Vision Based Laser Controlled Keyboard System for the Disabled

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ABSTRACT

In this paper, we have proposed a novel design for a vision based unistroke keyboard system for the disabled. The keyboard layout considers the commonly used character patterns, which makes it convenient for the user to type. In addition to this, Shift functionality is provided to accommodate a larger set of characters. A webcam is positioned so as to monitor the keyboard and the characters are identified based on the laser pointer which the user can control by minor head movements. Experimental results demonstrate that the design achieves very promising results, thus establishing a baseline for such models in this domain.

Categories and Subject Descriptors

K.4.2 [Computers and Society]: Social issues - *Assistive technologies for persons with disabilities*

General Terms

Design, Performance.

Keywords

Unistroke, keyboard, calibration, laser-pointer.

1. INTRODUCTION

Computers have become an integral part of our daily lives and the ability to operate them is vital. Operating a computer involves providing it with necessary input and keyboard is one of the most important means of doing this. Commonly used keyboards such as QWERTY require the use of both hands. However, this poses a difficulty for the physically challenged to use them.

Several solutions have surfaced to overcome this such as the MALTRON single handed keyboard, MALTRON Single finger or Head/Mouth stick keyboards [7], LUCY Keyboard [8], Eye Gaze. However, these technologies are very expensive. This motivates us to develop an affordable keyboard system to assist the handicapped. The core idea of our method is to design an inexpensive system which can be easily assembled using an ordinary webcam and a laser pointer.

We have designed one such unistroke keyboard system with optimized character placement based on frequently used digraphs and trigraphs. The system caters to the disabled people who have the inability to move their hands. A webcam is positioned to monitor the keyboard and the characters are identified based on the laser pointer which the user can control by minor head movements. Since the keyboard is unistroke, the laser can be moved in a continuous fashion rather than discrete movements, thus increasing efficiency [12]. Optimized character placement reduces the distance the laser has to be moved to type words. In addition, presence of the Shift key helps accommodate more characters. Experiments carried out demonstrate promising results thus setting a baseline for future work in this area.

This paper is organized as follows: background and related work is discussed in section 2, in section 3 we discuss the proposed design, section 4 describes the methodology, section 5 deals with testing; section 6 gives the results and analysis and section 7 concludes the paper.

2. BACKGROUND AND RELATED WORK

In order to improve text entry, hand writing recognition [2] has been proposed as opposed to using a keyboard. But it is difficult to effectively perform recognition and the system is slow [9]. Predictive input methods [10] have been proposed that predict the user's subsequent entry thus reducing effort. However, this does not guarantee faster typing [11] Layout optimization has been studied to improve text entry as well. The frequency of digraphs has been studied and layouts such as OPTI [5], have been proposed. Another factor influencing text entry is the type of entry interaction. Gesture keyboards do not require discrete movements like the keyboards mentioned before but instead, a single continuous movement to type a single word [12]. One such keyboard is Cirrin which has a circular arrangement of keys to minimize the distance between any pair of letters [3]. In menu augmented keyboards such as [13], a menu is shown while the key is pressed which shows a number of frequently occurring letters depending on the key being pressed. The characters in the menu can be entered by selecting them in succession. The above modes require the use of hands and cannot be used by those with the inability to do so.

Erdem et. al. designed a laser keyboard which employed webcam based laser tracking. The letters in the keyboard are arranged in alphabetical order [1]. However, alphabetic arrangement does not improve the typing speed [4].

Our proposed system is a unistroke laser based keyboard for the disabled with the inability to move their hands, operated with head movements and with optimized character placement based on the most frequently used digraphs and trigraphs. Since it is a unistroke keyboard, selecting a key requires only one activity.

3. PROPOSED DESIGN

The keyboard system uses a webcam to monitor a keyboard. A laser pointer mounted on the head or eyeglass is used for selecting keys. The keyboard design is discussed below.

3.1 Character Set

In order to support text entry, all the alphabets in the English language are included in the keyboard. The unistroke keyboards in [1] and [3] only contain alphabets. In our design we have included digits to support numeric entry and some commonly used special characters. In addition to this, the keyboard consists of Caps Lock, Space, Enter, Delete and Shift keys.

3.2 Character Layout

The design of the keyboard is shown in Figure 1. The keyboard is divided into seven parts. Four of the arms are inclined so that it is easier for the user to move the laser pointer around without accidentally pressing keys he did not intend to press. Also, it accommodates more number of keys in lesser height. The keyboard can be external (on paper) or virtual.

To accommodate more characters, some keys can represent multiple characters when used with the Shift key. When the Shift key is pressed, the key pressed immediately after displays the alternate character, if present.

The letters that comprise the most frequently used digraphs and trigraphs are placed next to each other. So the user can select adjacent letters as a unit. By reducing the distance the pointer has to move, greater typing speed is achieved. Table I shows the number of digraphs expected in 2000 words of text and Table II shows the 15 most common trigraphs in the English language [6].

Caps Lock, Spacebar, Delete and Enter keys are placed in the center so that they are easily accessible from all the letters.

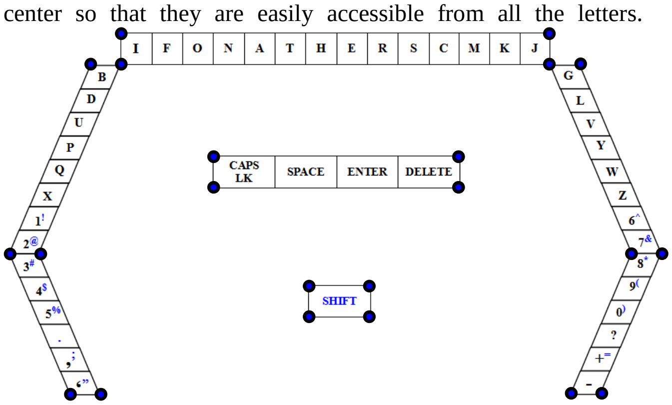

Figure 1. Keyboard Layout

Table 1. Number of digraphs expected in 2,000 words of English text

Digraph	Frequ-ency	Digraph	Frequency	Digraph	Frequency	Digraph	Frequency
th	**50**	nd	**30**	ea	**22**	ou	**17**
er	**40**	ha	**26**	ti	**22**	ar	**16**
on	**39**	at	**25**	to	**22**	as	**16**
an	**38**	en	**25**	it	**20**	de	**16**
re	**36**	es	**25**	st	**20**	rt	**16**
he	**33**	of	**25**	io	**18**	ve	**16**
in	**31**	or	**25**	le	**18**		
ed	**30**	nt	**24**	is	**17**		

Table 2. Fifteen most common trigraphs in the English language

No.	trigraph	No.	trigraph	No.	trigraph	No.	trigragh
1	the	5	ion	9	has	13	oft
2	and	6	tio	10	nce	14	sth
3	tha	7	for	11	edt	15	men
4	ent	8	nde	12	tis		

4. METHODOLODY

The flow of the system is shown in Figure 2. A webcam is set up and used to continuously capture an external keyboard. The webcam is then calibrated. Once this is done, the laser is tracked and the selected key is identified and displayed.

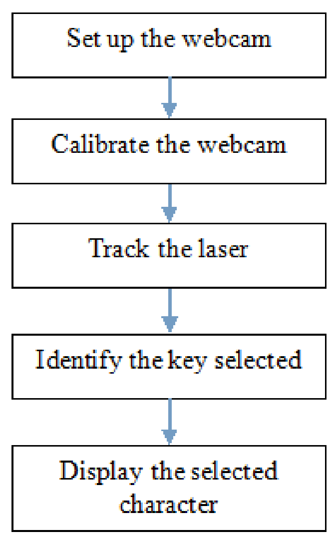

Figure 2. Flow of the system

4.1 Calibration

The angle and position of the keyboard can change every time it is set up and it is necessary to know the exact position and size of the captured keyboard. For this purpose, calibration is used.

4.1.1 *Calibrate keyboard position*

The method we have chosen for calibration relies on color detection. Each corner point of our keyboard is marked by a blue filled circle. The following algorithm detects blue from the frames being captured.

Steps: To calibrate keyboard position

Input: Captured frame.

Output: Set of points representing the corners of the keyboard.

1: Convert captured frame to hsv.

2: Define the range for blue color detection (lower and upper bounds)

3: Get the contours that lie within this range.

4: Filter the contours based on area.

5: Store the center of each of these contours.

6: Use these to calibrate the keyboard angle.

4.1.2 Calibrate keyboard angle

Figure 3 shows the detected blue circles with a number associated with each circle. This sequence of numbers is required to determine key boundaries which is discussed later. Since the keyboard and webcam can be placed at any angle, the order in which the blue circles are detected may differ every time. We have devised an algorithm to ensure that the sequence is achieved.

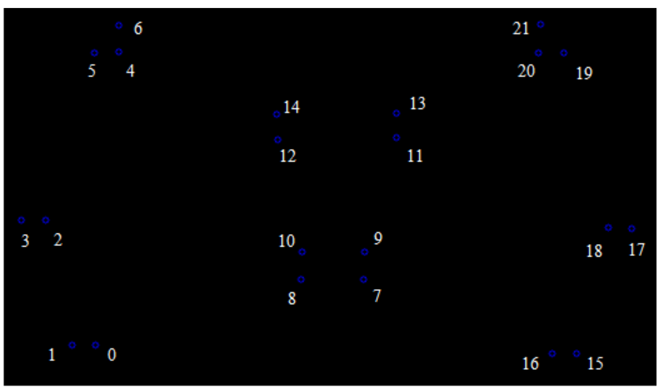

Figure 3. Calibrated points

Steps: To calibrate keyboard angle

Input: Set of points representing the corners of the keyboard.

Output: The calibrated keyboard.

1: Sort all points according to x distance

2: Divide sorted points into 3 parts as

Left: Points 0 – 6, Mid: Points 7 – 14,

Right: Points 15 - 21

3: To each of these parts apply the following

a. Sort based on y distance

b. Sort consecutive pairs of points based on x distance

4: Recreate the keyboard on the screen using these points.

Calibration is performed at regular intervals to ensure changes in the keyboard or webcam position don't affect typing.

4.2 Track the laser

When the webcam captures the keyboard, and a laser beam is focused on it, the camera perceives it as the brightest spot on the frame. The frame is converted to grayscale and a threshold is set to obtain this point. Since the position of the laser pointer is unstable, the average of a fixed number of frames is considered to find its position.

4.3 Identify and display the key selected

Based on the blue points detected during calibration, line equations are used to set the boundary for each key. The key whose boundaries within which the laser point lies is determined and that key character is displayed.

An example of this is shown in Fig. 5 which depicts laser tracking of the word 'part'. Output generated on the screen displays the letters p,a,r,t.

Table 3. Time taken, Total Error Rate and Not Corrected Error Rate recorded for each subject and trial

Subject No.	Subject 1			Subject 2			Subject 3			Subject 4		
Trial No.	wpm	Total Error Rate (%)	Not Corrected Error Rate (%)	wpm	Total Error Rate (%)	Not Corrected Error Rate (%)	wpm	Total Error Rate (%)	Not Corrected Error Rate (%)	wpm	Total Error Rate (%)	Not Corrected Error Rate (%)
Trial 1	10.97	**24.24**	**9.09**	9.25	21.21	6.06	10.06	**27.27**	**9.09**	9.81	**24.24**	6.06
Trial 2	11.04	21.21	6.06	9.63	**27.27**	**9.09**	10.26	**27.27**	**9.09**	10.03	**24.24**	6.06
Trial 3	11.28	21.21	9.09	10.26	18.18	**9.09**	10.26	24.24	**9.09**	10.40	21.21	**9.09**
Trial 4	**11.96**	18.18	3.03	11.11	18.18	0.00	10.62	21.21	6.06	10.88	18.18	3.03
Trial 5	**11.96**	21.21	0.00	**12.63**	15.15	3.03	**11.39**	18.18	6.06	**11.58**	18.18	3.03
Average	11.44	21.21	5.45	10.58	20.00	5.45	10.52	23.63	7.88	10.54	21.21	5.45

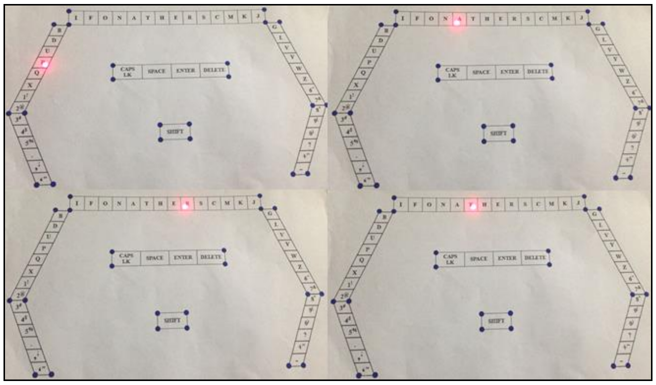

Figure 4. Laser tracking of the word 'part'

5. TESTING

5.1 Environment

The USB camera used for testing produces 640 pixel by 480 pixel color images. System processing is carried out in real time on an Intel Core i5 - 2.30 GHz processor with 4GB memory.

5.2 Methodology

User trials were performed to test performance of the proposed layout. Though the keyboard is designed for the disabled, the initial trials were conducted on 4 healthy subjects (females between ages of 17 and 22). The subjects were given the layout so as to familiarize themselves with the arrangement of keys. Their initial attempts to type were recorded for testing. They had no experience in using this system before this. Testing was carried out by giving the sentence, "this keyboard is for the disabled" to the test subjects each of whom typed it five times with a break of around 5 minutes between the trials.

5.3 Evaluation Measures

To evaluate the performance of the system, we use two measures proposed by [14], (a) Total Error Rate (b) Not Corrected Error Rate Character, as well as words per minute (wpm).

6. RESULTS AND ANALYSIS

The time taken, MSD Error Rate and KSPC of each tester is shown in Table 3. The bolded and underlined values represent the maximum and minimum values respectively.

The average session speed varies from 10.58 to 11.44 wpm. The average Total Error Rate ranges from 20.00 to 21.21% while the average Not Corrected Error Rate ranges from 5.45 to 7.88%. An increasing learning rate is observed in terms of the above measures. The testers were interviewed and they expressed that the initial unfamiliarity with the layout hindered typing. But with each trial, the testers grew more familiar and improved which is evident from the decreasing error rate and increasing speed. They felt that most of the errors were from focusing the laser on a key close by to the intended key due to inexperience in typing with head movements. Also, not knowing how long to focus the laser on the intended key caused them to type a letter more times than which they intended. They acknowledged that typing common digraphs like 'th' was easier due to adjacent placement of the characters.

The limitation of the system is that the calibration depends on the color of the circles at the corners of the keyboard. Hence calibration is affected if any blue object of approximately the same size as the circles is captured.

7. CONCLUSION AND FUTURE WORK

We have proposed a keyboard system to assist the handicapped in typing using a webcam and a laser pointer. The keyboard layout is designed based on the frequency of occurrence of letters, such that it is comfortable and convenient for the user. Future work will be focusing on improving the calibration technique and including commonly used keyboard shortcuts for copy, paste etc.

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