Motorized Wheelchair Mounting System

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Abstract

A speech generation device is a critical tool for an individual whose speech is impeded by a disability. However, for those confined to a wheelchair and who are also unable to physically move and position the device, the everyday operation and handling of the machine may be difficult. In addition, the position required for use of the device may interfere with one's ability to see or perform other functions. If the position does cause a significant decrease in the user's field of vision, the ability to drive or maneuver a wheelchair may be compromised. The goal for this semester is to develop a motorized wheelchair mounting system for a speech generation device that requires minimal user effort and input and enables physically impaired users to position the device in proper locations for use and storage.

Table of Contents	Page
Abstract	2
Table of Contents	3
Problem Statement	4
Background Information	4-5
Current Devices	5-6
Design Constraints	6-7
Design 1: Shoulder Position	7-9
Design 2: Side Position	9-10
Design 3: Lap Position	11-12
Design Matrix	12-14
Future Work	14-15
Conclusion	15
References	16
Appendix A: PDS	17-18

Problem Statement

Design a motorized wheelchair mounting system for a Vanguard Plus speech generating device. The client currently drives an electric wheelchair without the Vanguard mounted. However, with the device attached to his chair with the current mount, he cannot see to drive the wheelchair. Developing a mounting system that better meets his need would increase his independence by allowing him to use the Vanguard whenever necessary. We are interested to find out if a standard wheelchair mounting system could be adapted so that he is able to move his Vanguard into position to use it and then out of the way to store it and drive.

Background Information

Cerebral palsy (CP) is a non-progressive condition of brain damage that causes physical impairment, affecting body movement and posture. Seventy-five percent of all cases of CP are developed during pregnancy. While there is no cure at this time, therepy treatments continue making advancements and improve the quality of life for those living with the condition. (Bax et al, 2005) Our end-user, Will, is an 18-year-old male with cerebral palsy. His motor skills have been strongly affected and as a

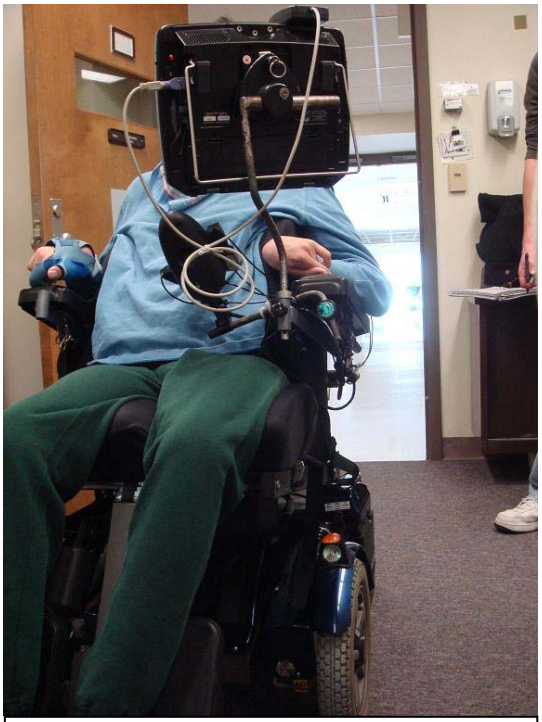

Figure 1: Wheelchair with attached speech generation device.

result, a wheelchair is currently used for mobility (**Figure 1**). In addition, his speech has been affected such that it is difficult to communicate with unfamiliar persons. However, recently he has made great progress in the tactile use of his left hand, which has enabled the use of a touch-activated speech generation device. The model he uses is a Vanguard Plus. In order to operate the device, it must be mounted on the left side of his wheelchair near his face so that he can easily see the display and comfortably touch the screen. When he uses his left hand to access the joystick, all his focus goes to the left.

Current Devices

At this time, there are no commercially available mounting devices sufficient to meet our user's needs. Thus, a custom device is currently the only satisfactory solution. The mounting device he presently uses has been custom fabricated by his father. It consists of a vertical steel rod that attaches to the armrest of his wheelchair (**Figure 2)**. Welded at the top of this rod is a horizontal steel cylinder. This horizontal piece serves as the interface between the mount and the Vanguard's standard mounting bracket (**Figure 3**). While this current mount does succeed in securing the device to the wheelchair, overall it is insufficient and does not meet user

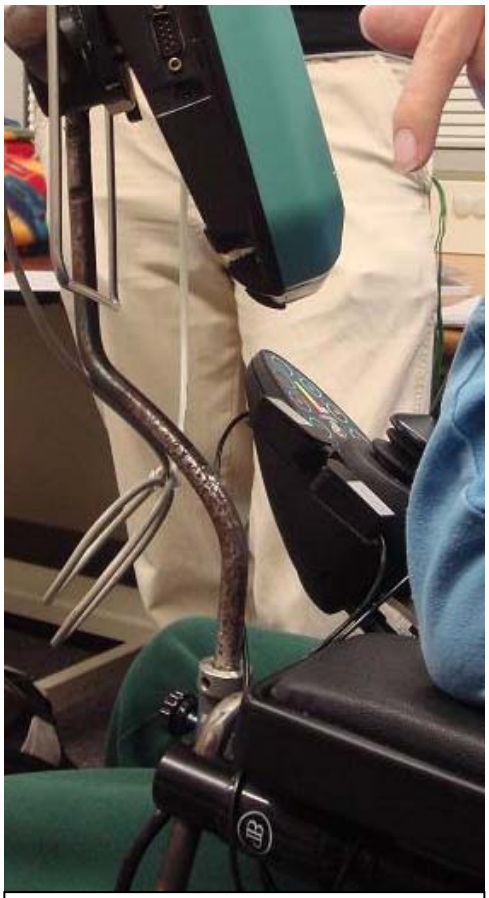

Figure 2: The current mount attaches to the armrest of the wheelchair.

Figure 3: Vanguard mounting bracket interface.

needs. With the device mounted in place as is, it severely hinders his field of vision and thus affects his ability to navigate and drive his wheelchair. As an additional problem with this mount, our end-user is unable to attach, position, or remove the device by himself at this time. Thus, in order to use the Vanguard, someone else is required to mount and position the device for him. Additionally, when he then wants to drive his wheelchair, someone else needs to remove the device and store it until the next use. Because of these problems, the speech generation device is currently only used during therapy sessions. Developing a custom motorized mounting system would increase the user's independence by allowing him to always have access to the device and thus be able to effectively communicate with others whenever necessary.

Design Constraints

The Vanguard mount needs to be motorized because the user has limited strength and mobility. This restricts him from being able to manually move any type of non-motorized mount and does not allow him to attach or remove the Vanguard on his own. Ideally, the only user input needed will be the touch of one button to move the system from its position of typical use (eye level and to the left) to its final storage position, and then return with the same switch.

The final storage position of the device needs to be such that the user can quickly access it while in transit. Currently, because the Vanguard is not usually attached when he is moving in the wheelchair, he has no way of effectively communicating with people that do not deal with him on a regular basis. With the system accessible, he will be able contact his parents if his ride does not pick him up. If he needs to communicate with someone unfamiliar with his speech, such as a bus driver, he needs to have access to the Vanguard in order to do this. The final storage position also needs to be safe and within the chair perimeter. The device is expensive ($7000-8000) and its protection needs to be ensured.

The motorized mount can be powered from the wheelchair 24 V battery or an independent battery attached to the chair. If the wheelchair battery is used, a 24 V to 12 V converter may be needed depending on the type of motors selected. With this in mind, the new attachment can not interfere with any of the current functions of the wheelchair (joystick and toggle switches) and cannot provide any backflow of current into the wheelchair. Finally, the parents have set aside $1000 for this addition to the wheelchair. A summary of these product design specifications is attached as **Appendix A**.

Design Alternatives

Each design consists of a motorized mechanical system capable of repositioning the device between the operation and stowage positions. The user will activate this system by depressing a sensitive spring-loaded button. This button will act as a toggle switch to cycle between the two positions.

Design 1: Shoulder Position

Overview

The storage position for this design is behind the user's left shoulder, above the armrest of the wheelchair. When the switch is activated, the Vanguard will slide forward, rotate so the screen is visible, and move up and toward the midline of the wheelchair to be in the best position for use (**Figure 4**). This could be accomplished with a system of actuators and rotary motors. It could attach to either the base under the wheelchair seat or onto the armrest.

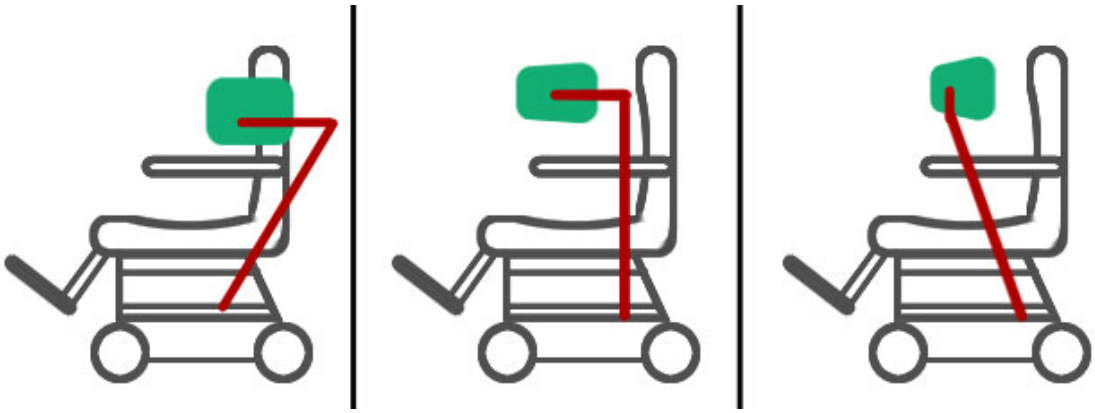

Figure 4: Transition of shoulder design from stowed position (left) to final operating position (right).

Advantages and Disadvantages

A good thing about this design is that it stores completely out of the user's sight and would not impair his driving ability. However, as evidenced by numerous scratches in the back corners of the wheelchair, this may not be the optimal position for storage of the Vanguard. He has previously hit door frames and walls while cornering which does not

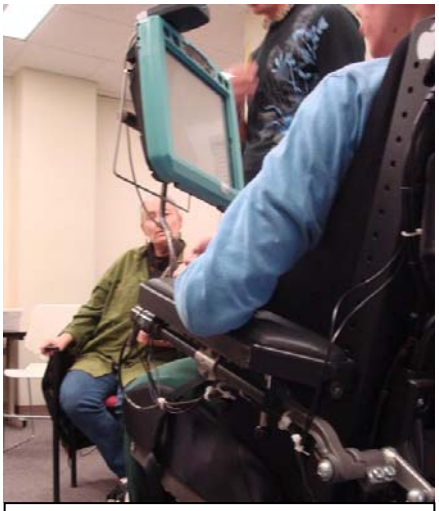

Figure 5: Shoulder area of wheelchair armrest.

bode well for the protection of the device. Also, this storage position does not allow for quick access to the Vanguard while in transit. If he were in need of the communication device, he would have to activate the switch and wait for it to move to its final position. In emergencies or situations where time is of the essence, the setup is not ideal. In addition, the user was not comfortable with this storage position.

While the actual mechanism of moving the device may be feasible for this design, the attachment of the mount and storage position may provide difficulties. As shown in **Figure 5**, the user's arm overhangs the armrest. This limits not only the area where the device can be stored, but also the mechanism that can be used if the arm is in the way of any of the moving mount components.

Design 2: Side Position

Overview

The second design candidate describes a mounting system that stores completely under the end-user's left armrest. The support rails that are used to extend the Vanguard Plus display outwards and upwards to its final operating position must be arranged next to the display due to the area constraints of the side space, which is depicted in **Figure 6**. To minimize screen damage, the rails rest on the outside in such a way that

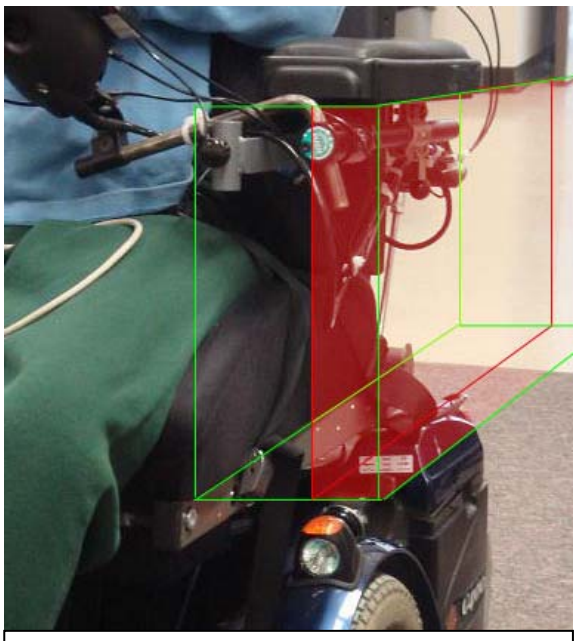

Figure 6: The green wire box depicts space occupied by the side design. The red highlighted area shows where design extends beyond the perimeter of the wheelchair.

they extend the perimeter of the wheelchair. When activated, the motor-driven rails must slide over each other and fold once fully extended, as seen in **Figure 7**. This type of movement is necessary because the system might be blocked from swinging outwards from the wheelchair's side, and must stay within the wheelchair's perimeter as much as possible.

Figure 7: Transition of side design from stowed position (left) to final operating position (right).

Advantages and Disadvantages

The best thing about the side design is that the entire assembly stows completely out of the end-user's immediate space as well as sight. However, because of the tight space occupied by the mounting device, the outer moving parts are directly in harm's way. Extreme wear and tear of the mounting device requires extra support and stronger materials, making this one of the most mechanically complex design alternatives. Furthermore, this design does not allow the end-user to access the Vanguard Plus while in transit. In the case of an emergency, there's a good chance that the extending and folding mechanism would be blocked by something like wheelchair restraint belts on a bus or any tables or walls in front of the wheelchair.

Design 3: Lap position

Overview

The third and final design alternative is motivated by the end-user's need to access the Vanguard Plus while in transit, and is stowed with the screen face-up above the lap and below the joystick. This mounting device, like the others, is secured and mobilized at the wheelchair's base. Because the display does not need to occupy the space below the armrest, the mounting rails can be contained entirely within the wheelchair's perimeter. When activated, a single actuator moves the lower rail which first slides the screen outwards from underneath the joystick, and then swings the screen upwards and over the joystick to the final operating position, as seen in **Figure 8**. A stationary rotating collar, which can be either mounted underneath the left armrest or held in position by a stationary rail fastened to the wheelchair's base, facilitates the elliptical path the Vanguard Plus takes during activation.

Figure 8: Transition of lap design from stowed position (left) to final operating position (right).

Advantages and Disadvantages

The key aspect of this design is the ability to operate the screen from the stowed position. Even if the end-user is unable to reach the screen while stowed, the path of movement for this device is contained entirely within the bounds of the wheelchair, making it much less likely to be blocked by an outside object. This space-conscious method also keeps the screen and mounting supports out of harm's way. Since the design is simple and effective, it will be possible to build and test by the end of this semester-long project. This is important because of the end-user's immediate need for this device. Although the device may seem to inhibit access to a desk or table, the end-user already has adjustable tables which eliminate this problem. Another proposed difficulty involves daily entering and exiting of the wheelchair, which would be blocked by a permanent mount over the lap. Easily removable parts and/or a fold-away mechanism would circumvent this problem altogether.

Design Matrix

With the three proposed designs in mind, each design idea was evaluated against several design criteria. The respective results were summed together and tabulated to form the design matrix (**Table 1**) in order to determine which design undertaking was the most feasible given the limitations of time, budget and expertise. Each design criteria was weighted differently according to order of importance for the end user and towards the design of a successful mechanism.

One design criteria used for the design matrix above was established to rate each design idea in terms of how accessible the Vanguard Plus would be for the end user while in motion, especially when transiting through narrow passageways. Stowage position

was how well the Vanguard would stow in the selected position provided that it is well-protected from physical contact with obstructing elements. Mechanical feasibility of each design was also evaluated based on how practical each device would be to construct and how durable it would be with repeated use. Deliverability was a measure imposed to determine whether the design could be successfully constructed, function, satisfy the end user and be sufficiently tested given the semester long constraint and budget limit. The cost criterion was an evaluation method by which each design was rated on cost-efficiency of design incorporation into a working model.

	Accessibility in Transit (*30pts*)	Stowage Position (*25pts*)	Feasibility (*25pts*)	Deliverability (*10pts*)	Cost (*10pts*)	Total (*100pts*)
Behind Shoulder Position	**10**	**18**	**15**	**7**	**8**	**58**
Under Armrest Position	**8**	**22**	**10**	**5**	**6**	**51**
Lap Position	**28**	**20**	**20**	**9**	**10**	**87**

Table 1: Design Matrix of the three design alternatives

Upon completion of design idea evaluations, it turned out that the lap position was the ideal design idea to be incorporated for this project due to the fact that its ratings for all criteria excelled across the board. Moreover, this design idea would be incorporated

such that device use in transit would be enabled due to the close proximity of the storage position to the end user.

Future Work

The final design idea will allow the Vanguard Plus to be tucked into the lap of the end user with the screen facing upwards. In this stowed position, all system functions can be accessed without impeding the end user's line of vision when navigating the wheelchair. In order to reach this stowage position, the Vanguard Plus will rotate approximately 55° clockwise about the long axis. It will employ the use of three rotary cuffs and a single linear actuator to synchronize a single elliptical stowage motion of the device that loops over the joystick and stows away almost directly under it. One of the rotary cuffs will allow for rotation of the screen about the horizontal axis to enable screen tilting for both enhanced viewing possibilities and stowage position. The other two rotary cuffs will function in concerted secondary horizontal and vertical axis rotation in order for the screen to be guided around the joystick and safely stowed into the lap position. The linear actuator will function to lengthen and shorten the long vertical bar of the designed mechanism in conjunction with the designated rotary cuff motions to achieve the anticipated lap stowage position.

Usability Testing

To ensure the quality of the designed mechanism, a proposed list of tests should be conducted such that the device functions properly and its function is convenient for the end user. Among these tests, a "stress and strain" test should be performed to evaluate structural integrity and reliability of the mechanism when loading and stowing the device.

A “load” test can be conducted to determine torque optimization of the design mechanism such that loading and stowing of the device is done in an efficient and effective manner.

In addition, a “motion” test could be conducted to guarantee the stowage effectiveness of the designed mechanism where the device moves according to designation and does not veer off track. The “electronics” testing will be conducted and is of high priority because it will be integral to the success of this project. The designed mechanism will be fully automated and therefore its electronic components must be maintained in working order with a constant supply of power from the wheelchair power source.

Conclusion

The end goal for this semester is to design and construct a motorized wheelchair mounting system for a speech generation device that requires minimal user input and enables the user to position the device in proper locations for use and storage. The speech generation device that he uses is a critical tool for him to be able to communicate with others not familiar with his speech pattern. However, because he is confined to the wheelchair and is unable to physically move and position the device, the everyday operation and handling of the machine is difficult. In addition, the position required for use of the device interferes with his ability to see and drive the wheelchair. Being able to have the Vanguard accessible at all times will greatly improve his independence and ability to communicate with everyone.

References

Bax M, Goldstein M, Rosenbaum P, *et al* (2005). "Proposed definition and classification of cerebral palsy, April 2005". *Developmental medicine and child neurology* 47 (8): 571-6.

Appendix A - PDS

Motorized Wheelchair Mount (February 2008)

Problem Statement

Design a motorized wheelchair mounting system for a Vanguard Plus speech generating device. The client currently drives an electric wheelchair without the Vanguard mounted. With the device mounted on his chair he cannot see to drive the wheelchair. We are interested to find out if a standard wheelchair mounting system could be adapted so that he is able to move his Vanguard into position to use, then out of the way to drive.

Client Requirements:

- Device should run on 12 V or 24 V wheelchair battery or independent source.
- Vanguard Plus should be stowed in position that does not impede user's line of vision.
- User must be able to drive wheelchair while device is still connected.
- Device stored in a safe position free from external collision damage
- Budget $1000.

Design Requirements

1. **Physical and Operational Characteristics**
    a. *Performance requirements:* Quiet, ergonomic, easy to use
    b. *Safety:* Must be safe for use and transport
    c. *Accuracy and Reliability:* Consistently relocate to intended position
    d. *Life in Service:* 5 years
    e. *Shelf Life:* N/A
    f. *Operating Environment:* Must be able to withstand year-round outdoor weather and endure collisions with walls, doorways, etc.
    g. *Size:* Should not extend beyond wheelchair perimeter or interfere with user.
    h. *Weight:* Should not exceed 10 kg.
    i. *Materials:* No specific requirements, but must be durable.
    j. *Aesthetics, appearance, and Finish*: Should not appear excessively gaudy.

2. **Production Characteristics**
    a. *Quantity:* 1
    b. *Target Product Cost*: <$1000

3. **Miscellaneous**
    a. *Standards and Specifications:* Must not create any back-current into wheelchair battery. Must not interfere with other wheelchair functions such as movement, joystick operation, or seat positioning.
    b. *Customer:* Should be accessible and user-friendly to facilitate Vanguard use to ultimately increase user's independence.

c. *Competition:* Currently there is no standard motorized wheelchair mount that meets the user's needs. Our product should provide increased functionality over non-motorized mounts.