Computer Input Device for Individual with Muscular Dystrophy

Written by:
Vince Mi – Communicator
Kuya Takami – BSAC
Hyungjin Kim – BWIG
Nathan Werbeckes – Team Leader

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Advisor:
John Webster, Ph.D.

Clients:
Richard Kunz
Mary Sesto, Ph.D.

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Abstract

Muscular Dystrophy is a strongly disabling disease that can leave its victims crippled. The worst part of the disease is that it doesn't affect your mind, so those who suffer through feel that they are trapped in their own body. Our client still has enough motor control to work a computer input device, but not efficiently or well. The group's goal is to build a device to improve the accessibility of the computer input device for the client. Our system must also be setup quickly and without confusing components. We decided that a small joystick would be best to control the on-screen cursor and an adjustable platform would be used to support the client's forearms while using the device. Future work includes designing a left hand clicking device, finalizing the arm support, and finally buying and customizing the device to optimally suit our client's needs.

Background

Richard Kunz (our client) has advanced Muscular Dystrophy. His disease is so advanced that he is unable to ever leave his bed under his own power. Even worse is that he would be unable to breathe if not for a respirator in his home. Although there are many things Richard will never be able to do he is not completely trapped in his body. He can still speak (with the help of the respirator) to communicate with others, but his primary source of communication with the outside world is via his computer. Unfortunately, his disease took a turn for the worse last year and he is now unable to use a keyboard at all. Towels prop up his forearms because he is unable to lift his wrist or elbow enough to resist gravity. He has resorted to moving a trackball with a pencil eraser, but even this is hard and slow.

Figure 1. Richard Kunz in his bed with current computer input device setup.

What Richard can do is move three fingers on each hand. His thumb, pointer, and middle fingers have adequate motor ability to control his computer. With his right hand he grips the pencil and is able to make circles just greater than 1cm in diameter. Each individual finger can not move this much or with as much control, but together they function pretty well. The trackball is rotated about 150 degrees so that his left hand is able to reach the buttons normally on the top of the trackball. However, these buttons are too slanted and in a bad position for Richard's hand to click them properly. Therefore, pieces of plastic have taped onto the trackball buttons to help him reach and click them properly.

Problems with Current Device

Our client is currently using a trackball as an input device for his computer (Figure 2). He rolls the ball part with the eraser part of a pencil, controlled by his right hand, and clicks the buttons with his left hand. However, he has some problems with this current device. First, the setup takes a long time. In order to use the input device, he needs the trackball in a very specific position. Also, the setup position is slightly different each time he uses the computer due to slight shifts in arm and body positions. Thus, the nurse keeps moving the device slightly until he feels comfortable with the position. In this way, it takes about 10 to 15 minutes to get the correct height of towels to support his forearms, get the correct height of books to raise the trackball, and correctly position his hands on the trackball. The second problem is that the trackball is slippery. As mentioned before, he needs an accurate setup, and if the device slips he will not be able to use the device. When he slips off the trackball, the trackball and his hands must be repositioned, which takes a while. Another problem is that the buttons are inconvenient. On the current trackball, the location of the buttons is

Figure 2. Current device used by client. Right hand holds pencil and moves the trackball, left hand rests on top of buttons.

lower than the desirable position. Previous problem solvers attached plastic pieces on the button with the tape so that the buttons are elevated. However, because his room is humid and warm, the tape slips easily. After a slip the plastic pieces need to be repositioned and taped. Then the trackball and his hands need to be precisely setup again.

Problem Statement

In order to improve client's input device, we need to minimize the setup time. We also need to make the design easier to use, so that the nurse will not have hard time setting up the device for the client. The input device should be more sensitive, so that the device is easier to use with his limited motor control. Since our client can move his finger only 1 cm in diameter, the device should be designed so that the cursor can travel the entire screen with only 1cm of input. Also, the support system should be more comfortable and durable, since our client's arms will be on the support for several hours a day.

Client requirements

Our client requires a more accessible mouse control device. The input device should be sensitive so that he can use it easily with his limited motor control. Also, he requires better wrist and forearm support. Currently, he is using stacks of folded and rolled hand towels for the support. These towels get old and thinner and then no longer support his forearms to the same degree. The new supports will be more comfortable, easier to setup, and adjustable. The client requires that the support system be not only comfortable, but safe. Safety is a concern because the client has very sensitive skin and he will be resting his arms on the supports for several hours a day. Lastly, the setup time shall be reduced, and the whole device shall be easy to adjust.

Design requirements

Our improved device will connect to the client's computer via USB. Since there are several empty USB ports, we will not encounter any problems even though we use separate devices for moving the cursor and clicking buttons. This will not complicate setup for the nurses, and it will reduce the setup time. The input device will also be required to have great sensitivity so that his limited motor control can adequately move the cursor. The buttons shall be easier to grip. We will adjust the clicking element to a comfortable position, and we will prohibit the device from slipping. Also, the device should not chafe his sensitive skin.

Forearm Support Alternative Designs

Blocks

The first design uses blocks of different thicknesses to adjust the height of the arms. The blocks will be made out of some sort of light polymer with a thickness ranging from 1 to 10cm. By using multiple blocks with different thicknesses it is possible to create height changes of specific magnitudes. However, the precision of the height changes will not be very good unless there are a large number of different blocks. Also it will cost setup time to switch blocks and the client's forearm will have to be removed from the set up each time. Transportation of the forearm is not a good thing because movement of his body often is accompanied with pain. Also, this design will require larger storage because it needs many blocks to adjust the height precisely. The advantages of this support system are cost effectiveness and also the simplicity of the construction.

Adjustable Shelf

The second design contains a mechanism for both height adjustment and angle adjustment of the forearm (Figure 3). The part directly supporting the forearm is shaped using a semi-circular tube, which increases the area supporting the weight and therefore reduces the pressure on the arm. This in turn will be lined with a soft material to prevent skin chafing. This design can change the angle of the support relative to the table. This design also has the ability to change the height precisely and quickly by using the adjustable mechanism on the leg. However, this could

Figure 3. Adjustable shelf design. The leg height and angle of shelf can be adjusted.

be unstable because of it only has a single leg and doesn't have the wide base that the first design would have.

Adjustable platform

The last design uses the adjustable platform and a soft material to support the client's forearm. An example of the adjustable platform is shown in figure 4 and has an adjustable knob on the side of the device and is made of steel (adjusting arms) and aluminum (square plates 15cm x 15 cm, coated with paint). This example is used in a chemistry laboratory and weighs about 4 lb. It can be adjusted from 5.5cm to higher than 20cm. Because this is adjustable while the client's arm is on top of the plate, it will decrease the time required to set up the system and be able to make quick and precise height changes. The most important aspect of this forearm support system is its great stability due to its weight and wide base. The size of the plates shown in the figure might be excessively large to support our client's arms, but it is easy to find a different size of adjustable platform.

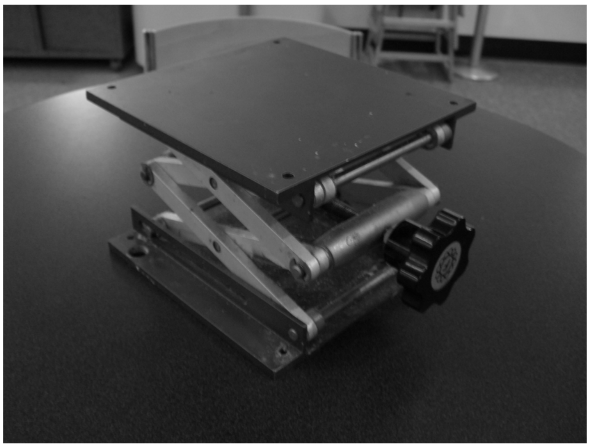

Figure 4. An example of an adjustable platform design. The knob allows careful and precise heights while locking the mechanism in place.

Design Matrix for Forearm Support

In order to determine which design to pursue for the next half of the semester we constructed a design matrix. Weight for stability and ease of adjustment was highest because it contributed most to decreasing the set up time, which was the first priority of this project. We also considered comfort and safety, ease of construction, and cost. For each criterion, the scores were assigned using scale of 1 (worst) to 10 (best). In the end, we decided to pursue the adjustable platform support system because it has most stability and is easiest to adjust. Using this designs ability to change the height quickly and precisely would shorten the setup time tremendously. Even though the adjustable shelf has the same ability it does not have same stability, which is important for the patient's safety. The blocks will not be good due to their lack of precision in setting the height.

	Weight	Adjustable Platform	Blocks	Adjustable Shelf
Stability	0.3	9	10	6
Ease of adjustment	0.3	8	3	8
Comfort/Safety	0.2	9	9	7
Ease of Construction	0.1	5	10	6
Cost	0.1	7	10	8
Result	1	8.1	7.7	7

Table 1. Design matrix for evaluating forearm support mechanisms. Adjustable platform won because of its high marks in both stability and ease of adjustment.

Cursor Control Alternative Designs

Tablet

This apparatus consists of a pen-like device (stylus) held over a receiving surface (tablet) which will detect movements of the stylus and communicates this information to the computer to move the cursor on the screen (Figure 5). The device itself is fairly common among graphics artists and CAD designers and prices range anywhere from $30 to $4000 depending on quality and available features. Sensitivity of the device depends mostly on the quality of the device and usually varies with price.

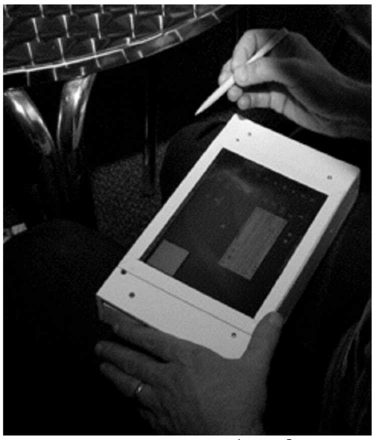

Figure 5. Example of a tablet with stylus. If used we would obtain a more compact model.

More modification will be necessary to fit a tablet to meet the current requirements. The stylus will most likely need to be modified for the client's comfort. Accurate positioning will be required to account for the limited motion of the client. Also, software modification and maybe even hardware modification will be required to allow the clients movement of the stylus to affect the entire area of the monitor.

Joystick

The second design consists of a simple joystick used in place of a mouse or trackball to control the movements of the on-screen cursor. As most joysticks today are fairly large gaming joysticks requiring large arm and wrist movements, most of these did not fit the client's needs. Instead, a small yet precise device will be used, similar to—if not—a modern gaming console controller as seen in Figure 6. These joysticks are usually thumb operated, and therefore require a very small range of motion while being very sensitive. Even with such a small range of motion (about 1 centimeter in diameter) the client is still incapable of moving the device through the entire range of motion, thus sensitivity adjustments and modifications to the device to increase mechanical advantage will need to be considered.

Figure 6. A small joystick about the size we would use.

Currently, there are multiple companies with hundreds of variations of similar devices on the market, usually at fairly economical prices (less than $50). The large availability provides a wide variety of different joysticks on different controllers with varying designs, increasing the chances of finding an ideal product. After finding a fitting design, the device will be modified to accurately fit the operating environment. This includes height and angle adjustments to allow for comfortable operation, sensitivity tuning to ensure precision operation by the client, and any additional mechanical modifications that may be required to allow for increased performance by the client.

Pointing Stick

The last alternate design, very similar to the joystick design, is the pointing stick, or isometric joystick. These small joysticks are currently found in the middle of keyboards on some laptops (Figure 7). Isometric joysticks essentially do not have any movement, but instead detect applied pressure which is then translated to

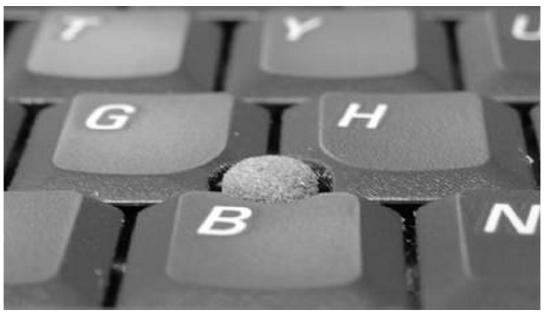

Figure 7. Pointing stick typically seen in the middle of the keyboard on a laptop, small but requires large force.

appropriate signals and sent to the computer as input for cursor movement. The fact that the device doesn't actually need to be moved is very advantageous for the small range of motion our client is capable of. Also, the sensitivity is highly adjustable, and is already very high to account for the small amount of movement.

The largest obstacle of this design is its lack of availability. Although these pointing sticks are currently found on many notebooks, they are basically obsolete as a stand-alone device. The only models currently on the market and available for desktop use are fairly expensive (~$200) and attached to a keyboard, which is unnecessary for the intended application. Thus the device will either need to be heavily modified or a stand-alone device will need to be located.

Design Matrix for Cursor Control

To decide which mouse control device we were going to pursue we again constructed a design matrix. The most important aspect of the mouse control device is that it can be easily moved with our client's limited motion range and that it will be easy for the nurse's assisting our client to setup. Ease of operation was also important because although he can move 1 cm fairly well he is not able to produce any large forces. Although the pointing stick has the highest sensitivity it is unlikely that the client will be able to create enough force to move the stick at all. The tablet would be very quick and easy to set up, but would take the client several stylus strokes to get across the screen. We decided to go with the joystick because of its reasonable sensitivity and ease of operation while easily being the cheapest and most customizable device.

Input Device	Weight	Joystick	Tablet	Pointing Stick
Sensitivity	0.3	7	5	8
Ease of Operation	0.3	7	4	5
Setup Time	0.2	5	7	5
Cost	0.1	8	3	3
Ease of Construction	0.1	5	8	7
Total		6.5	5.2	5.9

Table 2. Design matrix for deciding best cursor control device. We will be using a joystick because of its good scores in sensitivity and ease of operation.

Future Work

We have decided to pursue a joystick to control the cursor and an adjustable platform to support our client's forearms. These designs are more ideas right now that need fine tuning. Although we have an idea of what type of device we want to get, we have not picked out a certain joystick or platform that we want to buy. Our first step is to decide exactly how we want to use each device and buy the most appropriate model. For an adjustable platform we want something a little less wide and with a smaller minimum height than the example product we have now. We tested our client's motor abilities on a game controller joystick (usually used by a thumb) and found them to be capable. We are interested in finding a joystick of this size and sensitivity, or we may augment an existing controller for our needs.

The major problem with the joystick was that the client can't move his head enough to see the joystick. This caused him to lift his pencil off the joystick occasionally and he was not able to get it back on without help. These kinds of issues may be solved by simply getting used to the new equipment, but we would like to take a more proactive stance. Our group would like to test different heights of joysticks with different lengths of the pencil to see which setup allows optimal control and range of motion. We also need to find a may to attach his pencil (or similar moment arm) onto the joystick top so that it won't slip off, ever.

Our design alternatives addressed right hand cursor control, but left hand clicking was left out. We have asked and tested to see in which ways the client has the strongest and easiest ways of clicking buttons. Although these ideas are relatively simple (buying a certain kind of mouse with the correct button positions) the group has not come to a conclusion about which exact item will be purchased.

Forearm support designs addressed how height and/or angle would be adjusted to get the client's hand in the proper orientation to control the devices; however, these support designs did not lay out a plan for physically cradling the arm. We do know, through conversations with the client, to what extent his forearm needs to be supported, but we haven't drawn anything up to address these issues. We have talked about a PVC pipe cut in half and lined with some sort of replaceable, and comfortable, lining. Another idea was creating a cast mold of the arm to create a perfect support, but again the group needs to decide these details.

References

Tablet: www.blaptops.com/computers/hacks/

Pointing stick: www.fief.org/sysadmin/

Joystick: http://kotaku.com/gaming/

Adjustable legs: www.sammonspreston.com/ca/Supply