1) Problem Statement/Research Question and Background

1.1 Hippotherapy Overview

The American Hippotherapy Association defines hippotherapy as the use of equine movement by physical, occupational, speech, and language therapists in treating patients of various musculo-skeletal, neurological, and emotional disorders such as attention deficit hyperactivity disorder (ADHD), autism spectrum disorder (ASD), cerebral palsy (CP), and Down syndrome. In general, hippotherapy targets improvements in motor control, core strength, posture, visual-physical coordination, response timing and grading, and thought expressivity. In addition, patients are aided emotionally and psychologically through positive interactions with the animal itself, social interactions with other people, and a sense of accomplishment (“Hippotherapy”, n.d.).

1.2 Current Limitations of Hippotherapy

Although hippotherapy can be significantly beneficial to a wide group of users, it is currently inaccessible to many patients for two main reasons. First, hippotherapy is expensive: a typical hippotherapy session costs between 50 and 250 dollars per hour. This cost can quickly add up to a large amount, especially for those who wish to attend the sessions regularly. In addition, hippotherapy is only available far from urban centers. Because a large amount of empty land is required to train and maintain a stable of horses and to hold various trails, most hippotherapy centers are located in remote areas. This distance is problematic as many families have trouble finding time to travel to and attend hippotherapy sessions (American Hippotherapy Assoc., n.d.).

Some potential mechanical alternatives to hippotherapy exist in the market such as iGallop, Equicizer, REST, and Ridemaster Pro. Unfortunately, these devices all have issues that make them insufficient substitutes to hippotherapy. iGallop, Equicizer, and REST have very limited simulation of a horse’s motion, merely mimicking the periodic motion of a horse. They also do not simulate the riding experience of controlling a horse which is a crucial aspect of hippotherapy. Lastly, Equicizer and Ridemaster Pro do not adequately solve the problem of inaccessibility because of their high cost.

1.3 Problem Statement

We will develop a medical device that simulates both the motion of a horse walking on varied topography and the experience of controlling a horse. Our device will be safe for human trials and adaptable to different demographics.

2) Methods/Approach/Solutions Considered

Customer Needs	Functional Specifications
Safety	User-controlled stop function will stop the device within 2 seconds

	Stop button for non-user will stop the device within 2 seconds
	Pressure loss triggered stop will stop the device within 1 second
	Harness to protect users from falling can support users weighing up to 200 pounds
	Complies with FCC regulations and ASME, NEC standards
Accurate Simulation	3 degrees of freedom
	Accelerations of device match those of a horse by at least 80%
	Interactions between user and device achieved by using reins
Adaptability	Adjustable height supports users from 3 feet to 6.5 feet tall
	At least 2 different gaits
	Supports weights of up to 200 pounds
Ease of operation	Intuitive user-interface, including a console, that is rated at least a 7 out of 10 by users
	Well-documented user manual that is rated at least a 7 out of 10 by users
	Takes an experienced user less than 30 seconds to set up
Affordable	Bill of materials for the prototype is less than $1,800
Durability	Lasts 2 years when operated for 3 hours a day

3) Description of Final Approach and Design

Our final design includes a realistic back, a working rein mechanism, and a moving head to make using our device feel like riding a horse. Our device also performs two different horse gaits, walk and trot, to closely approximate the motion of a real horse. In addition, we have installed a variety of safety features, such as emergency stop mechanisms and a harness, to make our device safe, and a touchscreen to make our device easy to use.

2.1 Safety

Our most pressing concern was safety, which is paramount to the success of any device that humans interact with. To ensure that our device is safe, we designed three stop mechanisms that end all motion quickly in case of an emergency. We designed both manual and automatic stops, so that if the user or an observer feels insecure, he or she can stop the motion, and if the user falls without being able to manually stop the device, motion will be stopped automatically.

The first stop mechanism is a stop button placed in the front of the device that an observer standing next to the device can reach and use to stop the device, shown in Figure 1. Pressing the button will result in the motors stopping regardless of the micro-controller signals from the Arduino. In addition, in order to 'reset' the stop button, the button must be twisted, so there is no way to accidentally turn the device on again after pressing the button.

The next stop mechanism is a manual stop triggered by the user abruptly pulling both reins in the same manner that a person stops a horse. To simulate pulling a rein, we designed two spring-loaded sliding triggers to be installed on the left and right side of the horse head, shown in Figure 2. As the user pulls on the rein, the spring compresses and the sensor gets closer to the magnet and gives a reading that we interpret to find the proximity and stop the device.

Our third stop mechanism is an automatic stop function that stops the device if the horseback seat experiences a decrease in applied pressure. We placed a force-sensitive resistor pad on the horseback to detect the vertical force applied by the user on the seat, connected its output to a pin on our Arduino microcontroller, then developed a control algorithm based on the readings reported by the sensor. Thus, if a user begins to fall off the device will stop automatically.

Additionally, we purchased a surcingle on Amazon, and modified it to fit onto the device. The surcingle is strapped tightly to the back so that it will not slide, making it ideal for attaching a harness. We also included a lower-body harness that is loosely yet strongly attached to the surcingle, giving the users a full range of movement without creating other safety concerns.

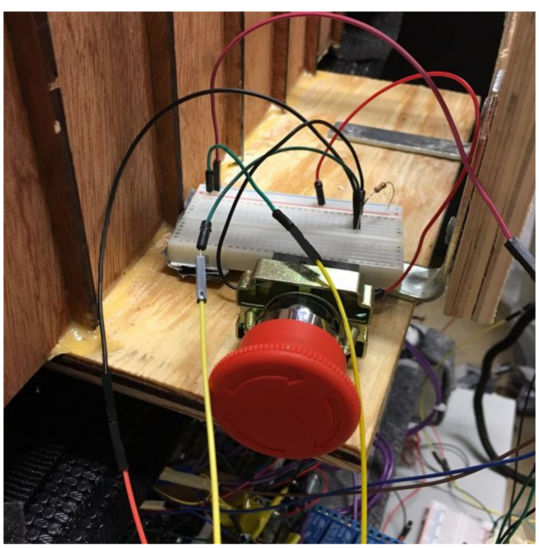

Figure 1: Emergency Stop Button

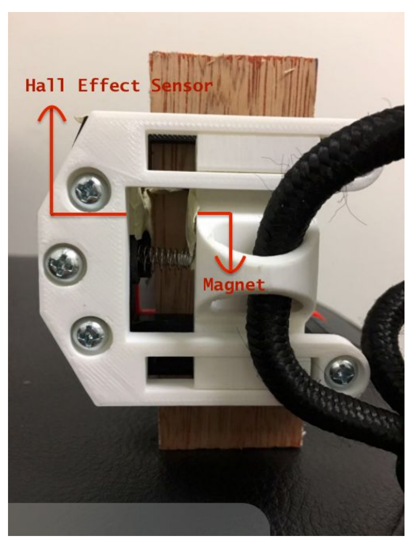

Figure 2: Rein Control Mechanism

2.2 Simulation

In addition to making our device safer, we also wanted to make it more like a real horse to improve its attractiveness and effectiveness.

We constructed a new back and head that better recreate the shape and the size of a real horse. In replicating the curvature of a horse's back, we traced the inner edges of a typical saddle by bending a copper wire along the edges. We designed our back to be a grid structure where plates on the xy-plane and the yz-plane interlock with each other, shown in Figure 3. This design allows us to use thinner plates of materials and still achieve a sturdy back that can accept weights of up to 200 pounds without failing. We then covered up this wooden structure with foam and faux leather to finish the back.

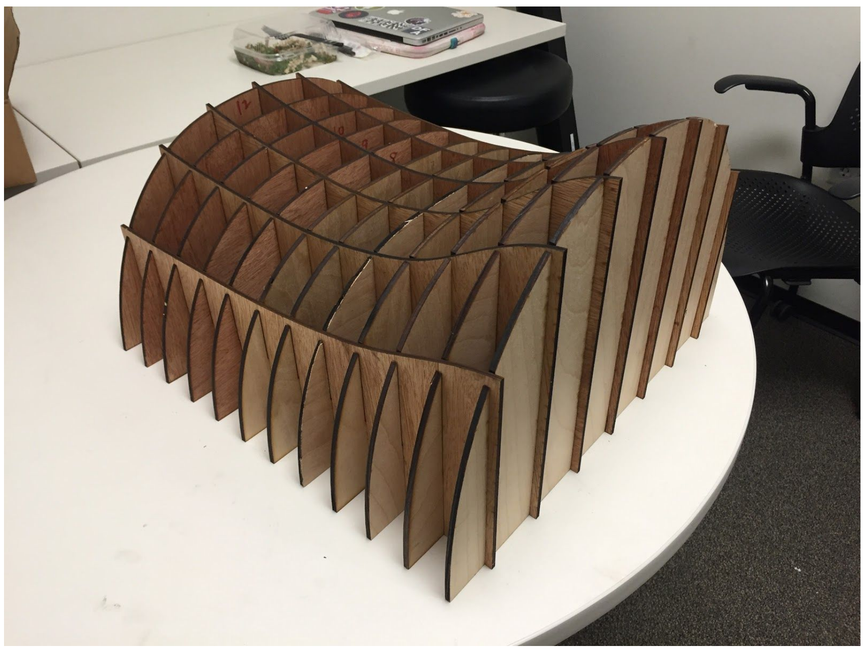

Figure 3: Wood panels of horse back

The head is glued to the neck, a length of PVC pipe, via a wooden rod, and is secured so that the head only moves when the neck moves. When the user pulls on on the right rein, the stepper motor will rotate the PVC pipe so that the head moves towards the right. Similarly, when the user pulls on the left rein, the horse head will move to the left.

As our device is built to simulate horse motion, closely matching the motion of a real horse is among the most important criteria in evaluating the device. However, the motion of a horse is difficult to quantify. We used accelerometers to acquire data from real horses, as we placed a phone at the base of the neck of a horse and recorded accelerometer data as it moved through various gaits. We then used this data to design our own gaits to closely mimic the motion of a real horse.

In our final design, we have two distinct gaits: the walk and the trot. While there are at least four different horse gaits, not every horse gait is equally used for hippotherapy. We used the walk and the trot because the two gaits are significantly different, and both gaits are also much gentler than a canter or a gallop, making them more appropriate for hippotherapy.

2.3 Ease of Use

While improving the safety and making better individual components are important for the device, so is making it usable for patients. This manifested itself in many ways, but in general we made the device more adaptable and easier to use. Many of these changes involved the Arduino, the microcontroller that we used to control the device.

We purchased a hydraulic scissor cart to adjust the height of the device, as shown in Figure 4. Making the height of the device adjustable makes our device more usable for users with different heights, as shorter users (particularly children) do not have to be worryingly high off the ground while taller users do not have to put their feet on the ground, which would make the device much less effective.

We also added a console, shown in Figure 5 with buttons that start and stop the device and transition between specific gaits. The home screen lets the user select their desired gait mode - walk or trot - via virtual buttons on the touchscreen, and lets the user start or stop the device, while also keeping track of the time elapsed since the user's current riding session began.

Figure 4: Hydraulic Scissor Cart

Figure 5: Console

4) Outcome (Results of any outcomes testing and/or user feedback)

We have not been able to perform rigorous testing on our device, but we plan to do so in the near future. We have had some children ride it at a design showcase, and their feedback was universally positive. In addition, we have tested the device ourselves to make sure our features work as intended. The finished device is shown in Figure 6.

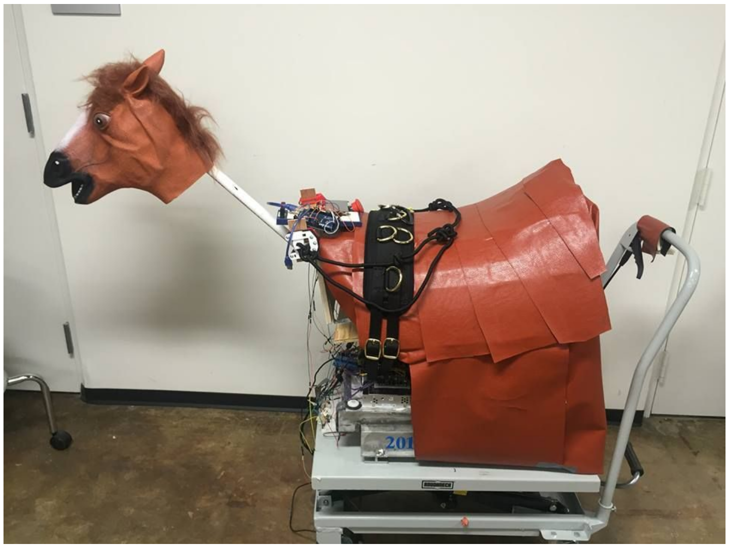

Figure 6: Final Device Side VIew

5) Cost (Cost to produce and expected pricing)

One of our design criteria is to make the mechanical horse affordable within the tentative cost of $1,800. Since this was a continuation project from last year, we first analyzed the bill of materials (BoM) from last year in Appendix 4.1. The BoM added up to $1,295.18 for the existing prototype, and it was only for one unit. For example, an acrylic box for containing the electronics cost $46.95 inside the BoM, while in reality during production, the unit price for the acrylic box is likely to be less than $5 for 10,000 or more units. Thus, the $1,800 price goal is well within reach for our team.

6) Significance

Our device has the potential to revolutionize hippotherapy, allowing more patients to reap its benefits by overcoming the accessibility and cost barriers. It is suited for both residential and clinical use, and after rigorous testing we expect to be able to bring our device to market.

7) Acknowledgements and References (not included in 6 page maximum)

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