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Gesture Algorithms Based on Geometric Features Extraction and Recognition

Rafiqul Zaman Khan*
Department of Computer Science,
Aligarh Muslim University,
Aligarh, India

Noor Adnan Ibraheem
Department of Computer Science, College of Science for Women, Baghdad University, Baghdad, Iraq
Department of Computer Science, AMU, Aligarh, India

Abstract—The interaction between human and computer occupies an important level recently with the spreading of the aided tools that facilitates human-machine communication systems. Gesture recognition system considered as one of the main effective issues that raised in last few decades by including different applications in our daily life especially in our life appliance. The aided tools comprise various input device technologies and gesture detection and analysing and classification algorithms and techniques. This paper introduces the main stages for constructing hand gesture classification system and investigates various studies that utilized different algorithms and techniques adopted to build hand gesture recognition system. Gesture recognition system challenges that hinder the performance of any recognition system has been explained. Comparisons between various recognition factors are demonstrated as well in the conclusion and results..

Keywords—Human Computer Interaction (HCI), Hand Gesture, Hand Posture, Hand Segmentation, Features Extraction, Gesture Recognition

I. INTRODUCTION

Recently, virtual applications witness a lot of attention especially with the fields that require natural interaction between human and machine. It is easily to observe that most of the recent cinema movies deal with the virtual systems as one of the postulated issues for the communications with all human environments in the soon recent future. Nowadays gestures systems utilized widely in our life appliance [1]. For example, refrigerator which is used for saving the food and its surface used to keep some notes [1], designed interface can be used to check food expire date and the available amount of the food with digital note device [1]. Vacuum cleaner and Stove top have switches that can be used for controlling these devices [1]. Gestures can be static or dynamic. Static gestures which can be represented by posture or single pose generally require less computational complexity [3] comparing with dynamic gestures that are complex and mostly utilized for real time environments [3][4]. The input data methods used in any hand gesture recognition system are glove devices such as instrumented data glove devices [6], colored markers [4], or the visual appearance image [4]. Using the visual based techniques are more natural and require less cost when comparing with glove based techniques which require the user to be connect via wires to the glove device and connected to the computer to read the device information, and this will limits the ability to communicate naturally between users and computes [7]. Some reviews newly explained gesture recognition systems and applications using different tools [8][9][10][11].

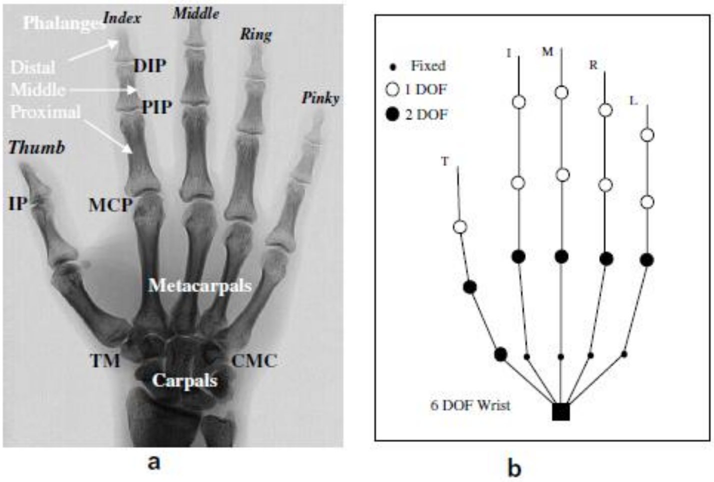
The organization of the paper is as follows: the next subsection provides an overview of hand structure. Section 2 explained gesture interpretation system with system sub-stages detail explanations. Gesture system Challenges are explained in Section 3. Discussion and conclusions are presented in Section 4.

II. HAND STRUCTURE: A REVIEW

Human hand is an articulated object [12][11] with links and joints between the links [13]. The joints named as their locus for the fingers of the hand [11] and used to define the degrees of freedom (Dof) in the hand [12]. The skeleton hand structure consists of 27 bones, the four fingers except the thumb have 2 DoF for Metacarpophalangeal (MCP) which jointing palm and fingers, and 1 DoF for proximal Pnterphalangeal (PIP) joints and 1 DoF for distal Interphalangeal (DIP) which joints the finger segments [11]. for the thumb there is no distal and proximal since it different from the other fingers with one segments [14], so the finger have only Interphalangeal (IP) which joining finger segments with 1 DoF. And 2 DoF for Trapeziometacarpal (TM) or Carpometacarpal (CMC), and 2 DoF for Metacarpophalangeal (MCP) which joint the metacarpal bones with the wrist [15],and 6 DoF for the wrist [14]. In general the IP joints which are 9 joints have 1 DoF as mentioned above, for flexion and extension, and MCP joints which are 5 joints have 2 DoF, for abduction and adduction, and flexion and extension. The TM of the thumb is more flexible and hence difficult to formulate [11]. From this elastic and flexible configuration the shape of human hand are formed as described in Figure 1.

A. Gesture Interpretation System

In the gesture interpretation system, the input image is acquired by a camera(s) or video(s). The hand gesture is extracted from the input image and the hand is processed in the analysis phase by extracted the feature of modelled parameters [12], where the estimated parameters are used with some classifier to recognize the visual image [12]. Figure 2 shows a portray view of gesture interpretation system.



a: Hand gesture anatomy, b: Hand kinematic model.

Fig. 1 Skeletal of human hand model [11]

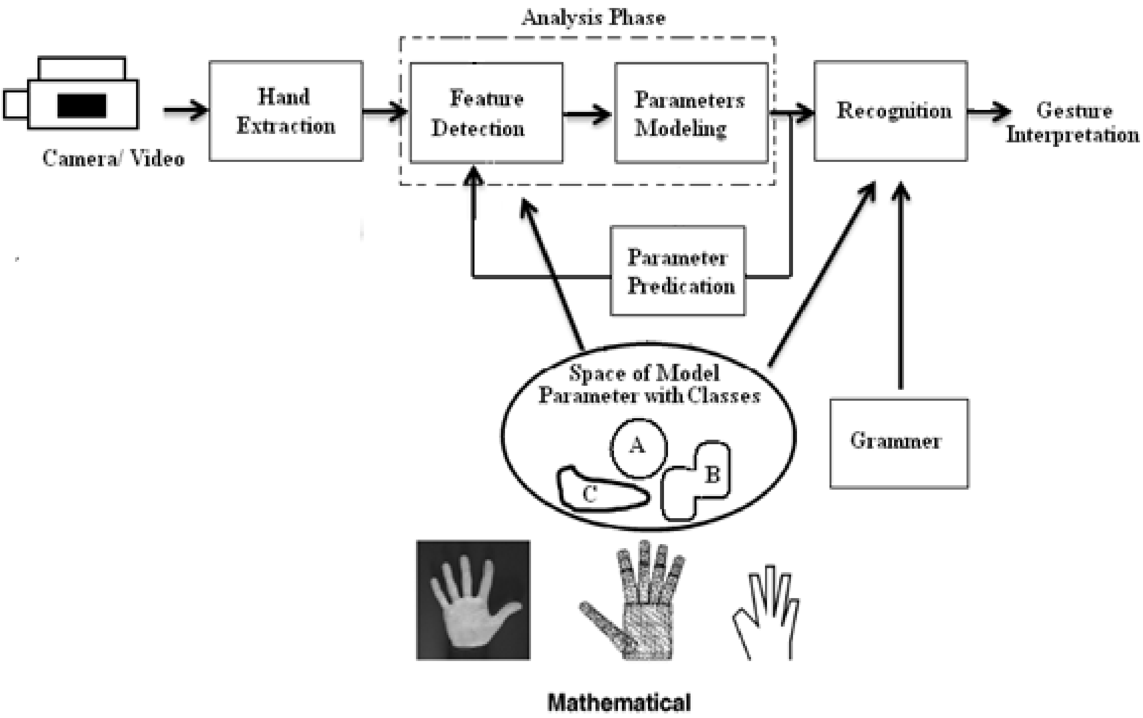


Fig. 2 Interpretation of gesture system [12]

The main steps for a general gesture recognition system are: acquired gesture, features analysis, and finally classification tool. Figure 4 demonstrates these steps.

Fig 3 Recognition gesture system stages

B. Acquired Hand Gesture Techniques

For any gesture system, firstly, the input gesture should be acquired using the proper input device to gather the required information for the recognition task. Plenty of techniques are available for this purpose, these techniques are: colored markers [14], instrumented data glove and tracking device [9][16], computer vision based technologies [16][9] and comprises; appearance based and 3D model based system which in turn can be classified into two models; volumetric model and skeletal model. The following subsection will provide a brief demonstration of these technologies.

1) Instrumented Gloves and Trackers Technology

The use of instrumented data gloves and trackers required the user to be connected with the computer physically [9]. The instrumented gloves provide data about the movement of the hand, and fingers flexibility [17][9], and the quantity of data values acquired from these devices depends on the type of and quality of the glove used [9]. It is not easy to gather information for temporal gestures, where the hand gesture needs to be localized [18] and isolated form the background [18]. 2D tracking devices applied information about bounding box [18] and centroid of the hand [18]. Many algorithms are available for 2D tracking such as color tracking [18], blob tracking [18], motion tracking [18], template matching [18], however these 2D tracking devices do not provide any information about hand orientation [18] and configuration [18]. 3D tracking devices provide information about hand position [18] and orientation [18] in 3D plane [18]. Since the hand is highly articulated object it is difficult to estimate hand orientation [18], while hand position can be localized using stereo camera [18] or model based approach [18].Tracking and instrumented data gloves are accurate [14], provide full description of most hand parameters (angles and position) [4], and detect rapid hand fingers motion [4].

To attain full depicting of hand motion two important aspects should be available as mentioned in [6]: hand shape and position. The hand shape represented by the joint bending [6] or joint positions [6][18], while the hand position represented by location [9][6] and orientation for the 6 DoFs [9][6] for both translations and rotations [6]. The first information is stored by the sensor gloves [6] and the second information is stored by the trackers [6]. Recently gloves and trackers are combined for different commercial applications [6].

Instrumented data glove can be defined as a system that uses diverse kinds of sensors [6], and electronics [6] for acquiring data necessary to calculate the movements of the fingers [9]. Various glove systems designed last three decade and still keep investigators busy with the growing technology [6]. In glove based and tracking technologies the user should wear a device which is connected to the computer through cables [4], however the glove based and tracking technologies limits the naturalness and the ease of interaction between the user and the computer [9]. Cyber Glove is an example of this technology with 22 sensors embedded in the fingers, palm, and wrist to measure the position, and fingers and palm motions [17].

2) Color Markers Technology

In color markers technology, either some markers are drawn on the hand or the user has to wear a colorful glove and the color property will guide the process of locating hand's palm and fingers [14], and easily extracting the hand features [14]. Different colors can be used as markers on the hand or on the glove [16], and in some researches the fingers are assigned one color, so that to easy the process of extracting the fingers from the palm and wrist [19]. Although, this technology is simple, and low cost than the data glove [19], yet hinder the nature user-computer interaction [14].

3) Computer Vision Technologies

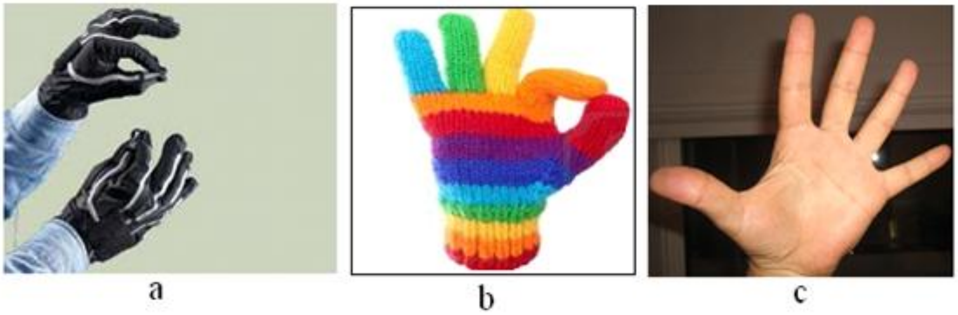
Computer vision or vision-based technologies [4][9][14] use bare hands to extract data necessary for recognition [14], these methods are natural [14][4], easy [4], and the user directly interact with the system [14]. Vision based technology deals with some image characteristics such as texture [4] and color [4] for acquiring data needed for gesture analysis [4].

Vision based technology consists of two different approaches: 3D model based techniques and appearance based or image based techniques [17].

i. 3D Model Based Techniques: 3D Model based approaches attempt to infer the pose of joint angles and the palm; such method would be useful in virtual reality environments [20]. This approach includes searching for the kinematic parameters by making 2D projection from 3D model of the hand to correspond edge images of the hand [20]. 3D Model can be classified into volumetric [12][21] and skeletal models [12][21]. Volumetric models deal with 3D visual appearance of human hand [12] and usually used in real time applications [14][21][12].

   Attempting to recognize the visual image with volumetric model, the output model is complex besides the computation time for computing model parameters to simulate the given image [12][14]. In this case the method known as analysis by synthesis [12][14]. The main problem with this modeling technique is that it deals with all the parameters of the hand which are huge dimensionality [12]. Skeletal models overcome volumetric hand parameters problem by limiting the set of parameters to model the hand shape from 3D structure [12][14].

ii. Appearance Based Techniques: these approaches model the extracted image features [22] depending on the visual appearance of hand image [12][22]. Usually a camera(s) or video camera is used. No transformations are required to model the gesture [17]. The resulted modeled features are stored in the database and then compared with the features extracted from input image [9]. An example of these techniques; predefined templates and deformable 2D templates.



a) Data-Glove [6]. b) Colored marker (from web gallery). c) Vision based (from web gallery).
Fig 4 Gestures input technologies

C. Detecting Gesture Techniques

In order to separate the hand from the background and other unwanted objects, the color of image pixels is the most effective cue utilized for extracting skin color pigment [14], other research make benefit from pixel information, and motion information.

A lot of studies in the literature are used to detect the hand gesture for example, [27] Fused the intensity image and range image generated by 3D (ToF) camera, as the input image [27], using the proposed K-Means Expectation Maximization (KEM) algorithm that combine unsupervised clustering algorithms; the K-means and Expectation Maximization (EX). K-means algorithm was employed to the initial clustering in order to minimize the sensitivity of initial points [27] and find out initial cluster's centre [27], and that will be the initial parameters for EM algorithm to find maximum likelihood estimation [28]. Some studies used color model only to simplify the work [24][15][29]. [26] applied YCbCr color space. and [29] applied normalized YUV color space and some image processing filters are then performed. Hasan [30] proposed new method for modeling the skin color distribution using Multiple of GMM (MuGMM) for extracting hand object and three popular color models which are: normalized RGB, HSV, and YCbCr, where each color model have been modelled using single GMM [30] with a parameter associated for each color model and these GMMs are then combined to form one superior model [30]. [31] employed multi-scale segmentation method from a sequence of video images and the image is converted from RGB to CIE LUV color space and the luminance component was neglected to generate homogeneous areas in each video frame, so that for consecutive frames, regions between these frames are matched to produce two-view correspondences [31]. Then Gaussian Mixture model (GMM) is used to model the distribution of skin color pixels [31].

TABLE 1
SEGMENTATION EMPLOYED IN SOME OF THE DISCUSSED METHODS

Method	Background	Color Model	Segmentation Technique
[25]	complex	HS and rg color spaces	Combined GMM and histogram based Bayes method
[26]	complex	HS and rg color spaces	Combined GMM and histogram based Bayes method with depth information
[30]	uniform	Normalized RGB, HSV, and YCbCr	Multiple of Gaussian classifier
[16]	black	Normalized YUV	Thresholding

D. Gesture Analysis and Features Extraction

Gesture analysis required the detection of the hand and then estimates it, usually the hand gesture is detected using some segmentation techniques in order to detect the hand [12] afterwards, the hand segment is used to extract the proper features that will represent the hand totally [14]. The selected features vector should be effective and robust [14]. In 3D model based, the two key parameters are; joint angles [12] and hand centroid [12], while in appearance based model, the main parameters can be represented by; active contour [12] [30], shape analysis [12], histogram based feature parameter and motion estimation [30]. Different methods have been applied to detect the hand shape and estimate the parameters. By capturing the shape of the hand [15][14], and then extract features vector parameters.

E. Gesture Classification

The final stage of gesture recognition system is to interpret the input gesture clearly by classifying the gesture command using classification tools, by computing the probability of the input gesture with a set of predefined gestures during the training time [14] and to be matching using their likelihood of its matching to this class [14]. Of course the recognition tools of static gestures are different form dynamic gestures. Where the former type classification tools are: linear classifier such as k-means and non-linear classifier like Neural Network [23]. The classification tools for dynamic gestures are: HMM [4][23], dynamic time warping, time delay NN, and FSM.

In [31], they applied time delay neural network to classify motion patterns. [15] applied cascade Gaussian function for classification the gestures. [28] after the classification of the fingers, 5- bit stream are used to locate each finger in a bit stream, and the integer number that corresponds to each bit stream is calculated, so the index of the fingers can be easily computed and the gesture classified accordingly, Figure 5 shows the bit stream assignments.

bit 4	bit 3	bit 2	bit 1	bit 0
pinkie	ring	middle	index	thumb

Fig 5 an example of gesture recognizer using fingers database indexing [28]

III. GESTURE SYSTEM CHALLENGES

For any system there are various difficulties that confronting the constructed system. Gesture recognition has a lot of challenges that might be raised at any stage during the establishment of gesture recognition system; these challenges are shown in Figure 6 as mentioned in [32].

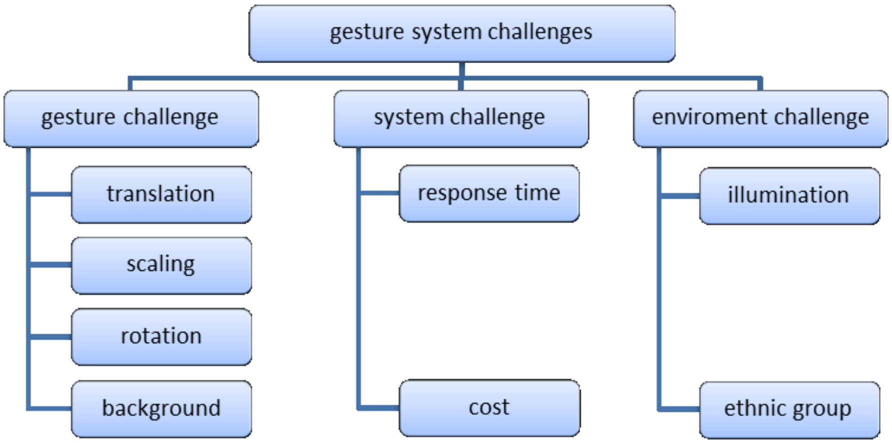


Fig 6 Gesture recognition system challenges [32]

As demonstrated in the previous figure, there are three main groups of challenges that facing the system; gesture challenges, system challenges, and environment challenges [32].

A) Gesture challenges

Many studies are claimed the gesture challenges which hinder the process of recognition [3][28][33][14][32] which are translation, scaling, rotation, and the background. Translation problem appears when there is a change in the location of the object of interest (hand) in the entire image, especially when the location of the hand or the camera is changed [32], histogram method has proved its efficiency for solving this problem [32]. Scaling problem, related to the problem of changes the size of the hand which can be obtained when the hand object changes its distance from camera lens [32]. Rotation problem, is the most difficult problem, where the input gesture can be obtained in any direction, most of the researches try to overcome this problem by ignoring these cases or by increasing the number of training samples for such cases [32]. Finally, background problem, is how to extract the foreground hand object from the intricate background [32], some of the researches used black [16] or uniformed background [2][30][31] to overcome this problem, systems that used complex background [15][19] usually applied some robust segmentation techniques.

B) B) System challenges

System challenges are response time and cost, the response time should be fast [32] especially for real time and virtual reality applications [32]. The cost of the system is represented by the hardware devices used for constructing gesture system, such as the camera used, data glove device [32].

C) Environment Challenges

This type of challenges defines the illumination and ethnic groups [32]. Illumination can be defined as the changing of the lighting conditions in the environment in both artificial lights and natural lights [32]. The most common solution is by using the normalized components (chrominance) only of the color space or by using other color model such as HSV and YCbCr [15]. Orientation histogram has shown satisfactory results to segment the edges even under dark lights [32]. The system should be designed to classify different ethnic groups of people (whitish, blackish, reddish, etc.), where different skin color is effected with skin saturation and produce same hue value [32].

IV. DISCUSSION AND CONCLUSIONS

Face and gesture recognition are classified as one of the fields of visual based HCI system that deals with the visual user sense to understand the interaction between users and computers. The development of the visual environments, allow the gesture system to contribute in the natural interaction with different life applications appliances. The explained stages for gesture recognition system represent the main steps for any gesture recognition system. Various studies applied different algorithms passing through the recognition stages to achieve acceptable results. Table 2 explains the recognition tools applied in some selected systems with systems description. Table 3 shows some recognition factors such as recognition rate and recognition time with number of recognized gestures of some selected gesture recognition methods.

TABLE 2
EXPLANATION OF THE CLASSIFICATION TOOLS APPLIED IN SOME SELECTED SYSTEMS WITH SYSTEMS DESCRIPTION

Method	Recognition technique	Description
[34]	Structural analysis for postures / HMM for gestures.	Used templates to detect hand postures/ and used hand location to detect gestures to control a mobile robot.
[19]	Learning Vector Quantization (LVQ).	Extracted nine numerical features to develop real-time hand classifier and can be implemented on devices with moderate computational resources, such as netbooks.
[35]	minimum distance classifier (matching technique)	Recognized hand pose by constructing a model of hand skeletal depending on fingertips positions

TABLE 3
SOME FACTORS RELATED TO SOME SELECTED GESTURE RECOGNITION METHODS

Method	# Recognized gestures	# Total gestures used For training and testing	Recognition percentage
[34]	5 static/ 12 dynamic gestures	Totally 240 training data set and then same data set are testing.	98.3%
[19]	13	1541 gestures	97.79 %
[35]		160 sample gestures for testing	93.25%

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