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Design and Development of Hand Gesture Based Virtual Mouse

1st Kabid Hassan Shibly
Dept. of Computer Science & Engineering
Dhaka International University
Dhaka, Bangladesh
khshibly00@gmail.com

2nd Samrat Kumar Dey
Dept. of Computer Science & Engineering
Dhaka International University
Dhaka, Bangladesh
samratcsepstu@gmail.com

3rd Md. Aminul Islam
Dept. of Computer Science & Engineering
Dhaka International University
Dhaka, Bangladesh
aminuloet@gmail.com

4th Shahriar Iftekhar Showrav
Dept. of Computer Science & Engineering
Dhaka International University
Dhaka, Bangladesh
shahriarshowrav@gmail.com

***Abstract*— The technique of establishing a process of interaction between human and computer is evolving since the invention of computer technology. The mouse is an excellent invention in HCI (Human-Computer Interaction) technology. Though wireless or Bluetooth mouse technology is invented still, that technology is not completely device free. A Bluetooth mouse has the requirement of battery power and connecting dongle. Presence of extra devices in a mouse increases the difficulty to use it. The proposed mouse system is beyond this limitation. This paper proposes a virtual mouse system based on HCI using computer vision and hand gestures. Gestures captured with a built-in camera or webcam and processed with color segmentation & detection technique. The user will be allowed to control some of the computer cursor functions with their hands which bear colored caps on fingertips. Primarily, a user can perform left clicks, right clicks, and double clicks, scrolling up or down using their hand in different gestures. This system captures frames using a webcam or built-in cam and processes the frames to make them track-able and after that recognizes different gestures made by users and perform the mouse function. So the proposed mouse system eliminates device dependency in order to use a mouse. Therefore it can be proved beneficial in order to develop HCI technology.**

Keywords—HCI (Human-Computer Interaction), HSV (Hue Saturation Value), Hand Gesture, Color Detection, Gesture Recognition.

I. INTRODUCTION

As the technologies are developing day by day the devices becoming compact in size. Some devices have gone wireless, some of them gone latent. This paper proposes a system that could make some the devices go latent in the future that is the future of HCI (Human-Computer Interaction). The proposal is to development of a Virtual Mouse using Gesture Recognition. The aim is to control mouse cursor functions using only a simple camera instead of a traditional or regular mouse device. The Virtual Mouse works as a medium of the user and the machine only using a camera. It helps the user to interact with a machine without any mechanical or physical devices and control mouse functions. In this gesture recognition system, it is very possible to capture & track the fingertip of hand with a webcam or built-in cam which is bearing a color cap or color sticky note paper and the system track the color and movement of the hand & move cursor with it.

Typically we use a mouse, keyboard or other interacting devices which is mainly compact with the computer machine. The wireless devices also need a power source and connecting technologies, but in this paper, the user's bare hand is the only input option using a webcam. So, it's a very interactive way to control the mouse cursor.

This system is implemented in Python programming language using the Computer Vision based library OpenCV. This system has the potential to replace the typical mouse and also the remote controller of machines. The only barrier is the lighting condition. That's why the system still can't be enough to replace the traditional mouse as most of the computers are used in poor lighting conditions.

A. Problem Description & Overview

To track fingertips as a movable object, and to utilize it for mouse functions, the camera should be positioned in a way so that it can see the user's hands in the right positions. This can be used in space-saving situations, for those patients who don't have control over their limbs and for other similar cases. It's a virtual mouse instead of a physical mouse which will work only based on webcam captured frames & tracking colored fingertips.

B. Significance in Real World Application

Video conferencing is very popular nowadays. For this reason, most of the computer users use a webcam on their computer and most of the laptops have a built-in webcam. The proposed system which is webcam based, might be able to eliminate the need of a mouse partially. The process of interaction with a computer using hand gesture is a very interesting & effective approach to HCI (Human-Computer Interaction). There is some really good research on this interest. The hand gesture recognition technology is also popular in sign language recognition.

C. Objective

The objective is to develop and implement an alternative system to control a mouse cursor. The alternative method is hand gesture recognition using webcam and color detection method. The ultimate outcome of this paper is to develop a system which recognizes hand gesture and controls mouse cursor using color detection method of any computer.

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II. Related Work on This Theory

Cursor control application using hand gesture is used in many ways, but most of the time, it requires of wearing a DataGlove. This reduces the efficiency of performance between the user and the system. And system complexity is also an issue in this process.

There could be two possible gesture recognitions for HCI, one is hardware based & another one is computer vision based. One of the early hardware-based systems was proposed by Quam (1990) in which, the user had to wear a bulky DataGlove to use the system [1]. Though this method gives a high accuracy control, it is very difficult to use as some gesture is not meant for everyone and also very impractical for mass users in the everyday world.

Meanwhile, the vision-based hand gesture recognition is also two types: marker-based & non-marker based. Non-marker based recognition generally is not as accurate as the marker based recognition. And the maker based recognition has better accuracy compared to the other gesture recognition systems, though the user has to use a simple color cap on the fingertip. But this way is lighter and almost nothing in comparison with the DataGlove of the hardware-based system.

Gesture recognition might be a futuristic way to the computers to understand human gesture (Body Language). It will build a greater interaction between human & computer machines rather than primitive text-based interaction.

Most of the marker based gesture recognition mouse uses at least two color markers to track. Because of detecting multiple colors, the system gets slow and some laggings appear on the system during the time of performance.

In 2010, ChenChiung Hsieh and Dung-Hua Liou proposed a paper "A Real-Time Hand Gesture Recognition System Using Motion History Image" [2] based on adaptive skin color model & motion history image (MHI). In their work they used an adaptive skin color model and a motion history image-based hand moving direction detection method. The prime limitation of the paper is a problem with working for more complicated hand gestures recognition.

In 2011, Chang-Yi Kao and Chin-Shyurng Fahn published a paper "A Human-Machine Interaction Technique: Hand Gesture Recognition Based on Hidden Markov Models with Trajectory of Hand Motion" [3] that is basically learning based interaction between human & machine. Their work is very accurate but it worked only in high configuration computers.

In 2013, Angel, Neethu. P.S proposed a paper named "Real Time Static and Dynamic Hand Gesture Recognition" [4] in which design, develop and study a practical gesture recognition that can be used in a variety of human-computer interaction applications framework for real-time. But, it was unable to work at a complex background and was computable only under good light.

In 2013, Ashwini M. Patil, Sneha U. Dudhane, Monika B. Gandhi proposed a paper titled "Cursor Control System Using Hand Gesture Recognition" [5] where they developed a machine-user interface which implements hand gesture recognition using simple computer vision and multimedia techniques. But a major limitation is before working with gesture comparison algorithms, skin pixel detection and hand segmentation from stored frames needs to be done.

In 2014, Abhik Banerjee & Abhirup Ghosh proposed "Mouse Control using a Web Camera based on Color Detection" [6] titled paper where the methodology is Hand gestures were acquired using a camera based on color detection technique. The limitations of their work are the operating background has to be light and no bright colored objects are present. It works well on certain computers of high configuration.

In 2016, Yimin Zhou, Guolai Jiang & Yaorong Lin published "A novel finger and hand pose estimation technique for real-time hand gesture recognition" [7] based on directly extract fingers from salient hand edges. Considering the hand geometrical characteristics, the hand posture is segmented and described based on the finger positions, palm center location and wrist position. But this method is only compatible with high configuration computer machines.

In 2016, Pooja Kumari, Saurabh Singh & Vinay Kr. Pasi developed "Cursor Control using Hand Gestures" [8] is based on multiple color bands where different colors perform different actions. The number of colors is the key to perform mouse functions. But, multiple colors were used to control the system. It is relied on the number of colors to perform a function instead of different gestures.

In 2017, Aashni Haria, Archanasri Subramanian, Nivedhitha Asokkumar, Shristi Poddar, Jyothi S Nayak developed "Hand Gesture Recognition for Human-Computer Interaction" [9] based on background extraction and contours detection system. But it is very slow to work with.

In 2018, Abhilash SS, Lisho Thomas, Naveen Wilson, Chaithanya C published a paper on "Virtual Mouse Using Hand Gesture" [10] which designed to work with the color detection system, functions works on the number of colors detected. But it can perform only a few mouse actions, and does not work without static background.

III. Methodology

The methods used in each & every part of the system proposing in this paper are explained separately.

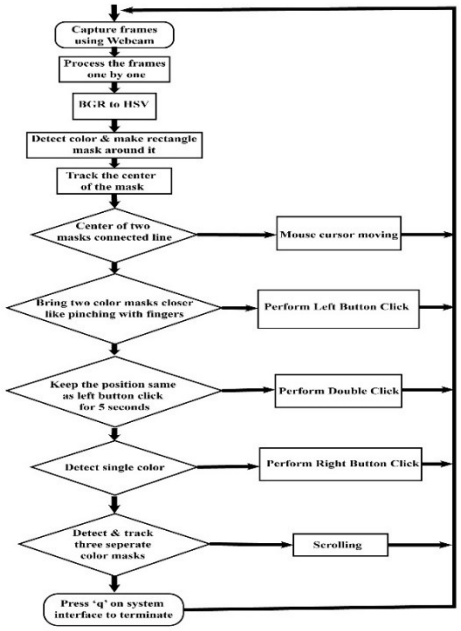

Fig. 1. Flowchart of The Methods of Gesture Based Mouse

A. Camera

The system works on the frames captured by the webcam on the computer machine or built-in camera on a laptop. By creating the video capture object, the system will capture video using webcam in real-time. In order to use a single camera with this system the device index would be "0". To add additional camera device index would be 1, 2 and so on. This camera will capture frame by frame and will pass it to the system.

B. Capturing

By using an infinite loop the webcam captures each and every frame till the program termination. The frames from the real-time video are processed from BGR to HSV color space.

C. Color Detection & Masking

In this proposed system, color detection is done by detecting color pixels of fingertips with color caps from the frames that were captured by the webcam. This is the initial and fundamental step of the proposed system. The outcome of this step will be a grayscale image, where the intensity of the pixels differs the color cap from the rest of the frame and the color cap area will be highlighted. Then rectangle bounding boxes (masks) will be created around the color cap and the color cap will be tracked. The gesture will be detected from the tracking of these color caps.

IV. Gesture Recognition

A. Mouse Movements

At first, calculation of the center of two detected color objects which is done by the coordinates of the center of the detected rectangle. To create a line between two coordinates, the built-in OpenCV function is used and to detect midpoint equation given below is used:

$$M = \left(\frac{Xa+Xb}{2}, \frac{Ya+Yb}{2}\right) \quad (1)$$

This midpoint is the tracker for the mouse pointer and the mouse pointer will track this midpoint. In this system, the coordinates from camera captured frames resolution is converted to screen resolution. A predefined location for the mouse is set, so that when the mouse pointer reaches that position, the mouse started to work and this may be called open gesture. This allows the user to control the mouse pointer.

B. Mouse Clicking

The proposed system uses close gestures for clicking events. When the rectangle bounding boxes come closer to another rectangle, bounding box is created with the edge of the tracking bounding boxes. When the newly created bounding box becomes 20% of its creation time size then the system performs left button click and it can be clicked. By holding this position more than 5 seconds, the user can perform a Double click. And for the right button click again the open gesture is used. To perform the right button click, the single finger is good enough. The system will detect one fingertip color cap then it performs a right button click.

C. Mouse Scrolling

To scroll with this system, user needs to use the open gesture movement with three fingers with color caps. If the users use their three fingers together & changes its position to downwards, it will perform scrolling down. Similarly, if its position is changed to upwards, it will perform scrolling up. When three fingers move up or down the color caps gets a new position and new coordinates. By the time all three color caps get new coordinates, it performs scrolls. If their y coordinate values decrease, it will perform scrolling down and if the values increase, it will perform scrolling up.

V. Result & Evaluation

In this work, we have used HCI (Human Computer Interaction) and computer vision in order to contribute in future vision based interaction between the machine and human.

The proposed paper is on controlling the mouse functions using hand gestures. The main functions are mouse movement, left button click, right button click, double click and scrolling up or down.

In this system, the users can pick any color from multiple colors. There are a few color bands defined & the users can pick any color from the colors according to the backgrounds and the lighting conditions. This may vary in a different background. For example, when a user starts the system, it will provide the choice to pick a color from multiple colors (Green, Yellow, Red, Blue & two others). The user will have to pick one color such that, the color wouldn't match with the background or else, he has to choose the color which will be highlighted in the current background.

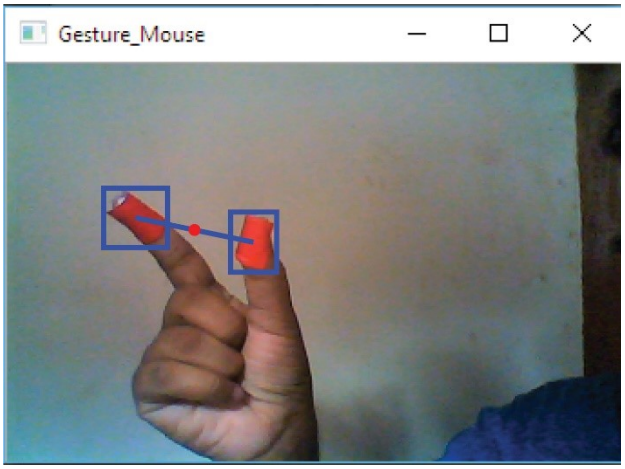

Fig. 2. Mouse Movement (Open Gesture)

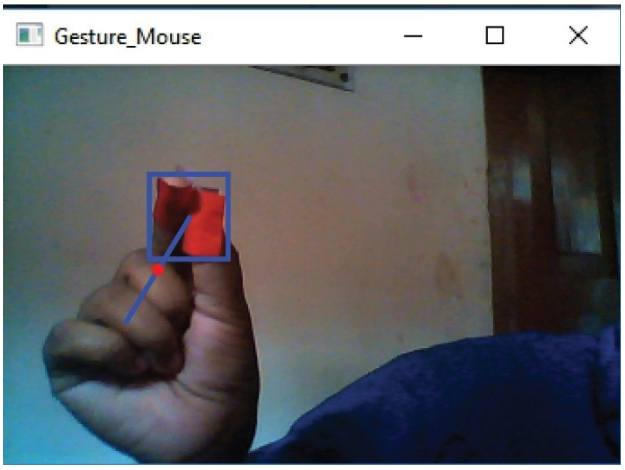

Fig. 3. Left Button Click (Close Gesture)

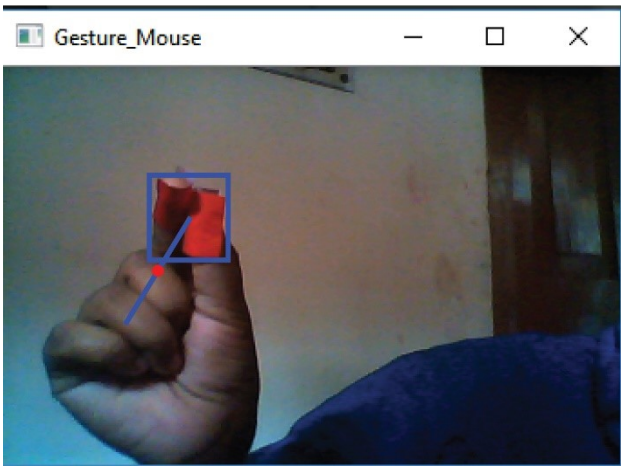

Fig. 4. 5 Seconds Perform Double Click (Close Gesture)

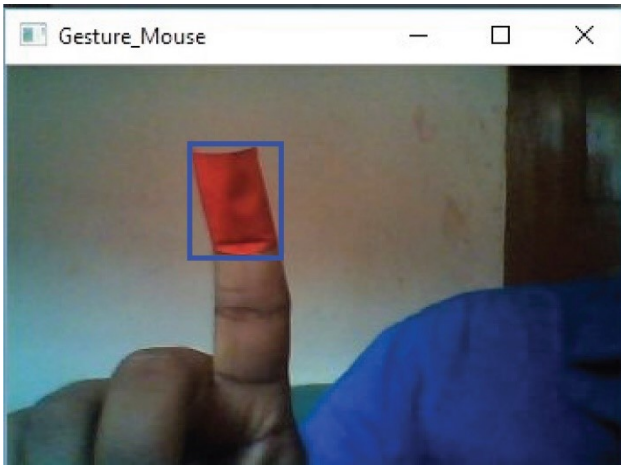

Fig. 5. Right Button Click (Open Gesture)

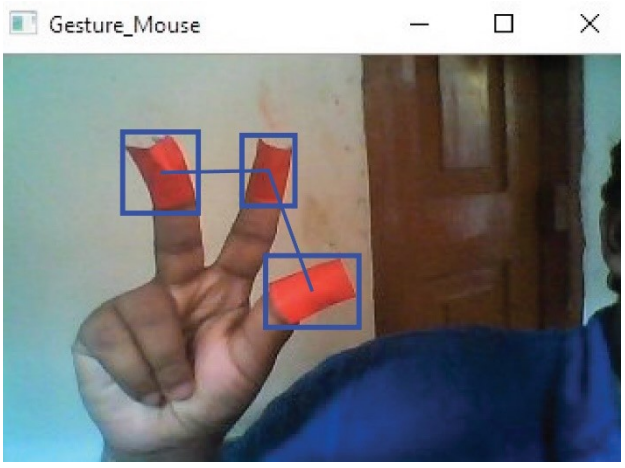

Fig. 6. Scrolling Up & Down (Open Gesture)

These testing are done with a plain background. It works very fast and the accuracy is 78-90 percent. It is also tested with some complex backgrounds, such as check printed shirt, colorful t-shirt (Though most of the people sit in front of the laptop or computer wearing regular shirts or t-shirts), complex home backgrounds, indoor daylight environments, indoor home light environments etc. These events are evaluated with the accuracy, and which is showed in a table.

TABLE I. MOUSE EVENTS & EVALUATIONS

Gesture Input	**Evaluation**		
	Mouse events	***Accuracy with plain background (in %)***	***Accuracy with complex/ non-plain background (in %)***
Two color caps (Open Gesture)	Mouse Movement	91	41
Closer two color caps (Closed Gesture)	Left Button Click	88	40
Keep closer for 5 seconds (Closed Gesture)	Double Click	87	42
Single color cap (Open Gesture)	Right Button click	95	79
Three color caps (Swipe Up/Down)	Scrolling up or down	78	40

Clearly, the system is not much efficient in the complex and rough background. But, our system is faster than the other gesture-based mouse control systems. This accuracy can be increased by using high definition camera. The readings of the table are taken from a built-in laptop VGA (Video Graphics Array) camera. Though this system is developed in Windows OS, in some events, the accuracy rate might be better in Linux base or Macintosh OS computer rather than Windows OS computer.

TABLE II. COMPARISON WITH EXISTING SYSTEMS

Existing methods	**Comparison**		
	Recognized Gestures	***Average Accuracy (in %)***	***Control Type (Static/Dynamic)***
Color tracking & counting[8]	Five (05) : Mouse Movement, Left Click, Right Click & Double Click etc.	Not Available	Dynamic
Finger & palm tracking[9]	Seven (07) : Opening Media Player, Web Page, Launching Powerpoint etc.	78	Static
Color masking & pinchflag [10]	Three (03) : Mouse Movement, Left Button Click, File Transfer	Not Available	Dynamic
Our proposed method	Five (05) : Mouse Movement, Left Click, Right Click, Double Click, Scrolling	78	Dynamic

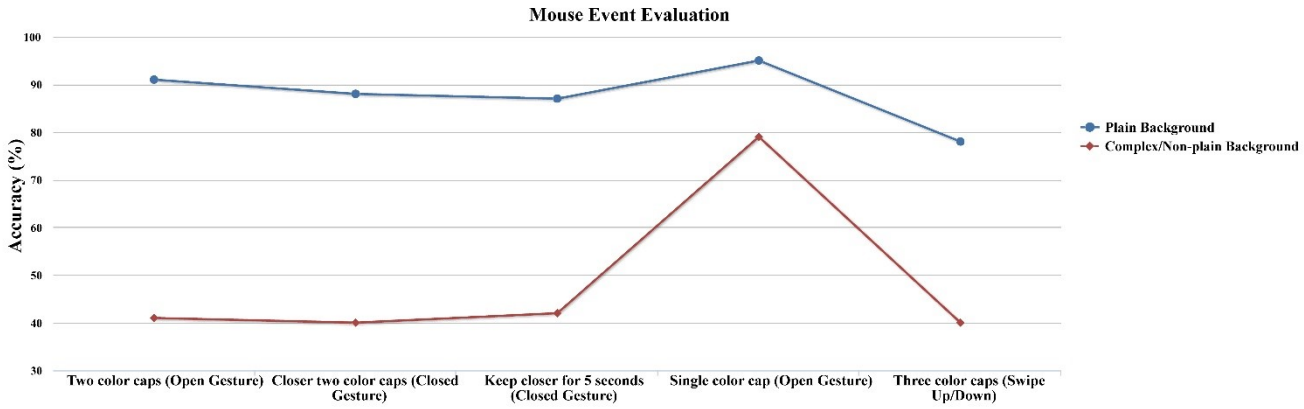

Fig. 7. Mouse Event Accuracy(%) Evaluation

VI. Application

This project can be useful for presentations and for reducing workspace and burden of extra hardware devices. In critical events such as battleground, operation theater, this project will be able to withstand itself, as it is wispier than any other contemporary system in the market for computer interaction. Since it removes the burdens of devices, it brings the user and the workspace more closer than before.

Major applications:

- Robot controlling is one of the major applications of this system. Controlling robots without machines or extra devices can be an excellent addition to this technology.
- Digital artist can draw 2D or 3D images using this gesture-based mouse on digital canvases. It will allow more freedom more dynamic more space to artists to create their art.
- Critical events like a battleground, operation theater, mining fields can be controlled by gesture mouse.
- Virtual Reality or Augmented Reality based games can be played without any extended or wireless devices with bare hands more comfortably.
- For patients with no limb control, this system can be proved very useful and effective.
- This mouse system can be applicable for sign language for the dumb & deaf people. It can help them to interact with computing machines.

VII. Conclusion

Virtual gesture control mouse is a system that profound to guide the mouse cursor and execute its task using a real-time camera. We implemented mouse navigation, selection of icons and its functions and tasks like left, right, double click and scrolling. This system is based on image comparison and motion detection technology to do mouse indicator movements and selection of the icon. Analyzing results, it can be anticipated that if we provide enough light, decent camera, the algorithms can work at any domain. Then our system will be more systematized. In future, we want to merge more features such as interaction in multiple windows, enlarging and shrinking windows, closing window, etc. by using the palm and multiple fingers.

Acknowledgement

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