Building a Laser Harp

[Names Redacted]

Computer Science 207

Trevor Tomesh

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Table of Contents

Introduction

The project undertaken for this term was the construction of a laser harp. This was done as a means of combining a passion for music with a love of lasers. A laser harp is a hacker's musical instrument. The basic structure of this laser harp is a frame that has six lasers at the bottom aimed vertically at the photo resistors on the top of the frame. The lasers are analogous to the strings of a harp.

The basic idea of the harp is that there is a line of a six beams of light going vertically through the frame of the harp. Photo-resistors are used to sense the change in light when a beam is broken. The Arduino chip senses the change and sends a signal to a piezo speaker to produce a note. Just as strings on a harp, each beam is responsible for the production of a different note.

There are a few makers out there that have created a laser harp. Some are framed and some are frameless. This project's laser harp is a framed. The frame is constructed out of plywood and the details will be further discussed later in the paper.

There have been a few changes in the project since the proposal was submitted. This includes using LED's instead of photo diodes, then using photo resistors instead of LED's, and using a piezo speaker instead of a MIDI synthesizer. The change to photo resistors was for the betterment of the project. The change to a piezo speaker rather than MIDI was a sacrifice due to time constraints and difficulty finding parts. Those major changes were instrumental in the process of the laser harps construction.

Inspirations

Our group was not the first to build a laser harp. While trying to come up with a design there were multiple sites browsed to see what other people have done. Obviously the laser harp in this project is nothing spectacular when compared to higher-end harps. Some laser harps are powered by very powerful lasers that produce beams powerful enough that some form of eye protection would be wise. This laser harp does not need someone to wear safety glasses in order to play it but as a precaution it is always good to do so while using lasers.

The main source used for prototyping as well as the general idea of the way to build the laser harp came from Chris Ball's "Quick Arduino MIDI Laser Harp" from Instructables.com [1] This site helped the project greatly. Useful information was gathered from his project including what lasers to get, what power of resistors to use, and how to wire everything. It was mainly useful for the early prototype as later in the project much of it was not integrated into the harp.

Chris Ball's laser harp differs from the laser harp in this project in a few ways. For one his harp is frameless and a very simple design. The lasers and photodiodes stay hooked up right to the breadboard and Arduino. The laser harp made for this project is framed. The breadboard was split in half and the connections were hidden under the top rail of the frame. It gives the harp a more aesthetically pleasing look. In addition to this, photo resistors rather than photodiodes were used as light sensors.

Chris's laser harp was not meant to look pretty but the sound quality is great. The laser harp done for this project won't sound as good as Chris's because the sound output is different. Chris used a MIDI synthesizer to produce the sound for his laser harp. Using MIDI was in the original plans for this project but was later omitted. A piezo buzzer was used instead to make the sound. Both partners were more familiar with coding piezo buzzers and supplies for MIDI are hard to find.

Other projects were briefly looked at but the only project that's ideas were used was Chris Ball's laser harp. It was the perfect project to help with the prototyping of a laser harp because it was simple enough to understand yet complex enough to intrigue people.

Designing Process

The design process was fairly simple. The harp is made of six laser modules, sis photo resistors, and six 100 kΩ resistors, a breadboard, the Arduino UNO, one piezo buzzer, and a wooden frame. The frame was designed later in the project. Photograph of the frame can be viewed in Appendix E.

The frame has holes at the base which the laser modules were screwed into. The lasers were facing vertically to shine on the top of the frame. Photo resistors were placed at the top of the inside of the frame facing downward. This allows a steady stream of light for each laser. The photo resistors were placed at the top of the frame rather than the bottom because if they were at the bottom the photo resistors would have been more susceptible to ambient light in a room with lights in the ceiling. It also allowed for the laser to illuminate the bottom of the players hand rather than reflecting the light into their face.

The reason a frame was made is because it makes the laser harp look very neat. Without a frame it is hard to line up the lasers correctly and the wires and breadboard are exposed. The frame hid the mechanics of the harp as well as kept the lasers lined up in a uniform matter. The short stature of the frame aided in lining the lasers up properly with the photo resistors.

The original prototypes of the project can be found in Appendix A and Appendix B. The circuits include the design of the *Light Sensing November 13th, 2014* circuit and the *LaserHarp2Notes* circuit. The *LaserHarp2Notes* circuit is the more accurate prototype to the final laser harp. The *Light Sensing November 13^{th,} 2014* circuit was for early prototyping and much of the design is different now.

Building Process

The building process was more complex in the initial prototype. When the LED's were being used the breadboard was almost completely full. At that time six piezos were also being used and were wired up. There was 12 LED's, 6 piezos, 12 resistors, and overall 18 connections being powered by the Arduino.

Everything was very tightly packed which may have been one of the reasons the sensors did not work as well as they should have. All the piezos were wired correctly because they made sound on their own but when trying to connect the sound to the sensors things didn't work. Refer to Appendix B *Light Sensing November 13^{th,} 2014* to see this prototype.

It is interesting to note that the LED's that were used as light sensors in the early prototype were red because one must use LED's that emit a longer wavelength of light than what they are detecting. Since the lasers that were used for the harp had a ~520 nm wavelength it was effective to use the red LED's that came with the Arduino kit that was purchased for class as red light has a wavelength or roughly 620 nm.

The idea of using LED's as photo sensors was scrapped due to issues encountered involving reliability. From then on, the building process moved much quicker. There is an example of the earliest build using photo resistors in Appendix A labelled LaserHarp2Notes. This particular build had two light sensors. Two analog pins on the Arduino were connected between the photo resistors and 100 kΩ resistors. This allowed the Arduino to sense variation in voltage going to the analog pin based on how much light was reaching the sensor. A low reading such as 0 was an indication of a lot of light. As the amount of light reaching the sensor decreased, the value increased. The build included one piezo because it was determined to be sufficient for sound production. To generate sound from the piezo, the Arduino's tone function was used. This prototype was the basis for the final version of the project.

The final version of the project consisted of six voltage divisions between photo resistor and 100 kΩ reisitors for light sensing and six laser modules that were powered separately from the light sensors. The laser modules were connected in parallel and powered by a variable DC power supply. The voltage divisions were powered by the 5V pin on the Arduino. The frame for the harp was constructed out of plywood. The lasers were mounted to the frame in a manner that allowed them to be adjusted by sliding the lower section of the frame to line them up properly with the photo resistors. This can be seen in Appendix D. On the top section of the frame, the photo resistors were mounted to a breadboard which was again for the sake of easy adjustments. All six analog pins on the Arduino were used to read the values from the photo sensors. To do this, they were connected between the photo resistors and the 100 kΩ resistors. For audio, a piezo buzzer was connected to pin 11 on the Adruino as we needed to use a pulse-width modulation pin to use the tone library. The final product can be seen in Appendix E.

User Manual for Laser Harp

The laser harp is very easy to use, however it does require some effort to set up. The first step would be to download the code onto an Arduino UNO. The Arduino Uno supplies 5V to the voltage dividers used to detect light. The code is labelled “LaserHarp6Notes”. Refer to Appendix C for information where to find the code. Once the code is downloaded on to the Arduino there are just a few more things to do.

The Analog 0 through Analog 5 pins are to be hooked up to separate voltage dividers with a photo resistor and a 100K Ω resistor. Then a piezo buzzer is to be hooked up to pin 11~ which is a PWM pin.

The lasers, given the current build, must be connected to a variable DC power supply. The black wire is to be connected to ground and the red wire is to be connected to the wire supplying voltage on the power supply. To do this, it is helpful to have alligator clamps to connect the lasers to the power supply. Set the power supply to have a voltage output of 3.3V. This allows for all the lasers to glow at an appropriate brightness while not generating too much heat. This concludes the setup portion of using the laser harp.

To play the harp one simply needs to break the beams emitted from the lasers. It's best to this this with a single finger as the lasers are fairly close together. Each laser will produce a separate tone. The harp is tuned to be a pentatonic scale from middle C# to one octave above. It's important to note that only one note can be played at once due to the software.

Setbacks and Failures

The biggest difficulty of the project was in attempting to implement the idea of using LED’s as light sensors. It sounded like it would be a good idea to use something the group already had to be a sensor. It was also an intriguing idea to use an LED for something other than its intended purpose. It was the definition for hacking however it was not working as intended quickly enough and had to be omitted from the final version of the project.

The code for the early LED prototype was inspired by Zorink’s “LEDs as light sensors” on Instructables.com [2] as well as Kenyer’s “LED as lightsensor on the Arduino” on Instructables.com [3]. Zorink’s LED as light sensor was looked at briefly. The most looked at source was Kenyer’s design. The hardware took a minute to hook up and the code was the basis for the code used in the early parts of the project.

Mims “How to Use LEDs to Detect Light” was used for information gathering purposes only. [4] It had a lot of information about how the LED’s can be used as light sensors and why they are able to do that. It was very interesting to learn but there was no code or hardware used from this site.

While testing Kenyer’s code with their hardware the sensors worked perfectly. The code was manipulated as well as expanded to include multiple sensors. During this step something went wrong.

While trying to shadow one sensor it would activate two lights. It was only supposed to activate one. Sometimes it didn’t activate any at all. It was no good to have an inconsistent sensor because it was very important to be precise with each sensor. After hours of troubleshooting both the code as well as the, hardware it was decided that the way in which the harp would sense light needed to be redesigned. That is when the group decided to get rid of the LED's and order some photo resistors instead.

Another part of the project that was not achieved was using a MIDI synthesizer for the sound. The original plan was to use a MIDI synthesizer to make the project more complex and interesting. This would also have been useful because with MIDI the harp could have played multiple octaves and the notes would have come out a lot cleaner.

That being said there wasn't enough time to implement a MIDI synthesizer. It was difficult finding the pieces needed as well as the knowledge of how to use it. If there was more time MIDI may have been used.

The major setback for the group was probably distance. One group member lives in Regina and the other lives in Moose Jaw so it was hard to find the time to work together. The schedule of one partner was so full due to five classes and five labs so finding the time to do anything around school was next to impossible.

There were a few trips made out to Moose Jaw so the group could collaborate and work on the project. Since there were only a few times the group could meet the project wasn't done as fast as it could have been and it wasn't done as well as it could have been. The school, time, and distance constraints put limitations on how much each partner could get done and how much of the project overall could get done.

The project was done to the best of the ability of both partners in the situation they were in. There could have been more done to make the laser harp better in a different situation and at a different time but the group worked with limitations and did the best job they could with the little time they had.

Milestones

The project should considered a success because a framed laser harp that produced different notes was made. The main goal was achieved. It may have been done more simply than the group had originally intended however it will continue to be improved after the end of the class.

One thing that wasn't really built to expectations was the laser frame. Originally it was going to look a lot more aesthetically pleasing than it turned out to look. But due to time constraints and work constraints it was just not possible to build a well formed frame for the laser harp. This is something that can easily be improved in the future when there is no time limit on when it needs to be done and no other homework preventing it from getting done.

A major milestone in this project was reached rather late into the build. The laser modules that were used unfortunately came with buttons installed on their circuit board. This presented an issue with keeping the lasers on constantly. An early attempt that worked temporarily was using electrical tape to hold the buttons down. This allowed for the lasers to work however it was somewhat unreliable. Later in the project it was decided to remove the casing from the front of the buttons and to fill the button with solder to make a permanent connection. This milestone brought forth by a simple and effective hardware-hack marked the point where the lasers worked consistently.

Group Contributions

[Redacted]'s main contributions to the project was the prototype harps code and the hardware. [Redacted] researched how to use an LED to detect light. The photodiodes the group ordered were 10V and too powerful to use so the group had to improvise. Destinee worked on the coding and hardware design of the LED harp for a few weeks. Unfortunately while trying to test the LED’s for sound the sensing was inconsistent at first and then eventually just stopped working all together.

Although [Redacted]'s code and harp were not used in the final product, they pushed the project towards a more successful direction. The inconsistency seen when testing the LED's led [Redacted 2] to suggest using photo-sensitive resistors as light sensors due to their simplicity and reliability. After the initial code was removed, [Redacted 2] created a new code and wired up the photo resistors and the piezo. He created the framed harp as well as soldered the lasers every time they broke. This happened many times due to over-handling the lasers. James was also involved with writing the proposal and the final write up.

Overall the teamwork for this project turned out well. Although the group lived in different cities they made time to work together and figured out what they could do on their own. One partner was considerably more experienced than the other but there was lots of teamwork and contribution from both sides. Even the mistakes made was a learning experience and helped push the project further.

Conclusion

The laser harp was very fun and interesting to build. There were times when things got so frustrating that it would have been easy to give up on it but the group powered through. This lead to the success of the project and the formation of a not-so-elegant but functional laser harp.

The group would have liked to do more with the laser harp than what was done up to the presentation. Although the project lacked some of the originally intended features such as MIDI, the project is likely to be continued beyond the class and could eventually see that being implemented.

Ultimately, using photo resistors to sense light and a simple piezo speaker for audio was a simple way to produce a laser harp. This kind of project would be a good introduction to making music with electronics as it is interesting and fairly straight forward if you know how to set up a voltage division.

A big part of the CS 207 class is to inspire people to become makers and spark a curiosity with regards to electronics. This project has definitely done that. The fact that the group still wants to tinker with the laser harp and find out different ways of making it better is a great example of how this class is supposed to make students feel. Inspired and curious. It also inspires the group to learn the know-how of improving the project before trying anything because as we learned in class there are a lot of different ways a person can kill themselves tinkering with a toy.

References

[1] Ball, C. (n.d.). Quick Arduino MIDI Laser Harp. Retrieved November 26, 2014, from http://www.instructables.com/id/Quick-Arduino-MIDI-Laser-Harp/?ALLSTEPS

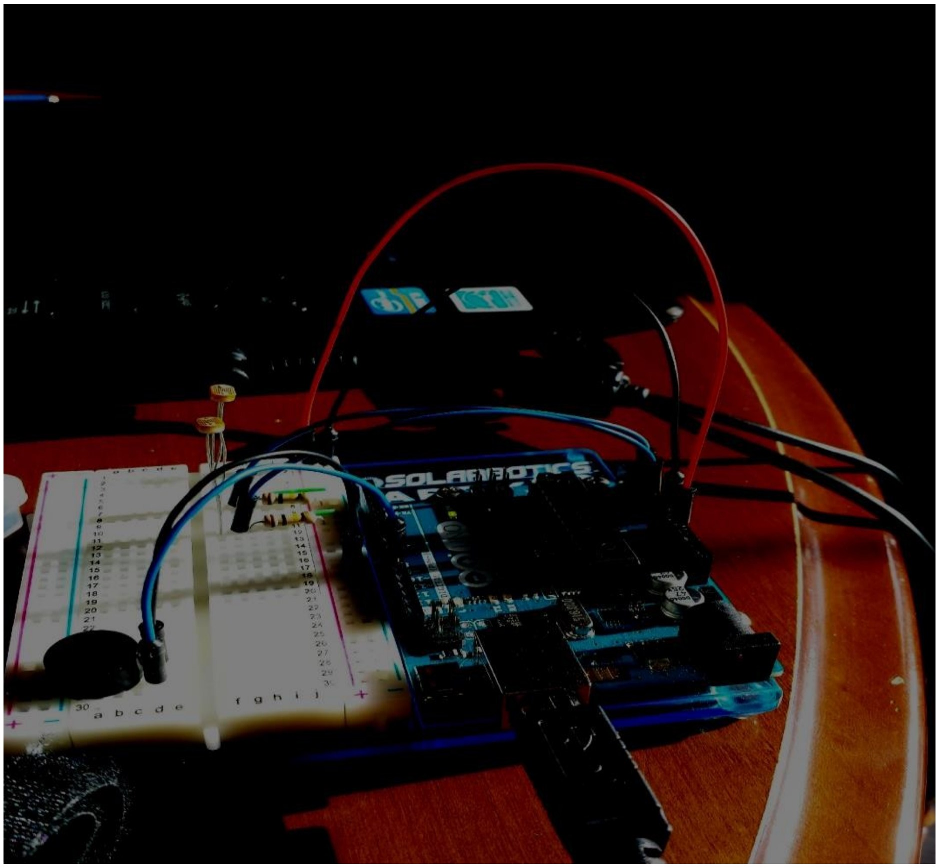
[2] Zorink. (n.d.). LEDs as light sensors. Retrieved November 26, 2014, from http://www.instructables.com/id/LEDs-as-light-sensors/?ALLSTEPS

[3] Kenyer. (n.d.). LED as lightsensor on the arduino. Retrieved November 26, 2014, from http://www.instructables.com/id/LED-as-lightsensor-on-the-arduino/

[4] Mims, F. (n.d.). How to Use LEDs to Detect Light. Retrieved November 26, 2014, from http://makezine.com/projects/make-36-boards/how-to-use-leds-to-detect-light/

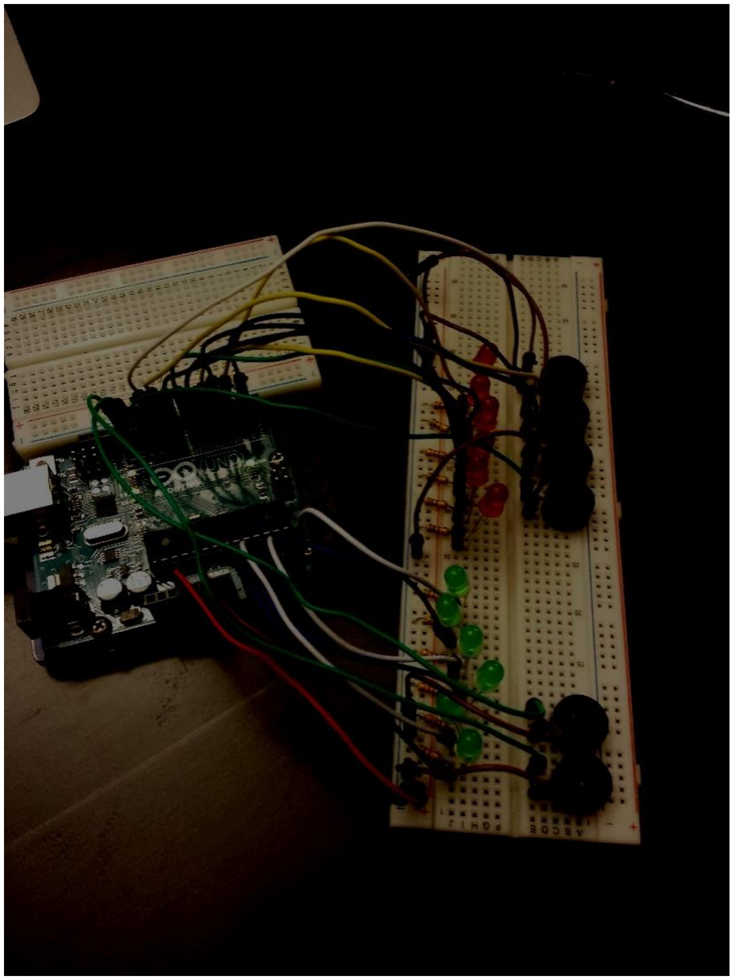
Appendix

Appendix A: LaserHarp2Notes Hardware Design



This design was created after the fallout with the Light Sensing November 13th, 2014 design. The design of the laser harp before it was put into a frame is the very same idea as this only with 4 other photo resistors hooked up to the Arduino.

Appendix B: Light Sensing November 13th, 2014 Hardware Design



This was the original design for the laser harp prototype. The prototype had to be eliminated because the LED's were not working as proper light sensors and the group no longer needed all six speakers.

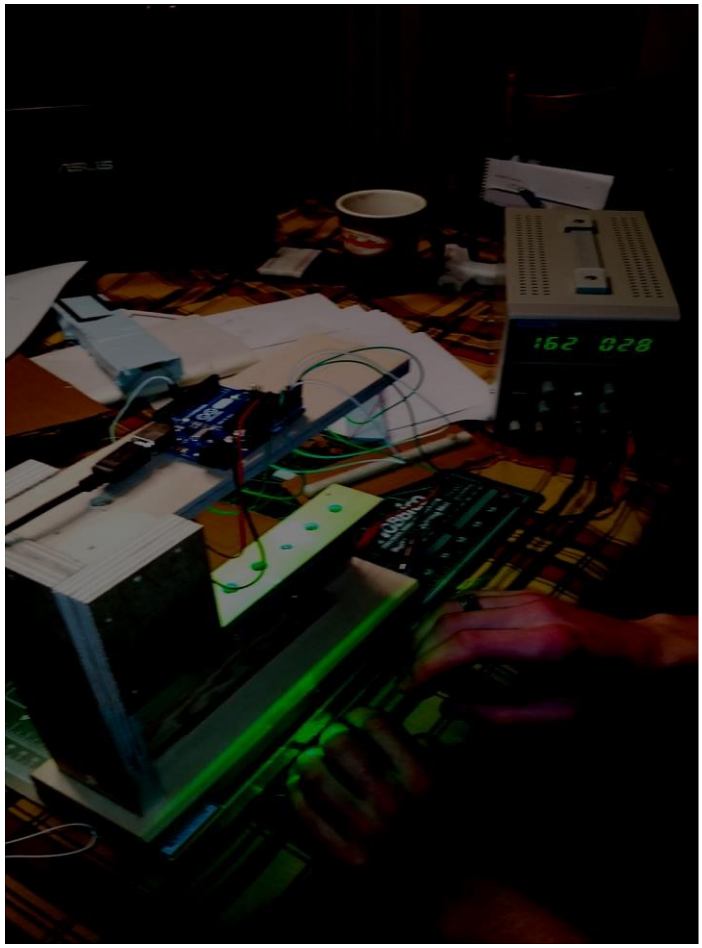
Appendix C: Code Listings

All code useful to this project can be found in 5 repositories located at https://github.com/DLMFraser

Appendix D: Frame and lasers

The lasers mounted to the frame and connected in parallel. The section of the frame to which they are mounted is able to be adjusted.

Appendix E: Final Product



The final product connected to a DC power supply and functioning. It was determined after this photo was taken to use 3.3V on the power supply.