RESNA 2019 Student Design Competition: Design Brief

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ReACH: Rehabilitation for Augmenting Children's Healthcare

Background

Cerebral Palsy is a disorder with a range of symptoms characterized by physical and mental impairment due to abnormal brain development. Approximately 500,000 children and adults are affected, with about 8,000 babies and 1,200-1,500 preschool age children being diagnosed each year. Previous work has shown that a virtual reality therapy game coupled with a social robot can improve the efficacy of rehabilitation outcomes on individuals with or without cerebral palsy (Xu et al. 2018). Our prior research focuses on using socially interactive robot as a therapeutic coach for children with cerebral palsy in rehabilitation scenarios. Building upon our previous studies, this new design project focuses on developing a real-world kinematic reaching game. The ReACH game is designed to further rehabilitation opportunities in the home environment. The goal of our design project is to provide a tangible learning system for patients with motor disabilities. It will contribute to validating the usefulness of robots in rehabilitation therapy sessions as well as provide additional methods for understanding the interactions between children and assistive robots.

Project Description

In previous studies, we have evaluated the effect of using a socially interactive robot on enhancing human motor performance when engaged in a virtual reality game; however, it is unclear how the effect on motor performance would change when a reaching task is performed with physical objects in the real-world environment. Thus, our goal in this design project is to further evaluate human motor performance in a real-world reaching task. Major symptoms of cerebral palsy include poor coordination, difficulty with movement, abnormal reflexes, and difficulty maintaining posture. The ReACH game is designed to exercise everyday motions through repetitive arm movements. The main hardware components of this system include a socially interactive robot, NAO, a structural frame, and two physical targets. The game design involves the participant sitting under the structural frame with two targets hanging from the top bar, such that the participant is able to reach and touch the targets reciprocally. During game play, the participant is tasked to first touch the target to their right and then the target to their left in a repetitive fashion. The robot then provides both verbal and gestural feedback, which is adapted based on the participant's movements during completion of the task and time it took to complete the movements.

Design Process and Final Design

There were various design considerations made throughout the process. The first prototype consisted of utilizing a kid's toy limbo set and PVC piping as the structural frame and touch sensor targets made of wooden circles covered in copper foil and sealed with electrical tape. The limbo set was chosen so that the height of the frame could be vertically adjusted based on the participant's individual arm length and height. For horizontal adjustability, sliding cardboard rings (as shown in Figure 1) were utilized as attachments between the targets and top bar of frame. The ability to vary the target's position in space both vertically and horizontally was due to the intent to work with both children and adults.

Figure 1. First Prototype of Target

Figure 2. First Prototype of Frame

Development of Structural Frame

Following the construction of the first prototype, we wanted to prioritize design improvements in terms of stability, adjustability, and portability. In order to select a material to construct the frame, we created a design matrix to compare several materials.

Table 1: Design Considerations of Different Materials

	Wood	Metal: Aluminum	PVC Pipe
Strength	High	High	Medium
Load Capacity	Medium	High	Low
Portability	Low	Medium	High
Easy to Assemble	Low	Medium	High
Costs	Low	Medium	Low
Safe in-Home Environment	Low	Low	High
Durability	High	High	Medium
Aesthetics	Low	High	Medium
Adaptability	Low	Medium	Low
Stability	Medium	High	Low

The decision was to utilize aluminum tubes from Metal Supermarkets in Atlanta. Aluminum metal prioritized our need for strength and stability, while still using a relatively lightweight material. The design requires several aluminum square tubes, aluminum angles, and aluminum base plates. The parts are connected utilizing nuts, bolts, and washers. After initial construction of the frame (Figure 3), the size of the base plates was increased for greater stability. To incorporate portability, the base plates of the frame was designed to have caster wheels, with brakes (Figure 4).

Figure 3. Frame Build

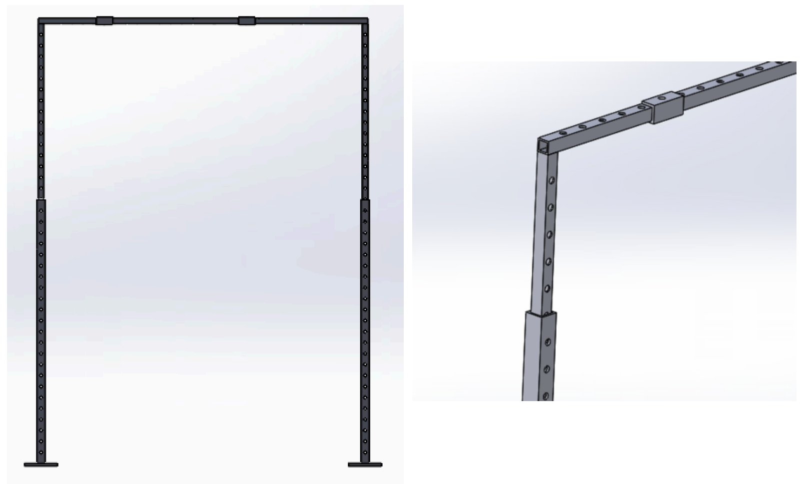

Figure 4. Computer Aided Model of Frame

To adjust target position vertically, the frame is designed to have telescoping aluminum tubes. To adjust the target position horizontally, the top bar of the frame has holes drilled every two inches in order to change where the target is attached. The entire width of the frame measures to be sixty inches and the height of the frame ranges from forty-eight inches to seventy-eight inches. These measurements are based on calculations utilizing average arm lengths of children, women, and men. Calculations were done based on the height of the chair utilized and the targets positioned thirty degrees from the vertical centered on the participants non-dominant shoulder. Additionally, a small storage casing is attached to the side of the frame to hold the Arduino and electronic components relevant to the touch sensors. Since we plan on testing ReACH game with children further safety design considerations were made. The longer ends of the bolts are to be cut off and all sharp edges will be covered with rubber. The entire frame is to be painted matte black for better recognition when using camera image.

Development of Targets

There were several design tradeoffs that had to be considered concerning the material, size, and form to be considered for the development of the targets. Our analysis resulted in selecting a cube form rather than a sphere due to it being easier to attach to the frame and being easier to construct. In order to minimize cost and time, we decided to laser cut pieces and assemble them to construct a cube. In regard to general human behavior, we discovered that participants were more likely to grab a spherical form versus being more likely to touch or tap a cube form. We thus decided to design the physical targets in the ReACH game with both five inch and three-inch sized cubes. The decision on the size was based on children's average hand sizes. We selected the material of the target to be a wood composite material, since the material is low-cost and lightweight yet sturdy. The targets were attached to the frame with a bolt, nut, and washer going thru the top face of the cube.

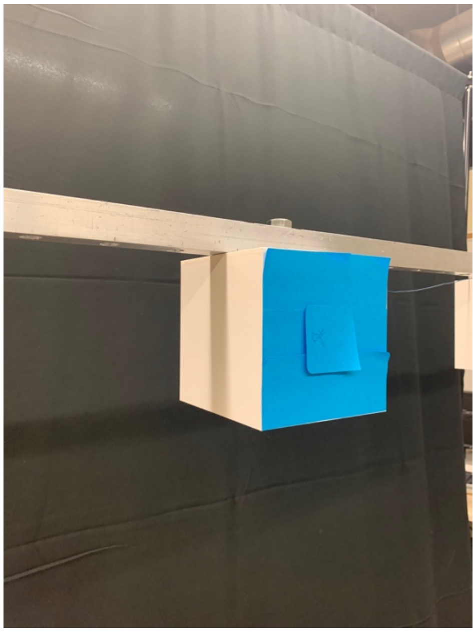

Figure 5. Target Build

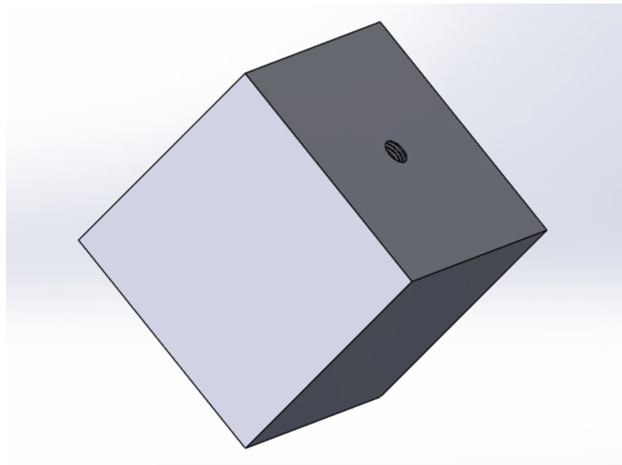

Figure 6. Computer Aided Model of Target.

The primary costs of this build are for the structural frame's casters and aluminum parts and the target's wood composite material.

Integration

Once the structural frame and targets were constructed, they were integrated with software and electronics to complete the development of the ReACH game. The two targets were covered with copper conductive tapes and connected to a capacitive touch sensor (Figure 7). An Arduino board was used as microcontroller to log the time when the target was touched or released (Figure 8). The software was integrated to work with a Microsoft Kinect. The Kinect camera tracks the user's arm movements in real time and records the participant's kinematic data while the participant played the game.

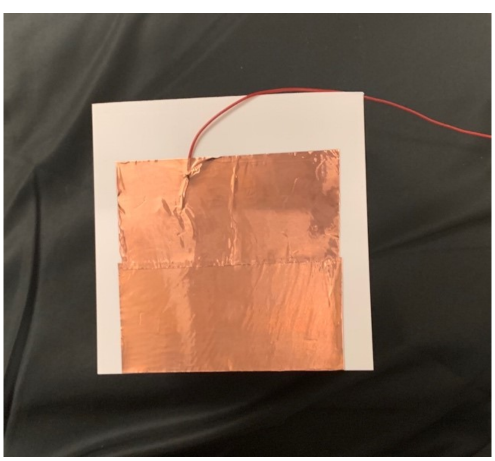

Figure 7. Targets covered with conductive tapes

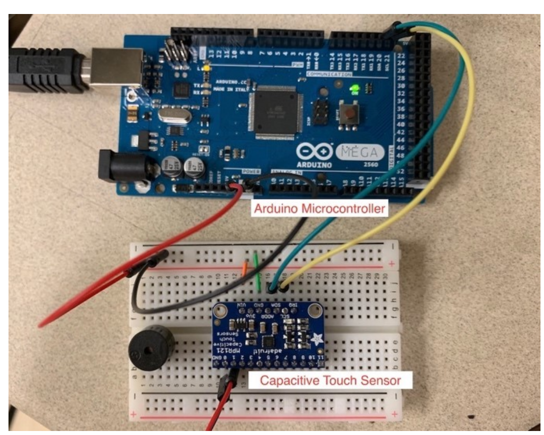

Figure 8. Arduino board and capacitive touch sensor

Analysis of Data

A pilot study was conducted to evaluate the usability of this device. Data collection focused on movement time (MT) of the users. The participants were asked to reach for two targets reciprocally. One target was located outward at 30 degreed and the other target was located at 30 degrees inwards. Movement time was defined as the difference in time between when the first target was touched and when the second target was touched. Each subject was asked to complete this reaching task ten times, and the average movement time was computed for each participant. Table 2 lists average movement time for each participant. The comparison of groups' average movement times shows no significant difference in movement time between dominant hand and non-dominant hand (Figure 9). This preliminary result provides us a baseline movement time for users when completing a basic reaching task with this setup. Furthermore, it gives insight into future integration with the SuperPop system and NAO robot.

Table 2: Results – Average Movement Time (Average, Standard Deviation)

Subject	MT Dominant Hand (ms)	MT Nondominant Hand (ms)
1	582, 58	604, 084
2	691, 97	752, 142
3	487, 74	437, 44
4	707, 111	621, 146
5	654, 77	602, 45
6	558, 81	566, 64

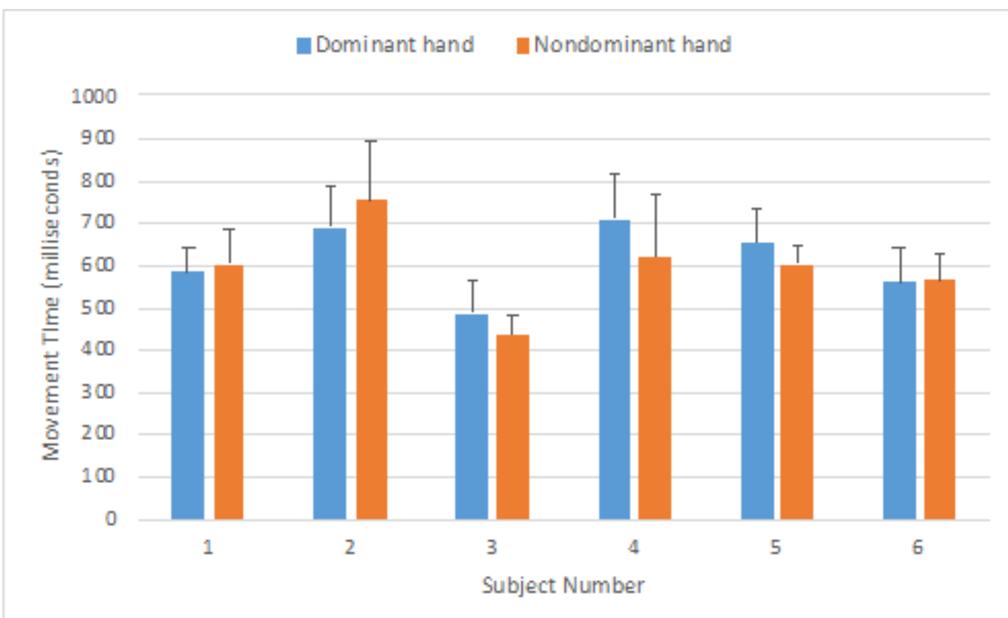

Figure 9. Comparison of movement time between dominant hand and non-dominant hand

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