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An Efficient Web Camera Based Mouse Cursor Controlling System Using ComputerVision and Human Computer Interaction Approaches

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***Abstract*— This paper presents an integrated Human Computer Interaction (HCI) and Computer Vision based approach for controlling the cursor of the computer mouse and executing its other functional events such as left-right clicks and scrolling. Movements of three color taps namely red, green and blue are detected by a web camera that can automatically generate a signal in the developed .NET Framework based software. Based on this signal, appropriate operation of the mouse is performed. Here, a core algorithm determines the pixels movement from the subtracted color image from the original image considering both its current and previous positions in terms of nearest neighbors. These subtraction and neighboring ideas greatly improves the accuracy of the proposed method. In real time, the proposed scheme performs nearly as equal to the existing hardware based system but has gained more than 75% improvement in performance over the existing vision based system. Moreover, the proposed implementation is more light weighted and much more scalable than the other conventional works.**

***Keywords*— Computer vision, Color detection, Hand gesture, Human computer interaction, Mouse, Web camera.**

I. INTRODUCTION

Personal computer system are playing significant roles in our daily needs as they are being used in various aspects of trade, education, scientific research, entertainment and many other applications. Human Computer Interaction today greatly focuses on the development of more spontaneous and natural interfaces. The Graphical User Interface (GUI) on person computer is quite developed, well defined and efficient interface for a user to interact with the computer and access the various applications effortlessly [1]. Most importantly, all these applications have one thing in common which is use of an input method using mouse and keyboard. Many researchers of HCI and robotics have tried to control mouse movement using video devices. However, all of them used different methods to make clicking events. Touch screens are also becoming a common input method and nowadays it is used globally in many applications. However, touch screens cannot be applied to desktop systems because of costs and other hardware limitations. It may be an unavoidable barrier for people with limited freedom of movement of their limbs. In this circumstances it would be much more preferable to use an input method based on the motoring abilities of our head region such as movements of our hands specifically figures. Enabling such an alternative input method could be an unique technique that has been proposed to handle such problem. The system follows a low-cost approach to control a mouse cursor on a computer system. Here development of an efficient mouse control system is the central challenges [1-3]. It also allows a novel interface for the recent computers [4]. The existing interfaces such as touch screen, embedded-keyboard, folder-keyboard and mini-keyboard are costly and have many limitations such as space requirements and motionlessness problems. Thus, the researchers always try to develop an alternative input method for the recent computers specifically for the desktop and laptop based machines [5]. Existing mouse cursor controlling systems for these machines can broadly be categorized in the following two dimensions:

(a) Hardware based approaches: A separate and external hardware device such as mechanical or computing device is used to control the mouse cursor and perform necessary operations [6- 8].

(b) Vision based approaches: Movements in front of the computer are detected by a camera. The mouse is then operated based on these movements or functions. It uses theories of image processing and a computer webcam works as a primary input method. In these approaches, vision based gesture recognition systems are generally used to broken down the stages into skin detection, hand contour extraction, hand tracking and gesture recognition. The input frame is captured from the webcam and then skin region is detected. Finally, the hand contour is calculated and used for hand tracking and gesture recognition. However, all these approaches [1,5,9-15]. Due to significant amount of variations between the vision based and hardware based mouse controlling approaches, the task mouse controlling becomes much harder specifically for the end users. In addition, these methods are costly with respect to performance accuracy and are unscalable, because few require expensive hardware whereas others perform poorly in real time. In these consequences, this paper presents an efficient vision based and HCI mouse cursor control system for the recent desktop and laptop computers. The proposed system not only excludes the use of additional hardware but also performs efficiently in real time. The proposed system can be used in the development of the biomedical instrumentation [6, 16], computer gaming and prosthetic [7], augmented reality [8] etc.

Figure 1. Work flow diagram of the proposed mouse controlling system

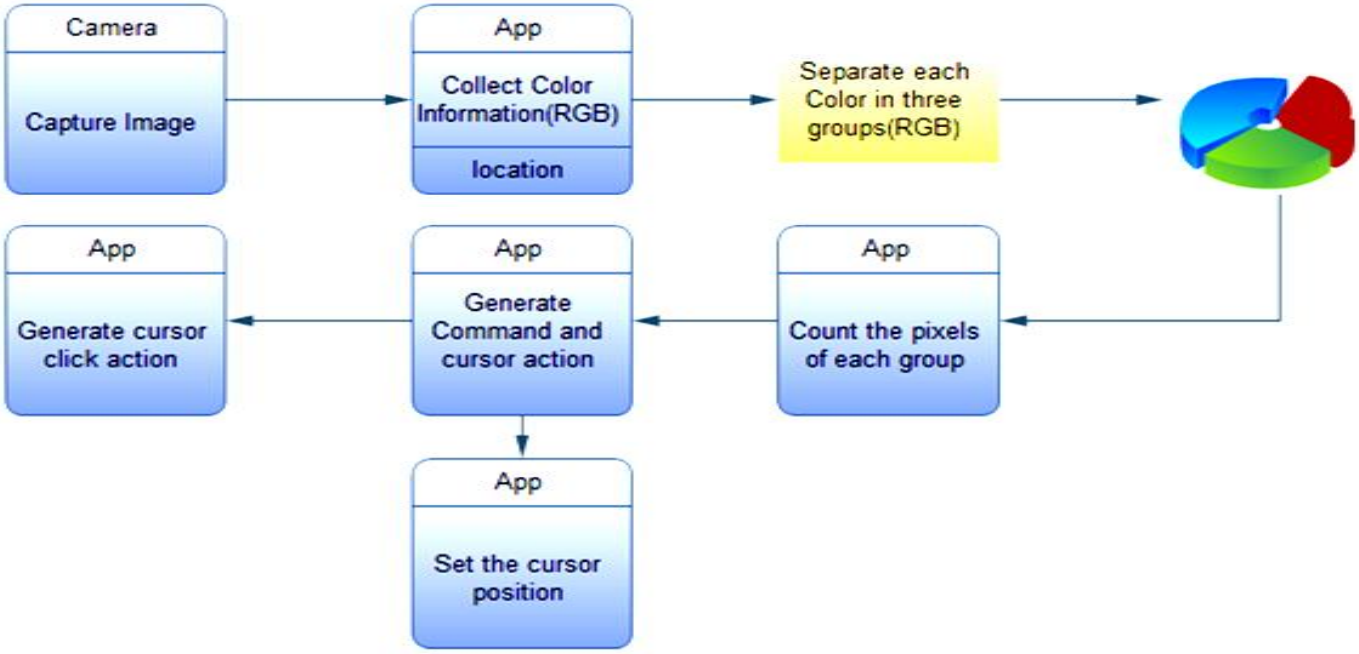

Figure 2. Data flow diagram of the proposed mouse controlling system

The rest of the paper is organized as follows: Section II describes detail the background. The proposed mouse cursor controlling system is presented in Section III. According to the proposed design, the working procedure of the proposed mouse cursor controlling system is also described in this section. Section IV shows the performance analysis of the proposed system while some concluding remarks are presented in Section V.

II. BACKGROUND STUDY

A brief survey on the existing mouse cursor controlling system is already presented in Sec. I. This section illustrates the other necessary background which is required to understand the proposed work.

A. Steps in the vision based mouse cursor controlling

The functionality of the vision based mouse controlling systems can broadly be divided into following four stages:

(a) Image capturing: A camera (additional digital camera, web camera or real time camera) is used to capture the images. Existing approaches differ in the number of image taken per unit time and the use of devices.

(b) Object tracking: It is the process of locating the moving object. Object tracking by itself has variety of uses forexample in human-computer interaction [1,2], security and surveillance [11], video communication and compression [17], augmented reality [7], traffic control [12], medical imaging [6, 18] etc.

(c) Images Processing: Processing the captured images is one of the most laborious tasks as it requires lots of computation. Few of existing techniques process entire images whereas others process a part of it. The techniques also differ in their algorithmic execution, operation and timing.

(d) Object recognition: It is the ability to comprehend the properties of an object such as edge, shape, color, texture etc. Generally, vision based system applies supervised learning for the object understanding.

B. Existing works

An early work in the vision based mouse controlling used finger tip tracking to control motion of the mouse [10]. A click of the mouse button was implemented by defining a screen such that a click occurred when a user's hand passed over the region [10, 15]. Another work used a combination of finger-tips and image density to control the mouse [11]. However, it demands that the user should hold the cursor in the particular spot for a period of time which directly affect in the real time performance. In [10], a motion based mouse controlling system is discussed. Here the movement of

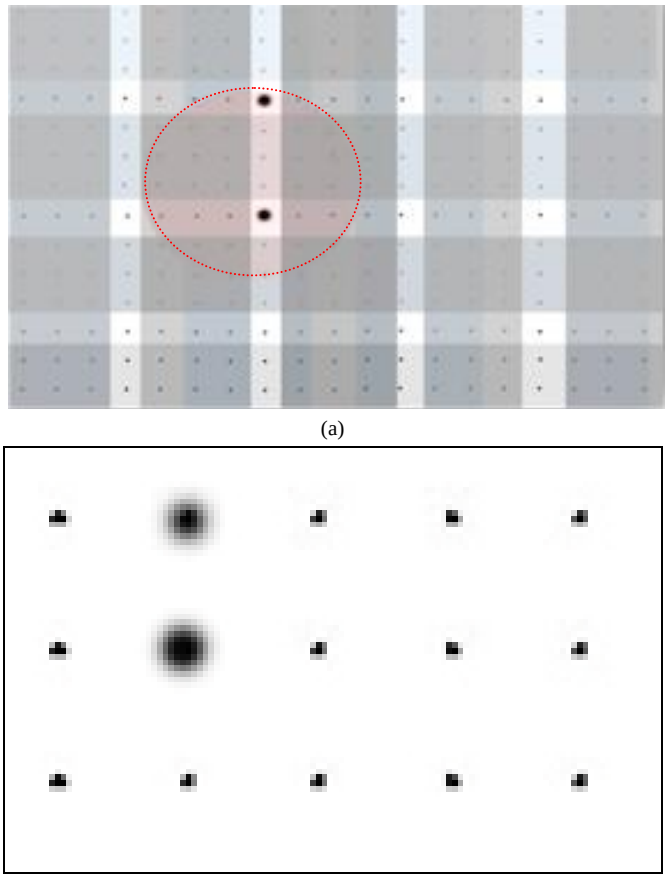

Figure 3. (a) Main image (b) Magnified subtracted image.

the hand while making a special hand sign moved the mouse pointer is discussed. An approach of [1] used web camera to detect color tapes for cursor movement. The clicking actions were performed by calculating the distance between two colored tapes in the fingers. However, this work performs poorly in real time. In paper [9], the authors have represented some of the innovative methods of the finger tracking used to interact with a computer system using computer vision. They have divided the approaches used in HCI in two categories: (ii) HCI without using interface and (ii) HCI using interface. Moreover, they have mentioned some useful applications using figure tracking through computer vision. This method used gesture based interactive experiment using figure movements to stimulate mouse operations. As compared with the traditional segmentation method this method has two benefits one is that it uses colored tape and another is that it requires no special object model with relative high performance. These two benefits make the system applicable to the augmented reality systems or other real-time systems. Since the system is based on image capture through a webcam, it is dependent on illumination to a certain extent. Furthermore, the presence of other colored objects in the background might cause the system to give an erroneous response. Object tracing using web camera and finger-tips is shown in [5]. Here, angle between the thumb and index finger is used for clicking and thus performs much better.

III. Proposed Mouse Cursor Controlling System

The proposed system utilizes red, green and blue colored tapes for the necessary computation. Movement of these taps i.e., real time are captured by a web camera which provides necessary information for system control. This basic working procedure is shown in the work flow diagram of Fig. 1. The data flow diagram of the proposed method is shown in Fig. 2. Here in the proposed algorithm, each of the captured frames is processed in real time in terms of current and previous pixels positions. The processing starts with the image subtraction which is shown in Fig. 3. This subtraction reduces the size of the image. According to our proposed scheme, subtracted image is at least fifteen times smaller than the original image and it contains all the information need to control the system. In the proposed system, the objects are detected using color pointer instead of finger tips. This makes the process much easier and faster. Here three circles of identical radius are used as three color pointers. Once the colors are detected, the system performs various operations to track the cursor and performs control actions. The following subsection provide more detail about this computational procedures:

A. System Description

According to our design procedure, the proposed mouse controlling system consists of following five steps few of which contain two to three sub-steps:

Step 1: In the initial step, the proposed method captures the real time video. A web camera is used for this purpose which reduces the cost of additional hardware as well as provides a convenient environment for the end user. This image capturing procedure is shown in Fig. 4(a). Here, the web camera works as sensor to detect the hand movements of the user. It captures the real time video at a fixed frame rate and resolution which is roughly depended on the hardware of the camera. Then the captured video is divided into image frames based on the FPS (Frames Per Second) of the camera.

Step 2: In this step, image is reduced in size with respect to pixels. As discussed earlier, image subtraction mechanism is used for this purpose. Then, each of the individual frames that have been captured is processed.

Step 3: This step involves in flipping of each image frame. Flipping is needed because the captured images are inverted similar to an image obtained from the mirror (Left is detected as right and right is detected as left). In other words, when we move the color pointer towards the left, it actually moves towards the right in the images and vice-versa. To avoid this problem we need to vertically flip the image. However, direct flipping the captured RGB (colored) images are quite difficult and may cause some information loses. Thus, the individual color channels of the images are separated flipped individually. After flipping the individual channels (red, blue and green colored channels) the concatenation is performed and then we obtain the flipped RGB image. The effect of flipping is shown in Fig. 4(c). From this figure we find that the entire image is vertically flipped.

(a)

(b)

(c)

Figure 4. (a) Image capturing procedure of the proposed mouse controlling system (b) Captured image (c) Image after flipping.

Step 4: In this step, we collect RGB information from the image. This is the most important step in the entire procedures. Here, the red, green and blue color objects are detected based on their range of pixels values. Thus, we set the range of color code for red, green and blue objects. Then, we select pixels according to their color (RGB) range, separate them and insert in a data table of three different groups. Each individual group is then counted to fix up the color existence.

Step 5: Next, it is necessary to determine a point whose coordinates can be sent to the cursor to control the mouse pointer. In the proposed system, we average the center point of the pixels that indicate the mouse movement (BLUE). The output of function is a matrix consisting of the *X* (horizontal) and *Y* (vertical) coordinates of the center point. These coordinates change with time. Once the coordinates have been determined, the mouse driver is accessed and the coordinates are sent to system. It places the cursor in the appropriate position. Here, it is assumed that the object moves continuously. Thus, a new center point needs to be determined each time. As an example, when the user moves his hands across the field of view of the camera, then the mouse moves proportionally across the screen. The detection of other colors along with Red the system performs the clicking events of the mouse. The color codes can be customized based on the requirements. The detailed working procedure of the proposed system is shown in Fig. 5 in terms of a flowchart. **Step 6:** Once the mouse movements have been controlled by the previous step, our task is reduced to generate the appropriate click events by measuring the different color existence. Thus in the proposed system, we again count the pixels from the color information table. However, background noise and low illumination conditions make the system resistive. Then a predefine threshold is used to perform a command. For example, let the prefixed value is five. Then, we compare our calculated pixel amount with five and if the calculated value is greater than or equal five we perform the command *i.e.*, clicks otherwise ignore it. In the proposed system, clicking action is based on simultaneous detection of green and blue colors in addition with red.

(a) When the Blue along with Red passed threshold condition with respect to current and previous positions, the proposed system performs left click events.

(b) When the Green along with Red passed threshold condition with respect to current and previous positions, the proposed system performs left click events.

IV. Prerformance Analysis Of The Poposed Web Camera Based Mouse Cursor Controlling System

All the existing vision based mouse control systems have unsatisfactory performance over the external hardware based mouse controlling system. Thus, the performance of the proposed scheme is compared with the real hardware based mouse controlling system to prove the supremacy and scalability of the proposed method. The proposed method is tested in a system that has a built in web camera. Its resolution is 640×480 and it can capture 5 frames per seconds. Three experiments have been performed for the performance evaluation and analysis. In the first experiment, an icon is placed on the center of desktop window and put the cursor in the top-left corner. Then, time is measured to select the icon and perform left click operation, right click operation and open a folder (directive). The result of these operations in terms of experiments is shown in Table I to III. Here, seconds are considered as unit of measurements.

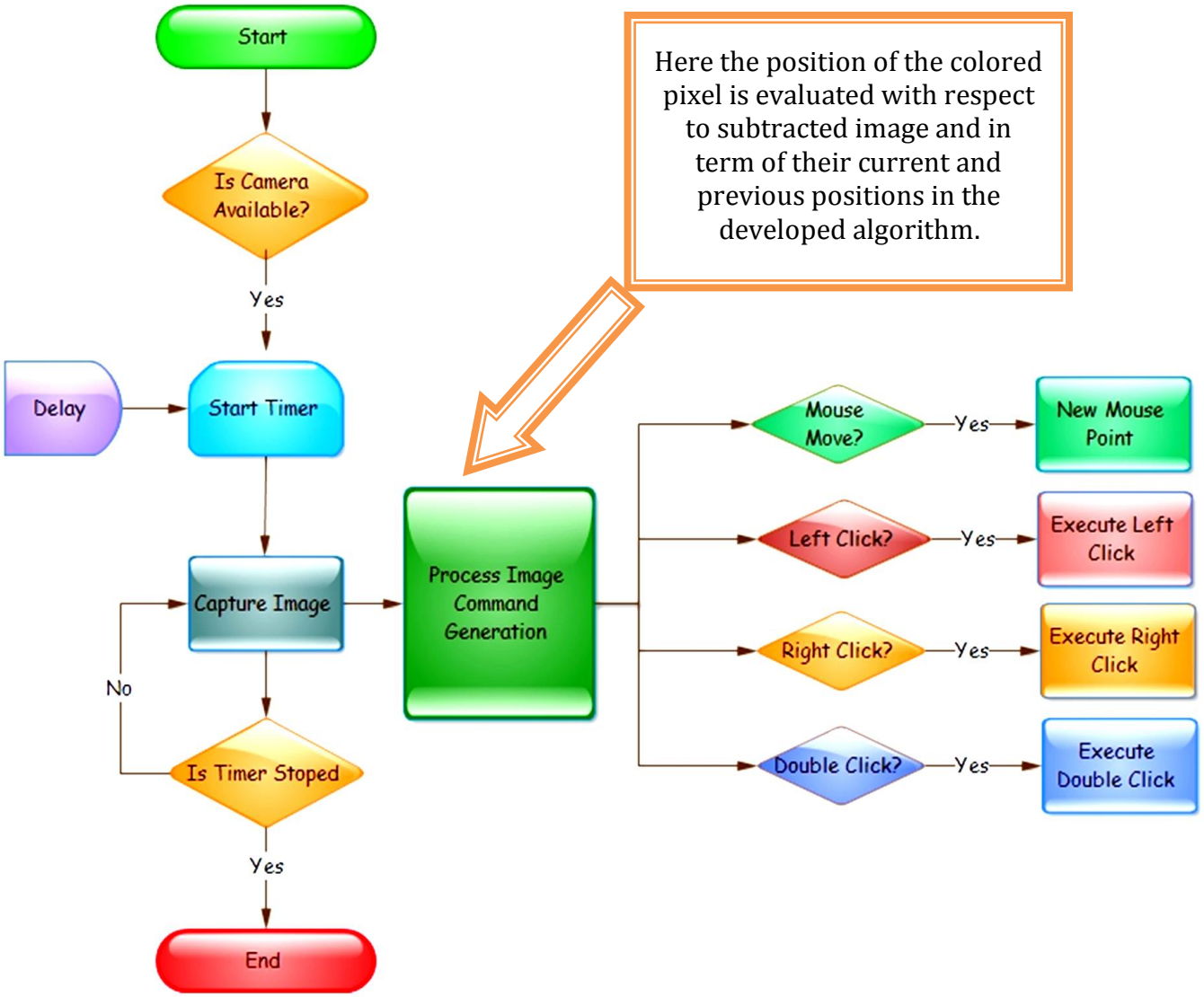

Figure 5. Working procedure of the proposed vision based mouse cursor controlling system.

In the second experiment, the co-ordinate position of the mentioned icon is kept in the identical position to the previous one. Then the time is measured for the operation of drop down menu on the icon for the proposed scheme. Total of 3 trials have been performed and each trial is measured for 15 users. Finally, the third experiment is performed. Here, the position of the icons is also kept as in previous two and then the time is measured for operation to open the icon for double click operation. In this task three, there are actually four different tasks, *i.e.*, folder selection, right clicking, menu opening and clicking open. Thus, from the table I-to-III we find that the average performances for the task I and II are much better than task III. Table IV shows the average performances of the users in the proposed system and the existing hardware based system. As the users are much familiar with hardware based mouse than proposed system, thus the user's performance in the existing system is very nearer to the hardware based system but much better than the existing vision based system.

TABLE I. PERFORMANCE OF THE PROPOSED SYSTEM: LEFT CLICK

	Trial 1	Trial 2	Trial 3	Average
End User 1	1.3	1.1	1.2	1.2
End User 2	1.5	1.25	1.15	1.3
End User 3	1.2	1.4	1.2	1.27
End User 4	1.2	1.2	1.2	1.2
End User 5	1.4	1.3	1.2	1.3
End User 6	1.2	1.3	1.2	1.23
End User 7	1.2	1.2	1.2	1.2
End User 8	1.3	1.2	1.2	1.23
End User 9	1.2	1.2	1.3	1.23
End User 10	1.5	1.4	1.3	1.4
End User 11	1.2	1.2	1.2	1.2
End User 12	1.2	1.2	1.2	1.2
End User 13	1.4	1.3	1.2	1.3
End User 14	1.3	1.2	1.4	1.3
End User 15	1.2	1.5	1.2	1.3

TABLE II. PERFORMANCE OF THE PROPOSED SYSTEM: RIGHT CLICK

	Trial 1	Trial 2	Trial 3	Average
End User 1	1.3	1.1	1.2	1.2
End User 2	1.4	1.2	1.2	1.27
End User 3	1.3	1.5	1.1	1.3
End User 4	1.3	1.2	1.1	1.2
End User 5	1.2	1.2	1.2	1.2
End User 6	1.3	1.2	1.1	1.2
End User 7	1.2	1.3	1.2	1.23
End User 8	1.4	1.3	1.2	1.3
End User 9	1.3	1.2	1.2	1.23
End User 10	1.2	1.3	1.2	1.23
End User 11	1.3	1.2	1.3	1.27
End User 12	1.2	1.4	1.3	1.3
End User 13	1.3	1.3	1.2	1.27
End User 14	1.2	1.2	1.3	1.23
End User 15	1.3	1.3	1.2	1.27

TABLE III. PERFORMANCE OF THE PROPOSED SYSTEM: OPEN FOLDER

	Trial 1	Trial 2	Trial 3	Average
End User 1	2.1	2.6	2.2	2.3
End User 2	2.8	2.3	2.1	2.4
End User 3	2.4	2.5	2.3	2.4
End User 4	2.2	2.0	2.1	2.1
End User 5	2.3	2.3	2.3	2.3
End User 6	2.4	2.45	2.0	2.28
End User 7	2.4	2.3	2.3	2.33
End User 8	2.5	2.4	2.45	2.45
End User 9	2.4	2.4	2.3	2.36
End User 10	2.2	2.5	2.4	2.36
End User 11	2.3	2.4	2.4	2.36
End User 12	2.4	2.2	2.5	2.36
End User 13	2.5	2.3	2.4	2.4
End User 14	2.8	2.4	2.2	2.46
End User 15	2.4	2.5	2.0	2.3

TABLE IV. PERFORMANCE OF THE PROPOSED SYSTEM WITH RESPECT TO HARDWARE AND VISION BASED SYSTEMS: EXPERIMENT ONE TO THREE

	Proposed Method	Existing Vision Based Method [9]	Existing Hardware Based Method [3]
Exp. One	1.257	2.237	1.204
Exp. Two	1.246	2.227	1.216
Exp. Three	2.346	4.185	2.156
Performance Ratio in 100%	94.38%	52.89%	100%

V. CONCLUSION

This paper proposed an efficient HCI and computer vision based mouse controlling system. It has been shown that the real time performance of the proposed system is almost equal to existing hardware based method but much better than the existing vision based system. Most interestingly, the proposed scheme eliminated the needs of extra hardware. The mentioned improvement in the proposed method is achieved as it consider both the current and previous position of the subtracted color image pixels i.e., neither the entire image nor the individual pixel. Several applications of the proposed system have also been shown in Sec I. The proposed system can further be used for the applications like digital canvas [14], modern gaming where the motions need to be tracked with filtering [15], bioinformatics applications [16], data collection platforms [17] and in semantic modeling [18, 19]. Another interesting future work can be increase the performance in noisy environment for virtual reality through filtering [20].

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