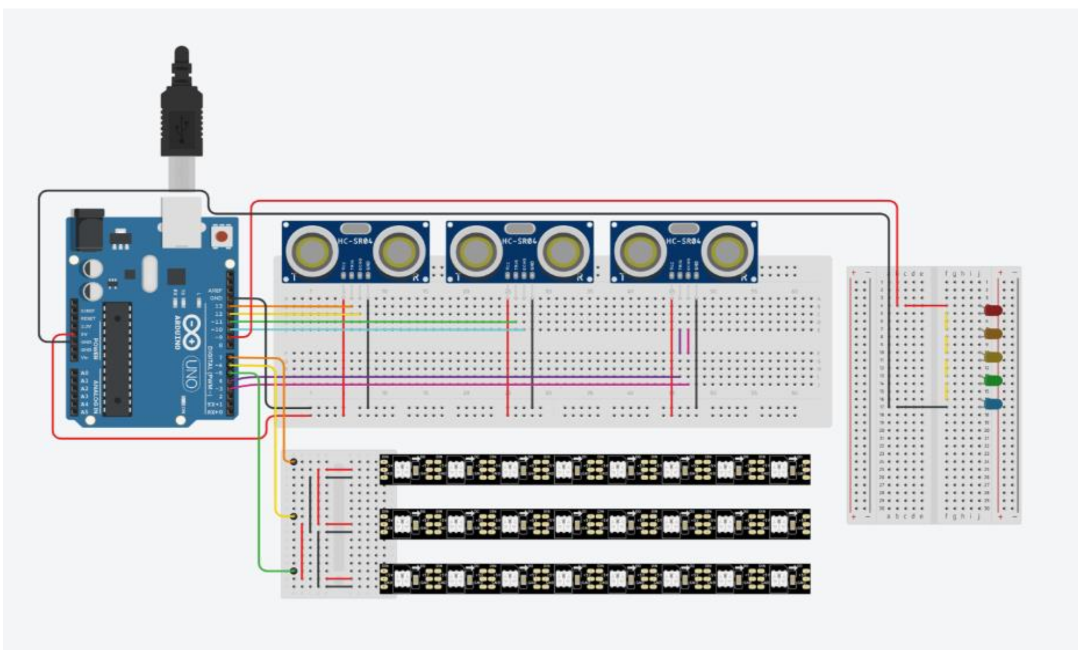

Figure 4. Diagram of Arduino used to light the Flatirons sculpture.

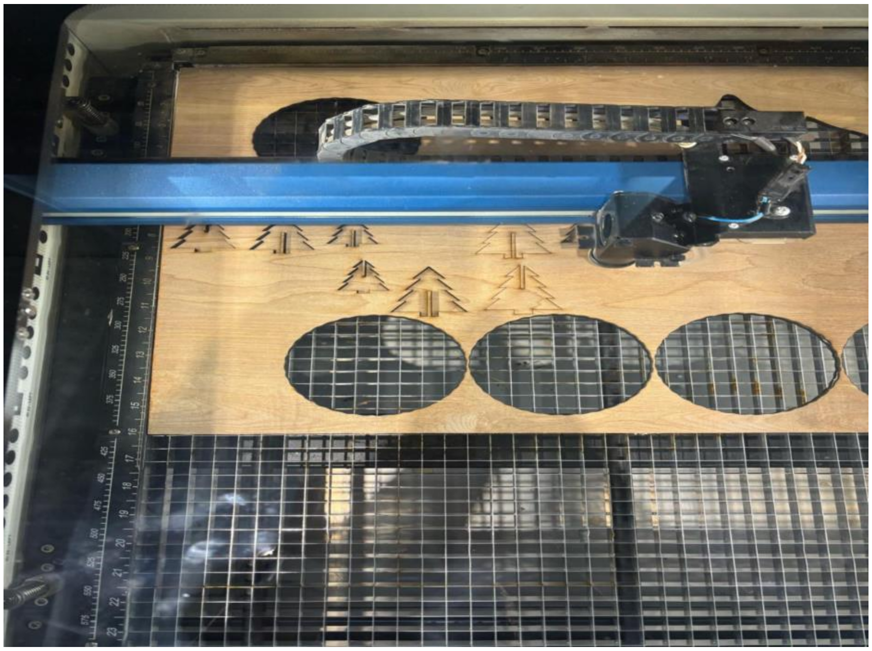

Figure 5. Richard III laser cut the trees from 1/8” wood.

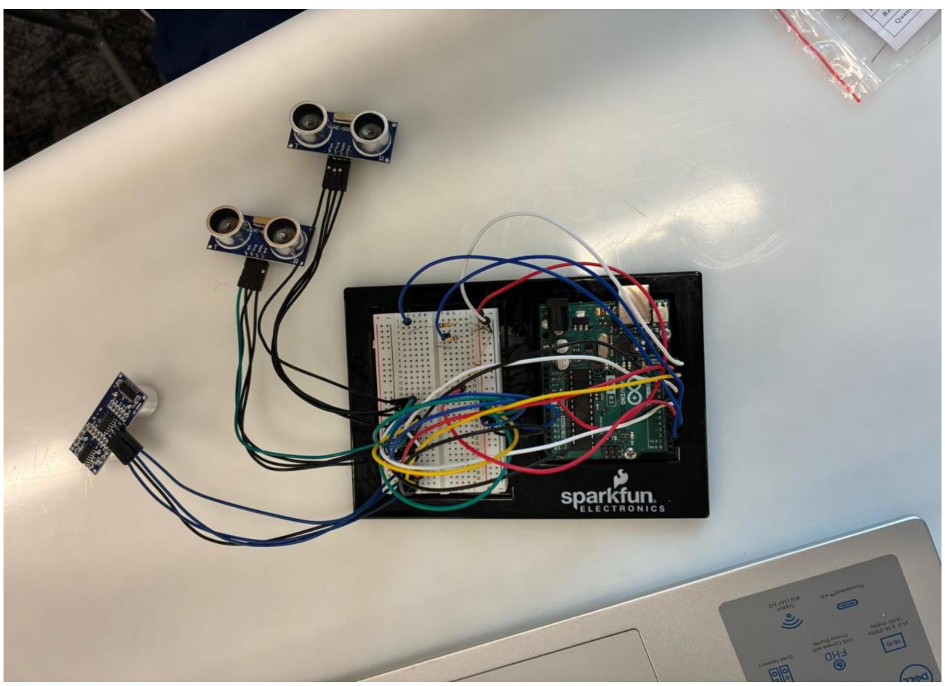

Figure 6. Arduino breadboard with attached ultrasonic sensors.

```
#include <FastLED.h>
#include <stdint.h>
#include <movingAvg.h>

#define PIN_LEDS_SHORT 5
#define PIN_LEDS_MED 3
#define PIN_LEDS_LONG 2

#define NUM_LEDS_SHORT 4
#define NUM_LEDS_MED 5
#define NUM_LEDS_LONG 6

template<int pin>
class Strip {
int count;

public:snip

CRGB* leds;

Strip(int num)
: count(num) {
leds = new CRGB[count];
}

void init() {
FastLED.addLeds<WS2812, pin, GRB>(leds, count);
fill_solid(leds, count, CRGB::Green);
}

void write(uint8_t val) {
for (int i = 0; i < count; i++) {
int offset = (255 / count) * i;
int brightness = constrain(val - offset, 0, 255);
leds[i] = CRGB::White;
leds[i].nscale8(brightness);
}
}

~Strip() {
delete[] leds;
}
};
```

Figure 7. Arduino Code for setup and brightness for LED lights.

```
Strip<PIN_LEDS_SHORT> led_short(NUM_LEDS_SHORT);
Strip<PIN_LEDS_MED> led_med(NUM_LEDS_MED);
Strip<PIN_LEDS_LONG> led_long(NUM_LEDS_LONG);

int trigPin1 = 13;
int echoPin1 = 12;
int trigPin2 = 11;
int echoPin2 = 10;

movingAvg short_avg(10);
movingAvg med_avg(10);
movingAvg long_avg(10);

void setPins()
{
pinMode(trigPin1, OUTPUT);
pinMode(echoPin1, INPUT);
pinMode(trigPin2, OUTPUT);
pinMode(echoPin2, INPUT);
}

int triggerSensor(int trigPin, int echoPin) {
// clean low
digitalWrite(trigPin, LOW);
delayMicroseconds(2);

// send wave for ten micros
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);

// stop
digitalWrite(trigPin, LOW);

// waits for echo in (blocking) with 30k micro timeout
return pulseIn(echoPin, HIGH, 30000);
}

// normalize
static inline int fix(int n)
{
return 255 - (constrain(n, 0, 2000) / 2000.0 * 255);
}
```

Figure 8. Arduino Code for assigning variables to control sensors.

```
void setup() {

setPins();

led_short.init();
led_med.init();
led_long.init();

short_avg.begin();
med_avg.begin();
long_avg.begin();

Serial.begin(9600);
}

void loop() {
int duration1 = triggerSensor(trigPin1, echoPin1);
int duration2 = triggerSensor(trigPin2, echoPin2);

// tied for power reasons
int distance1 = fix(duration1);
int distance2 = fix(duration2);
int distance3 = distance2;

// smoothing
int avg1 = short_avg.reading(distance1);
int avg2 = med_avg.reading(distance2);
int avg3 = long_avg.reading(distance3);

// display led
led_short.write(avg1);
led_med.write(avg2);
led_long.write(avg3);

FastLED.show();
}
```

Figure 9. Arduino Code for calculating average soundwave distance to control LED lights.

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