

A SPECIAL NEED TOOL TO ACCESS KEYBOARD FOR PEOPLE WITH UPPER LIMB DISABILITY

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ABSTRACT

A total upper limb disability due to trauma or disease is not uncommon. People with this type of disability are unable to perform many regular activities. A foot-operated mouse and voice recognition input can offer options for the disabled; however, still there is a need for their easy access to computer keyboard. The people with upper limb disability can access computer with their toes. A novel, low cost special need tool has been designed and built as a solution. This design utilizes optical reflection to reproduce an image of a keyboard in front of the user. The functionality of the design has been validated. In addition, experimental design parameters for the tool have been explored. With this novel tool, people with both hands disabled can potentially use a computer with ease which would otherwise be physically and visually stressful.

Keywords: Assistive Technology, Computer access, Independent Living, Optical system, Upper limb disability

INTRODUCTION

Limb loss due to trauma or disease is a global issue, causing disability and loss of freedom and job. Computer usage for the people with a disability is 25-50% lower than people without one [1]. The mainstream information and communication system devices and systems may be incompatible with assistive devices and assistive technologies; the upper extremity amputee may experience difficulty in using devices that require fine tune [2]. However, productive access to computer is critical to improve the quality of life for the people with a disability [3, 4]. Voice recognition can be an option for access to computer in this case, but it can be stressful for a long writing. A foot-operated mouse can also provide access to computer to some extent.

Generally, disabled people, in an economically challenged condition and in underdeveloped or developing countries cannot easily afford artificial limbs. Even in developed countries, prosthetic legs are more common than prosthetic hands. Many people with an upper limb disability are often resistant to using a prosthetic due to its size and weight [5, 6]. Artificial arms and hands are being improved but not without issues regarding the learning curve and the actual costs of the devices [7]. However, low cost and light weight 3D printing of artificial arms can be future solution to the issue. Still, there is a need of a tool for people with disabled upper limbs to assist them in computer usage specifically in underdeveloped and developing countries or for the people who are temporarily unable to use their hands. Considering these facts, we intended to build a tool with the help of an optical system for people with upper limb disabilities in order to improve and increase wider access to computers at a low cost.

METHODS

Structure and Functionality

The key components of this proposed prototype are optical system (mirrors), LED light sources along with the typical elements of a desk. The components are discussed in the next section.

The optical system, the most important part of the proposed prototype, consists of mirrors. Flexible mirrors in even numbers are inclined in specific angles which can be used to reflect the image of the keyboard in front of the user. Those mirrors are used to reverse the image and then make the keyboard appear normal, creating what is known as a true image. Flexible mirrors made of plastics or polymers (acrylic plexiglass) are preferred over glass to avoid the danger caused by the brittleness of glass

People without upper limbs can access computer keyboard generally by using their toes. They may need to wear specially designed shoes or shoe accessory for convenience and ease of use.

In the proposed design of the prototype, a keyboard is located at the base of the desk. One or more LED light sources are positioned on the two sides of the keyboard so that they can fully illuminate the keyboard when the room is dark. Since the LED light sources consume relatively low energy, the temperature of the keyboard will not be uncomfortable for the user.

Operating principle of the optical system and Design description

The image of a keyboard is reflected by the inclined mirrors which create an image of the keyboard with the position of the toes (or spikes of the shoes) directly in front of the user; this follows the basic principle of optical reflection by mirror. In dark condition, the keyboard is lit by LED lights. Otherwise, the keyboard is lit by ambient lighting or by diffused light in a room. By using the toes (or shoe accessory), the users can press the keys on a keyboard. Since they can see letters comfortably, the user can access a PC with ease.

Typically, upper limb disabled people have to position their feet on a table in order for them to access the keyboard with their toes. That is both inconvenient and physically stressful. Using the proposed tool, one can potentially use a PC in a normal sitting position.

A 2D view of the basic design of the optical system is presented in Figure 1.a. It shows how the image of the keyboard is reflected and seen by a user. In this design, a keyboard is placed at the base of the desk. Two mirrors, Mirrors #1, and #2, are arranged at the proper angles so that mirror #2 can reproduce the image of the keyboard at the tabletop level. It is worth mentioning here that even number of mirrors can create a true image. Figure 1.b. shows a 2D view of the basic design of the proposed system with inclination angles and geometric positions of the mirrors. The user can view the keyboard in Mirror #2 as if it is at the location of Mirror #2. In addition, because of the location of the mirror #1, the position of the toes on the keyboard will be visible in Mirror #2.

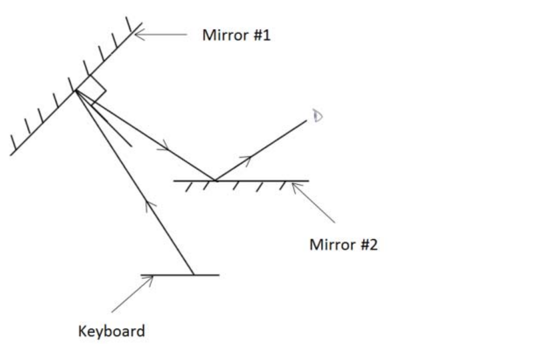

Figure 1.a. Figure 1. Basic 2D design of the optical system. The arrows show the direction of light from the keyboard to the eye. Mirror #2 is at the level of tabletop. The frame of the structure is not shown.

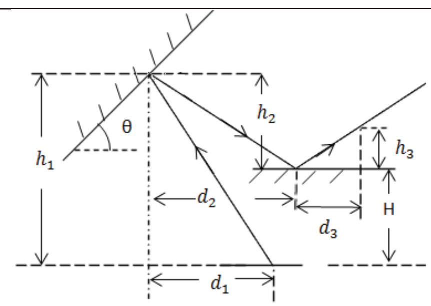

Figure 1.b. The figure shows the dimension of the design and angle of mirror in Figure 1.a. H is the table height.

Development of Prototype

The preliminary prototype was constructed using the materials available in the market. To minimize cost, low cost materials and less tooling were considered in constructing the prototype. For this reason, the prototype is in a raw form; however, it does perform its function as shown in Results section. For manufacturing the prototype commercially, the materials and structure will require improvement.

The crucial parameters of the prototype include mirror positions, and inclination angles. The information about the positions and angles of the mirrors and keyboard is listed in Table 1. The optimum values of them were obtained by the trial and error method. The position of the keyboard needs to be adjustable so that the user can use it with comfort

Table 1. Experimental data

H (inches)	d_1 (inches)	h_1 (inches)	d_3 (inches)	h_3 (inches)	θ (degrees)
35	21	40	8.5	4.25	45
	14	44	3.5	2	38
	17	39	4.625	1	53
16.25	14.5	25	4.5	2.25	45
	14.75	25.5	7	4.125	42
	15.75	24.75	5	2.25	50

The range of d_3 can be made variable with wide mirror. In our study, the mirror was 12 inch wide. The image can be formed along and within that dimension. A wider mirror can provide flexibility of viewing the keyboard for a user. While keeping all the parameters same, a user can move toward or away from the system or move the head up or down while still see the image provided that the mirror is wide.

Light Sources and Illuminance Level

Two LED light sources were employed to provide ample light to make the keyboard properly visible. In this work, the illuminance level on the keyboard was approximately 147 lux on the average. The LED light sources utilized have power of 3.5 watts each. The light sources are positioned 11 inch above the surface of the keyboard. However, in a lit room with average luminance level of 285 lux, no LED light source was required as shown in the next section. Note that the illuminance level was measured at table height.

RESULTS

The functionality of the prototype was tested for some parameters: illuminance level, various keyboards. Tests were performed with keyboards of different key colors and sizes. During all tests, the position of the LED lights was held constant. Because of the reflections by the mirrors, the size of the keyboard letters appeared smaller than the actual size. For that reason, a keyboard with large letters must be considered or magnification of the small letters of the keyboard is required. It has been observed that after two reflections, the letters appear to be unrecognizable.

A keyboard, Azio Vision Backlit USB keyboard with Large Print Keys [8], was used for investigation. The keys of the keyboard are LED back lit; they can emit pink, blue, red and pale yellow colors for the keys. The keyboard has thicker and larger letters compared to those of a typical keyboard. The investigation showed that the Azio keyboard did not yield the expected outcomes regarding visibility and legibility of the keyboard letters as the letters were not well visible for any of the colors. This could be due to low color contrast.

There has been research on how color contrast can influence readability. Studies show that high color contrast can be achieved by using black text on a yellow or light yellow background [9-12]. So, we improved the visibility and legibility of the keyboard letters by using a high contrast keyboard with large letters. For this purpose, we performed tests with black letters on a yellow background (EZsee Large Print, Low Vision, Ergonomic Multi-Media Keyboard with Low-Profile Yellow Keys [13]) as shown in Figure 2.

Figure 2. A reflected image of the keyboard with high contrasting letters color and large letters.

Figure 3 indicates that keyboards with high color contrast and large letters are essential for this design. At this point, one can conclude that best results for visibility and legibility can be obtained from the keyboard with black letters on a yellow background.

Figure 3. Toe pressing letter ‘M’. The figure presents the use of toe. The image is a reflected one that appears in front of the user. The keyboard was lit by the LEDs.

Experiments were performed at room lighting with the keyboards that are not lit by the LEDs. The reason for these experiments was to determine whether the prototype functions in a well or partially lit room. We determined that a high contrast keyboard with large letters yields better results in this case, see Figure 4, at tabletop illumination level of 285 lux. At this point, one can conclude that the prototype performs well under normal light conditions.

Figure 4. Reflected image of a high contrast keyboard with large letters. All the letters are visible and easily recognizable in the reflected image. The room light source is located on the left side of the keyboard; this is why the left side of keyboard looks brighter than the right.

DISCUSSION AND CONCLUSIONS

This study focused on the technological development of a simple and low cost optical system based prototype which can have potential use for the people with disabled upper limbs. It has been shown that the system can function in a well-lit room illuminated at 285 lux, requiring no extra light source. Important aspects of the design are its simplicity and utilization of easily available materials such as mirrors and high color contrast keyboard. Self-maintenance and self-repair of the prototype are the other important features of the design and can further reduce cost for long time use. For children with the disability, adjustments in the positions and angles of the mirrors will be required.

The main limitation of the system is that the optical system components will require adjustability for the people with different lengths of legs and trunks. The drawbacks of this adjustability are added components and cost. A full operation of a PC can be achieved by pressing one, two or even three keys of the keyboard when needed. Using only two toes, it is hard to operate the computer for a function that requires three keys pressed together. In order to improve the usage of keyboard, one function key of the keyboard can be programmed for the two of the three keys. A foot-operated mouse can be incorporated in the system for easy maneuvering of the cursor. This addition can, possibly, provide full and easy use of the PC.

The test results validate the functionality of the prototype which is presented in images. The results may not be altered by inclusion of modifications suggested, however the future studies focus on performing extensive target user evaluation which could reveal challenges of using the system; the resulting understanding will offer techniques to improve the system.

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DISCLOSURES

In the context of this article, one disclosure of invention is submitted to Jackson State University.

Conflicts of Interest: The author(s) declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

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