Assistive Mechatronic Piano Playing

Group Number 10

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Overview:

Music and the arts are an important part of the lives of many. The disabled and elderly can find difficulty or complete inability when it comes to the fine motor skills required to play an instrument. In particular, playing piano can be difficult for individuals with limited to no function in their feet or legs as piano playing involves pedals. In order to enable such individuals to take part in piano playing as fully as anyone else, this project seeks to create a solution for controlling piano pedals without use of the feet.

Background on Disability Technology and Issues that Disabled Musicians Face:

Throughout history, humans have made countless advancements in technology. Specifically, technology that helps people with issues involving their limbs. Take, for instance, the creation of prosthetic limbs. Soldiers of the medieval period were often left with severe injuries from battle. As a solution to this, Ambrose Parè, the royal surgeon of the French monarchy, designed artificial limbs to fit over the top of soldiers' severed limbs. (Hernigou, 2013) Not only did these prosthetics serve a cosmetic role, but they also helped victims return to somewhat normal life and retain as much function as possible.

Fast forward to today. In the United States, 61 million people have disabilities, with 13.7% of those disabilities being mobility issues. (CDC, 2020) The invention of motorized wheelchairs by Canadian inventor George Klein in the 1950's aimed to help those without function in their legs. (Bourgeois-Doyle, 2018) The electric wheelchair helped them regain the mobility they lacked or lost. However, while the electric wheelchair is an absolutely amazing invention which provides the most important aspect of human life, that being mobility, it does not address the finer aspects of one's life.

For our assisted mobility device, we look to address the problem of not being able to play the piano without movement in one's legs. Under normal circumstances, the piano is played by pressing keys with one's fingers. Pressing the keys then activates a lever called a "hammer" which strikes the strings located in the piano. After lifting your fingers from the key, a damper is then put on the strings to stop them from vibrating. (Yamaha Corporation, n.d) However an important part of the piano is the sustain pedal. This pedal removes the dampening on the piano strings, which lets notes ring out for longer and creates a legato feel to the music. Without being able to use a sustain pedal, a musician with an issue with leg mobility would not be able to adequately play and perform certain pieces of music. While this problem may seem niche in nature, our solution to this problem satisfies a major issue that disabled musicians face and without it, a portion of music and its history is lost to those with leg disabilities.

Objectives:

The objectives of this project are as follows; first, successfully press a piano pedal by mechatronic action. Second, successfully initiate this action by a peripheral control such as a button or motion sensor. Third, allow the initiated motion to imitate the speed with which a player would press the pedal so as not to inhibit or slow playing. Fourth, the prototype should be able to undergo repeated use without breaking or losing noticeable performance. Last, the prototype and, by extension, the projected final product should be as affordable as possible.

Significance:

There are many people around the world who play the piano as a hobby. The most accessible way for people to partake in this activity is with an electric keyboard due to its portability and relatively low price in comparison to upright and grand pianos. These electric keyboards are usually used in conjunction with a sustain pedal in order to properly play many pieces of music. This is a problem for people who are unable to use these foot pedals, due to various possible circumstances such as being paralyzed from the waist down, or from being physically disabled and having malformed or no feet available to use the pedal. One would think that you could just use your hand instead to use the pedal, but piano playing requires both hands, making that solution unviable. Therefore, by offering an inexpensive solution that allows disabled people to use a foot pedal without the use of their hands or feet, this would allow more people to enjoy the full enjoyment of playing the piano, regardless of their disabilities.

Project Description:

The idea for this project originated from research about a non-mechatronic assistive device that allowed people who might have been paralized from the waist down or simply unable to use the pedal on a piano for any reason. This non-mechatronic device came in the form of a wood bar that the performer would be able to push down with his or her wrists, and a brass bar connected that armrest with the top of the pedal, pushing the pedal down. This is a good idea, and it did work for the most part, people who were paralized or disabled could still play the piano close to the fullest extent. This is where the device being designed in the project comes into play, as a group, we thought this device could be improved a good bit, as it still required the use of your hands or wrists to push the pedal down, this restricts the motion of your fingers on

the keys and limits some people's ability to play the piano. The solution we all came up with came in the form of a device with 2 stepper motors, a piece of wood, as well as a few 3D printed connecting rods that join the shaft of the motor to the surface that pushed the pedal down. The most innovative part of this design is the control fix, with the other non-mechatronic device you had to occupy part of your hands to push the pedal. This mechatronic device will be controlled by a button or switch in the performer's mouth.

This device is just a proof of concept, but for the final product with a larger budget, there would be 3 of these devices next to each other in order to push down each of the 3 pedals. Each pedal will be linked to a different button in the performer's mouth, one in front and one on each side. There are many versions of inputs we could use to program the arduino to push the pedal down, this one could only be used if the person is not singing. So obviously it depends on what the performer wants, but this shouldn't be a problem because we would be able to simply find another method if input that doesn't involve the hands or mouth.

Below is a rough sketch of our design. We plan on having 2 stepper motors facing each other in front of the piano pedal (we're using an electric piano pedal because we do not have an actual piano). It will be connected by 2 connecting rods and come bar across the 2 that line up with the front of the pedal. The positioning of the pedal is also important, if we code the stepper motor to go 30 deg down from the equilibrium position of the pedal to press it, if the motor is too low it won't have enough torque to push it or the motor would fail when the pedal physically cannot go down any further.

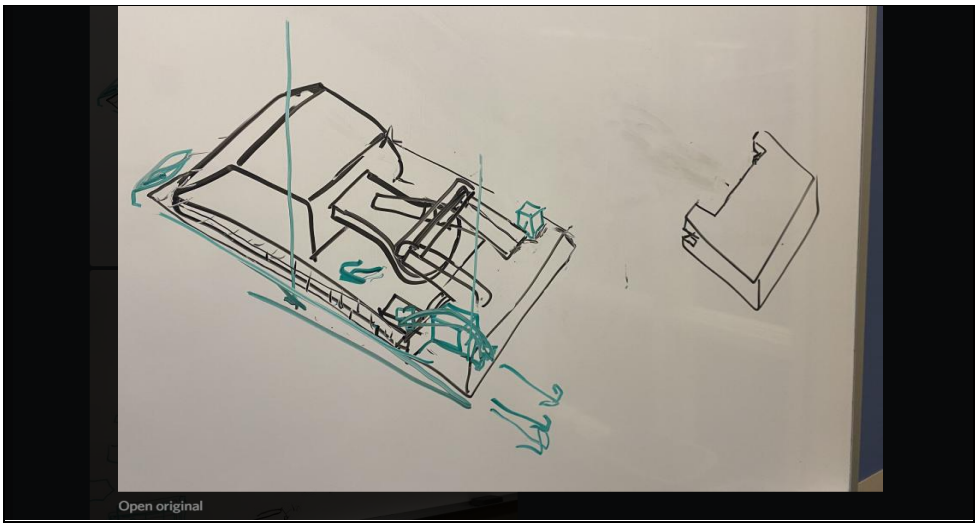

Figure 1: Sketch of the proposed prototype

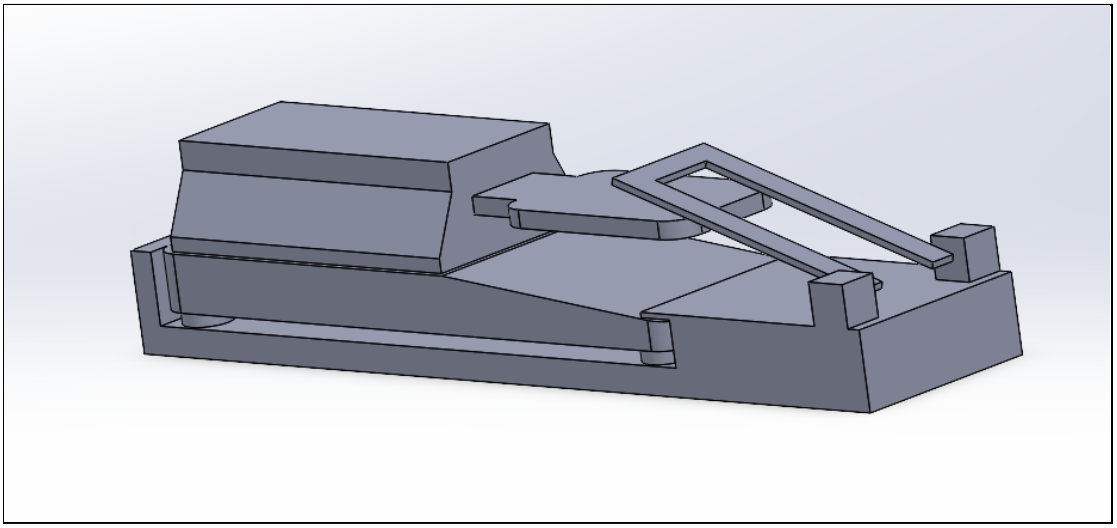

Figure 2: SolidWorks drawing of the proposed prototype

Outlined in the expected timeline, the proposition and design should take no more than 18 days, and the MATLAB programing of the arduino should take no more than 12 days, therefore this project is reasonable to be completed in the allotted time frame given to students, and complies with all of the project requirements outlined in the project handout.

Expected Results:

We expect to be able to build a full-sized and fully functional prototype during the period of this project. Although most of us have little or no experience with 3D printing, we believe that we have the ability to learn and implement it with our project within the timeframe. The project utilizes essentially everything we have learned from our labs, it is quite feasible for us to build a fully working prototype, especially since we already have a piano sustain pedal to work with. The only concern that we have is with the strength of the motor and its ability to provide a strong enough force to push down a weighted sustain pedal. If a single motor isn't enough, we would have to use two motors which would increase the cost and make the design slightly more complicated and possibly prevent us from achieving our expected goal of making a fully functional prototype.

Expected Timeline:

# of Task	Task Name	Duration	Start Date	Final Date	Predecessors	Resource Name	March 28	March 29	March 30	March 31	April 1	Apri
1	Brainstorm/Project Planning	3 days	3/26/21	3/30/22		Team						
2	Project Proposal	3 days	3/26/21	4/1/22	1	Team						
3	Gantt Chart	2 days	3/28/21	4/1/22		Team						
4	Team Charter	2 days	3/28/21	4/1/22		Team						
5	Aquire materials required	2 days	3/29/21	4/2/22	2	Team						
6	Matlab code	16 days	3/30/21	4/17/22	2,3	Team						
7	Edit Matlab code	3 days	4/6/21	4/19/22	4	Team						
8	Technical Report rough draft	7 days	4/7/21	4/24/22	5	Team						
9	Edit Technical Report	7 days	4/20/21	4/24/22	6	Team						
10	Technical Report	7 days	4/23/21	4/24/22	7	Team						
11	Create Presentation Video	3 days	4/25/21	4/26/22	8	Team						
12	Final PowerPoint/Presentation	3 days	4/26/21	4/29/22	9	Team						
13	Peer Review	3 days	4/27/21	4/29/22	10	Indiviual						
14	Presentation Feedback	3 days	4/30/21	4/29/22	10	Individual	due May 1st					

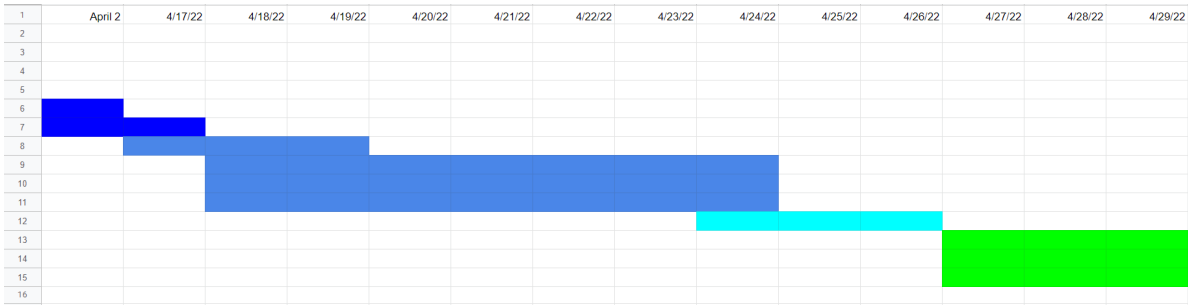

Figure 3: Gantt chart

Team Management:

Communication for our group is done through the online platform “Discord” and through texting. Through those platforms we can set up in-person meetings. An example of this was our first meeting at the Downtown Campus library.

As peers, we treat each other's ideas and concerns with care and respect. However we do have certain areas of expertise when it comes to sections of the project and of our research. For example, Karl Shaver has compiled a list of potential materials that can be used to build our solution, so naturally he created the budget table. The group has a democratic structure, which means that any group member is able to present their ideas to the group. During our first meeting, group members bounced ideas off of each other which led to our initial design. As a

result, all group members were involved in creating the initial design of the system. Though a democratic style of work may seem troublesome, we believe it is the best way to allow all ideas to be heard and for everyone to have an impact on the project.

Table 1: Team member responsibilities

Group Member	**Area of Expertise**
Karl Shaver	Budgeting and Construction of Mechanism
Matthew Hwang	Solid Works and design
Alex Naylor	Stepper Motors
Matthew Lombardoni	Construction of Mechanism

Budget:

Table 2: Prototype Budget

Component	**Cost**
Arduino UNO	$23
Arduino Motor Shield	$23
Single Stepper Motor	$14
Wood Bases	$6
Mounting Hardware	$12
3D Printed Base	$0
3D Printed Lever Arm	$0
Wiring	$8
USB Cable	$7
Interface Buttons	$5
Total	$98

The prototype budget shown in Table 1 addresses the costs of materials for development as opposed to the final retail cost of the product. Ultimate affordability is considered, simplifying parts of the design to cheaper options where possible without sacrificing integrity. This will ultimately also result in the cheapest possible projected price to an end user.

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