Freely Adjustable and Accessible Keyboard and Joystick for Client with Cerebral Palsy

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1.1 Introduction

This project report will describe the design of a custom made keyboard used in conjunction with a joystick for a child with cerebral palsy. The client this device is being designed for has athetoid cerebral palsy, and has trouble controlling his motor movements. He is a very smart child, but has trouble keeping up with his classmates because he is non-verbal. His only means of communication is by typing words on his computer. However, his cerebral palsy contorts his hand in a position that slows down his typing speed. This causes him to be slower than his other classmates, and fall behind in his schoolwork. The device being designed will be custom built to meet his requirements for a keyboard that will be easy for him to use. A joystick will also be implemented to take the place of a mouse, so he will have an easier time navigating through the computer.

To accomplish this, the keyboard must be in a vertical position, orthogonal to the desk. A stand will be used to hold up the keyboard, and it will have to be able to withstand the pressure of slamming keys without wobbling or falling over. The keys will be much larger than regular keys, so it is much easier for the client to hit the right key. The joystick will be purchased from PQ Controls, and will be connected to the computer using Bluetooth technology. The keyboard will also be connected to the computer using Bluetooth technology.

The design of the keyboard is somewhat complex. When designing a keyboard, there are several different types of switches that can be used. It has been decided that rubber dome switches are the best for this design. They are inexpensive, and flexible rubber domes containing a hard carbon center provide exceptional durability; a necessity in this project.

Figure 1 below shows how a keyboard functions, and the keyboard being designed must follow this format to work correctly.
Figure 1. Block Diagram of Keyboard Function

The design of the keyboard requires a key matrix, which is a circuit that works with the rubber dome switches. When a key is pressed, current flows through that area of the key matrix, and is sent to the microprocessor. This is then translated into the correct key, and this information is then sent to the computer. (this can be seen in Figure 1.) In addition to the normal internal architecture of the keyboard, LED’s will also be used to create a backlighting effect. The client is in elementary school, and having a keyboard that will look different may make him stick out. By using LED backlighting, the keyboard will look “cool”, and will help him fit in better.
1.2 Subunits

The keyboard will be designed in the correct form to accommodate the client’s unique typing style. As can be seen below in Figure 2., the keyboard itself will have roughly the same dimensions as a regular keyboard. It will be 20 inches long and 11 inches tall. When it is mounted on the stand, however, it will stand a total height of 15 inches above the desk. The keyboard will be made with plastic that will be able to withstand normal “wear and tear”. As can be seen in Figure 2., there are far fewer keys on this keyboard than on a regular keyboard. This is a necessity when using extra large keys. If all the keys of a standard keyboard were to be included, the keyboard would have to be much wider and taller than 20 inches x 11 inches. This would make the keyboard too big, and would render it obsolete for our client.

Figure 2. Front View of Keyboard with Stand
The keyboard will be designed to be 2 inches thick, which will provide enough room for the key matrix, circuitry, LED’s and batteries. The keys will protrude out 0.5 inches, and all except “Enter” and “Space” will be 1.5 inches x 1.5 inches. The stand will be circular in shape, and will be made using durable plastic. It will also need to be heavy so it will not move when the client is typing on the keyboard. Inside the plastic of the base will be steel ball bearings, which will weigh down the unit. This added weight will make the base heavy enough that it cannot move freely on a desk during typing, but it will still be light enough so the keyboard can be picked up and moved when needed. All of the dimensions mentioned above can be seen in Figure 3. below, which is a top view of the keyboard mounted on it’s stand.

Figure 3. Top View of Keyboard with Stand
The side of the keyboard on its stand can be seen below in Figure 4. As is shown in this view, the keyboard will be held on the top of the stand. The stand will be supported by a diagonal member that will connect to the top of the stand, and will extend down to the end of the bottom of the stand. This member will provide support for the stand when the client is typing on the keyboard.

Figure 4. Side View of Keyboard with Stand
The diagonal support member will not be a rigid member. Instead, it will consist of internal springs that will smoothly dissipate the force of the client typing. The spring constant, $K$, will have to be sufficient to handle the load of typing, and not be too small that the keyboard lurches back when it is pressed too hard. Figure 5 shows a free body diagram of the client typing on the top row, with a force of 20 lbs.

In this FBD, we are considering that the vertical member is not fixed at the bottom. By doing this, we can figure out the maximum force that the support must be able to withstand. In Figure 5., $F_s$ is the reaction force of the support, $F_t$ is the typing force exerted by the client, and $\theta$ is the angle the diagonal support member makes with the vertical support member. First, we must solve for theta. This can be done using equation 1:

\[
\theta = \tan^{-1}\left(\frac{7}{13.5}\right)
\]

Equation 1.
Solving for theta gives us an answer of $27.4^\circ$. This means that $F_s$ acts along a direction $27.4^\circ$ away from the y axis. Knowing that the stand is in equilibrium, the x force of $F_s$ must equal $F_t$, which is 20 lbs.

Equation 2.

$$F_s(x) = F_t = 20lbs.$$ 

The force of $F_s$ can now be solved for using equation 3.

Equation 3.

$$F_s = \frac{20}{\sin(27.4^\circ)}$$

This gives us a force of 43.5 lbs. This is the maximum force the support will have to withstand, given that clients max typing force is 20 pounds. Knowing this force, the stand can be designed by using a spring with a K value large enough so that there is not much movement. The equation for a spring is given below:

Equation 4.

$$F = -kx$$

K is the value of the spring constant, and $x$ is the change in distance of the spring at rest. It has been decided that an $x$ value of 0.25 inches is desired. This number can then be plugged into the equation, and $k$ can be solved for.

Equation 5.

$$k = \frac{43.5lbs}{0.25in}$$

The value of $k$ turns out to be 174 lbs/in, so this means that the diagonal support member must have a spring with a K value around 174 lbs/in.
As was mentioned earlier, the keys for the keyboard will be 1.5 inches x 1.5 inches. Below is a top view of a standard key, along with the “Enter” and “Space” key.

![Top View of Keyboard Keys](image)

As can be seen, the “Space” key is going to be 5.5 inches long at the base, and the “Enter” key will be 3.5 inches long at the base. The top of each key is a little smaller than the bottom. The dimensions can be seen in Figure 6, above.

Figure 7, shown below, shows a front view of the three different types of keys, and the dimensions of each key can be seen.
Figure 7 illustrates that the keys will be 1.25 inches in height. At the center of each key will be a depression, and this depression will be in contact with each key’s rubber dome switch.

The rubber dome switches will make up the key matrix of the keyboard. Each key will have an individual rubber dome switch, when which pressed, will send a signal to the microprocessor. Figure 8 below shows a preliminary layout of the key matrix made up of the rubber dome switches.
The circles above in Figure 8 represent the rubber dome switches that each key will be in contact with. Each of these switches will be connected to the microprocessor through a network of wires. The exact layout of the wires, and the position of the microprocessor will be determined when the rubber dome switch layout is being ordered.
2. Realistic Constraints

This project incorporates engineering standards and realistic constraints into the design of the keyboard and joystick. Although computer keyboards are incredibly common today, this keyboard is different in that it is being custom built for client, and will be significantly different than the average keyboard.

Economically, the keyboard will be somewhat more expensive than an average keyboard. The keyboard must be made to last a long time, so cheap parts cannot be used throughout the design. To save money, the parts must also not be too expensive. The keyboard was designed using parts that are good in quality but not too expensive. A good example of this is the rubber dome switches. They are inexpensive, but can withstand normal keyboard wear and tear for years, making them a good choice. Having custom built plastic parts is not going to be cheap, so this may be a real constraint in the design of the project. The stand in the design was modeled after a “common” flat panel monitor stand that can be ordered at a relatively inexpensive cost, if it is too much to order a custom stand. There are keys that are built for large key keyboards that come in the dimensions specified in the design, so these can be ordered. LED’s were chosen to give the keyboard an aesthetical appeal, because they are inexpensive and have a decent lifespan.

The keyboard and joystick will be used in a classroom environment, so there aren’t many environmental concerns that have to be considered. The average operating temperature is expected to be 70°F, which normal electrical components should have no trouble operating in.

When designing the keyboard in conjunction with the joystick, sustainability was a big factor. This keyboard will have to last the client throughout his elementary, middle and high-school education. He is in fifth grade right now, so this means it will have to last him seven years. To prevent broken parts, durable plastics are being incorporated in the design of the keyboard. The joystick is of high quality, and should last much longer than seven years.

Manufacturability of the keyboard is a serious constraint, because most keyboards are manufactured hundreds at a time. Manufacturing a single keyboard is difficult, because it requires custom built parts that may be hard to create. The switches used in the keyboard are very common, and should be easy to use in the design of the keyboard. As mentioned earlier, the keys themselves may be ordered from a company that builds large keys, avoiding the trouble of having custom built keys made. The stand may follow the same path, again avoiding the trouble of ordering custom built parts. The keyboard base may be custom built, but this should not prove a huge constraint in the manufacturing of the keyboard. Most of the other parts are very common, and should not be a problem.
The keyboard and joystick should pose no ethical constraints for the project. In no way does the project directly affect the health or well-being of the client. The keyboard and joystick do not attach to the client in any way. Bluetooth technology was used to make the keyboard and joystick portable. This also means that no wires are used, and these could pose a minor threat if anyone were to trip over them. Durable plastic was also incorporated into the design, so that no parts could accidentally break off and pose a hazard to people nearby the keyboard.

By using such a different looking keyboard, it was considered that the client may feel socially awkward. This is why LED backlighting was decided upon when designing the keyboard. With these added to the keyboard, the project will not be an eyesore to anyone who looks at it. Instead, LED backlighting will have quite the opposite effect. Instead of being socially awkward, our client’s keyboard will look “cool”, and other classmates may even be envious of it.

3. Safety

Safety was of course a major concern in the design of this project. It would be horrible if in any way this project caused physical harm to the client or anyone else. Precautions were taken in the design of the keyboard and joystick to make sure that the project meets safety requirements and in no way can pose a safety threat.

Mechanically, the keyboard could pose a threat if it is typed on with significant force. If a piece of the keyboard broke off, it would be a dangerous projectile that could cause harm. To avoid this from happening, the keyboard was designed with durable plastic that can withstand mechanical abuse. The rubber dome switches used for the key matrix act like plungers, and smoothly absorb the energy caused by typing on the keys.

Although it is a minor concern, excess wires lying around could pose a threat if someone were to trip on them. By using Bluetooth technology, this threat is avoided altogether. Our project is totally wireless, and there are no wires that anyone could trip on.

Another safety concern are the fire hazards that the LED’s pose. To overcome this danger, the LED’s will not be placed within a considerably close proximity to any electrical or plastic parts. By doing this, it can be ensured that no parts will melt or get burned, which could then pose a threat to the client.

All the corners of the keyboard will be rounded to prevent any sharp corners puncturing the skin. The wires will be insulated to prevent any electrical problems that could pose a threat to the client. Along with the keyboard, the joystick is made with glass-reinforced nylon, which is very durable and will not
pose any threat to the client. In this project, safety is addressed and the keyboard and joystick will not pose any threat to the client or anyone else.