Hand Gesture Modeling and Recognition using Geometric Features: A Review

Mokhtar Hasan
University of Baghdad

Hand Gesture Modeling and Recognition using Geometric Features: A Review

Mokhtar M. Hasan[1], and Pramod K. Mishra[2]
[1, 2]Computer Science Department, Banaras Hindu University, Varanasi, Uttar Pradesh, India
[1]mmwaeli@gmail.com, [2]pkmisra@gmail.com

Abstract — *The use of the gesture system in our daily life as a natural human-human interaction has inspired the researchers to simulate and utilize this gift in human-machine interaction which is appealing and can take place the bore interaction ones that existed such as television, radio, and various home appliances as well as virtual reality will worth and deserve its name, this kind of interaction ensures promising and satisfying outcomes if applied in systematic approach, and supports unadorned human hand when transferring the message to these devices which is more easiest, comfort and desired rather than the communication that requires frills to deliver the message to such devices, the gesturing is also important between human-human interaction especially with hearing impaired, deaf and mute peoples, in this study, we have presented different researches that done in this area regarding the geometric features which considered as a live features compared with non-geometric features which considered as blind features, and we have focused on the researches gathered to achieve this important link between human and his made machines, also we have provide our algorithms for overcome some shortcomings existed in some mentioned algorithms in order to provide a robust gesture recognition algorithm that does not have a rotation hinder which most of current algorithms have.*

Key Words — human-computer interaction, hand gesture, geometric features, hand model, kinematic hand model, hand recognition, palm detection, wrist detection, fingers detection, template matching, dynamic template matching.

I. INTRODUCTION

Ancient cave man was communicating with his surrounding people by gesturing and may be some other simple voice combinations which known as words, the modern man imitates this communication but this time with human-made devices or between these devices and the hearing impaired people as well, and this will facilitate the computer recognition for sign language which is very important for hearing impaired people [1]. However, the gesturing is rooted in our life and the human continues this behavior during his talk with others even those others were on phone [2], this form of communication is appealing since it provides the basic and easy effort done by a person to get the message delivered rather than the cumbersome devices like keyboard and mouse since the former reflect his nature. For that reason the keyboard and mouse have been replaced by hand, face, finger, or entire body [3] and those new natural input devices attracting more attention [4] since need no extra connections [4][5], more efficient [4], powerful [6], promising [7], and preferable naturalness [8].

The augmented reality [9] has improved and become user friendly especially with the increasing in the degree of naturalness; this done with the improvement of vision-based gestures that reduces the human burden, gestures can be separated within solution space for facilitating the discrimination in training phase in case of a limited gestures are need for such augmented reality system [10], but, however, large latencies can impaired the accuracy since the emotional attachment to the environment that done by the users are reduced [10].

In order to ensure a robust estimation of the presented hand especially for machine learning algorithms, a wide set of training samples must be provided [10], but, on the other hand, the increasing in the number of training patterns slows down the processing speed and enlarges database size, these problems have been address in [11][12][13][14] which are scaling, translation, rotation and illumination perturbations, by the normalization operation we can get rid of scaling and translation problem after perfect segmentation, illumination is segmentation task and can be overcome by normalization the color component or by using of other color space models such as YCbCr or HSV prior to segmentation process, rotation problem can be cured by unifying the object direction [15]; all these efforts can be combined all together to reduce the database size and speed up the processing speed, the traditional approach to obtain rotation invariant is by providing many samples per a single posture, for example, 2280 different templates to detect the rising finger has been employed in [10], furthermore, 6, 40, 124, and 20 templates for each single posture in [2], [16], [17], and [18] respectively; but, however, some researchers choose to keep this number low but, on the other hand, their method will affected by a rotation variance, this can be found in [1][19][5] and [20].

Finally, sign language requires special consideration since shape and motion are needed [5]; and the motion modeling is important and imperative [5] and the tracking will interfere with such term, the tracking can be done by two different ways, each single hand pose can be processed separately [20], in this case there are no tracking information can be preserved, the other way can be done through tracking information [21], some devices can be used like Kalman filter [21] , HMM, and neural networks for such purpose, however, an initial hand location is required to start the tracking process [7], skin color-based and haar pattern-based [7] can be used for such purpose, but, however, since the initial location of the hand object is important especially in cluttered scenes and in poorly controlled and varying lighting conditions [22]; for that the manual detecting is applied [7], however, tracking can help to detect the objects that may occlude or partially disappear [9], furthermore, other review studies can be found in [23][24][25][26][27].

II. OUTLINE

Section 3 is covering the applications of vision based system. Section 4 tries to bring to you the different hand models hitherto. In section 5; hand kinematic model has been explained. Sections 6 and 7 show the data models for the gesture system and their processing steps. Sections 8-10 show the segmentation techniques and their performance with the amenities of the color space based segmentation. Sections 11-13 show how to capture the hand structure, wrist detection and extraction of useful geometric features. Section 14 shows the representation of the features that will help gesture validation at testing time, and finally, Section 15 shows the shortcoming of some selected methods.

III. APPLICATIONS OF VISION-BASED SYSTEM

There are many applications for vision-based system which interfere with our daily life; we brief some of these usages herein:

1- Human-computer or human-robot interaction.
2- Sign language recognition especially for hearing impaired people.
3- Hand and finger annotation for pianist player and this annotation can be used for remote education and for facilitating the producing of music sheets [9].
4- Control of consumer electronics equipment and mechanical systems [28].
5- The interaction that done with visualization systems [28].
6- Interactive games [28][7], interactive environment [4], and intelligent rooms [7].
7- Vision-based augmented reality systems [3][10][4].
8- The surveillance and the tracking that applied with stationary camera model [22].
9- For mobile or hand held devices [4], the use of keyboard or touch screen become encumbered due to the limited size of such devices [4].
10- Main component of body language in linguistics [4].

However, Table I shows the applications for gesture system for some selected approaches.

TABLE I
APPLICATION OF SOME SELECTED METHODS

Method	Application
[29]	Used for gesture recognition system
[28]	As TV remote control, for home appliances
[6]	Used for gesture recognition system
[1]	Used for sign language
[8]	Tracking for hand writing purposes
[3]	Interface with home appliances
[22]	Used for fingertip detection
[10]	Used for fingertip detection
[4]	Navigation of image browsing
[21]	Augmented disk interface, tracking for drawing
[19]	Fingertip detection for command issuing
[9]	Pianist remote education, hand and finger details recording during the playing
[7]	User interface, number of raised fingers decides the operation to the controller
[5]	As a pointing mouse
[2]	Used for gesture recognition system
[20]	As a pointing mouse

IV. HAND MODELING

In order to go deeply with gesture system, we have to distinguish first between the meaning of a posture and a gesture, posture is a single image that represents a single command like stop sign, while gesture is a sequence of postures which refer to a unique meaning when combine those postures together like moving the hand in specific direction for changing the volume of a radio or TV. Hand should be modeled into the system in order to be processed correctly. The demanding application has a significant impact on the selection of the model employed [5]. Hand model can be temporal (motion) or special (shape) [5], special recognizers have been constructed to keep track of temporal modeling like hidden markov model (HMM) [21], neural network (NN), rule based and finite state machine [30], special modeling can be divided down further into appearance based model and 3D based model [28][4][31][5], appearance based model [10][31] is also referred as 2D model or view based model [5]. Appearance based model can be formed by templates [5], shape representation features [5], eigenvectors [5], shape representation features can be either geometric or non-geometric features, geometric features considered live features since it can be processed separately like fingertip locations and palm location, on the contrary, non-geometric features considered to be blind features since it cannot seen individually and a collective processing is required. 3D model describes the hand shape [28][4][31] and can be divided down into volumetric models and skeletal models [5], volumetric models are complex to carry on especially in real time applications [5] in which the speed factor is very critical, so, other geometric models like cylinders and spheres [5] are considered as alternatives for such model for hand shape approximation [5]. The other kind of model is the skeletal model which captures the hand structure with a 3D structure with a reduced set of parameters as compared with the former model [5]. When casting volumetric model on appearance based model, the result is complex and time consuming for parameters to calculate [5] and the approach can be called at this time as analysis by synthesis [5], Figure 1 shows a portray view of hereinabove classification. This classification is done through different categories which based on hand motion interaction which can take one of the following two types [21]: direct manipulation and symbolic gestures, in direct manipulation; the current hand location can be interpreted as the following command whereas the symbolic can be obtained from the object motion [21].However, 3D modeling solves the problem of self-occlusion [31] but it is not useful for real time applications since time is against this modeling [31][5].

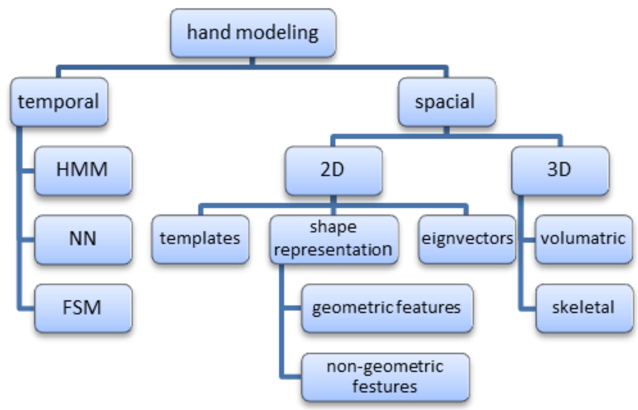


Fig. 1. Hand Modeling.

Furthermore, each of 3D and 2D models have different parameters can be used for model estimation, feature vector representation, and valid recognition, and also these parameters may be overlapped between these two models, joint angles [23][25][26][27][5], palm/hand spatial position [24][25], and spatial orientation [24] have been used intensively for 3D model [25] since it can capture the hand information, on the other side, image as an input for non-geometric features [25], geometric features [25], fingertip locations [25] can be used for 2D vision based system. However, for tracking information; we can use hand motion [25] and/or fingertip motion information [25] for that purpose.

The joint angles can be formed as a whole arm which are shoulder [23], elbow [23], and wrist [23], or may refer to fingers angle [23],

However, because the articulated property of the hand object that has an elastic degree of freedom which is difficult to model perfectly into the system, many models have limited these two main properties of the hand object [23] and assume a fixed number of hand joint flexion with specific degree of freedom [23], the following will focus some light on this latter issue with explaining its components and details.

V. Degree of Freedom

Human hand is considered as an articulated object [23] with 27 bones that form the hand structure and their ability for capturing, holding, grasping, and releasing objects smoothly, five fingers are in the human hand, four finger which are pinkie, ring, middle, and index are aligned together and attached to the wrist bones in one tie, the thump, in the other hand, has some distance away from them, this thumb is the main reason for all prosperity and development that we are witnesses and living through since this finger is used all the time in every grasp operation and this finger stands alone in the opposite side of other four fingers and the life will be very difficult and hard to accommodate if the human hand cannot grasp at all as in its current form of finger alignment, however, these 27 bones are distributed as 8 bones in the wrist area, and 19 bones for the fingers from nail end down to wrist area as seen by Figure 2. However, hand joints has the following names which inspired from their location [24], Distal Interphalangeal (DIP) and Proximal Interphalangeal (PIP) used for forming a single finger except for thumb which has neither distal nor proximal since the count of his bones are less by one comparing with other fingers, so, it has just Interphalangeal (IP), the connection joint between the fingers and metacarpal bones is called Metacarpophalangeal (MCP) which are five one for each finger, finally, the connection joint between the metacarpal bones and carpal bones (wrist) are called Trapeziometacarpal (TM) or also called Carpometacarpal (CMC), these different forms of connections have a different DoF as follows: DIP's have 4 DoF, PIP's have 4 DoF, one for IP, the total is 9 hitherto, MCP's have 2 DoF each, this will bring up the sum into 19 DoF, two more DoF for TM joint for thumb finger only and 6 DoF for wrist, so, 27 DoF are provided by this mystery creature, out of question, and outstanding human hand, Figure 3 shows DoF.

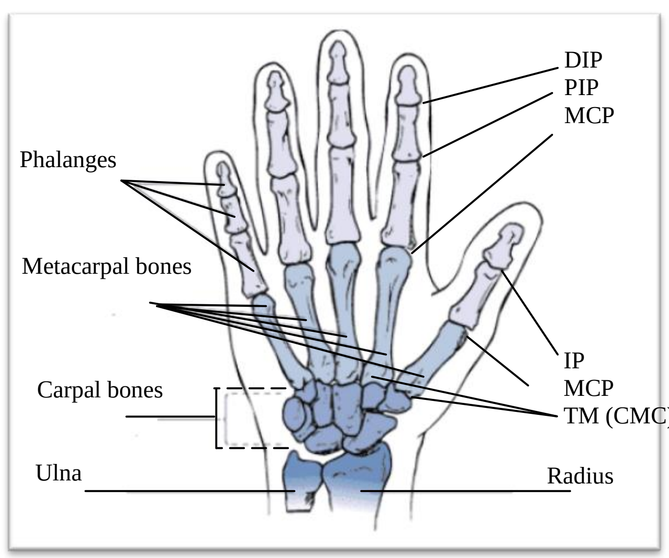


Fig. 2. Hand and Wrist Bones and Joints with their Corresponding Names (basic hand structure image taken from [32]).

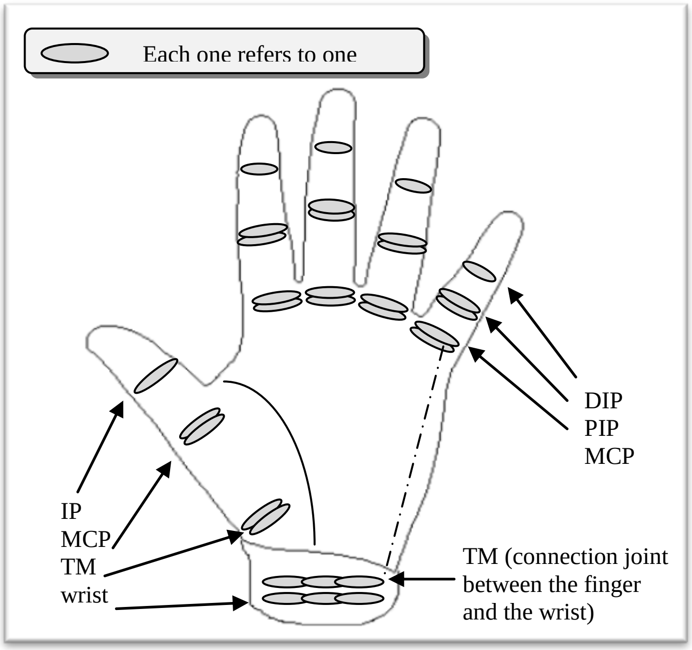
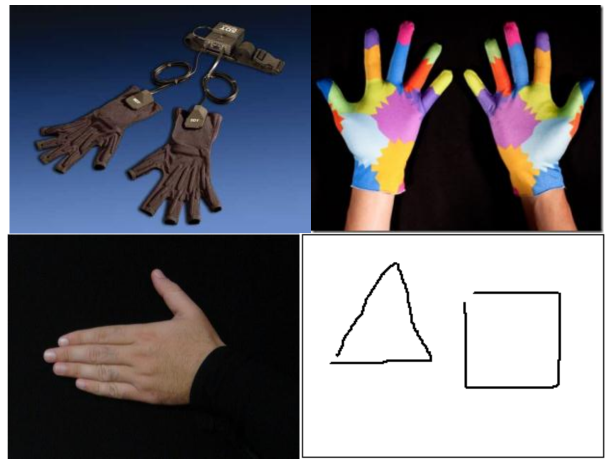


Fig. 3. Degree of Freedom in Human Hand.

For understanding the meaning of DoF, consider the xyz plane, if the object can change its direction only in one direction permanently, it is called has one DoF such as the railway that decides the direction of the train in one course all the times, for two DoFs, the object can move across two different coordinates permanently such as a driving car which can go in xy-plane at any time, so, regarding the fingers, each joint that has one DoF can perform one direction movement in two ways forward and backward which are flexion and expansion, for two DoFs, the finger can perform abduction and adduction as well as flexion and expansion, and so on.

VI. Collecting the Model Data

The input devices that are used for feeding the model with its necessary data for gesture system can be classified into four classes: data glove [31][1][3][10][7][5], marker [31][7], hand image, and drawing [33][34][35]. Data glove-based devices can be used for perfect input data and can provide the correct location and shape of hand with high accuracy and high speed [31] and can provide a correct measure for joint angles of the hand as well [5], and can be geared with many real time computer applications such as games, virtual reality interfaces, but, however, the existing cables can hinder the range of hand motion [31] and these gloves may transfer some skin diseases [36] as have been worn by different people especially in game parlours; some agreed that any touchable interface can cause the transmission and influence of diseases even mouse and keyboard [37]. The second technique for input data is coloured markers as a glove attached to human hand and hand localization is done by color localization; this method can provide a reliable detection of geometric feature extraction but still hinders the level of naturalness since it is similar to data glove [31] and also these markers have absolute locations of some points with a limited orientation [10], and possibly they trying to fit the already formulated model [10], the third method requires no additional hardware nor gloves to be worn by the user and the communication is done completely naturally with bare hands, these methods that embody unencumbered hand are usually based on appearance based model and machine learning techniques [10]. Drawing model has been used successfully for pen-based user interface to provide some commands to be carried out by the computer [33][34][35], Figure 4 shows these four classes.



a b
c d

Fig. 4. The Data Input for Gesture System, a, b, c, and d represent Data Glove (from [38]), Marker (from [39]), Hand Image, and Drawing Model respectively.

VII. General System Architecture

Gesture recognition system composed of several stages; these stages are varied according to application used, but, however, the unified outline can be settled, Figure 5 fulfils this step.

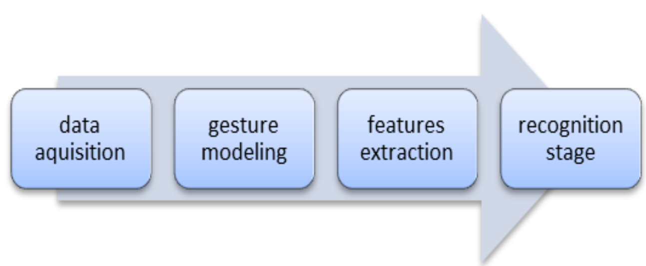


Fig. 5. General System Architecture.

These stages that mentioned in latter figure might broke down into several sub-stages, all these divisions are dependent on the application used, for example; the processing steps are different in case of vision-based or glove-based were employed as well as the vision-base and color-based hand gesture system.

A. *Data Acquisition*

This step is responsible for collecting the input data which are the hand gestures image for vision-based system or sensors reading in case of data glove, and the classes should be declared that the classifier classifies the input tested gesture into one of these predefined classes.

B. *Gesture Modeling*

This employed the fitting and fusing the input gesture into the model used, this step may require some pre-processing steps to ensure the successful unification, Figure 6 shows some common processing steps for successful fitting which will be briefed in the next paragraph.

C. *Feature Extraction*

After successful modeling of input data/gesture, the feature extraction should be smooth since the fitting is considered the most difficult obstacles that may face; these features can be hand location, palm location, fingertips location, and joint angles, the extracted features might be stored in the system at training stage as templates or may be fused with some recognition devices such as neural network, HMM, or decision trees which have some limited memory should not be overtaken to remember the training data.

D. *Recognition Stage*

This stage is considered to be a final stage for gesture system and the command/meaning of the gesture should be declared and carried out, this stage usually has a classifier that can attach each input testing gesture to one of predefined classes with some likelihood of its matching to this class.

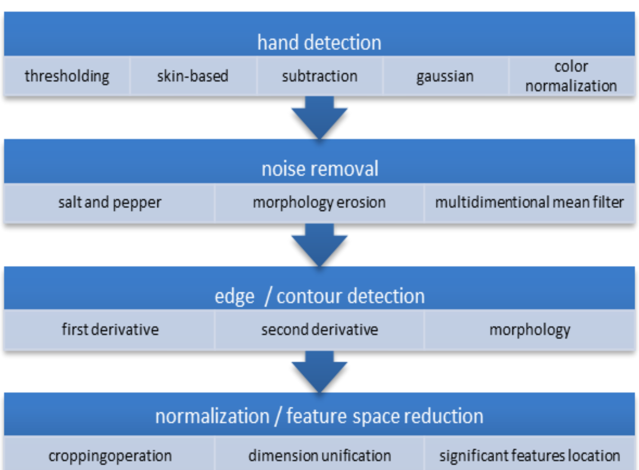


Fig. 6. Sub-stages of Gesture Modeling.

As seen by Figure 6, the gesture modeling includes some latent steps, these steps may be more or less according to application used, and can be rearranged, and these steps can be illustrated as follows:

1- Hand Detection: in which the main hand object which is the core of the work is detected herein, this can be done through variety of approaches, all of these approaches try to split the area of interest into two main segments, foreground which is the hand and the background which is anything else, as follows:

1.1 thresholding: *This splits the image into two regions of interest, foreground and background regions, which are the above and below a specific threshold value respectively.*

1.2 skin-based: *by taking the advantages of the human skin pigment and by transferring the RGB color model into luminance-chrominance one, the skin can be recognized correctly for those pixels that has their corresponding chrominance lie within a predefined range which equals to processed human skin.*

1.3 subtraction: *a static image has been used herein to be considered as a reference for later test images since the background is static and any change in this scene inspires to availability of new object in the scene.*

1.4 gaussian: *skin-based technique can be utilized and converted into a statistical model using Gaussian, this will assign a probability value for each pixel to be a foreground or background loyalty.*

1.5 color normalization: *a normalized RGB can be used to avoid color space conversion which speeds up the processing speed on the account of the accuracy.*

2. Noise Removal: the aim of this technique is to reduce the noise that is originally embedded into the image or the new emerged noise that creeps during the former processing step(s) [40], this can be done as follows:

2.1 salt and pepper: *this is a common used filter, median filter, morphological filter, contra harmonic mean filter [41] has been employed for this purpose as well.*

2.2 morphology erosion: *this method has been used by [42] to remove the noise creeped into image; the erosion operation affection on the object border can be compensated by dilation which forms the opening operation.*

2.3 multidimensional mean: *in which a combination of 8 filters can be used to detect the edge noise or fluctuating for more edge smoothness [22].*

3. Edge / Contour Detection: the hand edge is the color intensity difference which represents the moving from one region with high contrast to another with low contrast or vice versa, usually the edge is detected by using of 3x3 filter with certain magnitudes, the contour is a 1 pixel width silhouette that forms the object, as follows:

3.1 first derivative: *In this technique, the edge is characterized by a local maximum compared with its* *surrounding area with a higher value than a specific threshold; this must has a rapid [11] and steeping inclination of this edge information.*

3.2 second derivative: *zero crossing is used to locate the edge when the contrast change is not significant, many false edges may emerged, so, special treatment is required like pre-processing blurring operation [11].*

3.3 morphological operations: *these operations have been applied successfully to extract edge/contour information in which erosion and image subtraction are applied for this purpose, but, of course, a time consuming technique.*

4. Feature Space Reduction: instead of processing the whole image area, a small area of interest can be cropped and processed which speeds up the processing speed and helps of geometric features locating, as follows:

4.1 cropping operation: *this process calibrates and fits the hand object completely within the image window area, this took off any irrelevant area surrounds the hand object, and this process has been done by [19][13][43] and [14].*

4.2 dimension unification: *the purpose of this step is to set the image size to a specific dimensions which provides a fair feature matching across the database, 256x256 was adopted by [10], 320x240 by [4], 160x120 by [9], and 128x128 by [13][43][14], scaled normalization was adopted by [12] to preserve the original centre of gravity and the reduction is applied on each quarter with a different xy scales rather than one xy scale for whole image, this method proves a more reliable features.*

4.3 significant features location: *the feature space can be reduced for time consuming, Gabor filter were used in [29] to reduce the features from 6400 (80x80) to 35 by finding the net that captures the hand object rather than maintaining the hand object itself, the same done in [6] but by using of neural network, mapping of 320x240 to 32x24 in [8] by converting each 10x10 pixels area to a single pixel, this pixel is 'on' if there is any 'on' pixel from that corresponding region, furthermore, more than 65% of features has been removed in [11] since these features is irrelevant out of 625 feature vector size.*

VIII. SEGMENTATION

The hand segment detection and extraction plays a major role for the successful application of pending processes to validate the hand recognition, and considered the most difficult ring of this processing chain [7], some studies have used infrared camera [44][21] to overcome the background [8][19] influence factor and to achieve reliable hand detection, however, the fast hand motion still an obstacle for such techniques [19]. Some studies have used the video camera [21], [19], [9],[7] for recognition of the hand gesture for fair input, some other used 2 cameras [20], this video recognition has been considered [9] for computer-human interaction, automatic sign language recognition, robotic hand learning, and multimedia. After maintaining the video image; the hand should be detected, this can be done in one of the following two techniques depends on the prior knowledge of the segmented object, which are [9]:

1- Background Isolation: this technique is used when object shape or color is not defined in advance.

2- Object Extraction: that is used if the object has defined before the processing.

In all of detection techniques, the color cue is the principal information for this purpose [5]. The application of background isolation can be found in surveillance applications [9], in which the camera is stationary with respect to the surrounding background [9], and in this case a statistical mixture of Gaussian can be used to model the background [9], the second method can be used when the shape, color, or texture are known in advance [20], color-based technique is used intensively for face and skin detection [9], however, image object segmentation can be done in one of the following methods [45]:

1- Discontinuity: finding the hard changes in image intensity which detects the object edges.

2- Similarity: finding the similar properties/values that join one region which is commonly the color value.

For fingertip detection and geometric features extraction, the correct modeling for hand object relies on a reliable segmentation [8], and this segmentation aims to reduce the amount of processed information [8] for speed and accuracy purposes. However, for more reliable segmentation; the degree of background, motion speed, lighting condition [22] [8][4] can be lowered and infrared camera can be used as well [8]; these factors limit the performance of vision based system [4].

A. Segmentation Techniques

The segmentation has been applied for one common objective which is the object detection, gray thresholding technique is applied in [29][10][7] which considered simple and unreliable segmentation for complex scene, a more reliable segmentation is the color space based skin filter which detects the human skin pigment; moreover; researchers claim that the chromaticity of the skin is immune among different ethnic groups [6], accordingly; the luminance can be neglected and the chrominance can be used for skin color-based approach, many models have been introduced for that purpose, YCbCr is applied in [6][22][9], LUV has been used in [28], HSV has been used in [4][19], YUV has been used in [5]. Table II summarizes some techniques with their respective background and segmentation applied. However, the color space based techniques are unreliable to lighting variance [4];

even though, the proper adaptation of the color tone under different lighting conditions can cure this problem [22].

TABLE II
SEGMENTATION APPLIED ACROSS SOME RESEARCHERS

Method	Background	Segmentation Employed
[1]	uniform	canny edge detector
[2]	cluttered	gabor filter
[7]	n/a	thresholding the closest object to camera
[10]	black	thresholding
[21]	cluttered	infrared camera with thresholding
[29]	uniform	thresholding
[5]	almost uniform	color based YUV
[6]	uniform	color based YCbCr
[19]	almost cluttered	color based HSV
[22]	almost uniform	color based YCbCr
[28]	cluttered	color bases LUV
[3]	cluttered	background subtraction with reference image
[4]	cluttered	statistical gaussian model using HSV
[8]	cluttered	background subtraction with reference image
[9]	fixed colors	MoG for background subtraction, color based USC for hand detection
[20]	uniform	background subtraction with reference image

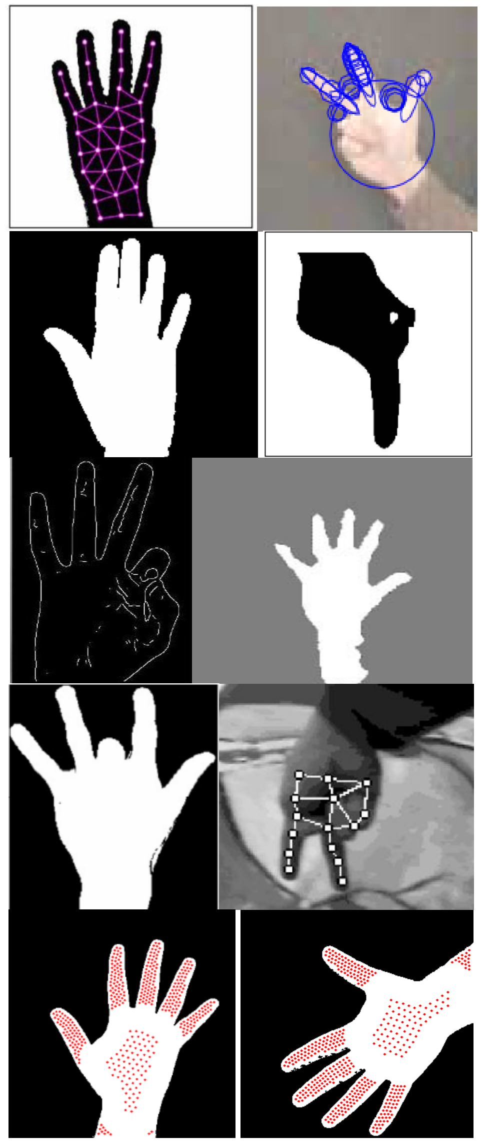
B. Color Space Based Amenities

Many researchers have address the amenities of using color space based skin filter detection, this color space can be located within the input image regardless of the rotation, scaling, or morphologic variance of this hand object [6], and can be distinguished easily among different ethnic groups [6] as well, fast and simple [6] implementation, and the use of such information can simplify the locating of fingertips even in complex background [22]; but, however, this requires the correct modeling of this color tone within the system for proper segmentation [22].

IX. CAPTURING THE HAND STRUCTURE

After correct segmentation of the hand object, this hand should be captured and modelled within the system properly, this modeling takes different formats, a self-organizing neural network has been used in [29] which helps to find the fingertips locations, a modified self-growing and organizing gas (SGONG) [6] for building a neuron net covering the hand segment, the biggest blob is also taken into consideration for hand object extraction in [28][4][19][20], hand extraction as contour is applied successfully by [1][8][5], hand region is extracted based on color segmentation in [3][22][10][21][9][7], Figure 7 shows different capturing done by some selected methods, Table III gives a quick portray.

Our algorithm for hand capturing is by applying a dynamic templates; finger and palm templates with different radius can be used for such purpose, the palm template will capture the hand area since it cannot fit inside a finger premises, finger templates will fit inside the palm area as well as fingers area but should be ousted from palm area by using the coordinates of matched palm templates, in this way the hand will be captured and palm area as well as fingers area have been decided and this method provides a promising technique for capturing the hand structure regardless the orientation of the input hand.



a b
c d
e f
g h
i j

a: neural network [6]. b, c, d: biggest blob [28][19][20] respectively. e: contour [1]. f, g: color based segmentation[3][10] respectively. h: graph [2]. i, j: our suggested dynamic template matching for finger/palm locating using two different templates in which the centers of the templates are shown.

Fig. 7. Hand Capturing Examples done by Different Techniques.

It is noticed in Figure 7(i, j) that some groups are non-fingers; these groups can be removed by using the threshold of number of points in the finger, or finger length can be adopted as well to remove these non-fingers groups.

TABLE III
HAND CAPTURING METHODOLOGY USED BY SOME SELECTED METHODS

Method	Hand Capturing
[1]	Boundary tracing
[2]	Labeled graph
[3]	Acute angle detection
[4]	Extended adaboost
[5]	Contour analysis
[6]	SGONG neural network
[8]	Grid sampling
[9]	USC color segmentation
[10]	Hand silhouette
[19]	Biggest blob in the resulted segmented image
[21]	Morphological erosion for hand region extraction
[22]	Multidimensional smoothing and thinning
[28]	Scale-space extrema
[29]	Self-organizing neural network

X. WRIST DETECTION

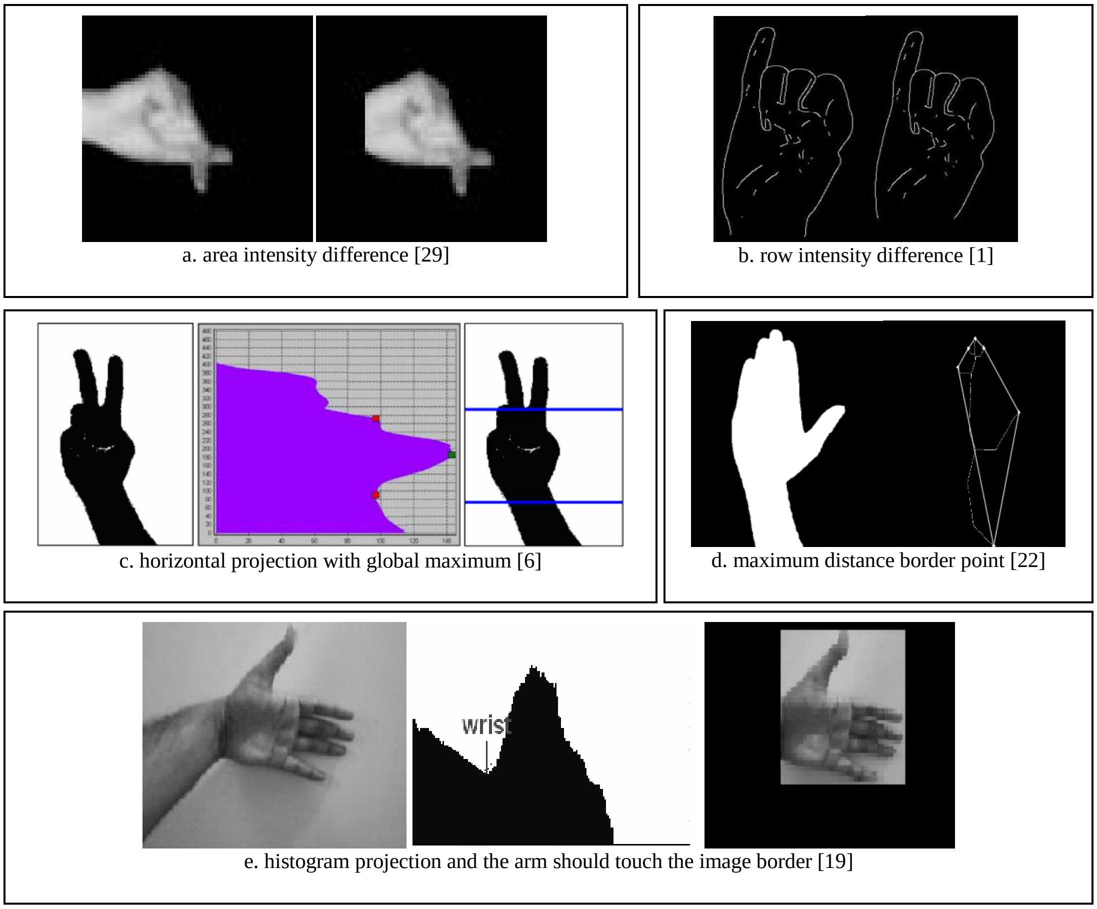
The human hand can be broken down into three parts, hand palm, fingers, and wrist; many applications use a long sleeve to cover the wrist [28][8][3][4][21][9][31][7][5][2][20] for simplifying the processing steps and to reduce the search area from three parts to two parts which are palm and fingers, however, some other applications choose to consider the presence of wrist [29][6][1][22][10][19] which provides some information about the hand direction when connecting the centre of the wrist with the centre of the palm, a pair of black sporting wrist has been worn in [10] for easy hand disembodied, in [29]; the wrist has been detected by calculating by dividing the image into slices and the wrist area is when the number of pixels in these slices are varying dramatically since the arm is thinner than the hand [29], in [1]; the wrist has been located by calculating the number of end point in each y-level by exploiting the uniform and parallel shape for wrist, but, however, the hand should be pointed to a predefined direction, the wrist is detected in [6] by calculating the horizontal projection and disembody the lower part which lies under the global maximum in which the projection width starts to increase, the wrist has been assumed to touch the image border in [22][19], and its distance from the other end which are the fingertips is the wrist in [22], finally, [19] has detected the wrist by calculating the corresponding histogram and the wrist is the valley in that histogram which is the steeping inclination for histogram magnitude, however, we have introduced a multi figure listing each labelled alone and gathered all together to form one figure to show the wrist detection examples adopted by different researchers as shown in Figure 8.

However, we have suggested our novel algorithm for wrist detection without any limitation for the direction, we have achieved a correct wrist area locating as well as the wrist center, or algorithm based on rotated projection histogram, this rotated projection enables us to find the wrist location without any limitation that existed in previous algorithms such as the hand should be up righted or just one direction or the wrist should touch the image borders, our algorithm has non-of these stipulations, however, we need to find the fingers area and fit biggest circle inside palm premises in order to proceed to wrist locating algorithm, as we explained before we have applied two kind of templates which are finger circle template (FCT) and palm circle template (PCT), now, we will find the biggest circle can fit the palm area centered at the averaging of these matched PCTs as seen by Figure 9c.

This biggest circle is called the guiding circle (GC), we will scan all the degrees (0^o to 359^o) by the help of GC with a rotation traversal and each degree we will form a line from the border of that circle to the border of the hand object and the number of pixels in that line will be retained as the histogram value (y-axis) for this degree (x-axis), upon finishing of this process a histogram will be constructed and the peak point is the wrist area premises, we have decided a threshold for histogram value which is 20 for deciding the boundaries of the wrist area, this threshold will produce two pixels which are the boundaries and the wrist center is their average as seen by Figure 9d. As seen by our suggested algorithm, there is no limitation of which direction the hand should be, neither sleeve nor non-sleeve is stipulated, you can use any hand pose as an input and the algorithm will detect the wrist area as well as the wrist center, Figure 10 shows the histogram that corresponds for Figure 9e but with full density since latter mentioned figure is drawn with less density to give better understanding for the lines that emerged from border of the GC. Regarding Figure 10, the histogram area is the peak point and a threshold has been set as we mentioned hereinabove to be 20 that confines the wrist area boundaries, for Figure 9e, the wrist area is decided to be between 65^o and 126^o.

XI. GEOMETRIC FEATURES EXTRACTION

The fingertip detecting and locating is considered a high priority for geometric features in which a more flexible model can be built for this purpose, this model can be matched with the existent data extracted at the training phase, the prior step that validate the fingertip detection is how to search for this fingertip(s) within a segmented hand, the hand has been captured with multiple neurons in [6] and the fingers with one connection neuron are the fingertips since this neuron lies at the most-end of the finger, the palm has been located after a horizontal projection is calculated, the area that is above and below the global maximum is the palm area as seen by Figure 8c, fingertips have found in [1] by finding the area that is lie between ascend and descend of the hand contour by the help of a flag, the fingertips are also detected in [8][21] by the help of a template for fingertip shape which require a massive matching procedure to locate the fingertip location, this template can take a dynamic circular form as in [8] which depends on the user; cylinder with hemispherical cap in [21].



a. area intensity difference [29]

b. row intensity difference [1]

c. horizontal projection with global maximum [6]

d. maximum distance border point [22]

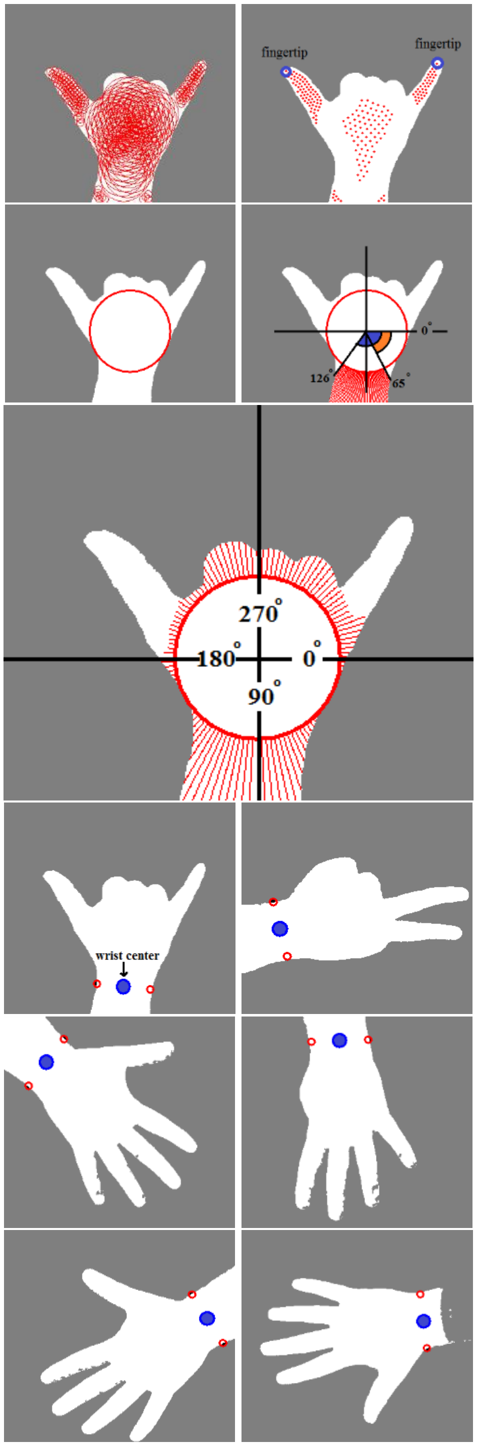
e. histogram projection and the arm should touch the image border [19]

Fig. 8. Wrist Detection.

Fingertip convex shape inspires some others such as [3][9][7] to adapt this method, this is accomplished by tracing the contour points looking for such acute angles to announce the fingertip(s), the multidirectional smoothing operation with 8 masks have applied in [22] before further processing in order to remove any noise or small fluctuating at the boundary area, after that; the morphological thinning operation has been applied to reduce the shape to a simple line preserving the hand topology as seen by Figure 8d; and the fingertip can be detected by a 3x3 filter for finding the areas with a total summation of 2 including the centre of the filter, the morphological operation is a time consuming process and can delay this detection operation regardless the number of filters employed, the decision tree has employed for deciding the fingertip and has been done in [10] with seven trees by splitting the data set into partitions, full data set requires one decision tree, two halves of the data set require additional two decision tree, four quarters of the data set require four decision tree which bring the summation up to 7 trees. An intensity value from 1 to 255 has been assigned in [19] for each row or column based on vertical or horizontal hand direction and the fingertip is the one that corresponds to the highest intensity value, the same idea is considered in [5][20] by finding the maximum y-value in that axis which represent the fingertip. In [6][1][19][5][20] limits the level of naturalness and reduces the number of presented gestures that can adopted in the system, Figure 11 shows an example for such feature extraction, none of these methods processes an input image with free-angle, each one assumes horizontal or vertical hand, our dynamic template matching ensures the correct locating of fingertips at any direction which is the maximum distance of FCT matched template of each finger area from the palm center after applying FCT and PCT templates and application of ousting operation for FCT matched templates that existed in PCT matched templates premises, fingertip can be seen clearly in Figure 9b but after removing the non-finger's group as we said before in last paragraph of section IX.

A. Features Representation

Blobs (palm) and ridges (fingers) draw high importance for the most researchers since they represent the crucial step for geometric features; their location has been extracted in [28][4], fingertip location has been used intensively which has been extracted in [28][6][8][3]and [22], the number of raised fingers has been extracted in [1]. Usually, the hand centre using the blob can be located by finding the point with maximum distances with the region boundary.



a b
c d
e
f g
h i
j k

a: template matching with FCT and PCT. b: centers of matched templates. c: GC fits palm area, d:wrist area decided after (e) sketched by seeking for peak point in the histogram that correspond to (e) and taking a threshold of 20 to be wrist borders. e: tracing the circle from 0^o to 359^o with calculating the number of point in each line. f: wrist center as well as boundaries have been decided that corresponds to (e). g-k: different samples with different rotations with and without sleeve for wrist deletion.

Fig. 9. Showing the Different Samples for Wrist Detection with their steps.

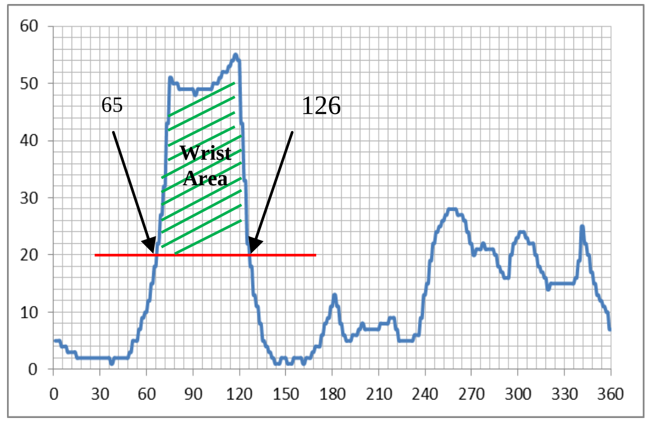
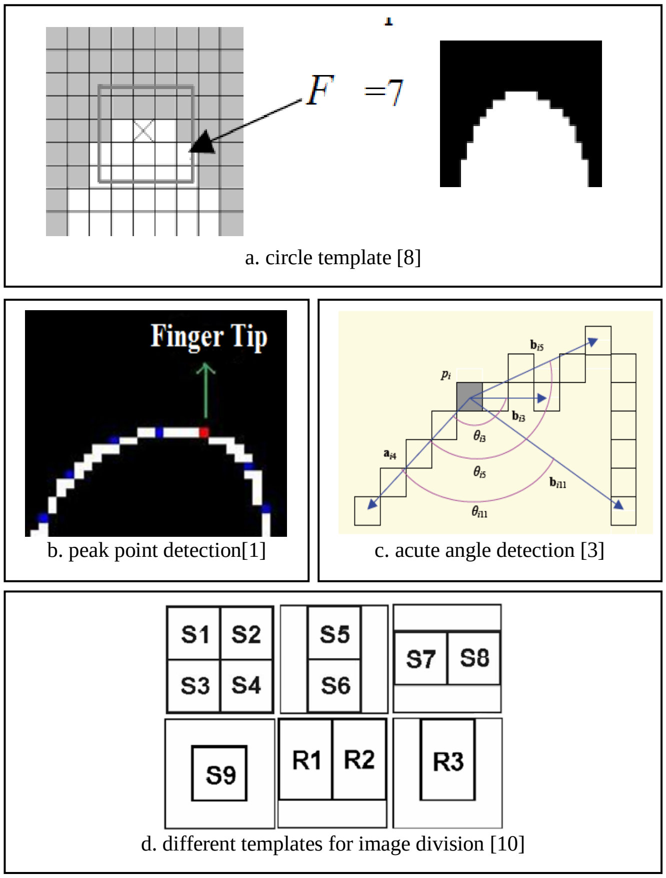


Fig. 10. The Rotated Histogram Projection corresponds to Fig. 9e (full density) and dashed green area above the threshold is for Fig. 9d.

This hand centre is calculated by the continuous application of the erosion operation which shrinks the hand to a small area and the centre of this area is the hand centre [21][31][5] [46].

The finger detection has been applied by using three distinguished features together in [6], root angle, tip angle, and root distance, the hand slope has been calculated which helps to formulate a principal line passing though the wrist centre and palm centre all together, then, the angle that lies between this main line and the line joints the finger root and palm centre has been calculated, the other angle is formed by the former line and the line joints fingertip and palm centre, finally, the third feature is the vertical distance between finger root and the main line which is invariant to scale since its normalized by dividing this value by the length of the palm [6], the palm length is calculated by finding the difference between leftmost and right most neurons [6]. The thumb has been distinguished in [21] from forefinger by their corresponding angle which has been calculated between the finger and the palm centre, the natural property of the thumb angle which is greater than any angle makes the distinguish possible.

Some non-geometric features technique has been applied for fingertip locating, in [10], the input image is divided into 56 by overlapping different sub-image (35 squares, 21 rectangular), a total of 224 feature vector size has been extracted from each sub-image, and a seven decision trees has been employed for finding the maximum output which corresponds to fingertip location. In [2], a labelled graph has been used for capturing the hand structure and to fit the hand model with graph nodes, the matching is done with stored templates according to their locations with the possibility for some elasticity in nodes locations. Pictorial representation for these features can be seen in Figure 12, Table IV compares between several selected techniques for gesture system in order to discover some facts. However, features should be separable within solution space and discriminated by the classifiers used which is the main benchmark them, and should has less error at testing phase.



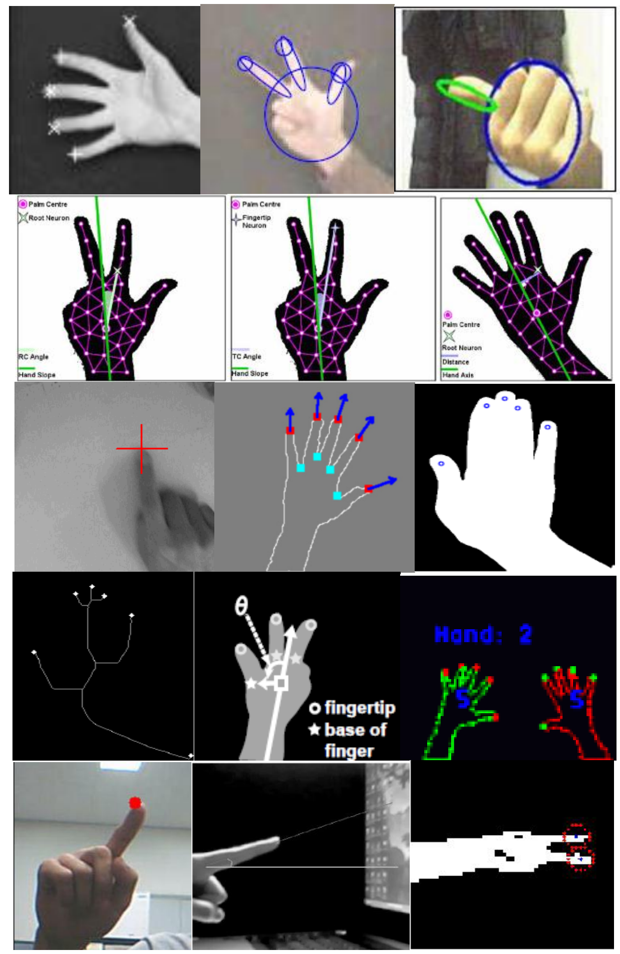
a. circle template [8]

b. peak point detection[1]

c. acute angle detection [3]

d. different templates for image division [10]

Fig. 11. Different Techniques for Fingertip Detection.



a b c
d e f
g h i
j k l
m n o

a: fingertip locations in [29]. b: blob and ridges in [28]. c: blob and ridge coordinates in [4]. d: angle between principal direction and finger root in [6]. e: angle between principal direction and fingertip in [6]. f: distance between finger root and principal line in [6]. g: fingertip location in [8]. h: fingertips, bases and fingers direction in [3]. i: segmented hand in [22]. j: fingertips and wrist base locations after morphological thinning operation. k: fingertips locations and thumb distinguishing in [21]. l: fingertips detection in [7]. m: fingertip location in [5]. n: pointing location in [20]. o: fingertips locations in [42].

Fig. 12. Geometric Features that Extracted for Different Gesture Applications.

We have suggested a different set of features for finger classification as well as hand recognition, we have employed four different features in our algorithm, for a finger to be classified we have to apply just three of them, which means the features are classified into two groups, the first group is the collective features that has two of these four features, the second group is selective group in which we apply one of them, these features are as follows:

1- Perpendicular Distance (PD): which is the distance between the casted base of the finger on the main principal of the hand and the palm center, this feature proves a high discriminate of their output for thump, middle, and pinkie finger which is what we wanted.

2- Base Angle (BA): This is the angle that formed between the following two lines, finger's base to palm center line, and main principal of the hand.

3- Base-Base Angle (BsA): This is the angle that formed between the following two lines, finger's base to palm center, palm center to finger's base.

4- Base Border Angle (BB): This is the angle that formed between the following two lines, fingertip to finger base of the same finger, and finger base to a selected point on the hand border, this feature is designed for index and ring only.

After application of the collective features, thumb, middle as well as pinkie will be recognized correctly, for index and ring, we have to follow one path out of the following:

1- First Path: if the hand has a thumb, thumb base will be used for application of third feature (first feature out of selective features) for final decision of all fingers since the use of thumb's base will discriminate other fingers with no error.

2- Second Path: same as first path but the difference is there is no thumb but pinkie instead.

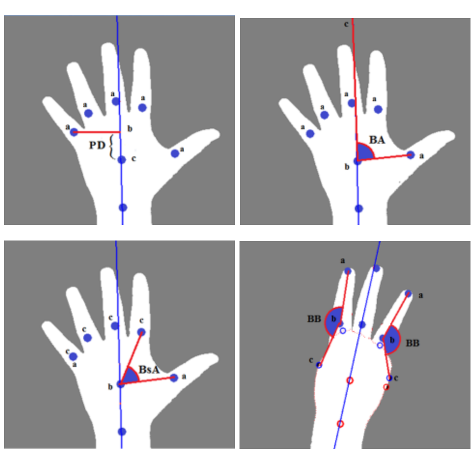
3- Third Path: in case of no thumb neither pinkie, we have to apply fourth feature (second feature out of selective features) to recognize index and ring fingers since the middle finger has been classified in first application of features.

TABLE IV
SOME FACTS RELATED TO SOME SELECTED GESTURE RECOGNITION METHODS

method	number of recognized gestures	total gestures for training and testing	time consuming	recognition percentage
[1]	Number of open fingers	N/A	N/A	N/A
[2]	12	72 postures for training	N/A	92.9 % for simple background 85.8 for complex background
[3]	Moving, clicking, and pointing	N/A	Real time	90.5 %
[4]	6	N/A	90 to 110 milliseconds	98.1 % uniform background 89 % cluttered background
[5]	12	360 postures for testing	N/A	99 %
[6]	31	180 testing gestures	N/A	90.45 %
[7]	5	N/A	N/A	96 %
[8]	For writing recognition	N/A	20 to 26 milliseconds	98.5 %
[9]	Finger and hand location only	N/A	Real time	N/A
[10]	Rising fingertips only	2280 postures for training, 190 from 6 different persons for testing	Real time without segmentation time	92.1 %
[19]	Fingertips locations only	N/A	N/A	N/A
[20]	Index finger pointing only	N/A	N/A	N/A
[21]	12	N/A	N/A	99.2 % for single finger detection, 97.5 for double finger detection
[22]	Fingertips locations only	N/A	N/A	N/A
[28]	5	N/A	N/A	N/A
[29]	N/A	320 total gesture for training and testing	N/A	N/A

The reason behind this combinations of features is we want to present a model that can recognizes the fingers and hand with no prior deciding whichever left or right hand has been used and our system can recognize the hand without such prior knowledge, Figure 13 shows these features.

a b
c d



a: PD. b, BA. c, BsA. d: BB.

Fig. 13. Representation of our Suggested Features for non-condition Hand/Finger Classification.

XII. DRAWBACKS

Each gesture system has some shortcomings since there is no perfect simulation of the nature, since all human researches fall into the attempt to simulate the nature, and, certainly, the simulation should has some sort of errors.

The hand must be in a static direction in [6][1][5][20], horizontal or vertical as in [19] for wrist detection purposes that use the fact that says the connection area between wrist and hand is narrower than the both sides, the hand object should be closest object to the camera since the segmentation process depends on this fact in [7], the input image should be the only visible part of the human skin in [4] with a care selection for adaboost filters, using only the right hand for processing in [6], a lot of storage space and processing time are required for matching stage in [10] since a total of 2280 templates have been employed, 56 sub-image, 4 features per sub-image, then, the database features are 510720 need to be matched at recognition time. The time delay is tolerable in [2], it spends 16 seconds for single posture recognition using Sun Ultra Sparc Workstation [47] and also one arm can be detected at one time [47], moreover, 216 different graph models have been built for recognizing 12 different postures only [47].

Acute convex is the main course of the method applied in [3], which leaves the rest of the hand boundary without this acute convex, if the segmentation process or lighting variance produces some convex edges, the fingertip detection will go wrong, and the hand object should be the only image object that burden the segmentation process as well as in [22], the latter approach needs intensive calculations; 8 different masks be applied for multidirectional smoothing, another 8 for thinning operation using morphological operation that repeats itself over and over until approach, another 3x3 filter traversed over the final output for detecting of the fingertips in which the wrist should touch the image border, and for [4] the hand object should lie completely at the centre of the image or its vicinity and should not reach the border with covering the wrist since it depends on Gaussian distribution and the detection will go wrong if the mentioned situation did not covered.

XIII. Conclusion and Discussion

Gesture system has captured wide applications areas that reflect the human natural desire for such kind of intuitive communication, we have introduced several techniques in this direction as well as our own algorithm and we have listed their applications, their algorithms, features extracted, and their shortcomings.

The algorithms used can take a simple background to simplify the hand detection, most of these methods depend mostly on the correct segmentation and any fluctuation or misdetection of the region will cause a major collapse of the whole method, so and for that reason, many pre-processing steps have been adopted to make sure of correct hand region detection, multidimensional smoothing operation has been applied in [22] for smoothing out the hand boundary that will help in the correct feature extraction phase, or, some others prefer to use infrared camera which provides good solution for hand segmentation. Another issue can be addressed which is how to locate the hand direction that gives a pre-estimation for finger locations, some researchers choose to fix the hand direction as in [6][1][5][20] to be up righted, or horizontal or vertical as in [19], or emerged from the image border as in [29][22][19], or the image should be almost in the vicinity of the centre of the image with long sleeve to cover the wrist as in [4], after these issues have been covered correctly, the contour tracing process starts for finding the geometric features, this can be applied by a simple tracing process as in [48] for seeking for peak and valley points which are the fingertips and the joint points between two fingers respectively, peak point in [5][20], dramatic change during tracing also employed in [1] for finger detection, templates in [8][21], high curvature angle in [3][9], the neuron out of a grid with only one connection in [6], the pixel that has one connection after thinning operation in [22], maximum intensity in [19] as we have described this in detail hereinabove, however, these extracted features are depends on the application and purpose that extracted for, and, for example, to detect which finger is raised, three different types of features are employed in [6], but, to detect if there any raised finger regardless the finger class, one single feature can be employed as in [2][20], however, many hand gesture systems assume a certain value for degree of freedom [23] for correct modeling and to reduce number of samples adopted since the hand is an articulated object with many degree of freedom [23], in [10]; 23 DoF has been employed but with 2280 image samples taken.

Finally, we have introduced an algorithm that can detects the geometric features of the hand, fingertips, finger's base as well as palm and wrist centers can be detected without any limitation or prior stipulated and any direction or rotation can be processed and correct features can be supplied, we have adopted dynamic circle templates with two different size circle templates, PCT and FCT, used for palm premises and finger premises respectively, and we have applied a rotated projection and we sketched a histogram for finding the location of the wrist which can be detected in any hand pose and with or without sleeve, for more detailed, please refer to [49] and [50].

Acknowledgment

Our thanks to the experts who have contributed towards development of the template and to the editorial board who have supported us with their guides.

References

[1] Ravikiran J, Kavi Mahesh, Suhas Mahishi, Dheeraj R, Sudheender S, and Nitin V Pujari," Finger Detection for Sign Language Recognition", Proceedings of the International MultiConference of Engineers and Computer Scientists (IMECS 2009), vol. I, Hong Kong, March 2009.

[2] Jochen Triesch, and Christoph von der Malsburg, "A system for person-independent hand posture recognition against complex backgrounds", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 23 (12), pp. 1449-1453, Dec 2011, doi: 10.1109/34.977568.

[3] Daeho Lee and SeungGwan Lee, "Vision-Based Finger Action Recognition by Angle Detection and Contour Analysis", ETRI Journal, vol. 33(3), pp. 415-422, June 2011, doi: 10.4218/etrij.11.0110.0313.

[4] Yikai Fang, Kongqiao Wang, Jian Cheng and Hanqing Lu, "A Real-Time Hand Gesture Recognition Method", In Proceedings of IEEE International Conference on Multimedia and Expo (ICME 2007), Beijing, China, July 2007, pp. 995-998, doi: 10.1109/ICME.2007.4284820.

[5] Sung Kwan Kang, Mi Young Nam ,and Phill Kyu Rhee, "Color Based Hand and Finger Detection Technology for User Interaction", IEEE International Conference on Convergence and Hybrid Information Technology, 2008, pp. 229-236, doi: 10.1109/ICHIT.2008.292.

[6] E. Stergiopoulou, N. Papamarkos, "Hand gesture recognition using a neural network shape fitting technique", Engineering Applications of Artificial Intelligence (ELSEVIER), vol. 22,pp.1141–1158, 2009, doi: 10.1016/j.engappai.2009.03.008.

[7] Hyunjin An, Daijin Kim, "Hand Gesture Recognition using 3D Depth Data", Department of Computer Science and Engineering, Pohang University of Science and Technology, Korea, 2009.

[8] Duan-Duan Yang, Lian-Wen Jin, Jun-Xun Yin, Li-Xin Zhen,and Jian-Cheng Huang,"An effective robust fingertip detection method for finger writing character recognition system", Proceedings of the Fourth International Conference on Machine Learning and Cybernetics (ICMLC 2005), Guangzhou, China, August 2005, pp. 4991-4995, doi: 10.1109/ICMLC.2005.1527822.

[9] Dimitry Gorodnichy, A. Yogeswaran, “Detection and Tracking of Pianist Hands and Fingers”, Third Canadian Conference on Computer and Robot Vision (CRV 2006)Canada, June 2006, doi: 10.1109/CRV.2006.26
[10] J. Mackie ,B. McCane, “Finger Detection with Decision Trees”, University of Otago, Department of Computer Science.
[11] Mokhtar M. Hasan, Pramod K. Mishra, ”HSV Brightness Factor Matching for Gesture Recognition System”, International Journal of Image Processing, vol. 4(5):456-467, Malaysia, Oct 2010.
[12] Mokhtar M. Hasan, Pramod K. Mishra, “Brightness Factor Matching For Gesture Recognition System Using Scaled Normalization”, International Journal of Computer Science & Information Technology, vol. 3(2): 35-46, April 2011, doi: 10.5121/ijcsit.2011.3203.
[13] Mokhtar M. Hasan, Pramod K. Mishra, “Comparative Study for Construction Of Gesture Recognition System”, International Journal of Computer Science and Software Technology, vol. 4(1): 15-21, January-June 2011.
[14] Mokhtar M. Hasan, “Pramod K. Mishra, ”Performance Evaluation of Modified Segmentation on Multi Block for Gesture Recognition System”, International Journal of Signal Processing, Image Processing and Pattern Recognition, vol. 4(4), pp. 17-28, December 2011.
[15] Mokhtar M. Hasan, Pramod K. Mishra, “Direction Analyses Algorithm using Statistical Approaches”, SPIE International Conference for Digital Image Processing (ICDIP 2012), accepted.
[16] Xingyan Li, “Vision Based Gesture Recognition System with High Accuracy”, Department of Computer Science, The University of Tennessee, Knoxville, 2005.
[17] Agnes Just, Yann Rodriguez, Sebastien Marcel, “Hand Posture Classification and Recognition using the Modified Census Transform”, In Proceedings of the IEEE International Conference on Automatic Face and Gesture Recognition (AFGR 2006), Southampton , UK, April 2006, doi: 10.1109/FGR.2006.62.
[18] Simei G. Wysoski, Marcus V. Lamar, Susumu Kuroyanagi , Akira Iwata , “A Rotation Invariant Approach On Static-Gesture Recognition Using Boundary Histograms And Neural Networks”, In Proceedings of the 9th IEEE International Conference on Neural Information Processing (ICONIP '02), Vol. 4, pp. 2137 – 2141, Singapore, Nov, 2002, doi: 10.1109/ICONIP.2002.1199054.
[19] Jagdish Lal Raheja, Karen Das, and Ankit Chaudhary, “An Efficient Real Time Method of Fingertip Detection”, 7th International Conference on Trends in Industrial Measurements and Automation (TIMA 2011), Chennai, India, Jan 2011, pp. 447-450.
[20] Noor Shaker, M. Abou Zliekha, “Real-time Finger Tracking for Interaction”, IEEE 5th International Symposium on Image and Signal Processing and Analysis (ISPA 2007), Istanbul, 2007, pp. 141-145, doi: 10.1109/ISPA.2007.4383679.
[21] Kenji Oka, Yoichi Sato, and Hideki Koike, “Real-time Tracking of Multiple Fingertips and Gesture Recognition for Augmented Desk Interface Systems”, Fifth IEEE International Conference on Automatic Face and Gesture Recognition (FGR.02), Washington DC, USA, 2002, pp. 429-434, doi: 10.1109/AFGR.2002.1004191.
[22] Ahmad Yahya Dawod, Junaidi Abdullah, “Fingertips Detection from Color Image With Complex Background”, The 3rd International Conference on Machine Vision (ICMV 2010), 2010, pp.88-91.
[23] Thomas B. Moeslund, Adrian Hilton, and Volker Kruger, “Survey of Advances in Vision-Based Human Motion Capture and Analysis”, ELSEVIER Computer Vision and Image Understanding, vol. 104 (2), pp.90-126, 2006, doi: 10.1016/j.cviu.2006.08.002.
[24] Ali Erol, George Bebis, Mircea Nicolescu, Richard D. Boyle, and Xander Twombly, ” Vision-based hand pose estimation: A review”, ELSEVIER Computer Vision and Image Understanding, vol. 108 (1-2), pp. 52–73, 2007, doi: 10.1016/j.cviu.2006.10.012.
[25] Vladimir I. Pavlovic, Rajeev Sharma, and Thomas S. Huang, “Visual Interpretation of Hand Gestures for Human-Computer Interaction: A Review”, IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 19 (7), July 1997, 10.1109/34.598226.
[26] G. R. S. Murthy, and R. S. Jadon, “A Review of Vision Based Hand Gestures Recognition”, International Journal of Information Technology and Knowledge Management, vol. 2(2), pp. 405-410, July-December 2009.
[27] Ankit Chaudhary, J.L. Raheja, Karen Das, and Sonia Raheja, “A Survey on Hand Gesture Recognition in Context of Soft Computing”, Advanced Computing, Springer-Verlag, vol 133, pp. 46–55, 2011, doi: 10.1007/978-3-642-17881-8_5.
[28] Lars Bretzner, Ivan Laptev, and Tony Lindeberg, “Hand Gesture Recognition using Multi-Scale Colour Features, Hierarchical Models and Particle Filtering”, Proceedings of the Fifth IEEE International Conference on Automatic Face and Gesture Recognition (FGR.02), Washington DC, USA, May 2002, pp. 423-428, doi: 10.1109/AFGR.2002.1004190.
[29] Claudia N¨olker, Helge Ritter, “Detection of Fingertips in Human Hand Movement Sequences”, Gesture and Sign Language in Human-Computer Interaction, Proceedings of the International Gesture Workshop, Published by Springer, 1997, pp. 209-218.
[30] Ying Wu, Thomas S. Huang, “Vision-Based Gesture Recognition: A Review”, International Gesture Workshop on Gesture-Based Communication in Human-Computer Interaction (GW '99), Springer Lecture Notes in Computer Science, London, UK, 1999.
[31] Kenji Oka, and Yoichi Sato, “Real-Time Fingertip Tracking and Gesture Recognition”, IEEE Computer Graphics and Applications, vol. 22 (6), pp.64-71, 2002, doi: 10.1109/MCG.2002.1046630.
[32] Available at: http://www.chakras.org.uk.
[33] WeeSan Lee, Levent Burak Kara, and Thomas F. Stahovich,” An efficient graph-based recognizer for hand-drawn symbols”, ELSEVIER Computers and Graphics, vol. 31 (4), pp.554-567, August 2007, doi: 10.1016/j.cag.2007.04.007.
[34] Levent Burak Kara, and Thomas F. Stahovich, ” An image-based, trainable symbol recognizer for hand-drawn sketches”, ELSEVIER Computers and Graphics, vol. 29(4), pp. 501-517, August 2005, doi: 10.1016/j.cag.2005.05.004.
[35] Leslie M. Gennari, Levent Burak Kara, and Thomas F. Stahovich, “Combining Geometry and Domain Knowledge to Interpret Hand-Drawn Diagrams”, ELSEVIER Computers and Graphics, vol. 29(4), pp. 547-562, August 2005, doi: 10.1016/j.cag.2005.05.007.
[36] “Guidance for the Selection and Use of Personal Protective Equipment (PPE) in Healthcare Settings”, Internet Power Point Slides.
[37] Juan Wachs, Helman Stern, Yael Edan1, Michael Gillam, Craig Feied, Mark Smith, and Jon Handler, “Real-Time Hand Gesture Interface for Browsing Medical Images”, TSI Press, USA, vol. 2 (1), pp.15-25, 2008.
[38] Available at: www.5dt.com.
[39] Available at: www.touchuserinterface.com.
[40] Mokhtar M. Hasan, Pramod K. Mishra, “Connected Boundary RegionTracing for Object Hole Filling”, International Conference on Advances in Engineering and Technology, Bhubaneswar, India November 2011, , pp 67-72.
[41] Available at Wikipedia web site.
[42] S.M. Hassan Ahmed, Todd C. Alexander, and Georgios C. Anagnostopoulos, “Real-time, Static and Dynamic Hand Gesture Recognition for Human-Computer Interaction”, Electrical Engineering, University of Miami, Miami, 2009.
[43] Mokhtar M. Hasan, Pramod K. Mishra, “Gesture Recognition using Modified HSV Segmentation”, IEEE International Conference on Communication Systems and Network Technologies(CSNT 2011), Jammu, India, 3-5 june 2011, pp.328-332, doi: 10.1109/CSNT.2011.75.
[44] Yoichi Sato, Yoshinori Kobayashi, and Hideki Koike, “Fast Tracking of Hands and Fingertips in Infrared Images for Augmented Desk Interface”, Fourth IEEE International Conference on Automatic Face and Gesture Recognition (FG '00), Grenoble , France 2000, pp.462-467, doi: 10.1109/AFGR.2000.840675.
[45] Pei-Gee Peter Ho, “Image Segmentation”, Book, Published By InTech Janeza Trdine 9, 51000 Rijeka, Croatia, 2011.
[46] Chin-Chen Chang, Jiann-Jone Chen, Wen-Kai Tai, and Chin-Chuan Han, “New Approach for Static Gesture Recognition”, Journal of Information Science and Engineering vol. 22, pp. 1047-1057, 2006.
[47] Xingyan Li, “Gesture Recognition Based on Fuzzy C-Means Clustering Algorithm”, Department of Computer Science, The University of Tennessee, Knoxville, 2003.
[48] Ankit Gupta, Kumar Ashis Pati, and Simant Dube, “Finger Tips Detection and Gesture Recognition”, Project Report, Indian Institute of Technology, Kanpur, November, 2009.
[49] Mokhtar M. Hasan, and Pramod K. Mishra, “Real Time Fingers and Palm Locating using Dynamic Circle Templates”, International Journal of Computer Applications, March 2012, USA, accepted.

[50] Mokhtar M. Hasan, and Pramod K. Mishra, "Novel Algorithm for Multi Hand Detection and Geometric Features Extraction and Recognition", International Journal of Scientific and Engineering Research, France, accepted.

BIOGRAPHIES

Mokhtar M. Hasan is Lecturer in BGU, he is pursuing his Ph.D. in Banaras Hindu University, Varanasi, Uttar Pradesh, India. He has done the B.Sc. and M.Sc. in computer science from BGU in 1999 and 2001 respectively, he is interested in image processing, computer vision, database managements, and artificial intelligent.

Pramod K. Mishra is Associate Professor in Banaras Hindu University, Varanasi, Uttar Pradesh, India. His research interests include Parallel and Distributed Computation, Computational Complexity, Parallel and Clustered Data Mining, High performance Computing, VLSI Algorithms, and Image Processing.