Magical Bridge Playground Project

ENGR 110: Perspectives in Assistive Technology, Winter 2018

The Trolls

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Abstract

The Magical Bridge Playground in Palo Alto, CA has set a precedent for the creation of outdoor interactive play spaces that give access to everyone, including children with disabilities and those others who would traditionally be excluded from playground experiences. Our objective in working with the Magical Bridge Playground was to further their mission in creating a fully wheelchair-accessible feature that maximizes use of the underutilized areas of the playground, like the ramps, bridges, and fencing around the perimeter, to introduce a new, safe, sensory experience to delight every person that enters the park.

To achieve this goal, our team designed a prototype comprising of a model magical rainbow bridge which could be an accessible feature for a wide variety of users. When a user applies pressure to one of the colored panels that comprises the “walkway” of our model, the adjacent clear panel along the railing lights up in the corresponding color. We achieved this result using individually addressable LEDs, force sensitive resistors, and an Arduino microcontroller. After creating our prototype, we tested the model with potential users at the Magical Bridge playground and received overwhelmingly positive feedback from children and adults alike about the interactivity and accessibility of our product. Our future designs plan to incorporate a corresponding auditory component, options to make the programming of the bridge more customizable to users, and code adjustments to ensure the safety of seizure-prone users. Ultimately, the Magical Bridge Foundation purchased our prototype, and described plans to use it in their efforts in STEM education and in the long term, it may be used as inspiration for a full-sized Magical Bridge feature in the future.

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Introduction

Physical interactive play is instrumental for cognitive, social, emotional and motor development in children.[1] Although schools attempt to integrate children with different types of disabilities in daily activity, as soon as they leave the classroom to play, that inclusion ends. Cramped playgrounds without ramps or transfer platforms are the norm, and children in wheelchairs are often forced to sit on the sidelines of stimulating play.

The Magical Bridge Foundation looks to address this lack of inclusion with the creation of open, accessible playground environments with an emphasis on sensory stimulation. Our team, The Trolls, worked closely with two of the Magical Bridge Foundation team's leading members: Olenka Villarreal and Jay Gluckman, and through our many trips to the playground we identified several problems that could be addressed. The playground's overwhelming success means that on most temperate days, the main playspace is overrun with children of all abilities playing and exploring freely, while the boundaries of the playground which currently feature very few interactive elements, remain underutilized. Many of the main physical features require that children transfer from wheelchairs, which can be difficult to achieve safely if other children are already using the target feature. Olenka's request was to have our team explore solutions to maximize underutilized space and resources while creating a whimsical feature that could become a focal point of current and future parks.

[1] Berkley et al.

Objectives

After speaking with Olenka and Jay, spending time exploring and observing the playground's setup and conducting analysis of existing solutions and other playground features, we focused our ideas that satisfied a few central objectives. First, we wanted to create a feature that would be fully wheelchair-accessible to allow for increased safety and independence for children in wheelchairs. Second, we wanted to create a feature that would make an underutilized area of the park (in this case, the ramps, fencing and bridges around the playground's perimeter) a focal point, while preserving the existing, easy-to-navigate layout designed by the park's creators. Finally, it was important to us to create an interactive feature to stimulate the senses.

Ultimately, all of these objectives helped us meet our central goal of creating a delightful feature experience that captures the spirit of the Magical Bridge Foundation while honoring its emphasis on sensory stimulation and innovation. We wanted this feature to be one everyone who comes to the playground will be able to access and enjoy. In choosing to pursue the creation of a model of a Magical Bridge to be installed at the park's entrance, we identified another subgoal: to create a bridge with sensitive enough triggers to be activated easily by the wheelchair wheels without creating an uneven or dangerous surface.

Design Criteria

We began exploring requirements for a successful solution by spending several afternoons at the playground testing features and observing user play navigation. After considering Jay Gluckman and Olenka Villarreal's initial ideas about enhancing some of the more pedestrian areas at the boundaries of the park, as well as conducting observations at the park, we narrowed down and defined our specific design criteria.

First, to make independent play a real option for those who have limited mobility, we wanted to eliminate the need for users to transfer from their wheelchairs. Many features in the park allow wheelchair users to experience them fully; however, we wanted to create one that wheelchair users could enjoy alongside others, or even in an enhanced way. A design that would meet this goal had to provide enough space and physical support for a wheelchair, additional safety features if necessary, and a fun and stimulating experience for someone in a seated position.

Second, we wanted to design a solution that would capitalize on underutilized areas of the park. We knew that in order to do this we would have to add "magic" to a walkway, a fence, or a similar utilitarian structure that is already incorporated into the park's structure. Many of the most successful features we observed children playing with at the park had an interactive component; they made noise or moved to provide response stimuli. Little of this interactive whimsical spirit was manifested in the walkways and fencing, however, so we hypothesized that making such environments more stimulating and responsive to kids' input would draw people towards them.

Our final objective tied into meeting the design criteria of interactivity; we wanted to create an attraction that included a variety of sensory experiences to delight every playground patron. We wished to incorporate sight, touch, and sound as much as possible to make the feature accessible to the broadest audience of users. We noticed how promoting features with sensory experience had succeeded throughout the park, from the laser harp to the motion-activated sounds at the park entrance. Additionally, Olenka told us about some of the artistic water features and light displays she had previously considered for the park. We wished to build on these successes and ideas by creating a design that affected as many senses as possible to create a memorable and fun experience.

Methods

Most of our early work involved extensive research, both in-person observational studies in the parks and online research into understanding other existing solutions. We visited the playground on several occasions at different times during the week to witness varying user distributions and navigation patterns. At the Magical Bridge, we specifically focussed on examining two of the fully wheelchair-accessible features at the park already: the laser arch and the motion-triggered entrance gate. Both of these features use the motion-triggered stimuli that we hoped to incorporate into our solution, but both are sound-based, so are not ideal for hearing-impaired playground visitors.

We also visited other local playgrounds for inspiration. Throughout our time in these parks, we thoroughly documented what worked well and areas for improvement for existing equipment solutions. Finally, we consulted product catalogs found online. Looking through online catalogs, we discovered many standard wheelchair-friendly playground equipment similar to that already featured at Magical Bridge, like the merry-go-round, rocker, and spinners, or transfer-height accessible swings. Most existing solutions that are branded as “wheelchair accessible” require transfer of the individual from their wheelchair to the feature. When it came time to brainstorm designs, we used our notes and photos from this research as a starting point for our new ideas.

In comparing a nearby inaccessible playground to the Magical Bridge, we found a unique attraction at the inaccessible playground: a spinner that used gravity to spin the user’s torso and legs while the user supports themself by holding onto a wheel above, pictured in Figure 1. It went faster than the spinning rides at the Magical Bridge and allowed for more user control and a very interesting kinesthetic experience. However, it was small; only big enough for a user to stand on, not for a wheelchair.

Figure 1. A spinning platform at a local playground inspired one of our first designs.

Inspired by the concept of the ride, we envisioned a wheelchair-accessible version, our sketch of which can be found in Figure 2. Although we decided to forgo this idea in favor of more feasible and exciting solutions, this phase of the exploration process opened our eyes to successful existing non-wheelchair accessible features and the process in which these can be redesigned to provide an accessible experience to all.

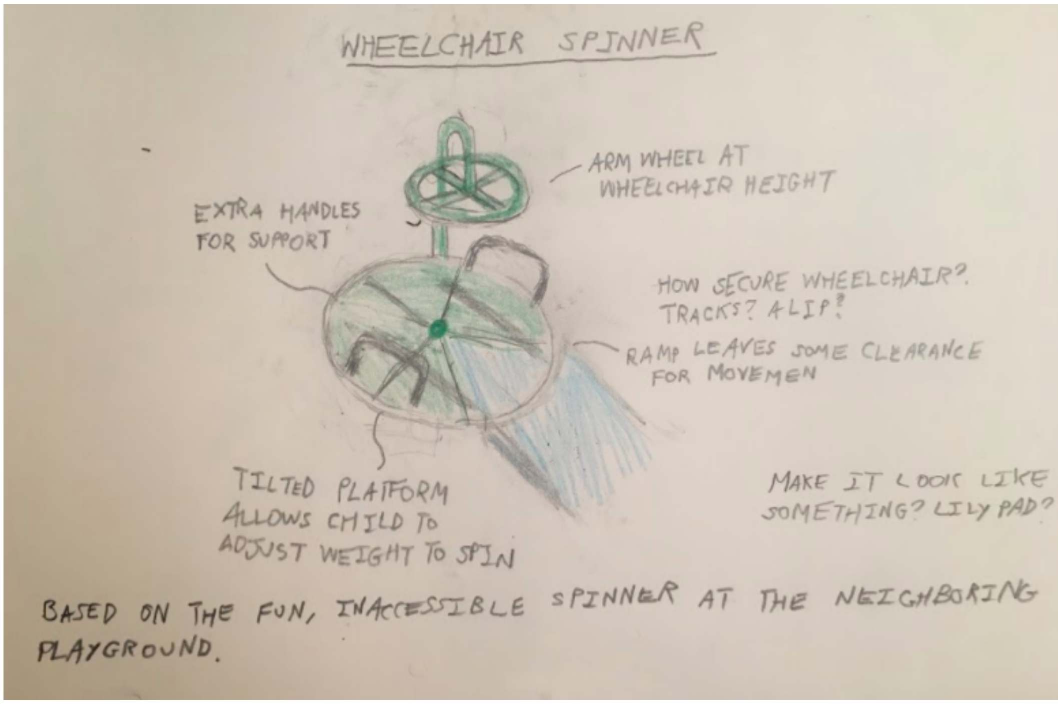

Figure 2. A sketch of a wheelchair spinner exposed problems.

Throughout our brainstorming process, we found sketching to be a very helpful tool to help us quickly understand the feasibility and relative promise of our theorized solutions. Iterative sketching allowed us to explore the nuances of our design ideas on paper and identify potential features and deterrents, where everything needed to go, and their subjective appeal. Using these sketches, we assessed the design's technical feasibility and recognized that "ride" solutions did not incorporate the criteria of maximizing underutilized areas of the park, so we decided to move away from the idea of building *rides* for wheelchair users (of which Magical Bridge already features several).

We used sketching to brainstorm several other potential designs and brought them together to compare side-by-side. These included a xylophone positioned along the fence, which would be accessible to every park patron as they enter the playground and feature the parks pre-existing resources of the park. A sketch of this idea is shown in Figure 3. Another option was a play panel that would look like the cockpit of a helicopter, inspire imaginative play, and include knobs and switches to help kids improve their motor skills. Haptic feedback and sound would make the attraction fun for visually impaired playground visitors and stimulating for all the senses. It is pictured in Figure 4.

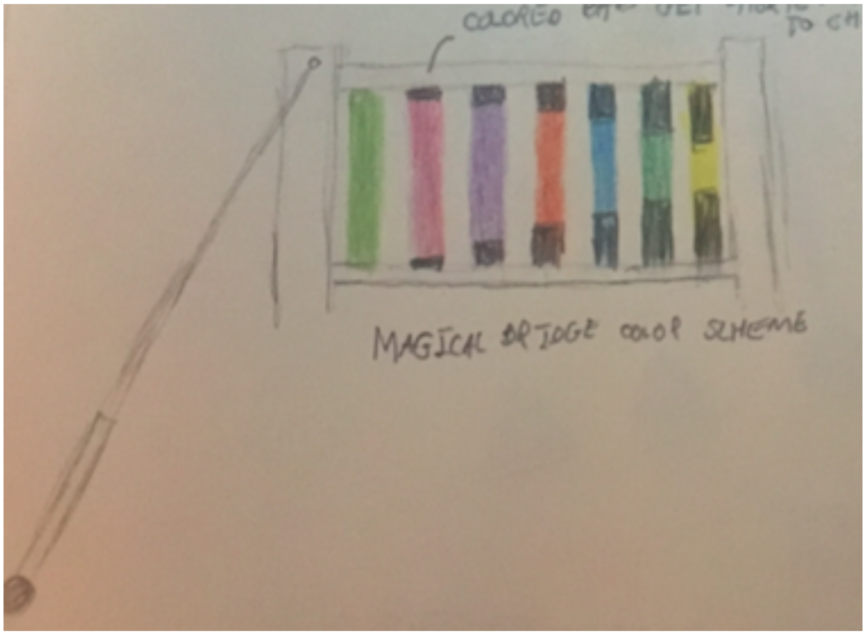

Figure 3. The fencing enclosing the park could become a xylophone for kids to play with.

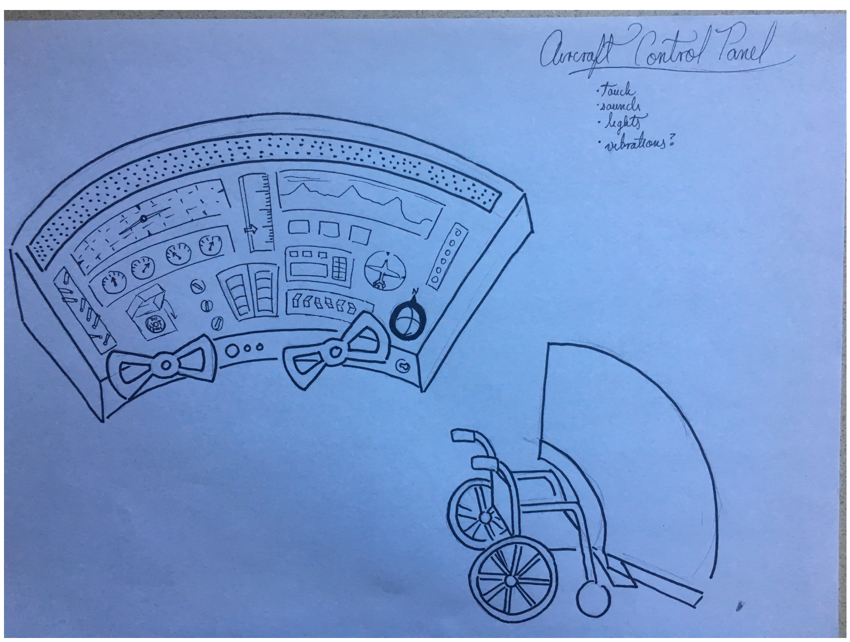

Figure 4. A control panel at wheelchair height provides auditory and haptic feedback.

Another design we sketched depicted a “magical” lilypad pond, pictured in Figure 5. Following the fairy tale theme “magical bridge” connotes, we were excited to explore building a water feature that contained the water entirely, allowing users to stay dry (and therefore avoiding sanitary concerns) while triggering effects with motion. We envisioned a clear glass or acrylic floor with large “lily pads” inset that would lie over an enclosed tank of water. When users stepped on or rolled across the lilypads, the motion would activate a light effect under the water, which would project a visible colored lily-shaped design up through the glass. Finally, we made a sketch of a magical bridge, which would use similar technology as the lilypad pond to create lights and sound, and perhaps even fountaining water, as users walked or rolled over it.

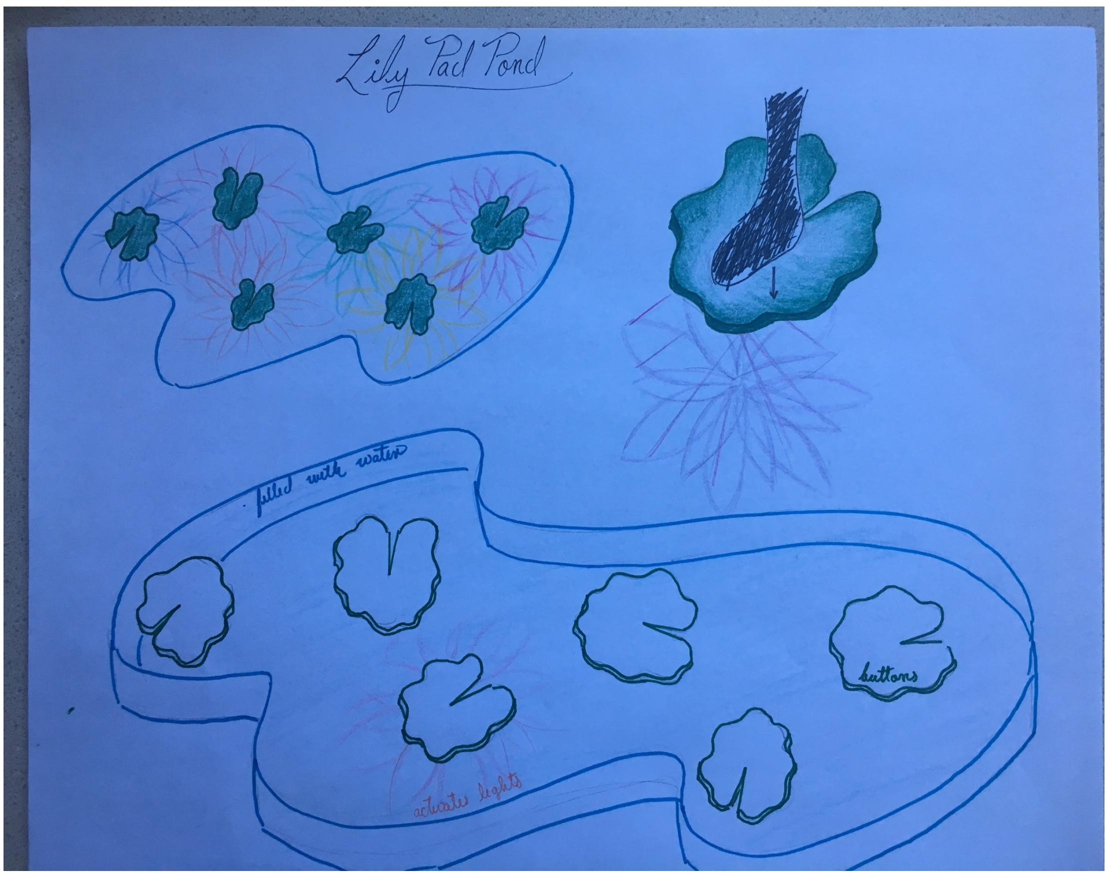

Figure 5. A lilypad pond incorporates water into the park without endangering its users.

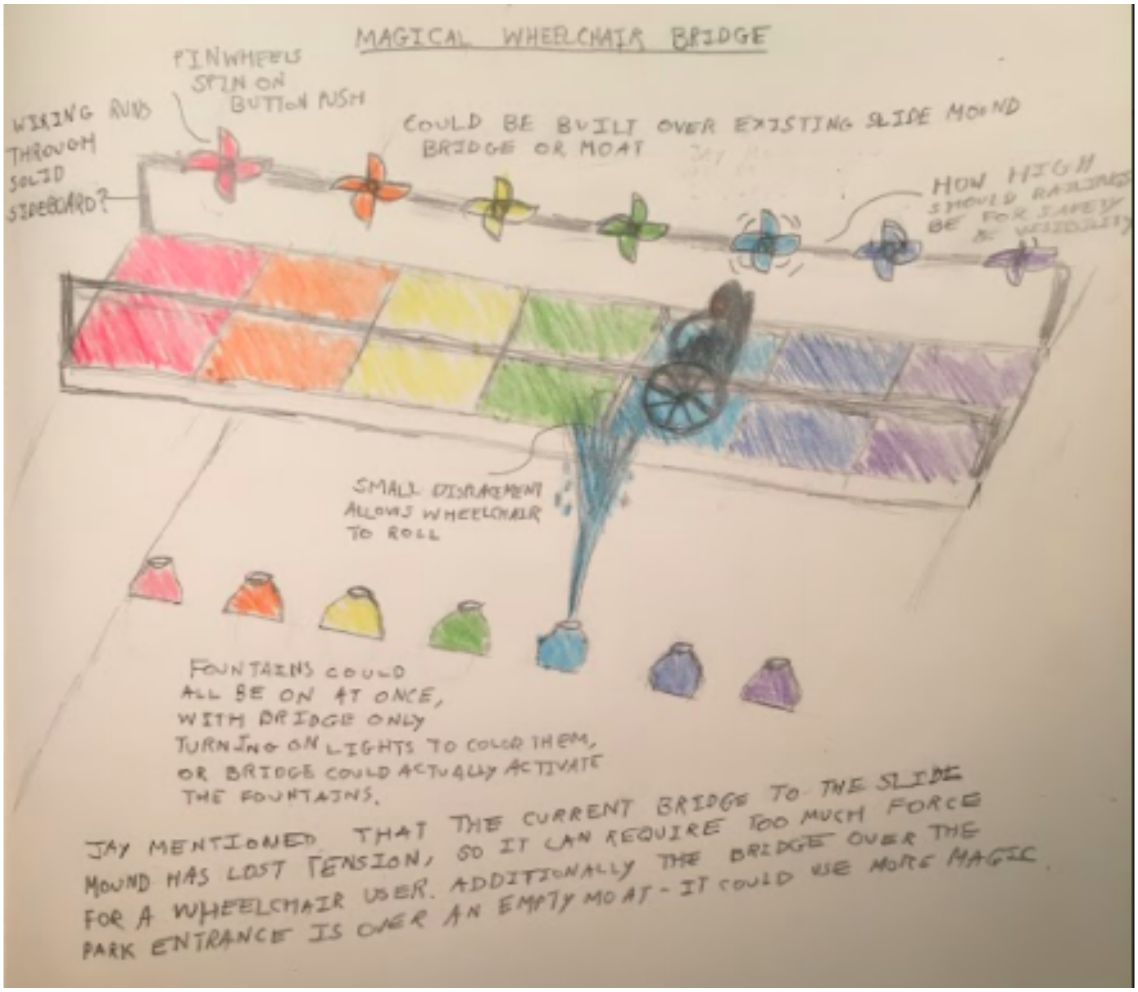

Figure 6. Our final design is a wheelchair-accessible magical bridge.

After creating sketches to explore these ideas and several others, we talked through their benefits and drawbacks together. We dismissed several ideas due to issues our conversations exposed. We were excited about the lilypad, magical bridge and control panel ideas and the imaginative, accessible play they would enable; however, we were concerned that the control panel would not fit into the park's theme, and that the water features would be too challenging to implement.

Ultimately, we made our final decision after consulting with Olenka. We presented her with sketches of all three candidate ideas and described them to her in detail. Though she liked all of the ideas, her eyes lit up at the magical bridge. She explained how it was exactly like something she had once envisioned and explained how it could solve new problems that had been drawn to her attention, like the difficulty a guest who uses a had in navigating the existent, slatted bridge. Her excitement about the idea helped make a decision to pursue it.

At this point, we began moving forward in the process of defining the bridge's design. We considered including a water feature that became activated when a user put weight on a particular part of the bridge; however, we were not sure how to implement this in a prototype. One way we brainstormed we could accomplish this would be by making the railings out of parallel pieces of clear acrylic, which we would fill with small beads that could be agitated to produce a color change, then collected again at the bottom of the panel, rendering the water clear. This idea is depicted in Figure 7.

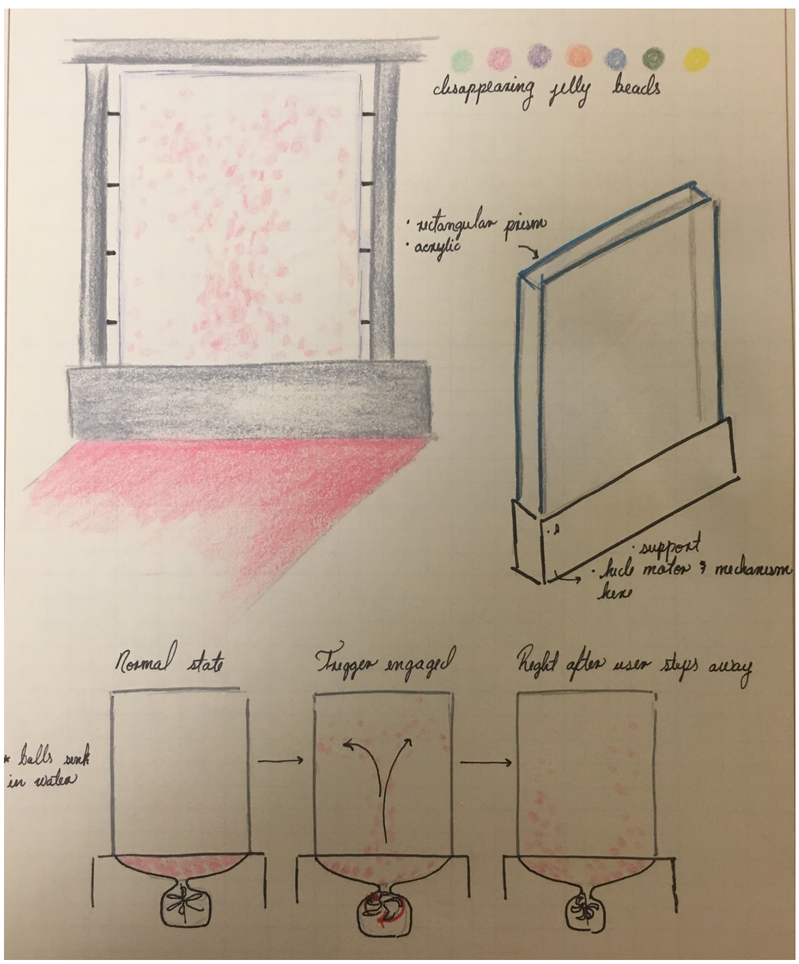

Figure 7. A potential mechanism had colored beads spreading through water.

However, this design still seemed incredibly challenging to prototype as we would have to contain the water and activate a mechanism to release and re-capture the beads, and ultimately, we realized we could achieve the same effect using a much simpler mechanism and eliminating the complications introduced by the use of water: LED lights connected to force-sensitive sensors.

After finishing our sketches and ideation process, we constucted a quick first model out of paper to visualize the bridge. From this model, we learned a lot about the form of our final design. We learned the importance of considering what kind of bridge railings we used. Deviation from a standard bridge height was also off-limits, as we wanted to create a solution that fit in seamlessly with the rest of the park. Additionally, we learned about the challenges of hiding any electrical wiring; if the bridge was to truly appear magical, the cords should not be visible. This meant we had to think carefully about where to place the electronics.

Results

Our final prototype consisted of a scale model magical rainbow bridge with clear, light-up panels reflecting the park's color scheme. When the user presses on an adjacent, matching panel, the light comes on; when the user removes pressure, the light turns off. This feature mimics what a real world implementation would do as a user rolled over or stepped on the various panels. Our prototype can be seen in Figure 8.

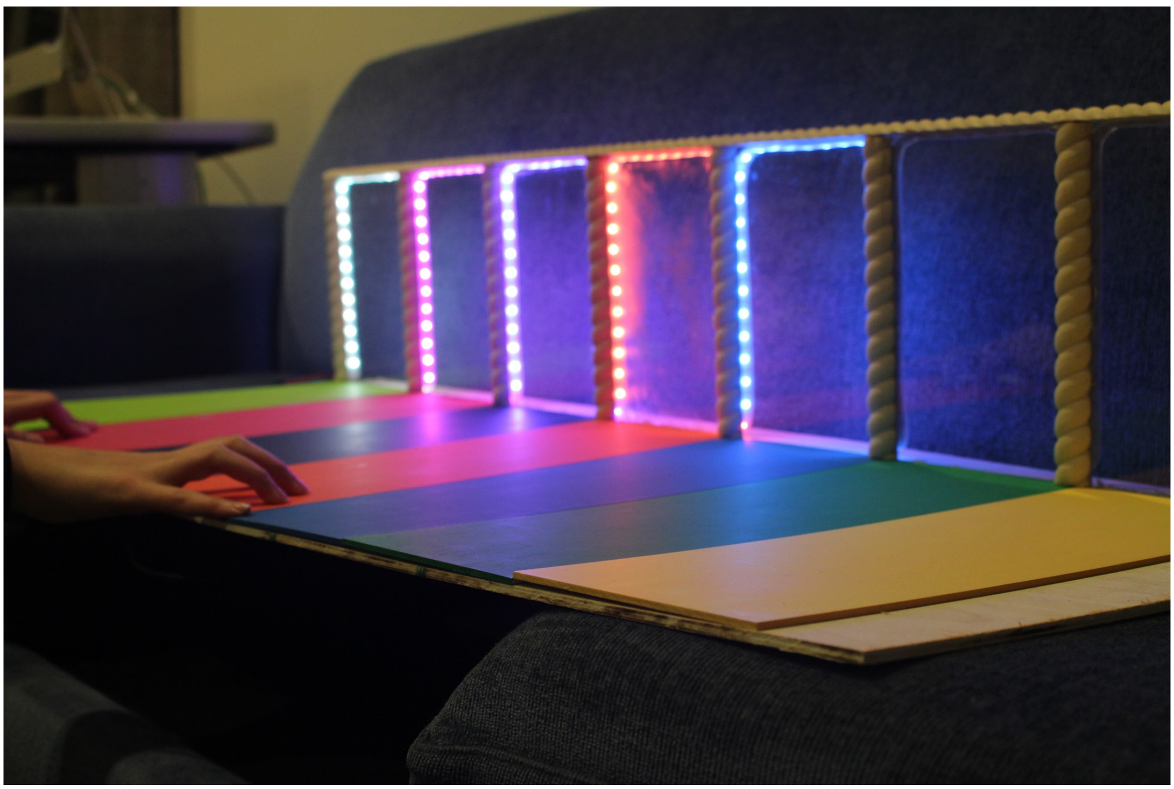

Figure 8. Our model lights up at the user's touch.

The physical structure of our design makes it accessible to a wide range of users. A railing above the lights provides support for those who need it. The panels that compose the walkway have no space in between them, making the bridge easy to navigate for users in wheelchairs or those whose canes might get caught in other bridges. And the walkway itself is wide, providing space for several people to use the bridge at once, or even people in very wide wheelchairs to wheel across it.

The electronics we utilized for our bridge are relatively simple, but allow for significant customization. The light-up parts of the bridge function by means of an individually addressable LED strip ($30.00), controlled by a microprocessor. Using Arduino software (Appendix), we selected the customized colors for each light, chose how bright we wanted them to be, and set the number of lights associated with each panel.

We also used Arduino code to turn on the lights only when pressure was applied to the associated panel in the walkway. We used force-sensitive resistors, fixed under the panels, to indicate when the user touched the panels. The resistors were the most costly component of our design, about $12.00 apiece; however, in future iterations, we could use longer, $4.00 resistors that our instructor has used before.

The force-sensitive resistors (FSR) were connected to fixed resistors to prevent excessive current in a series of breadboards underneath the model bridge. The Arduino's analog pins read the voltage values generated by the FSRs to determine when there was sufficient pressure applied to them. The code for the resistors allowed us to set the sensitivity of the lights, ensuring they did not turn on without user input, but that they did not require much force when the user did press a panel.

In testing our model bridge with users in the park environment, we found that children came back to it over and over again. The exploration process of users tentatively pressing one light and then learning how to use the mechanism to turn on different lights in succession was exciting for us to witness. Older children especially enjoyed pressing all the panels down at once or using the bridge like a piano. All of the users we talked to said they enjoyed playing with the model and wanted to see a full-size version; some even grew upset when we had to briefly turn off the bridge or when we packed it up to leave. One excited user is pictured on the Magical Bridge Foundation's Instagram story in Figure 9.

Figure 9. One child gives our design two thumbs up.

Adults and peers also appreciated our design. Olenka exclaimed that it reflected what she imagined, while Jay said he was almost getting misty-eyed. In class, we got overwhelmingly positive feedback from our classmates and community members, with one commenter noting that they wished they had a wheelchair to be able to experience the bridge from that special vantage point.

Discussion and Next Steps

Prototyping our design to attain the desired behavior proved relatively easy on a small scale, though issues in material properties would manifest themselves when building a full scale model. Choosing the appropriate sensors would be one of the top priorities as the small force-sensitive resistors employed in our prototype would not be adequate for a larger surface. Bigger pressure-sensitive conductive sheets made of Velostat/Linqstat that work similarly though changes in resistance could prove ideal for use in the park. They are inexpensive, a 11" by 11" sheet retails for about $4.[2] They are only 0.1mm thick, which is perfect for keeping the surface of the bridge smooth as each panel would not have to be deflected by much to be triggered.

Another key element in our design are the LED lights. Even as they were running on the prototype, setting the brightness too high would cause the strip to draw too much power and malfunction. A fix for this is could be setting a variable threshold for the LED brightness, but this creates a tradeoff between reliability of the system and its effect on the users. Their brilliance could be lowered when multiple panels are engaged, for example. Because playgrounds are most busy during peak daylight hours, and this is sunny California, this solution would not be effective. The lights would be at their dimmest when a greater number of people are passing over the bridge, which usually happens to be when it is sunny out. It is more recommended to simply replace the strips with higher intensity LEDs, like those used in flood lights, but on a smaller scale. To power these higher-wattage lights, solar panels could be installed.

If we were to continue this project, our main priority would be exploring how to scale up a functional prototype. This would inform design decisions such as selecting a bottom panel material for ideal deflection and traction for wheelchairs. The choice of material for the side panels would also have to be revised, as a larger piece of clear acrylic would be harder to "color" with lights. Thick stained or textured glass could prove an interesting alternative to the acrylic we used in our model.

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[2] Pressure-Sensitive Conductive Sheet (Velostat/Linqstat).

Although the prototype was successful in operation, it can be made even more interactive and engaging by modifying the code. A variable time delay between trigger and action could be introduced for a bridge with some personality. The connection between panel and light could also be miss-programmed so that it is not blue to blue, for example, to provide a surprising element of discovery. To involve the users even more, they could be made in charge of programming the bridge by connecting wires to and from the color they would like linked, which would produce a more customizable bridge. Making this safe and resilient to kids' mischievous efforts to break things could prove to be a challenge. As we look to the future, our team is excited about the prospects for the magical rainbow bridge design we have created, the resulting product from our 10-weeks of needfinding, designing and building, and working directly with potential users and stakeholders every step of the way.

Timetable

Week 1
- Construct base surface and railings out of wood

Week 2
- Purchase/ install individual pressure sensitive sheets
- Cover sheets with panel material, probably a rubber derivative

Week 3
- Wire pressure sensors to a microcontroller
- Code functionality
- Test in "lab"

Week 4
- Take steps prototype to playground and test with users to check failure modes
- Change material/sensitivity as needed

Week 5
- Install wall panels and LED lights

Week 6
- Wire LEDs to microcontroller
- Code functionality
- Test in "lab"

Week 7
- Take updated prototype to playground and test for brightness

Week 8
- Install solar panels to make design self-sufficient

Week 9
- Implement and test extensions to LED code (time delays, missprogramming, etc)

Week 10
- Present and Demo Project

References

Berkley et al., *The Importance of Outdoor Play and Its Impact on Brain Development in Children*. Retrieved from https://education.umkc.edu/download/berkley/The-Importance-of-Outdoor-Play-and-Its-Impact-on-Brain-Develpoment-in-Children.pdf

Pressure-Sensitive Conductive Sheet (Velostat/Linqstat). Retrieved from https://www.adafruit.com/product/1361

Acknowledgements

We would like to thank Olenka Villarreal and Jay Gluckman for bringing a bit of the enchanted into the world through their work with the Magical Bridge Foundation. Without their valuable suggestions and support at every step of the process, we would still be trying to figure out how to tackle the challenge, (and how to work a certain spinning attraction in the playground). We would also like to thank our instructor, Dave Jaffe, for his help through our design process and for his great feedback and ideas.

Appendix: Arduino Code

```
#include <FastLED.h>

#define LED_PIN     11
#define NUM_LEDS  228
#define LED_TYPE    WS2811
#define COLOR_ORDER GRB
#define STEP_SIZE  33 //Set number of lights on each panel
#define NUM_STEPS 7 //Set number of steps
#define BRIGHTNESS 100 //Set brightness from 0 to 255. A high brightness may draw too
much power.
CRGB leds[NUM_LEDS];

//Select analog pins to which resistors will be connected.
int fsrPin1 = 0;
int fsrPin2 = 1;
int fsrPin3 = 2;
int fsrPin4 = 3;
int fsrPin5 = 4;
int fsrPin6 = 5;

//FSR Reads
int fsrReading1;
int fsrReading2;
int fsrReading3;
int fsrReading4;
int fsrReading5;
int fsrReading6;
int reading_limit = 70; //Set resistor sensitivity

#define UPDATES_PER_SECOND 100

void setup() {
  Serial.begin(9600);
  delay(3000); // power-up safety delay
  FastLED.addLeds<LED_TYPE, LED_PIN, COLOR_ORDER>(leds,
NUM_LEDS).setCorrection( TypicalLEDStrip );
  FastLED.setBrightness(BRIGHTNESS);
}

void loop()
{
  int count = 0;

  fsrReading1 = analogRead(fsrPin1);
  fsrReading2 = analogRead(fsrPin2);
```

```
  fsrReading3 = analogRead(fsrPin3);
  fsrReading4 = analogRead(fsrPin4);
  fsrReading5 = analogRead(fsrPin5);
  fsrReading6 = analogRead(fsrPin6);
  fsrReading7 = analogRead(fsrPin7);

  Serial.print("/n Analog reading = ");
  Serial.print(fsrReading2);     // Open the serial model to check raw analog reading on given
resistor, currently, resistor 2
  Serial.print('\n');

  //Define colors.
  CRGB lime  = CRGB(190, 240, 80);
  CRGB magenta  = CRGB(240, 30, 140);
  CRGB purple = CRGB(150, 30, 240);
  CRGB orange = CRGB(255, 100, 0);
  CRGB blue = CRGB( 45, 125, 190);
  CRGB green = CRGB( 15, 110, 15);
  CRGB yellow = CRGB(255, 255, 0);

  //Set lights according to pressure on the resistors.

  for (int i = 0; i < NUM_LEDS; i++) {

    leds[i] = CRGB::Black;

    if (fsrReading1 > reading_limit && i < STEP_SIZE * 1)
      leds[i] = lime;
    else if (fsrReading2 > reading_limit && i >= STEP_SIZE * 1 && i < STEP_SIZE * 2)
      leds[i] = magenta;
    else if (fsrReading3 > reading_limit && i >= STEP_SIZE * 2 && i < STEP_SIZE * 3)
      leds[i] = purple;
    else if (fsrReading4 > reading_limit && i >= STEP_SIZE * 3 && i < STEP_SIZE * 4)
      leds[i] = orange;
    else if (fsrReading5 > reading_limit && i >= STEP_SIZE * 4 && i < STEP_SIZE * 5 - 1)
      leds[i] = blue;
    else if (fsrReading6 > reading_limit && i >= STEP_SIZE * 5 - 1 && i < STEP_SIZE * 6 - 1)
      leds[i] = green;
    else if (fsrReading6 > reading_limit && i >= STEP_SIZE * 6 - 1 && i < STEP_SIZE * 7 + 4)
      leds[i] = yellow;
  }

  FastLED.show();
  FastLED.delay(1000 / UPDATES_PER_SECOND);
}
```