Flex Array (Louisiana Tech University)

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Abstract

According to the National Spinal Cord Injury Statistical Center, NSCISC, approximately 117,500 individuals in the U.S. are spinal cord injured and have quadriplegia (2012). As a result, rehabilitation hospitals nationwide work diligently to fit individuals with assistive technology products specific to the end user's need. In addition, occupational therapists have been able to identify many mobility needs the end user encounters that have not been addressed by current assistive technology drive controls (TIRR 2013). The majority of current drive controls, presented to people with quadriplegia, are switched drive controls, which do not allow the driver to operate his/her wheelchair with the 360 degrees of control that our proportional drive control allows. This paper introduces a new device called Flex Array, a proportional drive head array that has an easy user interface, reduces user fatigue, universal DB9 connector, and low profile design giving the driver a better mobility experience.

Introduction/Background

In 2012, the NSCISC stated that approximately 250,000 people in the U.S. are spinal cord injured, and about 117,500 (47%) of the spinal cord injuries resulted in quadriplegia (2012). Quadriplegia can be caused by injury or illness which results in loss of mobility and sensation in all or part of the person's limbs and/or torso (Quadriplegia.). Quadriplegia affects the physical limitations people have over their body, but it does not necessarily restrict access to their environment. Individuals with disabilities use assistive technologies in order to perform functions that might otherwise be difficult or impossible. As assistive technologies become more sophisticated, people with quadriplegia are becoming more self-sufficient, and the quality of life for these individuals is continually improving.

Flex Array, the drive control designed for this project, continues the growth in assistive technology and introduces drivers to an improved design for controlling their power wheelchairs. This drive control allows the driver to have 360-degree control of the wheelchair while reducing user fatigue compared to previous products, thus improving the individual's ability to maneuver through various environments. Flex Array promotes independence and an improved quality of life for end users.

Problem Statement

Individuals with quadriplegia have limited mobility when maneuvering through various environments. Many patients with quadriplegia are compelled to use existing devices such as sip-and- puff, chin control, or switched head array, which are less friendly to use. The objective of this project is to design a head array that has proportional control, provides a wide range of movements, and has little fatigue on the end user. Some of the features that existing drive control devices lack, according to occupational therapists at TIRR Memorial Herman (Houston, TX) are low cost, proportional drive, and ease of use (TIRR 2013). Our goal was to assess these unmet needs in our head array drive control.

Design and Development (Methods/Approach)

Proper research was performed at locations such as TIRR Memorial Hermann Rehabilitation Hospital, and the focus was to understand the unmet needs of real world users. The occupational therapists at TIRR supplied the criteria that our device needed to meet, so the end user could have a great experience using the device. The other influential immersion we performed was located at Switch-It, Inc. in Houston, Texas. Andrew Parker, Vice President, mentored us and was our main source of knowledge in understanding the development of drive controls and the standards that the device needs to meet (2012). Merging the information from the immersions along with our engineering backgrounds was pivotal in the development process of the Flex Array design because we incorporated the end user's needs with the design and programming of the device.

How we chose the sensors:

A variety of potential sensors was researched that could hold the solution for our concept and device. Table 1 shows the criteria considered the most important for our sensors based on our immersion and user needs.

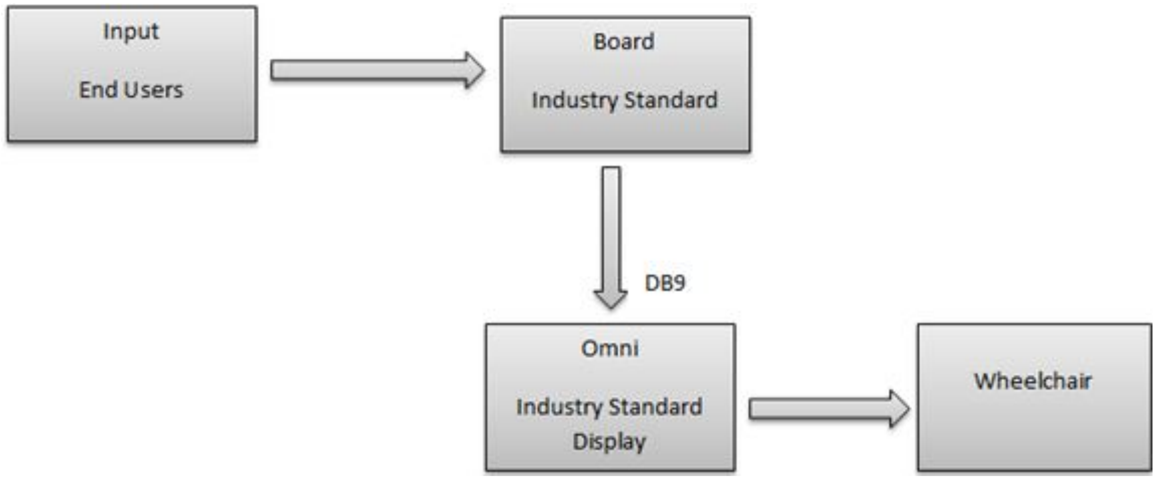
		Sensor Alternatives					
		Pressure Transducer		Flex		Zero Touch Proximity	
Criteria	Importance Weight (%)	Rating	Weighted Rating	Rating	Weighted Rating	Rating	Weighted Rating
Switch Control	1	0	0	0	0	5	0.05
Proportional Control	50	5	2.5	5	2.5	0	0
Low Cost	9	2	0.18	4	0.36	2	0.18
Ease of Use	20	1	0.2	4	0.8	3	0.6
Low Maintenance	20	4	0.8	3	0.6	4	0.8
	100		3.7		4.26		1.63

Decision Matrix

Flex sensors gave promising results after preliminary testing compared to proximity and flow sensors while being cost effective. Therefore, we chose flex sensors for the drive control.

a. Community board

An industry standard community board was used to implement the flex sensors for the head array system. Three flex sensors were soldered to the industry standard community board to be individually used for forward, left, and right movement. The industry board connected to the Flex Array that is connected to the power wheelchair display, and the display is connected to the actual power wheelchair. The output digital port, after the analog to digital conversion, was assigned to control the pulse width modulation (PWM). The PWM updates the DC motor on the power wheelchair to adjust for the change in flexion given by the end user. The adjustment includes speed and direction. Figure 1 illustrates how the device works.



How the Flex Array works

b. Programming

The community board was programmed with embedded C to execute the movement of the power wheelchair. This an industry standard program used in many applications. Programming adjusts the sensitivity of the Flex Array for direction and speed.

c. Designing the Physical Head Array

The final prototype, shown in Figure 2, was designed to accommodate the human head shape and proper location of sensors. The headrest has a slanted middle section to accommodate for the round feature of the skull. The slant allows for the occipital bone to rest on the Flex Array while not actuating the sensor. The sensor the user must tilt their head slightly back to actuate the sensor and move the power wheelchair in the forward direction. The Flex Array incorporates a thin curved band that houses the sensors that activate the chair to move right and left to incorporate a 'sleek design' to the control, which was outlined by the occupational therapists. This band allows the user to drive the wheelchair where they are looking by activating the sensors.

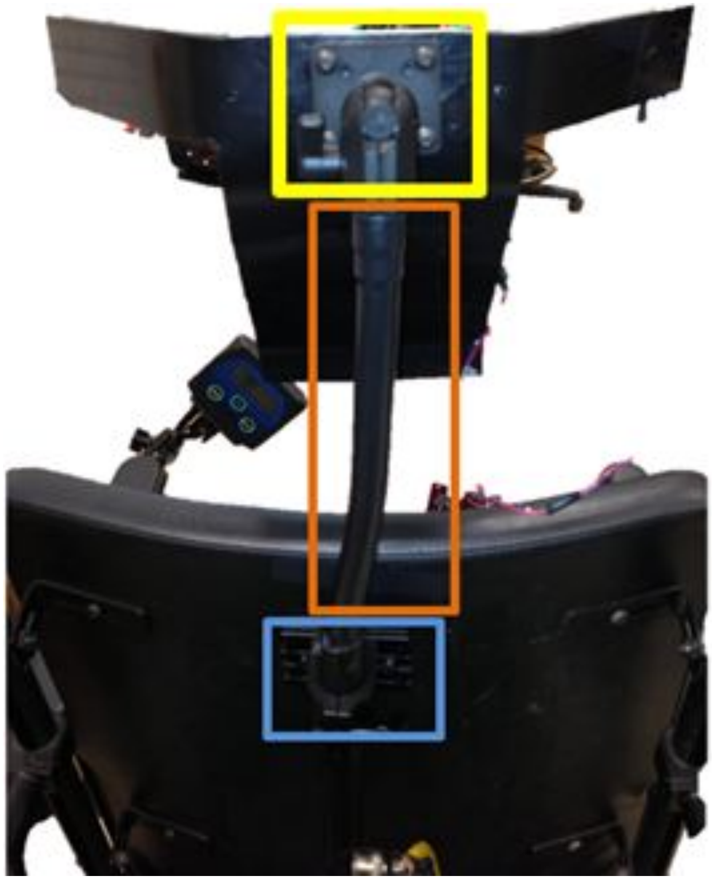
Front view of final prototype, Side view of final prototype

d. Fabrication

The padding used to house the sensors in the final prototype is an approved padding for existing assistive technology drive controls. The basic shape of the device is made from a 1/8 inch thick plastic sheet. This plastic sheet was cut, heated, and molded into the shape of the array. Next, a layer of padding with foam backing was adhered to the plastic. The sensors incorporate well with this schematic because our sensors need to flex to activate the wheelchair. A force amplifier was placed on specific areas of the sensor to focus the user's force, but the padding allows for flexion. The last layer of padding covers the sensors, force amplifiers, wires, and first layer of padding. This schematic allows the sensors to be encased within a material, so the sensors cannot move or become unattached to the community board. The final device cover is made with an approved fabric as well. The cover is handmade, and the material is hypoallergenic.

e. Mounting

The mounting hardware created for the Flex Array was created with existing mounting that is standard for most head drive controls for wheelchairs. Many end-users' heads will be in different locations depending on their condition when they sit in a wheelchair. The gooseneck, shown in Figure 3, makes the Flex Array to be moved in any position that will accommodate a user.



Yellow box: this joint allows the Flex Array to be adjusted to the angle most comfortable for the end user. Orange box: this gooseneck allows the Flex Array to be placed in the area most comfortable for the end user. Blue box: this joint allows for the Flex Array's height to be adjusted specific to the end user.

We have successfully designed, programmed, and built a proportional drive control head array that connects to power wheelchairs, giving the driver improved steering control to maneuver through daily life.

Youtube at http://youtu.be/ktVhwPhFSUQ

Evaluation and Results

The Flex Array prototype was tested based on standards taken from ISO 7176-14 document. This testing was to ensure feasibility and quality of the drive control; testing also ensured that the Flex Array met the specifications and unmet needs that we wished to accomplish. The wheelchair was tested by the group members and re-programmed to fix the required touch sensitivity. Pressure mapping devices have been purchased to accurately determine the pressure required to operate the wheelchair from the start to its maximum speed. Randomly selected classmates were asked to be volunteers to drive the wheelchair. All of the randomly selected individuals were able to use the wheelchair easily and efficiently. Meetings will be held with Center for Rehabilitation Engineering, Science, and Technology (CREST) to test the device with persons with quadriplegia and patients with mobility issues.

Discussion and Future Plans

The device has received an overwhelming positive feedback from students and teachers at Louisiana Tech University. Flex Array has been able to accomplish the objectives of the project which were as follows: increase the user accessibility, decrease the cost compared to the similar existing technologies, and introduce little/no fatigue to the user. The sensors that were purchased for the project were designed for small experiments in laboratories. The purchase of more robust and durable sensors can increase the life of the head array and can give accurate feedback to the users. Future plans are to purchase a new batch of similar sensors and test the durability of the device.

Acknowledgements

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