

# Gesture-Based Cursor Control: A Comprehensive Review of Techniques and Applications

Twinkle Shukla<sup>1\*</sup>, Pradip Mahajan<sup>2</sup>, Ayush Mandlik<sup>3</sup>, Pratik Divekar<sup>4</sup>, Suraj Burange<sup>5</sup>

## Abstract

*Although hand gesture detection for human-machine interfaces has advanced recently, many systems still have issues with background and lighting. We have developed a rapid motion history image-based system to categorize dynamic hand motions and a face detection method to adaptively detect skin color. For the up, down, left-, and right-hand gesture classifiers, four sets of Haar-like directional patterns were trained. To operate different household appliances, six hand gestures were defined, including fist and waving motions. To evaluate these gestures' potential for engagement, five people made 250 hand movements at various distances from a webcam. According to experimental results, the processing time is 3.81 ms per frame and the average accuracy is 94.1%. The results proved that the suggested system was feasible. Traditional input devices like keyboards and mouse are being supplemented or replaced by cutting-edge alternatives that offer a more intuitive user experience in the rapidly developing field of human-computer interaction. Using hand gestures to operate a cursor is a novel technology that uses people's natural movements to engage with digital interfaces. The concepts, tools, and uses of this revolutionary invention are explored in depth in this article.*

**Keywords:** Hand gesture recognition, adaptive skin color model, motion detection, motion history image, human-computer interaction (HCI)

## INTRODUCTION

Computer vision-based hand gesture detection for human-machine interfaces has advanced significantly in recent years. The ability to control equipment without making physical contact—such as touching panels, keyboards, mouse, or remote controllers—is a crucial benefit of these methods. To control the function, the user only needs to raise his or her hands while facing the camera. Systems that recognize hand gestures offer users a great deal of flexibility and natural engagement. Using a motion

history image (MHI) and an adaptive skin color model, this work attempts to develop a real-time hand gesture detection system. Gesture-based control systems have been developed in response to the demand for smooth and organic human-machine interaction. By doing away with physical contact, hand gesture-based cursor control offers benefits in terms of accessibility, hygienic practices, and user-friendliness. This technology is opening the door to more engaging and effective user experiences in fields like gaming and healthcare. The robustness of hand gesture detection is improved by the adaptive skin color model, which lessens the effects of illumination, ambient factors, and camera fluctuations. We identified six hand motions that are instinctive and don't require any prior instruction.

### \*Author for Correspondence

Twinkle Shukla  
E-mail: [twinkleshukla44@gmail.com](mailto:twinkleshukla44@gmail.com)

<sup>1</sup>Professor, Department of Information Technology, Parvatibai Genba. Moze College of Engineering, Wagholi, Pune, Maharashtra, India

<sup>2-5</sup>Student, Department of Information Technology, Parvatibai Genba. Moze College of Engineering, Wagholi, Pune, Maharashtra, India

Received Date: January 06, 2025  
Accepted Date: January 13, 2025  
Published Date: March 05, 2025

**Citation:** Twinkle Shukla, Pradip Mahajan, Ayush Mandlik, Pratik Divekar, Suraj Burange. Gesture-Based Cursor Control: A Comprehensive Review of Techniques and Applications. International Journal of Electrical and Communication Engineering Technology. 2025; 3(1): 9–13p.

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We successfully distinguish between the four directional hand motions using statistical techniques by employing four sets of Haar-like patterns. Furthermore, we look at a region of interest next to the face to identify fist and wave hand motions. The other Haar-like characteristic detects the first hand, and the amount of motion inside that designated zone is used to detect the waving hand. An *active* electronic motion detector contains an optical, microwave, or acoustic sensor, as well as a transmitter. However, a *passive* contains only a sensor and only senses a signature from the moving object via emission or reflection. Changes in the optical, microwave or acoustic field in the device's proximity are interpreted by the electronics based on one of several technologies. Most low-cost motion detectors can detect motion at distances of about 4.6 meters (15 ft). Specialized systems are more expensive but have either increased sensitivity or much longer ranges. Tomographic motion detection systems can cover much larger areas because the radio waves it senses are at frequencies which penetrate most walls and obstructions and are detected in multiple locations.

This paper is structured as follows: An overview of earlier studies in the subject of hand gesture recognition is given in the second section. The details of our approach, which is broken down into two sections—a face-based adaptive skin color model and an MHI-based moving hand direction detection system—are shown in the third section. The experimental results are presented in the fourth section. Finally, 11 static hand gestures for computer control have been defined. To recognize hand gestures, we used a backpropagation neural network. However, because each hand gesture has a similar shape, people can have trouble remembering what it means. The implementation of human-computer interaction (HCI) is made possible by several innovative interfaces, such as those that operate systems based on human movement. In addition to detecting cognitive actions, HCI can involve much more than just a simple interaction. In this case, the system and the human cooperate to generate a working capability. Human behavior makes sense in the context of cognitive info communications.

## LITERATURE REVIEW

The Leap Motion device and hand gesture-based mouse cursor control are presented in the paper by Sziladi et al. [1] along with an assessment of the mouse cursor movement. Test subjects are involved in mouse cursor movement analysis, which compares the actual movements made with a traditional mouse cursor and hand gesture detection [1]. Based on mouse pointer movement analysis results, variations were observed between hand gesture detection and the control process carried out by a traditional mouse [2]. Futane et al. [3] have discovered a mouse command substitute, particularly for apps that use a cursor. Convex hull, support vector machine, and fundamental mathematical computation are some of the techniques employed in the two application case scenarios—one involving hand gestures and the other including a hands-free interface, or facial gesture. They have been used to issue commands and carry out tasks like opening any notepad or office tool program with gestures rather than with a mouse. When tested with various people's motions and under various lightening situations, the system produces respectable results in terms of tracking and identifying gestures [3].

## Recognition of Gesture

Several cutting-edge technologies are combined to convert hand gestures into digital commands for cursor control. Using sensors or cameras, gesture recognition entails identifying and deciphering human movements [4]. Among the methods are:

Computer vision: identification and tracking of hand movements using cameras and machine learning techniques. Since vision and sound are the primary means of human communication, a man-machine interface that relied more on vision and audio recognition would be more intuitive. Another benefit is that the user does not need to be near the computer in order to interact [5]. A visual system would be better in noisy settings or in circumstances where sound would be disruptive, in contrast to auditory orders. Compared to rudimentary text user interfaces or even GUIs (graphical user interfaces), which still mostly rely on mouse input, gesture recognition can be viewed as a means for computers to start comprehending human body language, so creating a more robust bridge between humans and machines [6].

Wearable sensors are gadgets that measure motion, such as gloves with gyroscopes and accelerometers built in.

### **Components of Hardware**

Cameras and depth sensors: Three-dimensional (3D) hand movements are captured by gadgets such as Leap Motion and Microsoft Kinect. In low light, infrared sensors are used for accurate tracking. Processing units: GPUs (graphics processing units) or microcontrollers for real-time gesture data processing [7].

### **Dynamic Hand Gesture Recognition**

Dynamic hand gesture recognition was performed by utilizing motion information. Variations among frames could be accumulated in the motion history image. A simple direction detection method of moving hand based on motion history image is then proposed. Four groups of directional patterns are defined for measuring the quantities of directions.

$$\text{MHI}(x, y)_t = \text{MHI}(x, y)_{t-1} + \text{DF}(x, y)_{t-1} - \alpha$$

### **Hand Gesture Recognition**

Five persons were requested to do the defined dynamic hand gestures at three different distances (<1 m, 1–2 m, and 2 m) 50 times per type of dynamic hand gesture and 25 times per type of static hand gesture. Before testing, user could practice for one minute to prevent from wrong operation. Face detection algorithm overview is shown in Figure 1.

### **Processing Time Analysis**

The objective of this paper is to propose a real-time convenient hand gesture recognition system as a man machine interface. The system is designed to work efficiently. The total processing time is 3.81 ms per frame if frame capture time is not considered [8]. That is, our system processing rate can reach more than 250 frames per second. Our man machine interface was integrated with a well-known album browser Cooliris. Users can control the browser by their own hands. All six hand gestures were bound to six commands.

### **Algorithms for Software**

Algorithms trained to recognize various gestures are known as machine learning models. Image processing techniques are employed to detect motion vectors, fingertips, and hand shapes.

Gestures can be translated into precise cursor movements, such as clicking, scrolling, or drag-and-drop, using artificial intelligence (AI)-based gesture mapping. Raw data is collected by the system via input devices such as wearable sensors and cameras. From the data, important characteristics are retrieved, such as motion trajectory, hand location, and orientation. The system recognizes the gesture and associates it with a corresponding cursor action using pre-trained models. The cursor moves or an interaction event appears on the screen as a result of the interpreted command being executed [9].

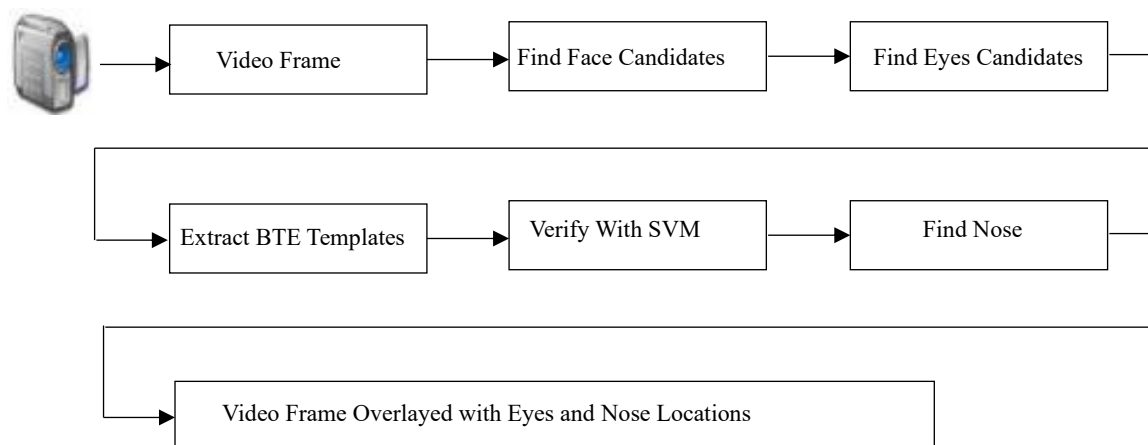
### **Motion History Image–Based Moving Hand Direction Detection System**

Motion history images (MHIs) capture the dynamics of hand motion by representing movement over time.

#### **Crucial Steps**

Motion segmentation is the process of using frame differences to identify areas of interest. MHI generation is the process of superimposing several frames to produce a single image that emphasizes the motion's trajectory [10].

Direction detection is the process of determining the direction of motion from the MHI's gradient or orientation. Its major benefits are that it manages quick and fluid hand movements. gives applications like gesture recognition direction-specific data.



**Figure 1.** Overview of the face detection algorithm.

### Adaptive Skin Color Model Based on the Face

This model uses facial features as a reference to dynamically adapt to changes in skin tones.

#### Crucial Steps

- Facial detection is the process of locating the facial region utilizing deep learning models like YOLO (you only look once) or SSD (single shot multibox detector) or techniques like Haar Cascades [11].
- *Skin Color Extraction:* Identifying a range of skin tones by extracting skin color attributes from the identified face region.
- *Dynamic Adaptation:* In response to changes in the lighting and surroundings in real time, the system modifies the skin tone range. Its major benefits involve minimizing false positives brought on by changes in the lighting or background. It also provides a customized and flexible detecting system.

### CONCLUSION

This research introduced a MHI -based hand moving direction identification approach and a face-based adaptive skin color model. In this work, two static hand gestures—the fist and the wave hand—as well as four dynamic ones—the hand moving up, down, left, and right—are defined. These hand motions are straightforward and instinctive. To identify the four directional dynamic hand movements, Haar-like features were created. The face-based adaptive skin color model was used to extract static hand movements, which were then identified by examining a face-based region of interest. We invited five people to try our suggested system. According to experimental results, the suggested system is feasible and has an average accuracy of 94.1%. The theories behind developing intelligent systems that can extract information from images are the focus of computer vision. The picture data can be captured in a variety of formats, including multi-dimensional data from certain scanners, video sequences, and views from several cameras. Even while computer vision has been around for a while, there are still not many businesses that use it. There are currently a sizable number of businesses and research institutes operating in this area. For instance, Microsoft's Natal Project 2 is creating the Xbox 360, a new generation of gaming machine that can be controlled with hand movements. As a result, further research into additional information for the recognition of increasingly complex hand motions will require a multi-camera-based strategy.

### Acknowledgements

We express our sincere thanks to all those who have provided us the valuable guidance towards the successful completion of this system as a part of syllabus for the bachelor 's course. We express our sincere gratitude towards our co-operative department for providing us with all the valuable assistance and equipment for the system development. We hereby take this opportunity to sincerely thank Prof.

Twinkle Shukla for her valuable guidance, inspiration, wholehearted involvement during every stage of this project and his experience, perception through professional knowledge which made it possible for us in successfully realizing the concept. We are also thankful to Prof. Abidali Shaikh – Head of the Department – Information Technology for his constant enlightenment, support, and motivation which have been highly instrumental in successful completion of our project phase 1. We are extremely thankful to Dr. Navnath Narawade, Principal – PGMCOE, Wagholi for his encouragement and providing us the opportunity and facilities to carry out this work. Finally, we like to express our deep sense of gratitude towards our parents, friends, and well-wishers who were always there for suggestions and help.

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