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Vision-Based Hand Gesture Recognition for Interactive Finger Guessing Games in Human–Machine Interaction

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Abstract-: ***Hand gestures constitute a natural and intuitive communication medium for human–machine interaction. This paper presents a vision-based hand gesture recognition framework designed for an interactive finger guessing game. The system avoids wearable sensors and relies solely on camera-based image processing techniques. Skin color segmentation, motion-based temporal analysis, and finger counting methods are employed to recognize rock, paper, and scissors gestures. The recognized gestures are integrated with a mobile robotic platform to enable real-time interaction. Experimental observations indicate that the proposed approach improves interaction naturalness, reduces misclassification, and maintains computational efficiency.***

Keywords: Hand Gesture Recognition; Vision-Based Interaction; Human–Machine Interaction; Computer Vision; Finger Guessing Game; Robotics

I. INTRODUCTION

Human–machine interaction (HMI) aims to create interfaces that allow humans to communicate with machines in a natural, intuitive, and efficient manner. Traditional interfaces such as keyboards, mice, and touch screens require physical contact and limit interaction flexibility. As a result, vision-based interfaces have gained attention for enabling contactless and expressive communication.

Hand gestures represent one of the most expressive non-verbal communication modalities used by humans. Gesture recognition systems generally fall into glove-based and vision-based categories. While glove-based systems provide high accuracy, they require external hardware that reduces usability. Vision-based approaches overcome this limitation by using cameras and computer vision techniques. The normalized RGB models are adapted to detect the hand skin color, while, based on the skin color distribution range, the threshold value is calculated to separate the binary image of the hand. The feature information can then be obtained from this binary coded image, while performing the recognition by sending such input to Radial Basis Function Networks (RBFN) in vector quantities, allowing the maneuvering of dog-shaped robots for particular responding behavior. The method used in this study for the signing motion and hand gesture recognition is that the threshold value of the skin color range is separated from the sophisticated background, and displacement quantity of the image barycenter at each of the consecutive points in time is calculated to obtain the hand motion information, by which the timing for the hand gesture recognition can then be obtained.

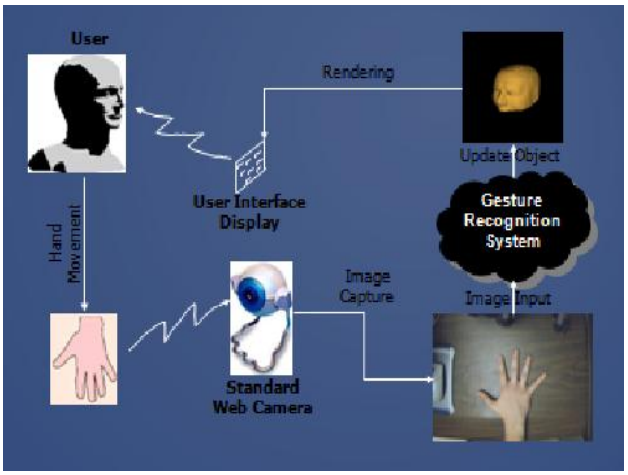
II. RELATED WORK

Extensive research has been conducted on vision-based hand gesture recognition for HCI applications. Early approaches relied on color-based segmentation and contour extraction, while recent methods incorporate depth sensors and machine learning techniques. Gesture recognition has been applied in robotics control, virtual reality, sign language interpretation, and gaming environments.

Despite significant progress, challenges remain in achieving robust recognition under varying illumination, background complexity, and gesture speed. The present work focuses on a lightweight and efficient solution suitable for real-time interaction without specialized hardware.

III. GESTURE MODELING AND SYSTEM ARCHITECTURE

It is crucial to first decide which model must be used to the hand gesture in order to methodically review the literature on gesture interpretation. In actuality, accurate hand gesture modelling has a direct bearing on the extent of a gestural interface for HCI. The desired use within the HCI setting is the primary determinant of how to model hand motions. A very basic and coarse model could be adequate for a particular application. However, a model that enables the computer to comprehend most, if not all, natural motions must be developed if the goal is a natural-like interaction.
Gesture modeling defines how hand movements are represented and interpreted computationally. In this work, gestures are modeled using spatial features (finger count and palm position) and temporal features derived from motion analysis.



There has been swift advancement in numerous studies concerning vision-based gesture analysis driven by the demand for creating more intuitive and effective human-computer interfaces. These studies are found in various literature and can be perplexing in their assertions and range. Consequently, there is an increasing demand to examine the current advancements in vision-based gesture recognition and to methodically assess the developments in vision-based gestural HCI. This discourse seeks to consolidate the latest advancements in visual gesture recognition regarding its significance in HCI. We structure the review by dividing the discussion into key elements rooted in the overarching perspective of a gesture recognition framework

IV. HAND GESTURE RECOGNITION METHODOLOGY

A. Skin Color Segmentation
Skin color segmentation is performed using normalized RGB and HSI color space models. These models reduce sensitivity to illumination variations and enable effective separation of hand regions from complex backgrounds. Morphological operations such as erosion and dilation are applied to remove noise and enhance hand shape continuity.

B. Motion-Based Temporal Analysis
Motion analysis is carried out by tracking the displacement of the hand barycenter across consecutive video frames. This temporal information helps determine the appropriate moment for gesture recognition and reduces redundant processing.

C. Finger Extraction and Classification
Finger extraction is achieved by separating the palm region from elongated finger structures using morphological filtering. The number of detected fingers is used to classify gestures: zero fingers indicate rock, two fingers indicate scissors, and five fingers represent paper.
In order to determine the sort of hand gesture, this study counts the fingers in the hand photographs. To do this, the fingers must be separated from the palm; first, the image is repeatedly eroded in by the hand's size. Because they are long and thin, the fingers are the parts that erode, leaving the palm area intact. After that, the palm image is enlarged and adjusted to serve as a mask for the palm's separation from the fingers. The picture of fingers after separation is created by subtracting the palm mask from the original palm image, as shown in Figure.

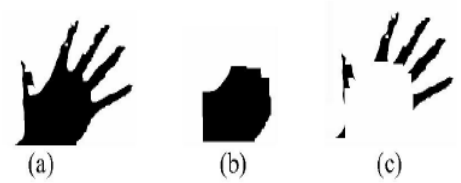


Fig. (a) hand image after pre-treatment (b) palm-shaped mask (c) finger Images after separation

Finger Guessing Interactive Games Given the three types of hand gesture required by the finger guessing game, ("scissors", "rock", and "paper"), there can be a total of nine types of possible combinations of signs provided by one player and one robot as illustrated in Table. Because the results of the combinations are simple and limited, a simple tabular cross-linking method will suffice the judging of one game result, according to the types of signing randomly selected by the computer and the types of hand gestures recognized by the image recognition system. Then, based on such findings, this study designs a simple human machine interactive games, with the racing field being a 20m track in length, the Om mark being the starting point, while the finger guessing winner gets to more forward by 2m (2 steps), and the loser moves backward by 3m (3 steps), and in the case when finger guessing ties even, one more signing is given, while the starting point is reached, players can do without further moving backward, and the one reaching the finish line is the winner.

V. INTERACTIVE GAME DESIGN AND ROBOT CONTROL

The recognized hand gestures are incorporated into a finger guessing game involving a mobile robot. Game rules determine the robot's forward or backward movement along a predefined track. A DSP-based closed-loop control mechanism ensures accurate navigation using encoder feedback.
This interactive framework demonstrates the feasibility of combining vision-based gesture recognition with robotic systems to create engaging and intuitive HMI applications.

CONCLUSION

This paper presented a vision-based hand gesture recognition system for an interactive finger guessing game. By integrating skin color segmentation, motion analysis, and finger counting, the system enables natural and contactless human–machine interaction.This approach not only decreases the frequency of hand gesture recognition in each finger guessing cycle to enhance performance efficiency, but also lowers the rate of misjudging the signing outcome. Furthermore, users can engage with the machine using natural body movements without relying on a human-machine interface that necessitates mechanical manipulation. Future work will focus on incorporating depth sensors, multi-camera setups, and machine learning techniques to enhance robustness and extend gesture vocabulary

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