DEVELOPMENT AND HUMAN PERFORMANCE EVALUATION OF CONTROL MODES OF A LIGHTWEIGHT SMART-ASSISTIVE ROBOTIC ARM (SARA)

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INTRODUCTION

There are a quarter of million Americans that are living with spinal cord injuries. Every year 10,000 to 12,000 estimated spinal cord injuries every year in United States [1-3]. Partial or full paralysis may result depending on the level of spinal cord injury. The focus of this research if towards the C5 to C7 level of spinal cord injured population. These individuals with limited strength and mobility require assistive devices to improve quality of life.

There is a gap where the technology transitions from a simple-assistive device to full exoskeletal body suits. Most of the devices are being developed for people with amputations. This device would increase individual independence and hence quality of life. The device targets individuals with spinal injuries from C5 to C7.

BACKGROUND

Assistive robotics includes a large variety of devices created to help people with limited mobility in their daily lives. Some of these devices are relatively simple such as the reacher [4-9]. Some are more technologically advanced like wheelchair robotics [10-12]. Prosthetics have been revolutionized by robotic arms [13-17] leading to full body bots [18-22]. All of these robotic devices are generally very bulky and require high power to operate. Some of these devices are shown in figure 1.

The project focuses on a specialized group of people with severe spinal injuries (C5 to C7). X is a participant and a client. As a result of an automobile accident, X sustained an incomplete C5 spinal cord injury. X has limited arm and very limited hand functionality. X uses a wheelchair, has poor balance, and is unable to reach objects at a distance (e.g., on the floor, counter top, book shelf). This limitation to reach common, lightweight everyday objects, such as cans of soda, CDs, books, or a box of tissues, negatively impacts the quality of his life. X has expressed the need for a simple, lightweight, voice-controlled mechatronic device that he could use with his limited arm functionality. The device would be conformably supported by a hand/arm passive configuration. X would use his available musculature to direct the device with an end-gripper to the object, and then issue a voice command to pick up the object. He would finally bring the reacher with the object to the desired location (e.g. his lap or a table).

DESIGN SPECIFICATIONS

In collaboration with an occupational therapist we established X's range-of-motion, specific movement patterns associated with reaching and lifting, and maximum weight lifting limits and carrying capacity. For this discussion it should be noted that X could lift 2.5 pounds. Hence the combined weight of the reacher device and object to be lifted must be less than or equal to this weight. The length of the reacher must enable X to reach objects on the floor, a table, or shelf and most critically; utilizing his unique range-of-motion and residual functional capabilities, pick and place objects it in a desired location.

METHOD

A prototype "voice-activated, ultra-lightweight mechatronic reach-assist device" has been designed and built. An inexpensive manual reacher gripper was purchased and modified. The total weight of the device is less than one pound. The end-effectors are flexible rubber suction cups. The manual trigger mechanism used for opening and closing the gripper was removed and replaced by an electric linear actuator linked to the band springs which are attached to the suction cup which forms the gripper.

A voice recognition chip identifies three simple voice commands; (1) Max (the unit's name – is a keyword that initializes the system so that the voice recognition chip awaits further command words), (2) close (a command word that closes the gripper by activating the linear actuator), and (3) open (a command word that opens the gripper by releasing the linear actuator [23]).

The device was tested by X as a participant and a potential user. The prototype device satisfies the project's design objectives and the laboratory trials have provided valuable data regarding the human/device user interface, ergonomic as well as communications. Figure 2, below, shows a close-up of the prototype voice-activated [24] reacher, named MAX. The sequence of images in Figure 3 shows X using the device to pick up a cell phone from the floor.

FIGURE AND TABLES

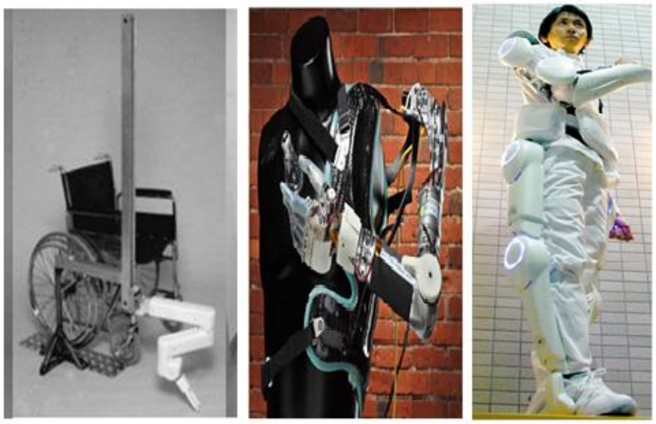

Figure 1: Showing different assistive devices

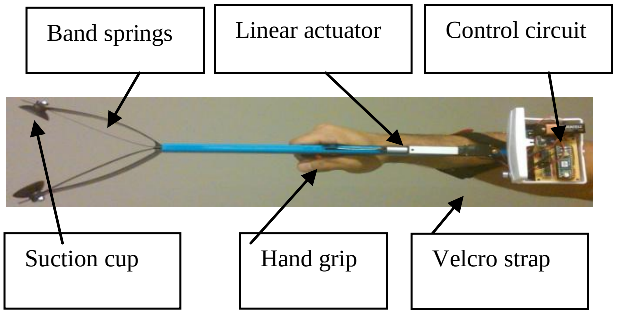

Figure 2: This is the current prototype voice-activated reacher. The hand grip is for stability. The control circuit pack rests on the forearm. A Velcro strap secures the reacher to the forearm. A linear actuator opens and closes the gripper assembly

(a) Cell phone falling

(b) Moving to pick up the cell phone using reacher

(c) Using voice commands X controls the opening and closing of the gripper to secure the cell phone

(d) X places the cell phone on his lap and then commands the gripper to open releasing the cell phone

(e) Success

Figure 3: (a) through (e) shows X dropping a cell phone then using the voice-activated reacher to pick up the cell phone and place it onto his lap

COMMENTS ON DESIGN

The prototype demonstrated the essential feasibility of the device and its usefulness for X. The simple gripper assembly is adequate for lightweight objects X specified as his target objects. The reacher length is adequate for the range-of-motion, positioning, and lifting requirements specified by X. The control circuit pack can be significantly reduced in size and cost. The prototype used a proto-board and components purchased at unit costs and while trying to stay as small as possible. We made no effort to significantly reduce the physical size of the circuit and battery pack or identify the least expensive electronic components. The linear actuator is relatively expensive and we will be working to identify a less expensive actuator that can deliver the necessary performance.

We have identified the design modifications necessary to modify the commercially purchased manual gripper for enhanced voice-activated functioning. The battery pack and control circuit pack with microphone can be designed so that they fit inside the reacher's frame.

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