Designing a Human Computer Interface Using Laser Track Pad (LTP) for the Physically Challenged People

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***Abstract* — In this paper, we have proposed a Human Computer Interface, replacing all the basic mouse operations by simple laser beam operations controlled by a Laser Pen (LP) & tracked by the Laser Track Pad (LTP). This approach helps to overcome the limitations of the physically challenged people for interacting with the computer systems. The main emphasis of this work is on mapping the Display Units (DUs) of various resolutions with our fixed-resolution LTP. We have introduced an algorithm to solve the Intermediate Pixel Reachability problem with minimal movement of the laser beam on the LTP (i.e., also with minimal movement of the body part holding the laser pen).The potentiality and possibilities for future works are considered.**

***Keywords*— Human Computer Interface, Laser Beam, Image Processing, Intermediate Pixel Reachability.**

I. INTRODUCTION

Research on Human Computer Interaction (HCI) has gone to a certain extent in the last two-three decades. In hand held devices the key pads are being replaced by the virtual key boards. Motion sensors [1] are being used to automatically set the screen position. Newer technologies are being introduced to ease the use of computer. Mouse is replaced by touchpad. The living standards of the physically challenged people also have been improved a lot within this period. Nowadays, using computer systems has become one of the essential requirements of modern daily life. The physically challenged people who cannot hold mouse or cannot use the key board has got some alternatives like "Camera Mouse" [2], [13]-[16], "hMouse" [3] etc. These solutions, which are currently available, are mostly hardware based and more focused towards the movement of the head position or the movement of a particular body part of the user.

Some popular methods like "Eye-gaze" [4] tracks the position of the eye balls as the users move their heads. "Camera mouse" is one which requires no body-attachments as it uses the web camera of the computer system. "hMouse" calculates the user's head roll, tilt, yaw and scaling, horizontal and vertical motion for mouse control based on the reliable tracking result of the hMouse tracker. A new approach "Black Pearl" [5] has recently been launched in the market. But it is almost using the same technology as of the "Camera Mouse". All these technologies depend on the movement of the users' head positions. But, practically this needs a huge movement of the head to navigate the mouse cursor between the extreme corners of the display units, which sometimes becomes impossible for a physically challenged people.

Laser Track Pad (LTP) focuses greatly on reducing the head movement/body part movement of the user and accurately tracks the position of the laser beam [6] on the track pad through a camera fitted within it. A physically challenged people can grip a pen in the mouth or between his toes (Hallux & Second toe) and can write or paint something. Similarly a Laser Pen is also very easy to grip & operate almost in the same way.

In this paper, the basic components required for the purpose are defined. Working principle along with the laser beam actions (equivalent to the conventional mouse operations) are also being mentioned in brief. In section-V the algorithms for mapping of the LTP with the DU have been proposed and analyzed with the help of an example. Section-VI discusses the implementation details & lastly, section-VII concludes the paper.

II. DESCRIPTION OF THE COMPONENTS

To implement all the different operations of a mouse we require a LTP fitted with a web camera and a source of laser light (i.e., a laser pen). According to the movement of the laser beam on the LTP, a mouse cursor is navigated to point the desired location on the DU. Interactions of the LP and the LTP with the DU are being shown in the Fig. 1.

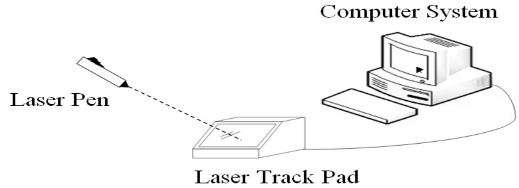

Fig. 1 Components and Their Interaction.

A. Description of the Laser Pen

The low-cost Laser Pen (of height 50 mm & diameter 13 mm), used in this work is very common & easily available in the market. It comes with an ON/OFF switch which can be easily operated by an effortless pressing (even by the lips). Fig. 2 shows the basic architecture of the Laser Pen.

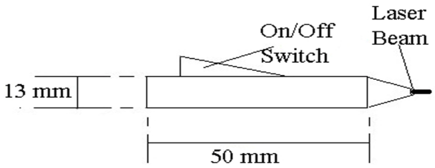

Fig. 2 Laser Pen

B. Description of the Laser Track Pad

A LTP is composed of a standard web-camera placed under a frosted glass sheet, focusing the centre of the glass sheet and maintaining a fixed distance (depending on the focal length of the lens used) from it such that the total area of the LTP comes within the Angle of view of the lens [11]. Angle of view can be measured horizontally, vertically or diagonally. Fig. 3 shows the basic architecture of the Laser Track Pad.

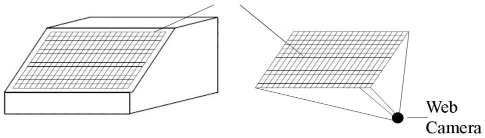

Fig. 3 Laser Track Pad

III. WORKING PRINCIPLE

In this system, we have first mapped the LTP with the DU. That is, through the incidence of a laser beam on the LTP, we can point to any of the desired locations on the DU. Now a LP is used as a source of the laser light to point on the frosted glass sheet of the LTP. The distance between the laser source and the track pad does not affect the degree of accuracy for the identification of the incident point of the laser beam [12] on the LTP.

Then from the video streams captured by the web camera fitted inside the LTP box, the co-ordinates of the laser incident point are identified and the mouse is navigated to the equivalent position on the DU by applying the LTP to DU Mapping Algorithms.

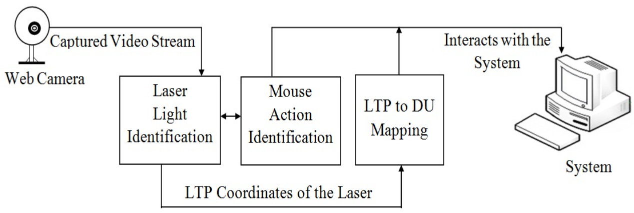

Fig. 4 Block Diagram of the System

Mean while, by analyzing the video streams we identify the basic mouse actions (e.g., mouse pointer move, single click, double click and right click) performed by the user at that point and accordingly the action is performed. So, in this way the physically challenged people can interact with the computer system with minimal head/body part movement. The block diagram of the system's work flow is shown in Fig.- 4.

IV. BASIC MOUSE OPERATIONS REPLACED BY THE LP ACTIONS

Table-I
LIST OF MOUSE ACTION

Mouse Operation	Laser Pen Action	Time Span
Mouse Pointer Move	{ON-MOVE}	–
Single click	{ON-OFF}	t
Double Click	{ON-OFF}, {ON-OFF}	t
Right Click	{ON-OFF}, {ON-OFF}, {ON- OFF}	t

1st column of the Table-I represents the basic mouse operations and the 2nd column represents the corresponding actions of the Laser Pen, (the action states are defined in the Table-II). 3rd column represents the fixed time span (t) for successful execution of different mouse operations.

Table-II
DESCRIPTION OF ACTION STATES

States	Description
ON	Start of laser beam emission.
OFF	Stop of emission.
ON-OFF	ON before OFF
MOVE	Movement of the laser beam.

According to the working principle, the number of {ON-OFF} pair(s) within the fixed time span 't' is counted and accordingly the corresponding mouse operation is executed, i.e. if the {ON-OFF} pair occurs once within the specified time span 't', it is treated as a single click. If it is counted as 2 or 3, then the mouse double click or mouse right click is executed respectively.

V. ALGORITHM

In this work, algorithms for laser light identification and mapping between LTP & DU are proposed & implemented.

A. Laser Light Identification

INPUT: Images captured by the web camera (at minimum speed of 7fps).

OUTPUT: Co-ordinates of the laser incident point.

Step1: Convert each and every image captured by the web camera in to gray scale.

Step2: Filter out everything except laser light of specific intensity range, using the Fourier transformation on each and every gray scale images.

Step3: Retrieve the position of the specific intensity laser dot within the image.

Step4: Return the co- ordinates and stop.

B. LTP to DU Mapping

This algorithm is to map the LTP of a fixed resolution with display devices of different resolutions (e.g.: 640 X 480, 800 X 600, 1280 X 1024 etc.). Otherwise, if the mapping was limited between the LTP & the DU of a specific resolution, then sometimes it might happen that the total area of the display screen is not covered by the laser beam movement on the LTP.

To map the x & y co-ordinates of the LTP with the same of the DU, two mathematical factors (RI_W & RI_H) have been proposed. In Fig. 5 we have shown the mapping of the above mentioned display devices (having two different resolutions & aspect ratios) with our fixed-sized LTP.

The LTP to DU mapping has been achieved by two algorithms -- "Basic LTP to DU Mapping Algorithm" and "Intermediate Pixel Reachability Algorithm".

1. Basic LTP to DU Mapping Algorithm

Now, let us denote the following terms,

PW_{LTP} : No. of pixels along the width of the LTP.
PH_{LTP} : No. of pixels along the height of the LTP.
PW_{DU} : No. of pixels along the width of the DU.
PH_{DU} : No. of pixels along the height of the DU.

IW_{LTP} : No. of intervals along the width of the LTP.
IH_{LTP} : No. of intervals along the height of the LTP.
IW_{DU} : No. of intervals along the width of the DU.
IH_{DU} : No. of intervals along the height of the DU.

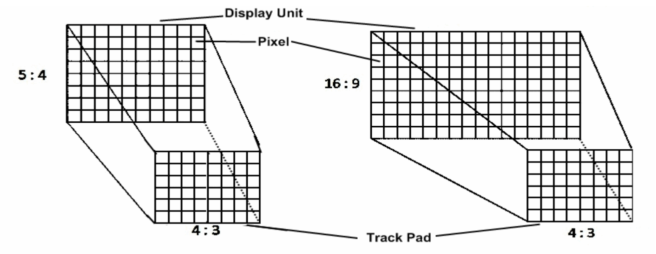

Fig. 5 Mapping of different displays with the fixed sized LTP.

Then, $IW_{LTP} = PW_{LTP} - 1$
$IH_{LTP} = PH_{LTP} - 1$
$IW_{DU} = PW_{DU} - 1$
$IH_{DU} = PH_{DU} - 1$

$RI_W = IW_{LTP} : IW_{DU}$
$= 1 : (IW_{DU} / IW_{LTP})$ ……………..(1)
$RI_H = IH_{LTP} : IH_{DU}$
$= 1 : (IH_{DU} / IH_{LTP})$ ……………..(2)

Therefore, if the point (x, y) on the LTP is mapped to the pixel position (X, Y) on the DU, then

$X = (1/ RI_W)^* x$ and
$Y = (1/ RI_H)^* y$

Example:

Let the resolution of the LTP be 4 x 4 and the resolution of the DU be 16 x 12. We have to map the LTP with the DU. Fig. 6 shows the pixel wise mapping.

Then, $RI_W = \dfrac{(4-1)}{(16-1)} = \dfrac{1}{5}$ ……………… from Eqn. (1),

$RI_H = \dfrac{(4-1)}{(12-1)} = \dfrac{1}{3.67}$ ...…………. from Eqn. (2).

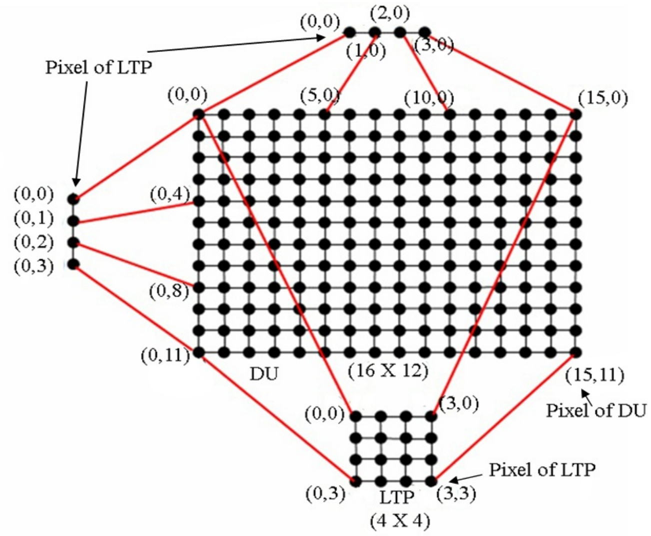

Fig. 6 LTP to DU pixel wise mapping.

In the above section we have discussed about the Basic LTP to DU Mapping Algorithm. But, this algorithm has a severe limitation as one pixel movement of the laser beam on LTP along the width & the height causes a movement of ($1/ RI_W$) & ($1/ RI_H$) pixels of the mouse curser on the DU respectively. That is, if the laser beam moves from (0,0) to (0,1) along the width on the LTP, the mouse cursor jumps from (0,0) to (0,5) on the DU. That is the intermediate pixels viz. (0,1), (0,2), (0,3) & (0,4) on the DU could not be reached by the movement of the laser beam on LTP.

To solve this problem in both horizontal and vertical directions, we have introduced two new speed factors (SF_W & SF_H) in the Intermediate Pixel Reachability Algorithm that will control the mouse cursor movement to reach the intermediate pixels.

2. Intermediate Pixel Reachability Algorithm

Let, "s" be the speed at which 1 pixel movement of the laser beam on the LTP causes maximum of (IW_{DU} / IW_{LTP}) = ($1/ RI_W$) (say N) pixel movement on the DU --- From Eqn. (1).

Now, we can understand that to reach the intermediate pixels on the DU, we have to move the laser beam at a speed fractional to "s" (lesser than "s", different for different intermediate pixels).

Experimental results are given in the following Table-III **where N = 5**. Here, the dots in the 4th column of the table represent the pixels on the DU and the connecting line represents the number of pixels covered.

Table-III
PIXELS MOVEMENT ON DU

Movement of beam	SF_W (Speed)	# Intervals moved on DU	Pixels moved on DU
1 unit	$\frac{(N-0)}{N} * s$	N - 0	●—●—●—●—●—●
1 unit	$\frac{(N-1)}{N} * s$	N - 1	●—●—●—●—● ●
1 unit	$\frac{(N-2)}{N} * s$	N - 2	●—●—●—● ● ●
1 unit	$\frac{(N-3)}{N} * s$	N - 3	●—●—● ● ● ●
1 unit	$\frac{(N-4)}{N} * s$	N - 4	●—● ● ● ● ●

Therefore, If the Laser beam moves 1 pixel horizontally on the LTP with a speed factor $SF_W = \frac{(N-i)}{N} * s$ then, the $(N-i)^{th}$ intermediate pixel is reached.
Here, $N = (1/ RI_W)$ and $i = 0, 1, 2, 3, \ldots, (N-1)$.

Using the same approach we can reach the intermediate vertical pixels (along the height) with $SF_H = \frac{(M-j)}{M} * s$ where $M = (1/ RI_H)$ and $j = 0, 1, 2, 3, \ldots, (M-1)$.

VI. IMPLEMENTATION

We have implemented the application of the LTP in Aforge.Net [7] framework. Aforge.Net is basically a library for image processing routines and filters [8], [9]. To track the laser light, Aforge.Net is provided with a number of standard methods, which can deal with image processing. We have used few such methods to process the video stream captured by the web camera.

Considering video as a continuous stream of images, for real time image processing we need to process each and every image captured by the web camera. We are taking an average of 7 frames per second (fps) within our application. More the fps, more smoothly the program will run.

The program searches for the brightest red blob [7] in web camera's field of views. It may be done by using two of the filter defined in AForge.NET Framework (blob counter and color filter).

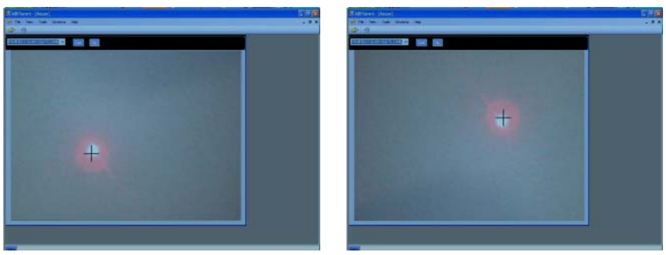

Fig. 7 Application output

In this application we have already implemented the portion to identify the specific intensity laser light and the co-ordinate of that laser light on the LTP. And we have mapped the LTP with the DU. We have also successfully implemented the ‘mouse left click’ and the ‘mouse double click’ operation through LTP. And we are working on the rest part of our proposed model. Fig. 7 shows the movement of the mouse cursor according to the movement of the red laser light.

VII. CONCLUSION

The implementation of LTP shows that it is a very effective pointing device and it significantly reduces the head/body part movement of the user, which is really helpful for the physically challenged people. In our implementation the LTP tracks and separates all the lights within a specific intensity range (the intensity range of the red Laser light). So, there is a possibility of some other lights within that intensity range to be unnecessarily tracked by the LTP. These unwanted lights may cause the identification of the Laser incident point erroneous. As future works it can be possible to implement the infrared version of the LTP. Still in the series of Camera mouse, Laser Track Pad (LTP) is a useful successor.

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