Virtual Laser Keyboards: A Giant Leap Towards Human-Computer Interaction

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Abstract— **this paper provides an alternative solution to the traditional physical-button keyboards. With implementation of laser technology, this virtual keyboard solves many problems faced with traditional keyboards, making it more practical. The keyboard consists of three modules respectively; the illuminating, sensing, and projecting module. The projecting module projects an image of a keyboard onto any surface, then the sensing module senses the user's fingers in coordination with the illuminating module, after which typed keys are displayed on the screen.**

I. Introduction

Technology, no doubt, is the fastest growing fields in today's world. Every day, new inventions in computers are made that are meant to simplify human's life. Laser Keyboard isan example. It works using the latest technologies and is a solution towards simplifying human's life.

Laser Keyboard is a virtual keyboard that contains no physical buttons. A picture of a keyboard is only projected on any surface, and placing a finger on the picture implies pressing a key. From the name, the laser keyboard works on the laser technology. The working of the keyboard largely depends on image processing and the algorithms in the code.

The virtual keyboard project aims at solving many of the drawbacks of the traditional physical keyboard. Some of these drawbacks include wear and tear when used for a long period, tendency to get destroyed with liquids, difficulty in carrying when travelling, utilization of large space area especially in public places and more. Moreover, this virtual keyboard project is a shift to a new technology that is good to explore for future benefits.

This prototype detects key presses, with the help of a projected beam of line laser above the typing surface and a webcam (an image sensor) that captures reflected light by the finger when a user presses a key. This project consists of 3 main modules; illumination, sensing and projection module. Each of these modules is responsible for a specific function. Illumination module consists of a 650 nm class II line laser which projects a beam of red light, at an angle of 60 degrees, above and parallel to the surface. Sensing module consists of a webcam with a CMOS sensor built in. It detects the light reflected from the user's finger when crossing through the red beam of light. Lastly, the projection module consists of a self made projector, only used to project an image of the keyboard onto a flat surface. The prototype has the functionality of displaying both Arabic and English keys. Moreover, the software code has been developed in such a way that any additional language can inserted into the keyboard. Thus, this virtual keyboard is a multiple-language-insertion device. It includes numbers, letters and modifying keys.

A few companies did invest to design virtual keyboard of their own. An example is the Magic Cube by Celluon Company. Almost all implemented the concept of three modules: illumination, sensing and projection. Though this technology is close to the sixth sense technology developed by Pranav Mistry, these products did not become so popular due to their expensive costs and product improvement requirements. Thus, this virtual keyboard has been designed with the lowest cost possible, making it suitable for majority customers.

II. Materials and Methods

There are three main modules to the project.

A. Projecting Module

The projecting module consists of a projector. It does not interfere with the working of the project, but only displays a keyboard picture in front of the user for the user's convenience. In this prototype, the projector is hand-built using simple Physics concepts.

B. Illuminating Module

A 650 nm Red Line Laser is placed right above the projected keyboard picture. The placing of the laser is such that it covers the entire keyboard picture size.

C. Sensing Module

Sensing is the major part in this project. For sensing the key pressed, a C110 webcam (that includes CMOS) is used. This

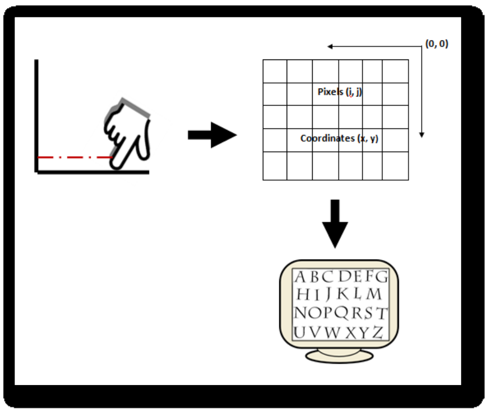

Fig.1. Project Main Architecture

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webcam has the ability to capture pictures continuously at the rate of 30 frames per second. When a user places his/her finger on a certain key, the laser beam hovering above that key is reflected from the user's finger into the camera. The camera, that is programmed to capture pictures continuously and processes each picture, will detect that reflected laser beam and interpret it to identify which key has been pressed.

The code of the project was written in MATLAB because of its capability in combining high-level languages with comprehensive math and graphics functions making a powerful image processing tool. It can also be interfaced with C/C++ which is needed to program the chip in this project. Fig. 2. shows the five main processes for the working of this virtual keyboard, while the hand-sketch flowchart in Fig. 4 describes in detail the implementation of this virtual keyboard. An Atmel Xplained kit and AVR ISP mkii In-system Programmer are used only to add features to this virtual keyboard.

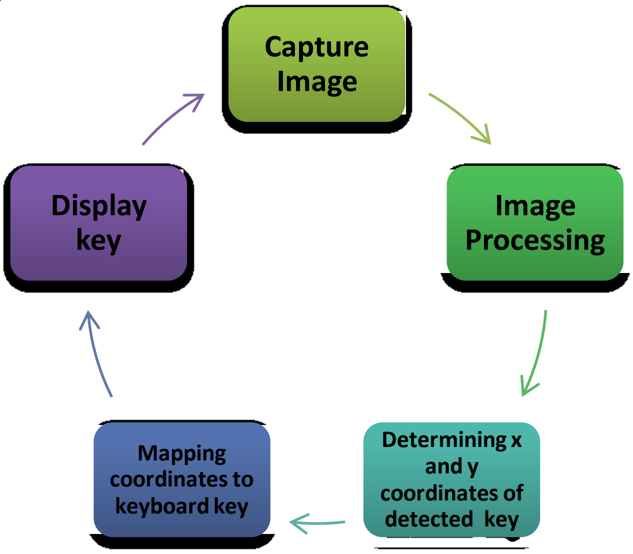

Fig.2. Major Software Parts

Fig. 3. Sample pictures to be processed

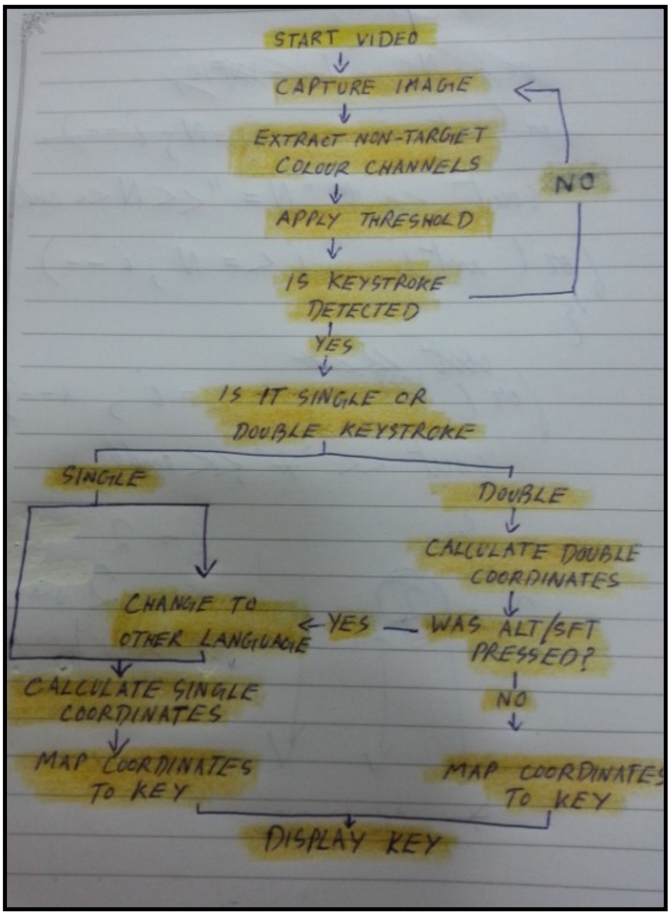

Fig.4. Software Implementation

III. RESULTS

The virtual keyboard is a project very sensitive to room conditions like room brightness, the source of the brightness whether natural (sun) or artificial(from bulb), colour of the typing surface, smoothness of the typing surface, and so on. It has the tendency to operate differently and give unwanted results in unsuitable environments. As such, major part of this project wastesting.

A. Testing Image Processinbg Code

First step in testing the project is to test the effeciency in the laser module. For this, a point laser module was directed onto different colour surfaces, then each picture was processed by applying a threshold (setting a value for the brightness of image pixels) on it in MATLAB. The purpose was to see if the laser dot could be separated from the background.

If this test succeeded and laser dots could be easily extracted from the background, the keystrokes on this virtual keyboard will be easily detected. With a threshold value of 200 (max 256) at the beginning, the device worked fine when projected onto different surfaces, except for few cases as shown in Fig. 5.

Fig. 5. Unwanted Result, Poor Image Processing

This problem could be solved by increasing the threshold to 230. But even then, the above testing proved that applying only a threshold was not sufficient to ensure the proper working of the project. Thus, the image processing code has been modified to achieve a successfully working project under all conditions. Table I summarizes changes done to the software code untill a working keyboard under all conditions has been achieved. Line lasers are less bright and are detected through the webcam in red, not white. As such, the software has been designed to extract all colour channels and to leave out only the red channel. Through testing, this method has proved to be more efficient, and meets the requirements of this project. By detecting the red colour of the laser and extracting out all other colour channels, all keystrokes are detected and the chance of an undetected keystroke is reduced to minimum.

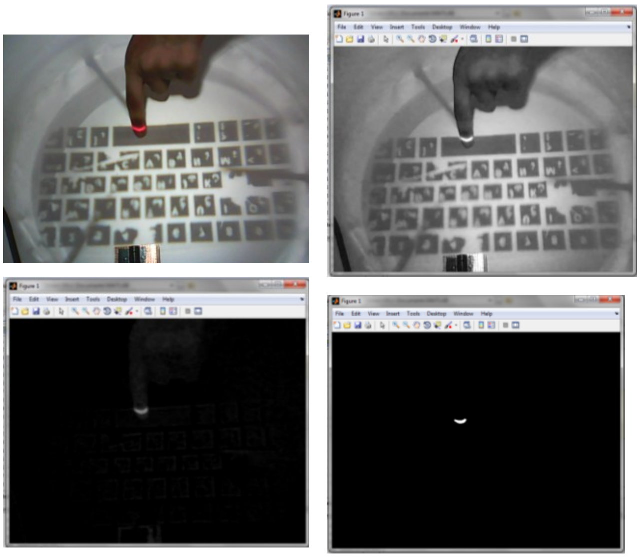

Fig. 6. Final Software Implementation

TABLE I
IMAGE PROCESSING ALGORITHM CHANGES

Steps Taken	Drawbacks Observed
Only Threshold	Poor performance in bright room
Threshold + Noise Removal	Poor performance in bright room
Threshold + Noise Removal + Removal of dots with eccentricity close to zero	Poor performance in bright room
Identifying round objects + Threshold	Poor performance in bright room + tendency not to detect keystrokes with eccentricity close to zero
Get difference between two images: one with keystroke, other without keystroke	Hand interferes with keystroke detection
Remove all colour channels except target channel	Not sufficient to detect keystroke
Leave behind only target colour channel, increase target colour brightness + threshold	Best performance, proved to work even in bright room

B. Testing using Test Cases

When random strings were entered using this virtual laser keyboard as shown in Table II, while all the characters are displayed and have gone unmissed, it was found that the keyboard has a tendency to display characters twice. This is not a default in the code, but is due to the capturing speed of the camera and running time of MATLAB code being faster than the time a human finger takes to press a key once. As such, this problem is not encountered if a key is pressed quickly. This problem was solved by adding a pause between capturing of images in the MATLAB code. Thus, the issue of a letter being displayed twice has been successfully solved. This virtual keyboard displays each character only once, unlike before.

TABLE II
RESULT FOR ON-SPOT CODE TESTING

S. No	**Expected Sentence**	**Displayed Sentence**	**Displayed Sentence (with 'pause')**
1.	i study at pmu	ii study att pmu	i study at pmu
2.	my name is	myy nme iss	my name is
3.	i love candies	ii love ccanndies	i love candies

The pause function inserting has been set to 1 second (this is the minimum that can be set in MATLAB). Thus, the camera will capture images at the rate of one image per second. While this will eliminate the problem of double display of characters on the screen, the pause function will reduce the number of characters that can be typed in a minute to 60 characters per minute (unlike previously, 120 characters per minute).

In terms of efficiency, this virtual keyboard has proved to be so accurate in the correctness of the characters displayed with a measured efficiency of around 98% when calculated from the result tables shown above. However, it has to be mentioned that the brightness of the room environment might affect the efficiency percentage of the virtual keyboard. As mentioned earlier, the darker the room, the better the algorithm of the keyboard works.

C. Testing Individual Modules

1) Testing Sensing Module: While the Logitech C110 Webcam is capable of capturing 30 frames per second, an

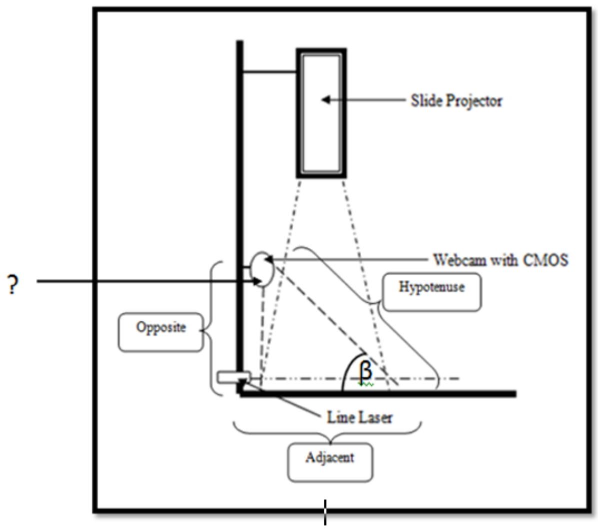

Fig. 7. Angle of Projection of Camera

issue occurred regarding the projection angle of the camera. Through trials, it was found out that best results are produced when the camera is focused only on the typing surface. The less the camera captures of the nearby surrounding environment, the less are the chances of failure of the code (particularly, image processing part) as shown in Fig. 7.

Opposite, AC = 61 cm
Hypotenuse, AB = 76 cm
Sin β = AC/AB = 61/76
$\beta = \text{Sin}^{-1}(61/76) = 53.4^0$
Therefore, Angle of Projection = $(180^0 - (90^0 + 53.4^0)) = 36.3^0$

Thus, the Webcam must be projected at an angle of 36.6 in order to cover only the keyboard area and ensure detection and display of the correct keys.

2) Testing Illuminating Module: It has been observed that the longer the distance of the typing surface from line laser (Working Distance), the dimmer is the laser that is detected when keys are pressed. However, the keyboard spreads up to 35 cm in length, which is equal to the standard DELL PC keyboard that has been measured that is around 35 cm.

Fan angle, which is the measure of angular spread of a line-generating laser, determines the line length produced at a certain distance. To achieve a keyboard of length 35 cm (Line Length), knowing from before that the line laser got a fan angle of 60^0, the minimum Working Distance has to be calculated to place to determine where to place the Laser so as to achieve the maximum possible brightness of the pressed key.

STEP 1: Divide the fan angle by 2, and take the tangent of it.
Fan angle/2 = 60/2 = 30, tangent (30) = 0.577
STEP 2: Divide the Line Length by 2.
Line Length/2 = 35 cm/2 = 17.5 cm
STEP 3: Divide result of STEP 2 by that of STEP 1, STEP 2/STEP 1 = 17.5 cm/ 0.577 = 30 cm → Working Distance

Therefore, to achieve a Line Length of 35 cm (length of our virtual keyboard) from a line laser of fan angle 60, we need a Working Distance of 30 cm.

3) Testing Projecting Module and Project Design: The first concern was the heat coming from the self-built projector bulb. The final decision was using a twisted white bulb of 11W, which produced the least heat and a bright enough image of the keyboard. Through testing, it was found out that the farther the keys were on the keyboard, the better and the more accurate the keys were detected and displayed on the screen. Thus, compensation had to be made between the comfort of the end users and the functionality of the virtual keyboard. This virtual keyboard has a QWERTY layout, and fully functional 48 keys (capable of displaying 82 different characters!).

IV. DISCUSSION

Thus, the group succeeded in designing a virtual keyboard with the speed of 120 characters per second (without pause between captured images) or 60 characters per second (with the pause between captured images). It has full 82 successfully displayed keys, and allows typing both in English and Arabic (it has to be noted that more languages can be inserted as well into the programmed code). Moreover, it has the tendency to detect single keystrokes (has been implemented), double keystrokes (has been implemented), and even triple keystrokes (has not been implemented here). The feature of flickering LEDs, on the Atxmega128a1 Xplained kit, when changing between languages by pressing on Alt/Shft has not been added. There seems to be issues with the chip ISP frequency that couldn't be figured out due to lack of time. Nonetheless, the keyboard functions properly even without this feature. Table III is a review of the disadvantages of this virtual laser keyboard. A comparison has been made between this virtual keyboard to the virtual keyboard that was already designed by the Celluon Company, the Magic Cube. Each of the two virtual keyboards implement different technique in terms of both software and hardware. According to one of the reviewers on Amazon, this product types 100 to 120 characters per minute on a perfect system. Thus, the group was able to successfully build a working prototype that can be marketable. While the Celluon keyboard costs SR. 750 ($200), this keyboard costs SR. 104 ($ 28) which makes it preferred by customers.

Table III
DISADVANTAGES OF THIS VIRTUAL KEYBOARD

Serial No.	Problem
1.	Keyboard poor performance in brightness
2.	Projector bulb gets over heated after long time.

For future work, this virtual keyboard can be developed and new features can be added, like connection through Bluetooth, mouse mode, replacement of light projector with a laser one, or improvements in the software code. Fig.8. is the virtual laser keyboard that has been designed by the group.

Fig.8. Virtual Laser Keyboard, English and Arabic enabled

With more enhancement in the technology used, this project could prove to be a giant leap for Human Computer Interaction.

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REFERENCES

[1] A, Khare (2003, Mar. 4th). “Virtual Typing” [Online]. Available: http://pcquest.ciol.com/content/technology/ 103030402.asp

[2] A. Kirillov (2007, Mar. 27th). “Motion Detection Algorithms” [Online]. The Code Project. Available: http://www.codeproject.com/ Articles/10248/Motion-Detection-Algorithms

[3] H. Xu et al. (2006, Oct). "User Interface by Virtual Shadow Projection" in *SICE-ICASE International Joint Conference 2006*.

[4] K, Nice et al. “Demosaicing Algorithms: Color Filtering” [Online]. How Digital Cameras Work. Available: http://electronics.howstuffworks. com/cameras-photography/digital/digital-camera5.htm

[5] Lawrence Erlbaum Associates Inc, “Human Computer Interaction,” in *HunterSmithHCIGalley*, pp 89-129, 2002

[6] TEDIndia 2009. “Pranav Mistry: The thrilling potential of SixthSense technology”. Available: http://www.ted.com/talks/lang/en/pranav _mistry_the_thrilling_potential_of_sixthsense_technology.html

[7] Wollert, T (2006). "About Portable Keyboards with Design and implementation of a Prototype Using Computer Vision". Department of Computer Science and Mathematics. Munich University of applied Sciences. Available: http://www.woellert.info/home/images/M_mmi_ paper.pdf

[8] “Reconfigurable Projected Keyboard”. Available: http://tiger.ece.stevens-tech.edu/10-11/11grp6/Spring%20Documents.ht ml

[9] “Sound Processing in MATLAB”. Available: http://homepages.udayton.edu/~rhardie1/ECE203/sound.html