PRINCIPAL COMPONET ANALYSIS BASED HAND GESTURE RECOGNITION

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Abstract: **Interacting with physical world using expressive body movements is much easier and effective than just speaking. Gesture recognition turns up to be important field in the recent years. Communication through gestures has been used since early ages not only by physically challenged persons but nowadays for many other applications. As most predominantly hand is use to perform gestures, Hand Gesture Recognition have been widely accepted for numerous applications such as human computer interactions, robotics, sign language recognition, etc. This paper focuses on bare hand gesture recognition system by proposing a scheme using a database-driven hand gesture recognition based upon skin color model approach and thresholding approach along with an effective template matching with can be effectively used for human robotics applications and similar other applications.. Initially, hand region is segmented by applying skin color model in YCbCr color space. In the next stage Otsu thresholding is applied to separate foreground and background. Finally, template based matching technique is developed using Principal Component Analysis (PCA) for recognition. The system is tested with 4 gestures with 5 images per gesture and results of the proposed system are compared with SVM classifier.**

Keywords: **hand, gesture, recognition, segmentation,**

I. INTRODUCTION

Gestures are the movement of any body part used to convey the meaningful information. Communication through gestures has been widely used by humans to express their thoughts and feelings. Gestures recognition refers to the process of identifying gestures performed by human so that machine can perform the corresponding action .Gestures have been classified in two categories static and dynamic[16]. Static gestures refer to still body posture and dynamic refers to movement of body part. Gestures can be performed with any body part like head , face, arms, hands, etc. but most predominately we use hand to perform gesture like we wave hand to say 'good bye'. Hand gestures have been widely used for many applications[like human – computer interaction (HCI), robotics, sign language[19], human machine interaction, TV interaction[18] etc. With the advancement of technology, human robot interaction (HRI) has become an emerging field in recent years. Hand gestures can be effectively used to give commands to the robot which in turn can be employed in large number of applications. Now-a-days, human robot interaction using hand gestures has widely been used in medical sciences[15]. But still challenges regarding robustness and efficiency are to be considered.

Hand Gestures Recognition techniques have been divided into two categories[13]- Sensor based and Vision Based recognition.

Sensor based recognition collects the gesture data by using one or more different types of sensors. These sensors are attached to hand which record to get the position of the hand and then collected data is analyzed for gesture recognition. Data glove[1][2] is an example of sensor based gesture recognition. Other sensors used were Wii controller, EMG sensors, accelerometer sensors[26], etc. Sensor based recognition has certain limitations. First of all it requires a proper hardware setup which is very expensive. Secondly, it hinders the natural movement of the hand. So to overcome the limitation of sensor based recognition vision based techniques came into existence.

Vision based techniques [1]uses one or cameras to capture the hand images. Various type of cameras used for capturing image can be stereo cameras, monocular cameras, fish eye cameras, time- of –flight cameras, infrared cameras, etc. Vision based techniques uses various image processing algorithms to get hand posture and movement of hand. Some vision based techniques uses colored markers to get the position of hand. But the vision based recognition also has some limitations that it is affected by illumination changes and cluttered backgrounds. Vision based techniques are further divided into two categories[28] – 3D model based and Appearance base recognition.

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Model based approaches uses 3D hand model to search kinematics parameters by comparing 2D projection of 3D hand image and input frame. 3D model are further divided into Volumetric 3D recognition [20] and skeleton 3D recognition[22]. Because of the complexity of 3D model it is not preferred. Appearance based techniques[24] are based on extracting features from the visual appearance of the image and compare it with already defined templates. Various features that can be extracted from the image can be shape based features[4] that can be geometric or non-geometric. Geometric features include- position of fingertips, location of palm, centroid[8], orientation[3], direction[7],etc. Non- geometric features includes color[9], silhouette and textures, contour, `edges, image moments, Fourier descriptors[10][23], Eigen vectors[21], etc. Some techniques uses skin color model[14] to extract skin colored pixels. Other techniques HOG features[5], SIFT features, etc. Appearance based technique is preferred over model based technique because of the complexity of the model based techniques.

The basic step of hand gesture recognition is to localize and segment the hand from the image. Various techniques are available for hand segmentation. The most popular and simplest technique is skin color model[7][14] which is used to get the skin pixels in the image but it has some limitations that skin color of different person can vary and background image can also contain the skin pixels. Other techniques are thresholding which divides the image into two regions foreground and background based on color, depth[6][10][12], etc. Some researcher uses background subtraction[9][11] for segmenting the hand. In our approach keeping in view the limitation and simplicity of skin color model we will combine it with thresholding for hand segmentation. Skin color segmentation[25] can be applied on any color space-RGB, HSV, YCbCr, YUV, etc. Every color space has its own benefits. We will use YCbCr color spce for skin color segmentation.For gesture recognition HMM[3][8], SVM[18][8][23],Nearest Neighbour classifer[10], neural network[17][14], PCA[21], finite state machine (FSM)[22] etc.

In our approach vision based hand gesture recognition technique is proposed using a database-driven approach based upon skin color model and thresholding along with an effective template matching using PCA which will used for controlling robotics hand in surgical applications and many other similar applications.

The rest paper is organized as follows: Section II describes the methodology, in section III results are discussed and finally conclusion and future scope in discussed.

II. METHODOLOGY

In this section we will discuss our proposed methodology step by step.

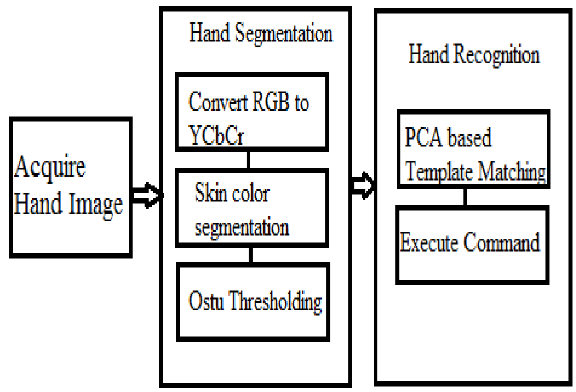

Fig. 1 Flow Diagram of proposed Methodology

A. *Image Acquisition:* Images are acquired using the 13 megapixel real-aperture camera in controlled background as well as by varying the lightning conditions.

B. *Hand Segmentation:* The main and basic step in hand gesture recognition is to segment the hand from the whole image so that it can be utilized for recognition. In our proposed color skin color segmentation is applied to segment the hand. As skin color of different person can vary and background image can also contain the skin pixels so after skin color model Otsu Thresholding is applied to remove the background.

- *Conversion from RGB to YCbCr:* The proposed skin color segmentation in applied to YCbCr color space. So first of all RGB color space is converted to YCbCr color space. Y represents the luminance and Cb and Cr represents chrominance. The RGB color space is converted to YCbCr color space using the following equation:

$$Y = 0.299R + 0.587G + 0.114\,B$$
$$Cb = (B - Y) * 0.564 + 128$$
$$Cr = (R - Y) * 0.713 + 128$$

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- *Skin Color Segmentation:* The skin color segmentation is used to classify the pixel as skin pixel or non-skin pixel. As or hand is connected component made of skin pixels we will get the hand after skin color segmentation. Steps for skin color segmentation:

1. The first step in skin color segmentation to specify the range for the skin pixels in YCbCr color space.

$$[R_{Cb}, R_{Cb}'] = [77, 127] \ \& \ [R_{Cr}, R_{Cr}'] = [133, 173]$$

R_{Cb}, R_{Cb}' is lower and upper bound for Cb component.
R_{Cr}, R_{Cr}' is lower and upper bound for Cr component

2. Find the pixels (p) that are in the range defined above:

$$R_{Cb} \leq Pixel\ value(Cb(i,j)) \leq R_{Cb}'$$
$$R_{Cr} \leq Pixel\ value(Cr(i,j)) \leq R_{Cr}'$$

3. Summation of all the pixels in the above step belongs to Region of interest i.e hand.

$$ROI = \sum p(i,j)$$

After Skin color segmentation we will the hand but may be some other pixels in the background also. To remove that background pixels we will use Otsu Thresholding.

- *Otsu Thresholding:* Thresholding is used to separate the object from its background by assigning pixel to either background or foreground based on threshold value. In our proposed system hand is in foreground. Otsu threshold is a global thresholding method which chooses threshold that minimizes within class variance.

1. Calculating threshold value:

In MATLAB there is a function Graythresh(I) which calculate global threshold value using Otsu Threshold.

TH = graythresh(I)

2. Convert Image pixel values into binary value according to THR.

Then

$$g(i,j) = \begin{Bmatrix} 1 \ \ if\ p(i,j) \geq T \\ 0, \ \ otherwise \end{Bmatrix}$$

C. Gesture Recognition

One of the important technique of recognition is template matching in which a template to recognize is available and is compared with already stored template. In our approach PCA method for feature extraction and matching is used.

Principal Component Analysis: PCA is used to reduce the dimensionality of the image while preserving much of the information. It is the powerful tool for analyzing the data by identifying patterns in the dataset and reduces the dimensions of the dataset such that maximum variance in the original data is visible in reduced data. PCA was invented by Karl Pearson in 1901. It works by converting set of correlated variables to linearly uncorrelated variable called principal components. Principal components are calculated by computing Eigen vectors of covariance matrix obtained from the group of hand images. The highest M eigenvectors contains the maximum variance in the original data. These principal components are orthogonal to each other and the first component is in the direction of greatest variance.

Mathematical Model for PCA:

The PCA approach has 2 stages: Training and Testing stage.In the training stage the Eigen space in established using training images of hand gestures and these images are mapped to the Eigen space. In the testing stage the image to be tested is mapped to same Eigen space and is classified using distance classifier.

Algo. for PCA:

Training Stage: Calculation of Eigen vectors:

1. Obtain the database containing N training images of dimensions M×M : $I_1, I_2, I_3 \ldots \ldots ., I_N$.
2. Convert these N images into vectors Z_i, $1 \leq i \leq N$ of dimensionM^2.
3. Obtain mean image vector Ψ $\Psi = \frac{1}{N}\sum_{i=1}^{N} Z_i$
4. Obtain the difference image by subtracting the mean image vector from the training image. $\Phi_i = Z_i - \Psi$

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5. Obtain the covariance Matrix C having dimensions $M^2 \times M^2$.

$$C = \frac{1}{N}\sum_{n=1}^{N} \Phi_n \Phi_n{}^T$$
$$= AA^T$$

$A = [\phi_1, \phi_2, \phi_3, \dots \dots \dots \phi_n]$ with dimension $M^2 \times$ N.

6. Compute the Eigen vectors v_i of AA^T

   As the dimensions of AA^T $[M^2 \times M^2]$ are very large so computation of eigenvectors is impractical.

7. Obtain Eigen vectors u_i of $A^T A$ [dimensions N × N.

   AA^T has M^2 Eigen vectors and Eigen values.
   $A^T A$ has N Eigen vectors and Eigen values.

8. Obtain the best N eigenvectors of AA^T by following equation.

$$v_i = Au_i$$

9. Take only V Eigen vectors corresponding to V largest Eigen values.

<u>Representation of Training Database using Eigen Vectors:</u>

Weight of each training image is calculated as:

$$w_j = v_j{}^T . (Z_i - \Psi) ,$$

where j =1,2,3,…..N.

Weight vector is represented as:

$$\mu = [w_1, w_2, w_3, \dots \dots ., w_N]^T;$$

Every image in training database is represented by weight vector:

$$\mu_i = [w_1^i, w_2^i, w_3^i \dots \dots ., w_N^i]^T;$$

TestingStage:

Let the image to be tested is ɋ, its weight (w_i) is calculated by multiplying Eigen vector v_i with the difference image.

$$w_i = v_i{}^T . (ɋ - \Psi)$$

Weight vector of unknown image is calculated as:

$$\mu = [w_1, w_2, w_3, \dots \dots ., w_N]^T;$$

<u>Compute:</u>

$$£_j = \min \| \mu - \mu_j \|; \; j = 1, 2, 3 \dots N$$

N is no. of training images.

So, ɋ is recognized as jth hand gesture from training database.

III. EXPEIRMENTAL RESULTS

In this section we will discuss the results of proposed system and will compare with other algorithm in which SIFT is used for feature extraction and SVM as classifier. The comparison is drawn based on accuracy ,spped and confusion matrix. For comparisons first of all dataset is collected. We have tested our system using 4 gesture nad have taken 5 images per gesture. So total images in the dataset are 5*4=20. Images are taken using mobile cameara of 8 megapixel.

Now, we will discuss the accuracy results which we have obtained using PCA and compare it with results obtained from SVM.

Gestures	**No. of Correctly Detected**	**Total images per gesture**	**Accuracy using PCA**
Gesture1	4	5	80%
Gesture2	5	5	100%
Gesture3	5	5	100%
Gesture4	3	5	60%
Average Accuarcy			85%

Table 1 Accuracy table for PCA

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Gesture	**No. of Correctly Detected**	**Total images per gesture**	**Accuracy with SVM**
Gesture1	5	5	100%
Gesture2	2	5	40%
Gesture3	4	5	80%
Gesture4	1	5	20%
Average Accuracy			60%

Table 2 Accuracy table for SVM

Next we will compare the accuracies obtained with PCA and SVM in figure 2.

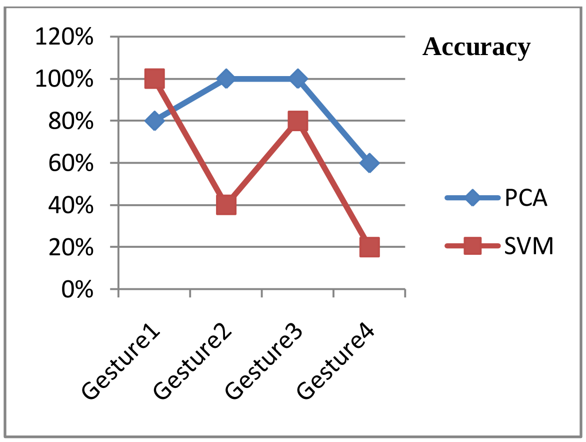

Fig. 2 Comparisons of accuracies per gesture

Next we will show the recognition time required to recognize the particular gesture in both the cases and compare their performance on the basis of recognition time in figure 3.

Table 3:Table for recognition Time

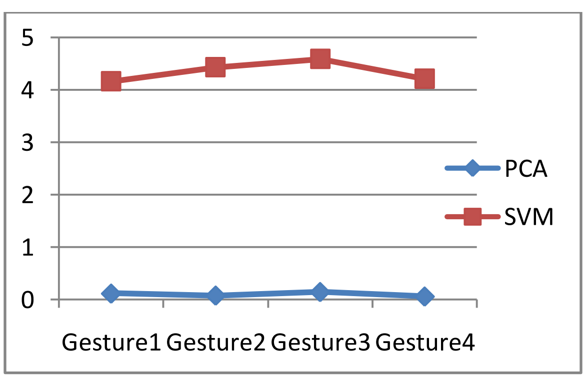

Figure3: Comparisons of recognition time per gesture

At last we will compare the performance using confusion matrix.Confusion matrix gives the percentage of gestures with are correctly recognized as same gesture and the percentage of gesture not correctly recognized and with what gesture it is confused.

Gesture	1	2	3	4
1	80			20
2		100		
3			100	
4			40	60

Table4: Confusion matrix for PCA

Gesture	1	2	3	4
1	100			
2		40	60	
3	20		80	
4	60		20	20

Table4: Confusion matrix for SVM

IV. CONCLUSIONS

In this thesis we presented the hand gesture recognition system is developed using hybrid approach. First of all hand is segmented using skin color model and Otsu thresholding and finally PCA is applied for recognition.Hand gesture recognition has many application areas –sign language recognition, robot control, immersive game technology, television assistance , healthcare and medical assistance , etc. We have developed the system which can be used to control robot for medical assistance.The system is tested in two cases. First case include implementation using skin color model, Otsu and PCA techniques

Recognition Time(secs)	**PCA**	**SVM**
Gesture1	0.114309	4.163941
Gesture2	0.076419	4.432374
Gesture3	0.144338	4.590962
Gesture4	0.057937	4.211367
Average Recognition time	0.098251	4.349661

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and the other include implementation using SIFT and SVM.

The proposed system is tested for 4 gestures with 20 database images.We have concluded that PCA gives better result than other case with accuracy 85% while the case 2 gives only 60% accuracy. We have also concluded that PCA is much faster than SVM with very low recognition time..The hand images have been obtained for the purpose of human-computer interactions for the operation theatre robots, which must understand the hand language in order to take the actions. Our research empowers the medical experts to pass the instruction to the robotic hands remotely to add the accuracy in the operations.

We have tried our level best to introduce a system that could recognize hand gestures successfully. Still there are many domains which we are not able to cover in our work. We hope to work on that some time in future. Also, we except that this work would pave the way for fellow researchers in this domain and motivate them to construct more robust techniques for hand gesture recognition. This work may be extended on the following lines:

- Our proposed system is not capable of working with images of other than skin color. So can be extended to work with images other than skin color images.
- It does not work with images taken in other light colors where the training images have benn taken. This issue should be considered in future.
- Our systems work only with static gestures. It can be extended to work with dynamic gestures.
- Our system can be further extended to develop real world application for medical experts by giving commands to robot.

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