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Interactive Touch Board using IR Camera

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Abstract — **This paper presents a novel and cost-effective approach to convert any projected display on a flat surface into interactive touch board, through the aid of computer vision techniques. An interactive touch board is similar to that of a touch screen available in mobile phones and tablets, but then uses a special stylus for its input and a LCD projector for projecting the display on the surface. Commonly used techniques fall under any of the four categories – Resistive, Capacitive, Electromagnetic and Optical. The paper proposes a method pertaining to the optical technique – involving an infrared camera, a light emitting stylus and an image processing algorithm to determine the position pointed by the user. The stylus has an infrared LED at its tip and capable of producing a tiny spot of light on the projected surface, which is invisible to human eyes. But an IR camera with IR pass filter can be used to capture the light spot and can be processed further. This is the principle technique behind the proposed method. The image from the camera is processed using an algorithm, which determines the coordinates of the IR light. This obtained position along with some calibration parameters is sufficient to calculate the mouse cursor coordinates and thus the cursor can moved to the intended position. The whole of the image processing algorithm has been implemented using the NI LabVIEW and its associated Vision and Motion toolkits. Further, the paper deals with the study of potential applications in education and scientific research.**

Keywords – Interactive Touch Board, Image Processing, Computer Vision, IR stylus, IR camera

I. Introduction

The advent of new technologies in class rooms like the LCD projectors, interactive whiteboards, smart attendance systems etc. have changed the conventional system of teaching. An interactive whiteboard is a display system that projects a computer's desktop onto flat surface like a whiteboard, wall or a screen. The user is free to interact directly with the projected display using a pen, stylus, finger or hand gestures.

These types of boards have evolved in their technology, since their inception in last few decades. Some of the commonly implemented technologies include [1]: Resistive, Capacitive, Active and passive Electromagnetic Boards, Optical, DST [Dispersive Signal Technology], Ultrasonic. While resistive, capacitive, DSTs require special screens and expensive array of sensors to be present on the projected surface, Optical technique stands unique since it can be used for any flat surface. This makes the system low cost and easily portable. A simple prototype of such a system has been demonstrated by J.C. Lee using a Wiimote [2]. Further development in the Wii based designs were demonstrated in the papers by Zhixun Wang, James Louey [3] and Koray Yucel et al. [4]. In a paper on using interactive board for collaborative Learning [5], an infrared glove has been used instead of a stylus to interact with the display.

Shuai Zhang et al. in their paper [6] have presented a method to use an infrared stylus to interact with projected display, using Microsoft's Kinect. They have implemented right click feature by varying the intensity of the infrared rays emitted by the stylus. Whereas Massimo Camplani et al. [7] have eliminated the use of stylus by utilizing the depth information from the Kinect. Technologies like Zero-Touch [8] use state of the art techniques to provide the users with seamless interfacing experience.

As a cost-effective and novel approach to the interactive technology, this paper presents an innovative idea to interact with the project display using IR camera and IR stylus. The main advantage of the design is the use of inexpensive camera, which is much lesser than Kinect or Wii based hardware and thus making the whole model to be much lesser in cost.

II. Hardware Setup

The Physical setup of the system is represented in Fig. 1.

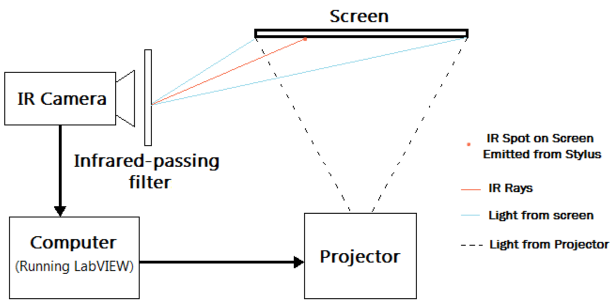


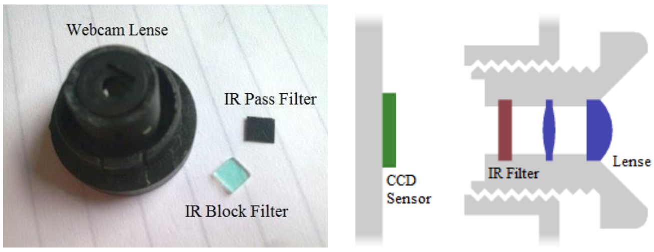
Fig. 1. System Setup

The main objective of this paper is to design a technique that is low cost, flexible and easy-to-install. The setup is simple and involves placing of the IR Camera in an appropriate position, so that the whole of the screen lies within the image frame. The camera can be placed at any angle, provided the screen is fully visible. This is followed by a user friendly calibration technique and at the end of the calibration the setup is ready for the user to interact with the projected display using the stylus.

A. Infrared Camera

A camera with Infrared filter is used as the image source for the proposed algorithm. This is used to capture the spot of light on the screen, emitted by the stylus. The IR rays being invisible cannot be perceived my human eyes. But an IR camera's CCD sensors can detect these rays and produces a bright spot in the image.

The visual band of spectrum doesn't have any information about the position of the stylus. Hence a filter is used to restrict the allowable band of spectrum into the camera's sensor. An IR pass filter is used for this purpose, which allows infrared rays to pass, while blocking visual rays. For the experimental purpose the IR Block (or Visible Pass) filter inside a web cam is replaced with IR Pass filter as shown in Fig. 2.



(a) (b)

Fig. 2. (a) IR Block and IR Pass Filters; (b) Filter position inside lens case

B. Stylus

The user interacts with the projected display using an IR Stylus. The stylus is equipped with an IR LED, Push to click button and a Battery to power the LED. When the user presses the button, pointing the stylus on the surface, a spot of infrared is produced on the screen and this is captured by the camera. Processing this image using the proposed algorithm is used in determining the user intended coordinate on the screen. The prototype of the IR stylus is shown in Fig. 3.

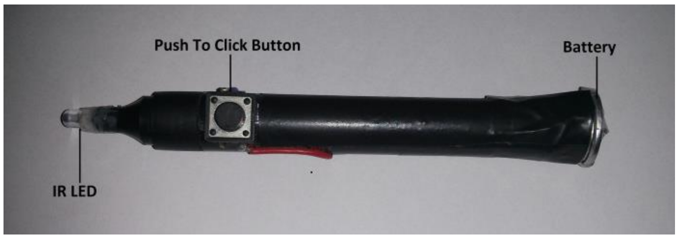


Fig. 3. IR Stylus

III. Proposed Algorithm

The proposed image processing algorithm has two main stages. In first stage the image captured in the perspective view is converted into font view of its orthogonal projection. Next stage involves computer vision techniques on the rectified image in order to detect the coordinates of the IR spot. The algorithm's flow has been represented in the Fig. 4.

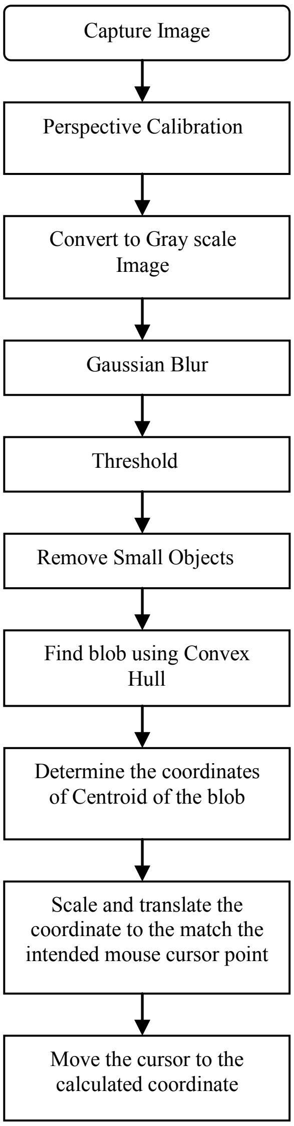
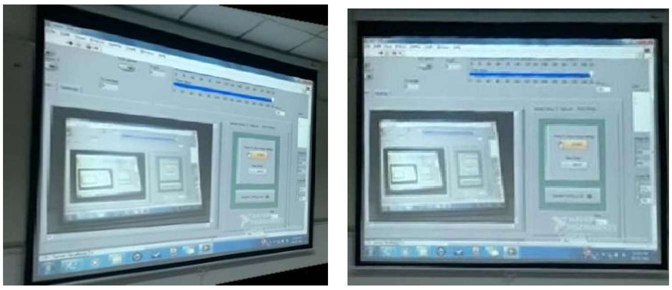


Fig. 4. Flow chart of the proposed algorithm

A. Inverse perspective transformation

The camera captures the 3D image and is translated into a 2D image plane. During this process, the image undergoes a distortion called perspective distortion. As a result, the real world coordinates (R_i) pointed by the stylus becomes a non-linear function of the coordinates (P_i) obtained from the raw image captured by the camera. In order to determine the real world coordinates, this distortion must be compensated. This is achieved by performing inverse perspective transformation on the raw image. Mapping the points on the distorted image to a 2D rectified image, establishes a linear relationship with real world coordinates and rectified image coordinates.

The transformation provides the orthographic view from the font of the flat projected surface. The Fig. 5. (a) and (b) shows the perspective and orthogonal front view of a projected surface respectively. Some of the self-calibrating techniques are discussed in the papers [9] and [10]. However the empirical evaluation has been carried out by manual four point calibration technique available in NI Vision Toolkit [11].



(a) (b)

Fig. 5. (a) Perspective View; (b) Orthogonal front view

B. Gray Scale conversion and Filtering

The rectified image from the perspective calibration consists of only brighter infrared spot and darker background. Hence further processing is carried out on grayscale, by extracting the luminescence plane from the RGB planes. This grayscale image is smoothened using Gaussian filter having a 3x3 window. The resultant image with the IR spot is shown in Fig. 6.

Fig. 6. Grayscale Image with bright IR spot

C. Blob detection

In-order to segment out the bright IR spot, binary thresholding technique is performed on the filtered image. Presence of noise in the image might cause some bright pixels to appear in the resultant binary image. This phenomenon is shown in the Fig. 7. By removing the bright segments with smaller pixel area and applying Convex hull function helps in segmenting a single White blob over black background, as shown in Fig. 8 and Fig. 9

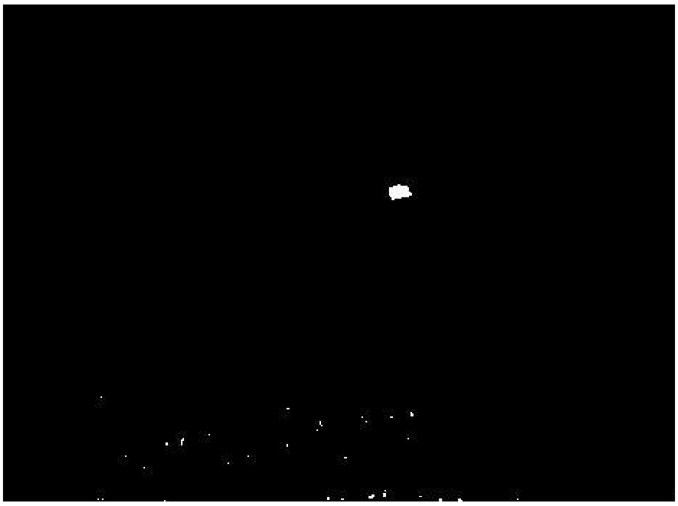


Fig. 7. After Threshold

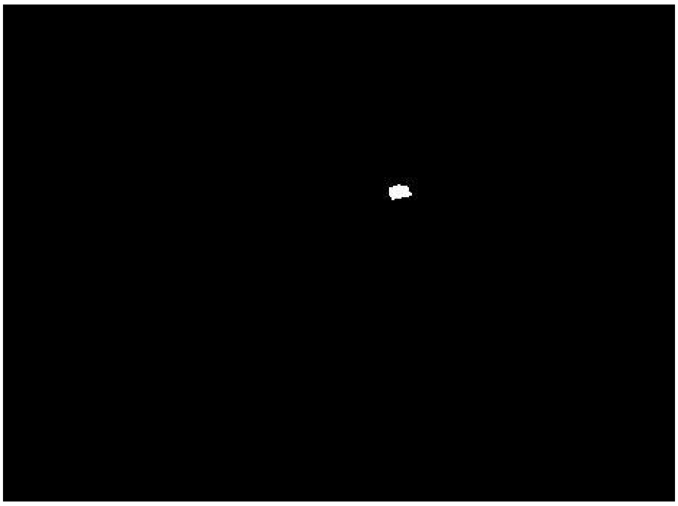


Fig. 8. Removing Small Objects

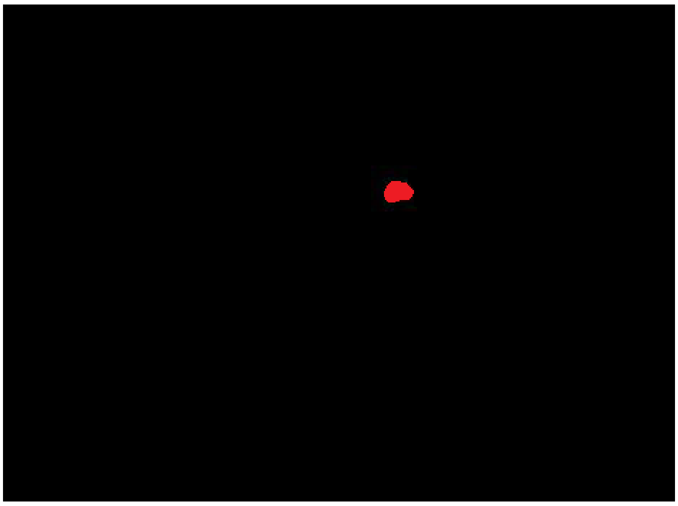


Fig. 9. Convex Hull

D. Centroid calculation and Cursor movement

After segmenting the blob, the coordinates of the blob is calculated using the centroid formula for irregular objects. This point corresponds to the scaled and translated position of the real world coordinate pointed by the stylus. The mouse cursor is set to the scaled and translated coordinate and thus moving the cursor to the user intended position. Mouse cursor controls are implemented through Microsoft's mouse event function [12].

IV. Empirical Results

The algorithm was implemented using NI LabVIEW, utilizing its vision and motion toolkit for image processing. The front panel of the program is shown in Fig. 10. A USB web camera fitted with IR pass filter was used as the capture source, providing an image resolution of 800x600 at 30 fps. The threshold value used in the algorithm determined depending on the type of camera and IR filter used and also depending on the ambient sunlight level. Assuming the setup is used in a closed room, the effect of variation in ambient sunlight can be considered negligible or zero. From the empirical analysis, a value in the range 95 to 110 is found to be an optimum for the threshold value.

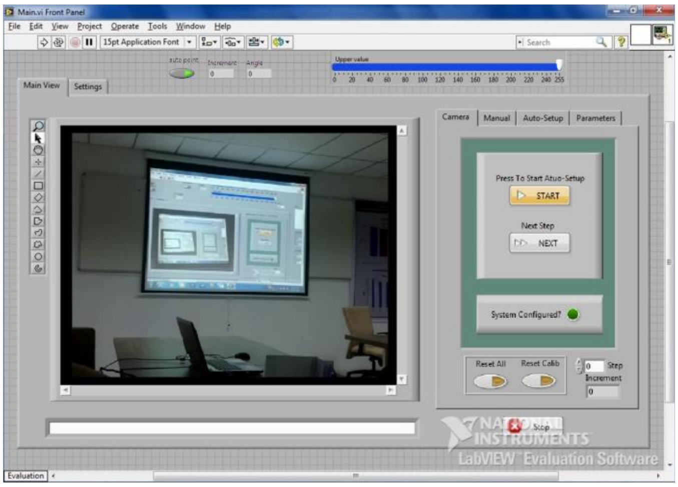


Fig. 10. Front Panel

The accuracy of the system directly depends on the resolution of the image from the camera and inverse to the distance from projected surface to the camera. Also the accuracy increases with increase in projected surface area. The latency of response is calculated as the time interval between the user's click and the cursor's response to it. This time depends on the configuration of the computer used and also the resolution of the image being processed.

The experiment was carried on a laptop having Intel Core i5 Processor @ 2.27 GHz, 4 GB Memory and running Windows 7 64 bit Operating system. The Table I. shows the obtained results from the experiment. Fig. 11 shows the efficiency of writing words using the stylus. Interacting with the computer using left mouse click is shown in the Fig. 12 and 13.

TABLE I. Results From Experiment

Parameters	**Values**
Display Resolution	1024 x 768
Image resolution captured by the camera	800x600 at 30 fps
Projected Size	2.25 m x 1.7 m
Distance from projected surface to the camera	~ 3 m
Threshold value used	103
Average Accuracy	98.9 %
Average Pixel deviation along X axis	± 4 pixels
Average Pixel deviation along Y axis	± 5 pixels
Average Latency in Seconds	0.28 sec

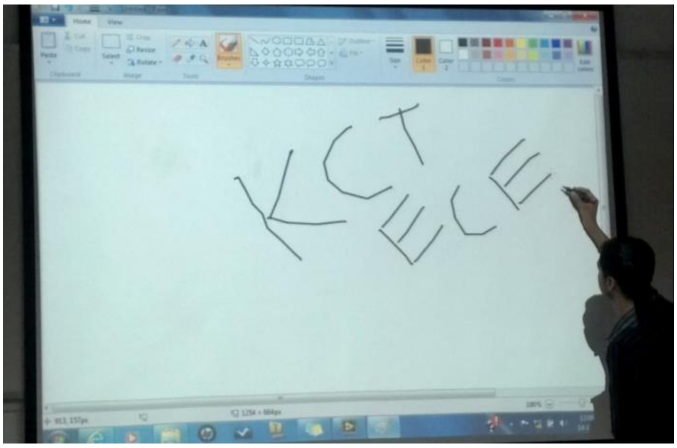


Fig. 11. Writing

Fig. 12. Interacting with computer using Stylus

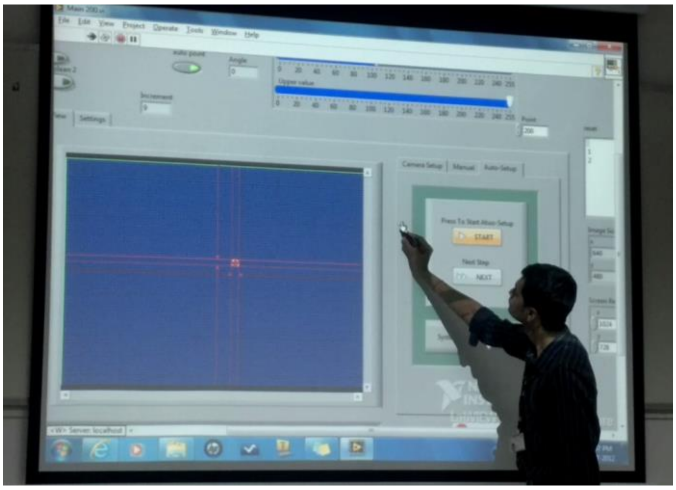


Fig. 13. Interacting with computer using Stylus

V. CONCLUSION

In this paper, a novel approach to an interactive touch board using an infrared camera and infrared stylus has been presented. Using minimum and low cost hardware makes the system cost-effective. With fast spreading digital media in schools, the system could find potential applications educational sector. Also eliminating complex hardware makes the design portable and user friendly. Results from Experiments are well promising and provides good accuracy. With high level of application, soon the system could be seen widely used in educational, research, business and similar sectors.

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