University of Ottawa
Bionics Team

RESNA 2019 Design Brief

Problem Statement/Background Information

Figure 1: Bottom: Sarah Horton, Cecilia Lou, Myriam Bonneville, Joshua Ching; Top: Hridyansh Sharma, Simon Tremblay, Joshua O'Reilly, Charles Choiniere, Jonathan Horton; Not Pictured: Zenab Bhamgerwala, Cédric Bohémier, Rachel Cohen, Claire Doris, Habiba Hegazy, Rapahelle Jean-Baptiste, Daniel Pachkine, Samuel Saint-Fleur, Daphne Stone, Austin Tambakopoulos, Tyler Tsang, Rebecca Villemaire, Sherry Wang, Reese Wunsche.

uOttawa Bionics is a multidisciplinary engineering team developing mechatronic and bionic devices to enhance quality of life and rehabilitation. The team is currently developing a 4 degree-of-freedom hip-mounted exoskeleton to assist in the rehabilitation of stroke patients with reduced muscular strength (see Figure 2). The torque provided by a motor located at the hip supplements the user's movement, allowing them to continue normal activities. It gradually decreases the provided torque until the user has fully recovered.

Figure 2: uOttawa Bionics' Device.

Generally, actuation feedback is achieved using a combination of gyroscopes, accelerometers, encoders and force sensitive resistors, and a precise control system to generate a controlled movement at the joint. Robotic devices can create reaction forces within the user's joint. These reaction forces can lead to dislocation and long-term cartilage damage, or create pressure sores on the skin at the interface with the device [1].

The following is an overview of two pre-existing hip exoskeletons:

Honda Stride Assist

The Honda Stride Assist was designed to assist elderly adults and other individuals with mobility impairments affecting gait (see Figure 3) [1]. Weighing 6.17lbs, it provides active support at the hip in flexion and extension using two brushless DC motors and a rechargeable lithium ion battery. It provides a maximum of 6Nm of torque. A study conducted in 2015 with 50 subjects, showed that the SMA "significantly impact[ed] spatiotemporal gait parameters in individuals with chronic gait impairments due to stroke" [1].

Figure 3: Honda Stride Management Assist (SMA) Device [1].

PH-EXOS

This Bowden-cable and servo motor actuated exoskeleton was designed to assist individuals with various walking impediments (see Figure 4). It is a 6 DOF exoskeleton. The onboard FRS sensors measured the contraction of the rectus femoris and biceps femoris muscle [2]. A study conducted in 2014 using a healthy subject showed the device could be effective at reducing the effort required for walking [2].

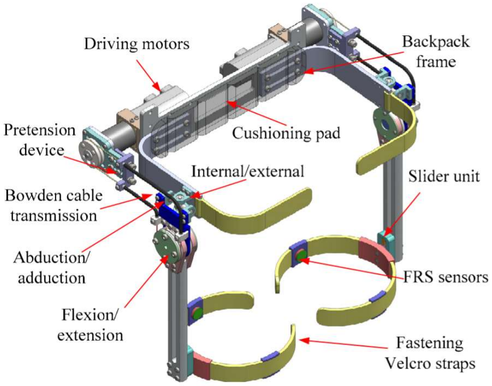

Figure 4: PH-EXOS Device [2].

Methods/Approaches to Solution

Since the beginning the project, three major design changes have been made. First, initial designs used hydraulic actuation, however further analysis determined the pumps required to provide the desired power would be too heavy. Electric actuation was selected as a simpler and lighter alternative. Second, the sensor system initially included a footswitch to determine the toe off phase of the user's gait cycle. However, this option meant the device extended to the user's foot. A series of 3 accelerometer-gyroscope packs were selected instead as a more elegant solution. Third, a control system will be like the one described by [3] and [4], using a Kalman filter to reduce noise and integration-related drag. The final design includes a machine learning algorithm that also compares the measured limb positions and accelerations with data collected from individuals with a healthy gait, to appropriately control the motor. Fourth, multiple components had originally been 3D-printed, however this method of manufacturing was determined to be inadequate. For instance, the hinge pieces that allow for passive abduction and adduction of the leg had to be cut out of aluminum due to high friction found while testing the original 3D-printed polymer hinge.

Description of Final Approach and Design

A CHF-25-160-2UH Harmonic Drive interfaces with an EC90-Flat Brushless Maxon Motor at its input, and a thigh piece fixed to the user's leg above the knee directly attached at its output (see Figure 2). As such, only the flexion and extension motions are actuated. A hinge allows abduction and adduction; however, this motion is not actuated.

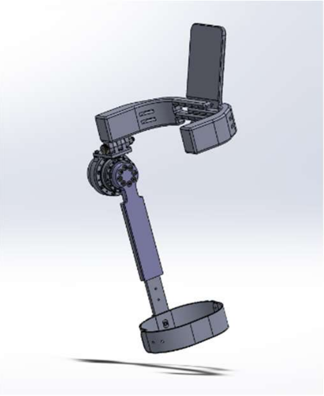

Figure 5: uOttawa Bionics' hip mounted exoskeleton with only the right leg.

The red component in Figure 6 holds the Harmonic Drive. The thigh pieces were manufactured out of a high strength polymer (Ultem1010). Drawings of the parts with dimensions relating to the HD product are provided. Finally, simple components such as the top piece of the adaptor shall be made in house in the Brunsfield Centre.

To ensure the suit fits the average member of the population, the leg length as well as waist and leg widths are adjustable. Anthropometric data was obtained from literature. The range for the thigh length was set between 43-73 cm, and hip breadth between 22.5 and 51.8 from values given in [5]. Hip breadth is varied by adjusting the selected screw holes on the back piece and the fingers on the piece that are secured to the waist.

Two sensor packs, each comprised of a 3D accelerometer and a gyroscope, will be placed along the thighs to determine the orientation of the limbs, and a 3D accelerometer will be placed on the lower back to identify heel contact events using the methods described by Mansfield and Lyons in [6]. A Raspberry Pi reads the data acquired from the sensor packs and sends the information via WiFi to a desktop computer for offline analysis.

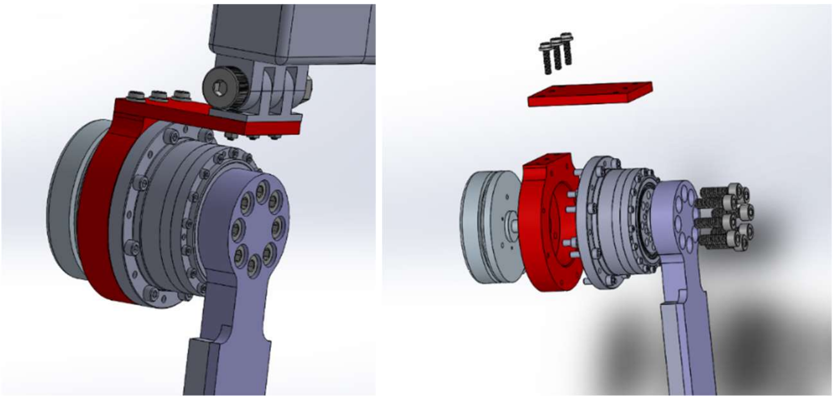

Figure 6: Close-up of the hip joint

Cost

The total cost for the device is found in Table 1. The total cost to manufacture the device is $ 6,249 CAD, or $ 4,683 USD. This includes expensive manufacturing costs from one-off purchases; if mass produced, the unit price would drop drastically.

Table 1: Cost analysis

Item	**Cost**
Padded suspenders and belt (Canadian Tire)	$120
Arduino Nano, general electric equipment and USB cables (Amazon)	$128
Wire, domain and website, gyroscopes, linear potentiometers and accelerometers (Variety of sellers)	$101
Raspberry Pi and Arduinos (Amazon)	$89
Harmonic Drive, Maxon controller, Maxon motor and HAL sensor	$4780
Wireless Module and SD cards (Amazon)	$66
Aluminum for motor support, hinges, and leg pieces	$138
Manufacturing motor support components	$622
3D Printed Components (printed at local Makerspace, Nylon & Ultem 1010)	FREE
Screws and other fasteners	-$205
Total cost	$6249

Outcome

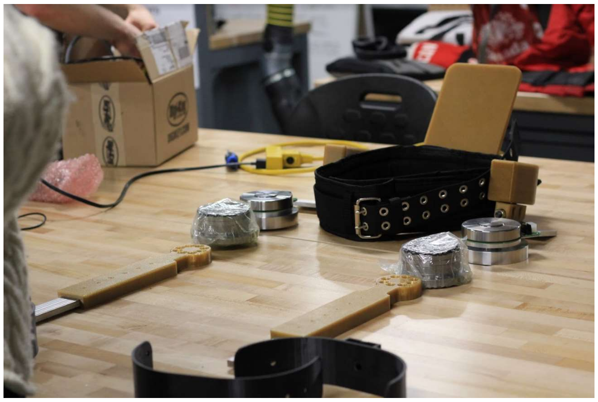

Figure 7: A deconstructed image of the physical device.

To validate the design, consultations were conducted under approval from the University of Ottawa's Office of Research Ethics and Integrity (File Number H-12-18-1382). The consultations took two forms: an online survey and in-person interviews. Using community contacts, face-to face interviews were arranged with individuals with mobility impairments (stroke, injury, spinal injuries, etc.) as well as their caretakers (nurses, family members, doctors, physiotherapists, etc.). All potential participants (both caretakers and individuals with mobility impairments) were given the option to either do an in-person interview or participate in an online survey, based off their availability or personal preference.

The interviewed individuals had never previously used the proposed device. The interviews focus on their experiences with mobility impairment, rehabilitation and exoskeletons.
The online survey was composed of very similar questions to the in-person interviews, without the option of physically interacting with the device. Instead, they were asked to provide feedback from images and videos.

At the time of submission, 2 individuals with mobility impairments, 4 caretakers were interviewed (2 family members, a physiotherapist and a medical doctor). General impressions were positive. One woman who had experienced a stroke was excited by the prospect of ascending stairs, a motion she has struggled with since her accident. To gain more physiotherapy in the months following her stroke, she mentioned she would sit at the door of the rehabilitation gym in the hospital in case another patient cancelled their appointment. Exoskeletons would help patients receive more care without the need for such extreme practices. One caretaker discussed the financial pressure caused by the cost of rehabilitation technology as an important barrier to many families, justifying the low-cost of the proposed device. None of the participants had any experience working with exoskeletons, indicating a lack of access to this promising technology.

The provided feedback will also be used to guide the design of future iterations of the device. For example, many participants expressed concern with regards to the bulkiness of the 3D printed hip pieces. More consultations will be carried out in the following months.

Significance

In the United States, stroke is the number one cause of severe long-term disability and of the 15 million people that experience a stroke each year worldwide, 5 million will be left with a disability [7]. These may include paralysis or movement problems, sensory disturbances, and language problems [8]. Exoskeletons are a form of wearable technology that aims to enhance or aid human motion. They are a valuable tool in assisting in muscle training and regaining independence after a stroke. Exoskeletons encourage neuroplasticity, a reorganization of neural connections in the brain throughout an individual's life, by providing patients with sensory input and learning through repetitive and intensive movements while reducing the labor required by caretakers. These devices are portable and can be used in day-to-day life, outside of a clinical setting [1].

In an aging population, there is a growing need for technology to assist in mobility. uOttawa Bionics' device answers that need.

References

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