Resilient, Real-Time Hand Gesture Recognition System

Project Report submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

Electronics and Communication Engineering

under the Supervision of

Mrs. Meenakshi Sood

By

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to

Jaypee University of Information and Technology

Waknaghat, Solan – 173234, Himachal Pradesh

Certificate

This is to certify that project report entitled “Resilient, Real-Time Hand gesture recognition System”, submitted by Ruchita Gupta and Mohd. Abbas Murtaza in partial fulfillment for the award of degree of Bachelor of Technology in Electronics and Communication Engineering to Jaypee University of Information Technology, Waknaghat, Solan has been carried out under my supervision.

This work has not been submitted partially or fully to any other University or Institute for the award of this or any other degree.

Date :

Meenakshi Sood

Assistant Professor

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Acknowledgement

Any endeavor in a specific field requires the guidance and support of many people for successful completion. It is our pleasure to be indebted to the various people, who directly or indirectly contributed in the development of this work and who influenced our thinking, behavior, and acts during the course of our training.

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Date :

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Abstract

Gesture based Human Computer Interaction (HCI) is one of the most natural and intuitive modes of communication between individuals and machines. Intelligent gesture recognition systems pave the way for a new era where the focus lies on the task itself, as it should be, and not on the interaction modality. Gestures of the hand itself can be used to communicate effectively as compared to computer peripherals, thereby empowering the visual and speech impaired population. In this project, we propose a technique that employs vision based approach together with dynamic gesture recognition techniques. The prototype architecture of the application comprises of a 2D webcam which continuously records the trajectory of the hand extracting information using a suitable colour model. This project focuses on developing a prototype of a robust, real-time hand gesture recognition system which works well under different degrees of background complexity and illumination conditions for dynamic gestures. The system is cost effective and works efficiently while interacting with objects in virtual environment using hand gestures. As an application, features of media player were controlled with hand gestures and an overall success rate of 97.5 per cent was achieved. While conducting the experiments, we have taken into account the challenges faced due to complex background, presence of non-gesture hand motions and different illumination environments in order to develop a system which can be used for innumerous further applications.

CHAPTER 1

INTRODUCTION

1.1 Overview

Human gestures constitute motions expressed by the body, face, and/or hands. Gestures have been extensively used as an alternative form of communication between humans and machines in an easy way. Among a variety of gestures, hand gesture is the most expressive and the most frequently used. The human-machine interface with gestures only allows a user to control a wide variety of devices.

Most of the recent work related to hand gesture interface techniques has been categorized as sensor-based method and vision-based method. Sensor based approach makes use of various sensors to collect the data of gestures. Vision based approach involves capturing image of gesture and extracting the feature to recognize it. Colour markers is one of the methods of vision based approaches. These techniques are further divided into model based and appearance based technique. In appearance based technique, the appearance of captured gesture is observed to create a recognition model whereas in model based technique, the captured image of gesture is analyzed and the model of gesture is created for gesture recognition. While working on hand gesture system, gestures are distinguished on the basis of movement: static and dynamic. A static gesture is a particular hand configuration represented by a single image. A dynamic gesture is a moving gesture, represented by a sequence of images. In this project, we focus our attention to vision-based recognition of hand gestures and our motive is to recognize dynamic gestures on complex background.

1.2 Aims and Objectives

The aim of this project is to design a system that employs vision based approach together with dynamic gesture recognition techniques so that a low cost computer vision system can be executed in a common personal computer equipped with USB web cam. The system should be able to work under different degrees of background complexity and illumination conditions.

The main objectives are as follows :-

- To implement a hand gesture recognition system.
- To control major features of a music player using hand gestures recognized by the laptop's webcam such as :-
  - Play
  - Pause
  - Volume Up
  - Volume Down
- To enhance user experience while using the interface.
- To make system robust against background complexity and illumination conditions.

1.3 Motivation

Human gestures constitute a space of motion expressed by the body, face, and/or hands. Among a variety of gestures, hand gesture is the most expressive and the most frequently used. Gestures have been used as an alternative form to communicate with computers in an easy way. This kind of human-machine interfaces would allow a user to control a wide variety of devices through hand gestures.

Over the past two decades, a lot of research has been carried out in the area of vision based hand gesture recognition with the objective of helping speech and language impaired people communicate effectively in their day to day life. The previous real-time hand gesture recognition systems required special hardware or lengthy training analysis. Our proposed technique uses only 2D video input and a single colour band. The removal of extensive wiring and hardware not only simplifies the system but also provides an easy mode of real time communication between humans and machines. The main motivation for our research has been to make the man-machine interface more flexible and more easy for the user.

CHAPTER 2

GESTURE RECOGNITION

2.1 Introduction

A form of non-verbal communication in which particular messages are communicated through visible bodily actions is using gestures. Gestures allow individuals to communicate a variety of feelings and thoughts, from contempt and hostility to approval and affection. A primary goal of gesture recognition research is to create a system which can identify specific human gestures and use them to convey information or for device control.

2.2 Hand Gesture Recognition Approaches

2.2.1 Sensor Based Approach

Sensor based approach makes use of various sensors to collect the data of gesture performed. This data is then analyzed and conclusions are drawn in accordance with the recognition model. In case of hand gesture recognition various sensors are placed on hand

and when the hand performs any gesture, the data is recorded and is further analyzed. Data gloves is an example of sensor based technique.

The invention of the first data glove was done in 1977. Sensor based approach uses external hardware which hinders the natural motion of hand. Also complex gestures cannot be performed using this method which is major disadvantage of this method.

2.2.2 Vision Based Approach

Vision based approach makes use of image data of gesture. This method focuses on captured image of gesture and extracts the feature and recognizes it. Colour markers is one of the methods of vision based approaches . There are restrictions on use of colour bands or colour markers. Therefore gestures performed using bare hands are preferred over colour markers.

In bare hand gesture recognition system for detection of hand, various skin detection algorithms are used. The problems faced by these types of system are of cluttered and dynamic background conditions. These problems can be resolved using proper background subtraction methods.

Vision based techniques have evolved with time. These techniques are further divided into model based and appearance based technique. In appearance based technique by observing the appearance of captured gesture the recognition model is created but in case of model based technique by analyzing the captured image of gesture the model of gesture is created and in accordance with that gesture recognition is done.

2.3 Phases of Hand Gesture Recognition System

Any hand gesture recognition system is divided into four stages which are depicted in Figure 1 :-

1. ***Acquisition*** of continuous video frames from the webcam.
2. **D*etection*** of the red coloured marker from the video image and forming a new binary image containing two regions; the marker region and the background.
3. ***Tracking*** the center of the marker region and extracting the total number of pixels indicating it.
4. ***Pattern Recognition*** based on the movement of the center of hand and the number of marker pixels.

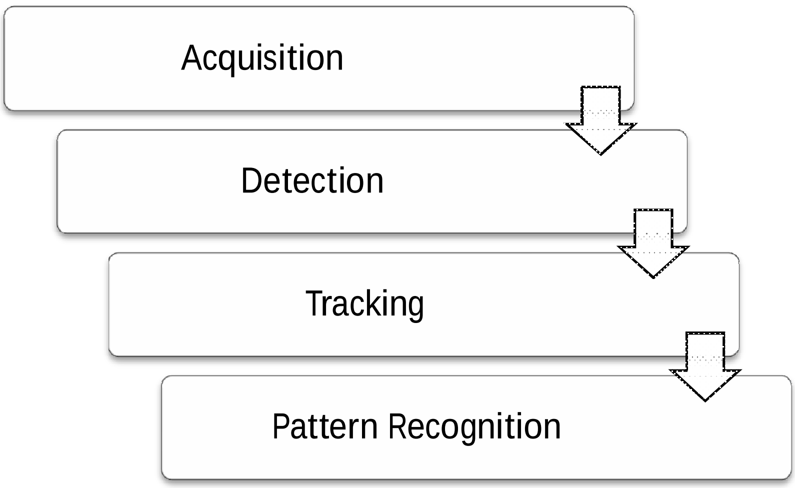


Figure 2.1. Sequential order of the steps involved in the proposed technique

2.3.1. Acquisition Phase

Image acquisition in image processing can be broadly defined as the action of retrieving an image from some source, usually a hardware-based source, so it can be passed through whatever processes need to occur afterward. Performing image acquisition in image processing is always the first step in the workflow sequence because, without an image, no processing is possible. The image that is acquired is completely unprocessed and is the result of whatever hardware was used to generate it, which can be very important in some fields to have a consistent baseline from which to work.

One of the forms of image acquisition in image processing is known as real-time image acquisition. This usually involves retrieving images from a source that is automatically capturing images. Real-time image acquisition creates a stream of files that can be automatically processed, queued for later work, or stitched into a single media format.

There are some advanced methods of image acquisition in image processing that actually use customized hardware. Three-dimensional (3D) image acquisition is one of these methods. This can require the use of two or more cameras that have been aligned at precisely describes points around a target, forming a sequence of images that can be aligned to create a 3D or stereoscopic scene, or to measure distances. Some satellites use 3D image acquisition techniques to build accurate models of different surfaces.

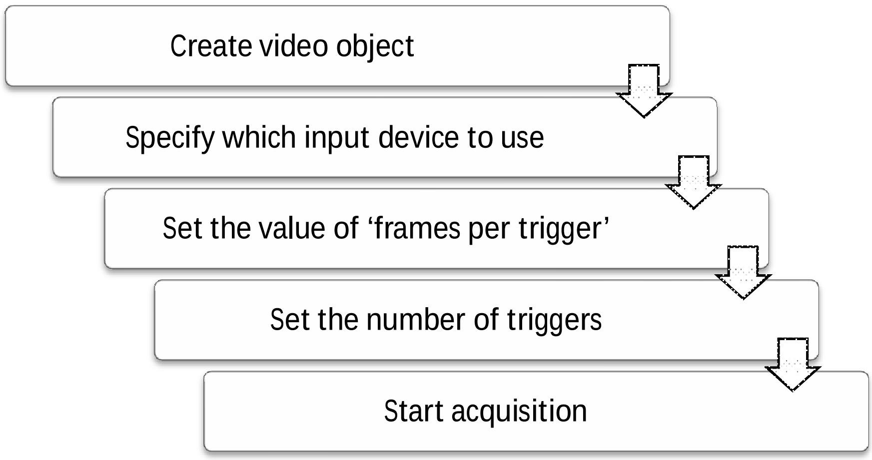


Figure 2.2. Sequential order of the steps involved in the Image Acquisition phase of the proposed technique

2.3.2 Detection Phase

The next step in gesture recognition systems is the detection of hands and the segmentation of the corresponding image regions. This segmentation is crucial because it isolates the taskrelevant data from the image background, before passing them to the subsequent tracking and recognition stages. We have utilized the YCbCr colour space in order to extract information of our colour marker from the acquired image which has been detailed in the following chapters. The tracking of the marker is based on the total number of marker pixels and the center of the marker, based on which different functions are controlled. The movement of the marker is tracked, the gesture is recognized and accordingly the respective action is implemented.

The tracking and pattern recognition phases have been discussed in the upcoming chapters.

2.4 Applications

A gesture recognition system could be used in any of the following areas :-

- **Man-machine interface** : using hand gestures to control the computer mouse and/or keyboard functions.
- **3D animation** : Rapid and simple conversion of hand movements into 3D computer space for the purposes of computer animation.
- **Visualisation** : Just as objects can be visually examined by rotating them with the hand, so it would be advantageous if virtual 3D objects (displayed on the computer screen) could be manipulated by rotating the hand in space.
- **Computer games** : Using the hand to interact with computer games would be more natural for many applications.
- **Control of mechanical systems** (such as robotics) : Using the hand to remotely control a manipulator.

CHAPTER 3
COLOUR MODELS

3.1 Introduction

A colour model is a system for creating a full range of colours from a small set of primary colours. There are two types of colour models: additive and subtractive. Additive colour models use light to display colour, while subtractive colour models use printing inks. The most common colour models that graphic designers work with are the CMY model for printing and the RGB model for computer display.

Skin colour segmentation has been utilized by several researchers for hand detection. A major decision is the selection of the colour space to be employed. Several colour spaces have been proposed including RGB, normalized RGB, HSV, YCbCr, LAB, etc. Colour spaces that efficiently separate the chrominance components from the luminance components of colour are typically considered preferable. This is due to the fact that by employing chrominance-dependent components of colour only, some degree of robustness to illumination changes can be achieved.

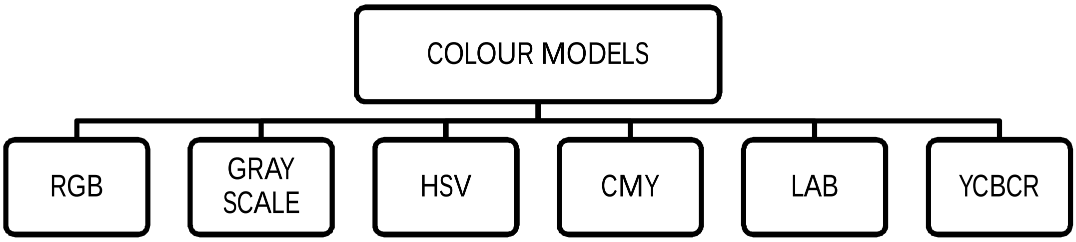


Figure 3.1. Different colour models that can be used

3.1.1. RGB colour model

The three primary colours (red, green, and blue) and their combination in visible light spectrum. With different weights, (R, G, B), their combination can indicate different colours.

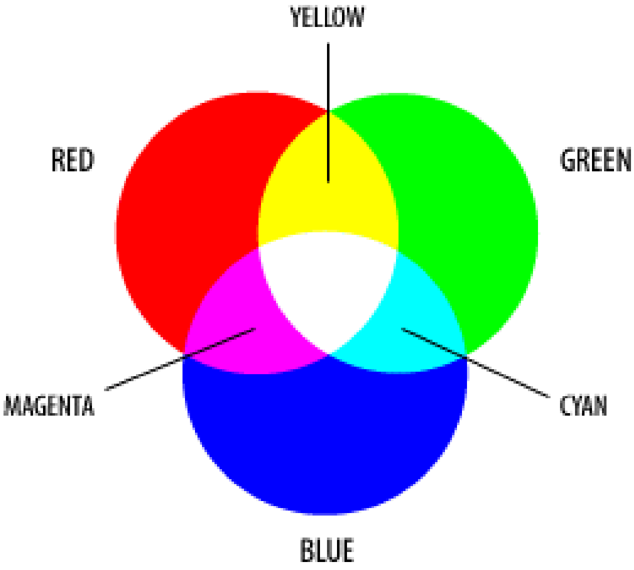


Figure 3.2 (a). RGB Graph of Primary Colours

Figure 3.2 (b). RGB Image of Hand

3.1.2. GRAYSCALE colour model

A grayscale (or graylevel) image is simply one in which the only colours are shades of gray. The reason for differentiating such images from any other sort of colour image is that less information needs to be provided for each pixel. In fact a `gray' colour is one in which the red, green and blue components all have equal intensity in RGB space, and so it is only necessary to specify a single intensity value for each pixel, as opposed to the three intensities needed to specify each pixel in a full colour image.

Often, the grayscale intensity is stored as an 8-bit integer giving 256 possible different shades of gray from black to white. If the levels are evenly spaced then the difference between successive graylevels is significantly better than the graylevel resolving power of the human eye.

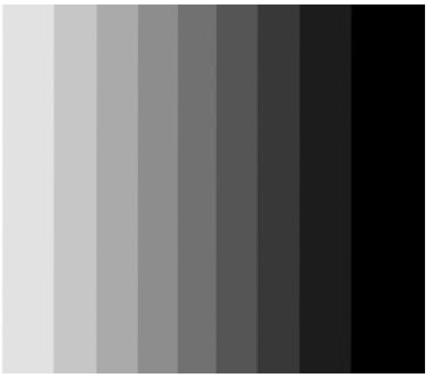


Figure 3.3 (a). Shades of Gray

Figure 3.3 (b). Grayscale Image of Hand

3.1.3. HSV colour model

The HSV colour model has a cylindrical structure. In HSV colour model, H represents hue, S represents saturation and V represents value. In this cylindrical coordinate representation , the angle which is around the central vertical axis of the cylinder represents hue(H), the distance from the central axis represents saturation(S) whereas the height of the cylinder represents value(V).

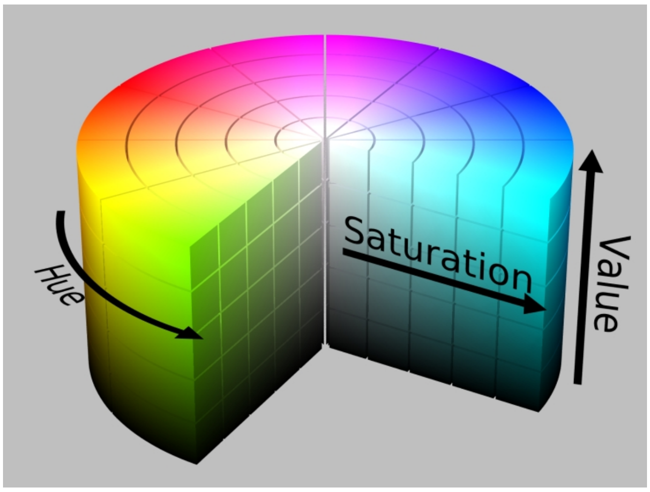


Figure 3.4 (a). Cylindrical Model Of HSV

Figure 3.4 (b). HSV Image of Hand

3.1.4. CMY colour model

This stands for cyan-magenta-yellow and is used for hardcopy devices. In contrast to colour on the monitor, the colour in printing acts subtractive and not additive. A printed colour that looks red absorbs the other two components G and B and reflects R. Thus its (internal) colour is G+B=CYAN. Similarly R+B=MAGENTA and R+G=YELLOW.

Thus the C-M-Y coordinates are just the complements of the R-G-B coordinates :-

$$\begin{pmatrix} C \\ M \\ Y \end{pmatrix} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix} - \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

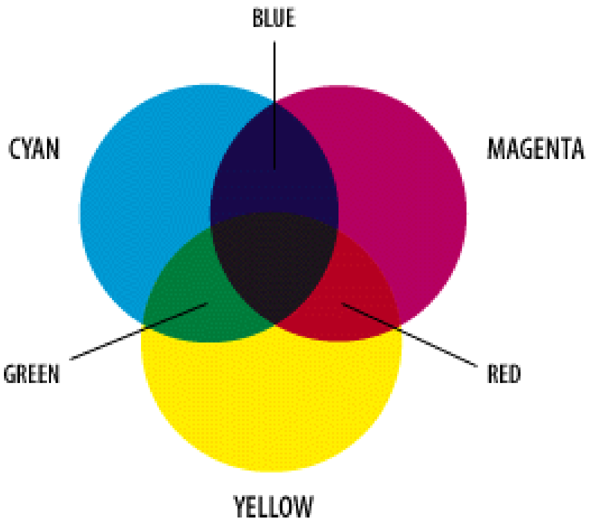


Figure 3.5. CMY Graph

- Used in electrostatic/ink-jet plotters that deposit pigment on paper
- Cyan, magenta, and yellow are complements of red, green, and blue
- Subtractive primaries: colours are specified by what is subtracted from white light, rather than by what is added to blackness

3.1.5. LAB colour model

Commission International del'Eclairage (CIE) proposed the Lab colour model as the international standard of colour survey in 1931.

A colour can be defined by a lightness component (L) and two colour components (a and b). a shows the degree from green to red. b means the degree from blue to yellow.

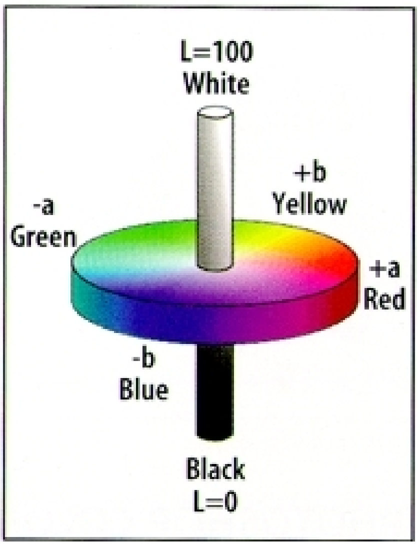


Figure 3.6 (a). LAB Colour Model

Figure 3.6 (b). LAB Image Of Hand

3.1.6. YCbCr colour model

The YCbCr is the collection of colour models which are implemented as part of colour image pipeline. The Y represents the luma component, Cb represents the blue colour difference and Cr is the red colour difference. YCbCr is a method of encoding the RGB colour information.

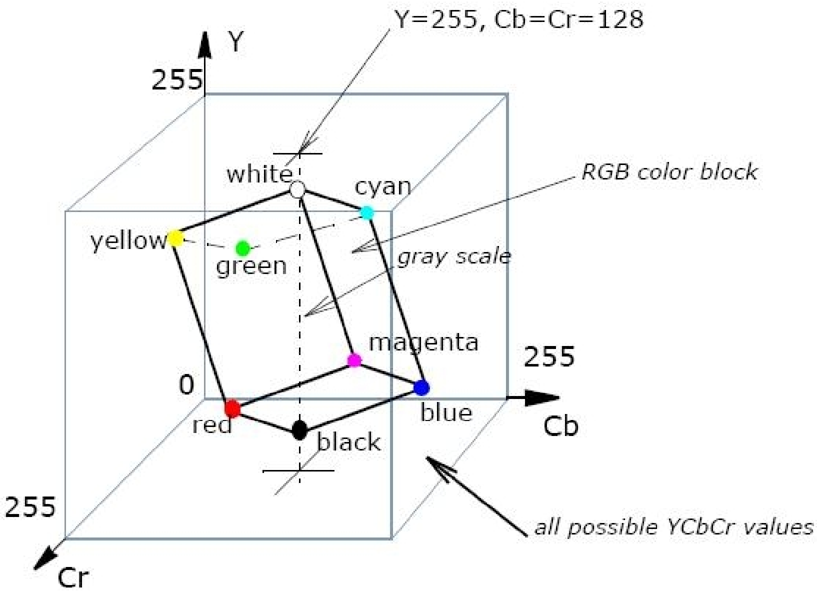


Figure 3.7 (a).YCbCr Colour Model

Figure 3.7 (b). YCbCr Image Of Hand

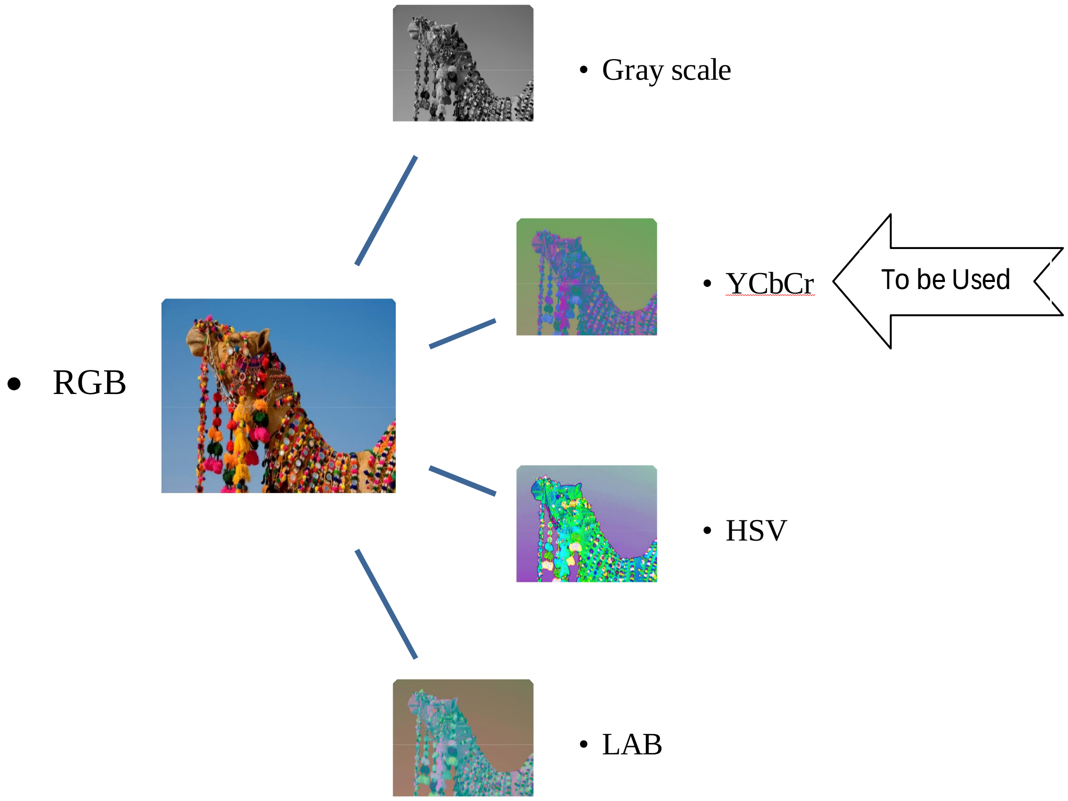


Figure 3.8. Comparison Of Different Colour Models

3.2 Colour Model Selection

Colour information is an efficient tool for identifying skin areas if the skin colour model can be properly adapted for different lighting environments. This fact leads to avoid the use of RGB, because the red, green and blue components are highly correlated and dependent on lighting conditions.

YCbCr colour space has been defined in response to increasing demands for digital algorithms in handling video information and has become a widely used model in a digital video. Y is luma component which represent the luminance and computed from nonlinear RGB. It is obtained as weighted sum of RGB values. Cb is difference between blue and luma component and Cr is the difference between red and luma component. The

Y in YCbCr denotes the luminance component, and Cb and Cr represent the chrominance component.

$$Y = 0.299R+0.587G+0.114B$$

$$Cr = R-Y$$

$$Cb = B-Y$$

In contrast to RGB, the YCbCr colour space is luminance independent, that's why it gives better performance.

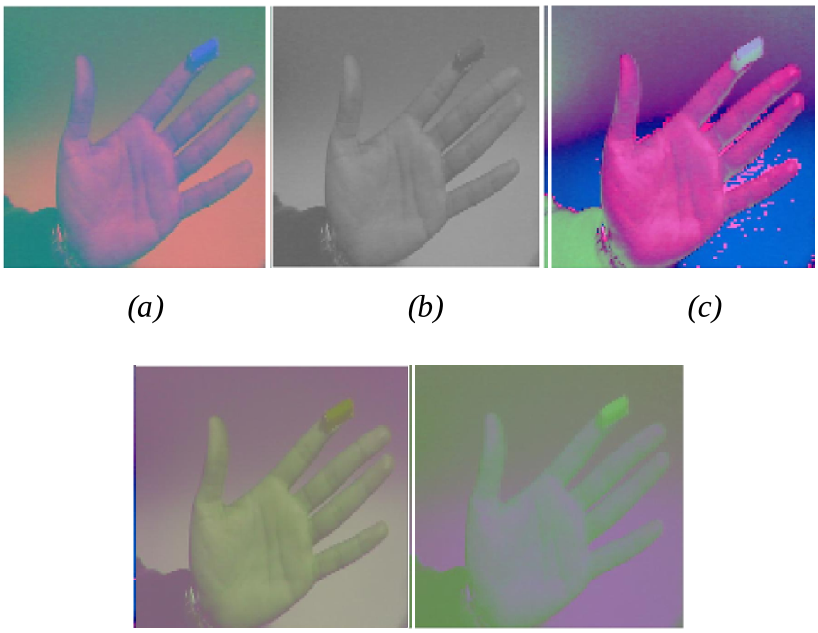
The threshold is used in our algorithm is given as :-

$$160< Cb <175$$

$$105 < Cr < 140$$

The transformation is simple. Unlike RGB, it has separate luminance and chrominance components which make this colour space attractive for skin colour segmentation.

Hence, our proposed method is based on YCbCr colour spaces.



(a) *(b)* *(c)*

(d) *(e)*

Figure 3.9. Image of Hand Using (a) RGB (b) GRAYSCALE (c) HSV (d) LAB and (e) YCbCr Colour Model

Figure 4(a) depicts the histogram of a RGB image showing a high of colour intensities present in it viz. 0-225 whereas Figure 4(b) portrays the histogram of the of the same image in the YCbCr colour space in which only the desired intensities lying inside our threshold region viz. (90-160) are present which makes it convenient for us to detect the red colour marker thereby tracking it efficiently and enhancing our implementation. Figure 5(a) shows the histogram of the Y component of the image, Figure 5(b) and 5(c) shows the histograms of the Cb and Cr components of the image respectively.

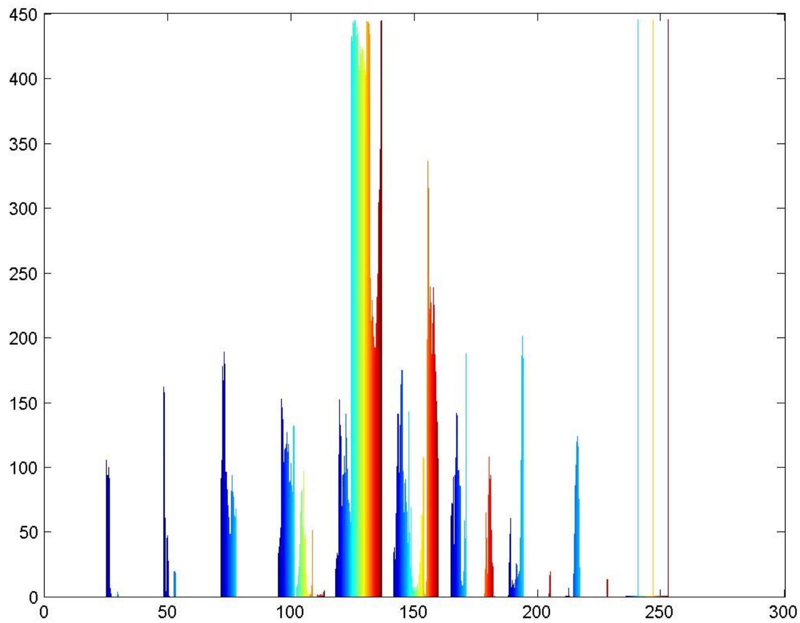


Figure 3.10 (a). RGB Image Of Hand and its Histogram

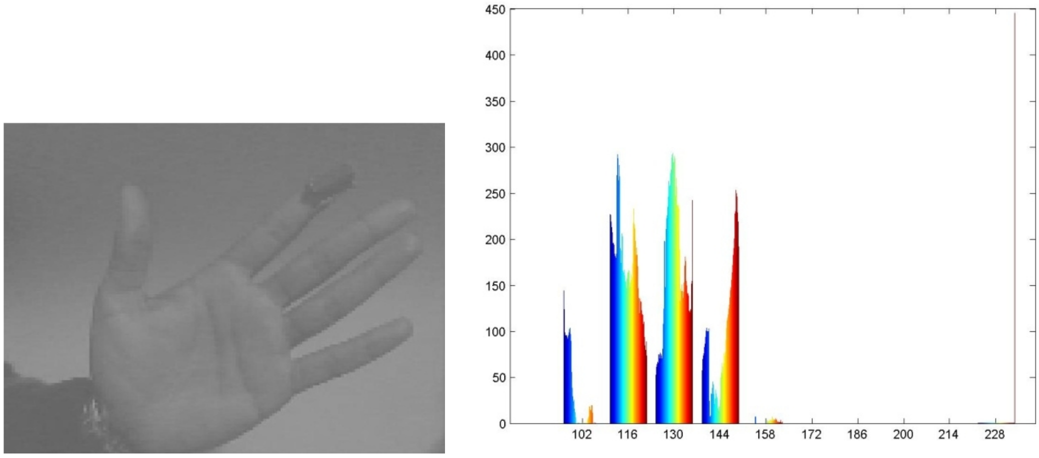


Figure 3.10 (b). Y Component and its Histogram

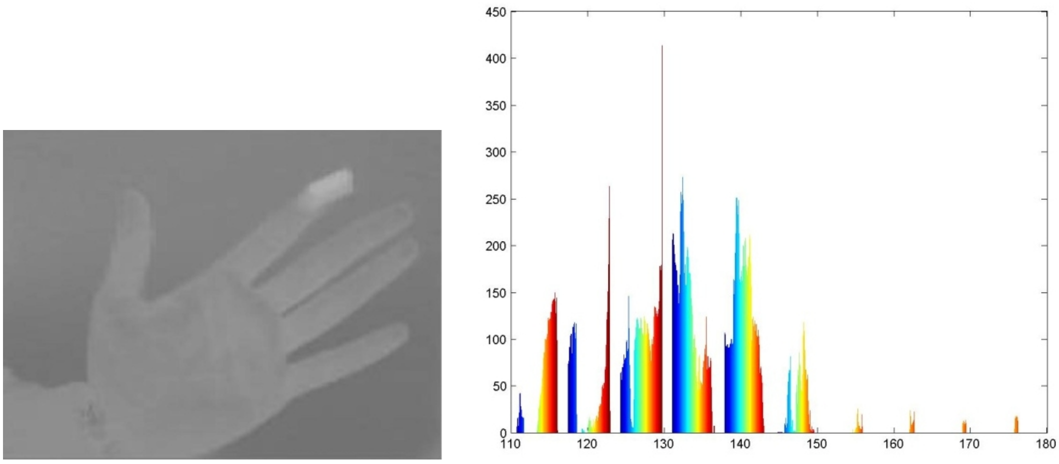


Figure 3.10 (c). Cb Component and its Histogram

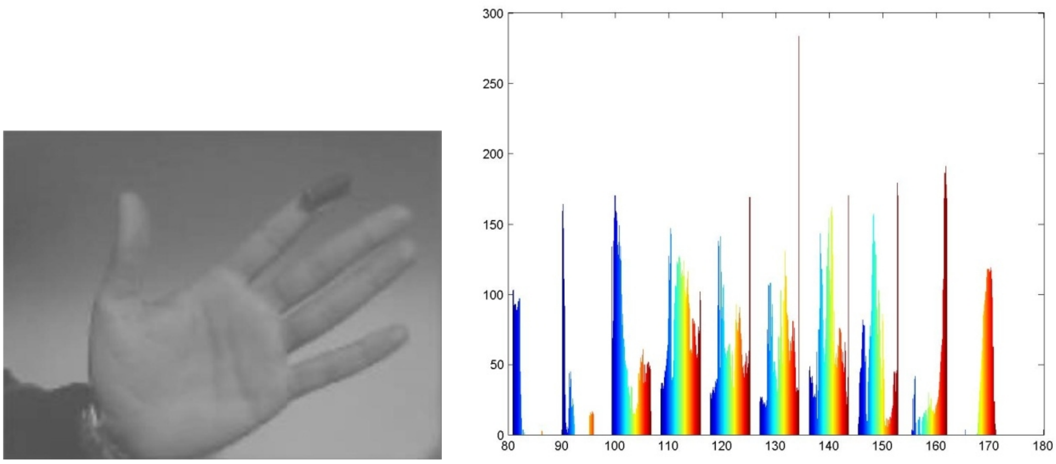


Figure 3.10 (d). Cr Component and its Histogram

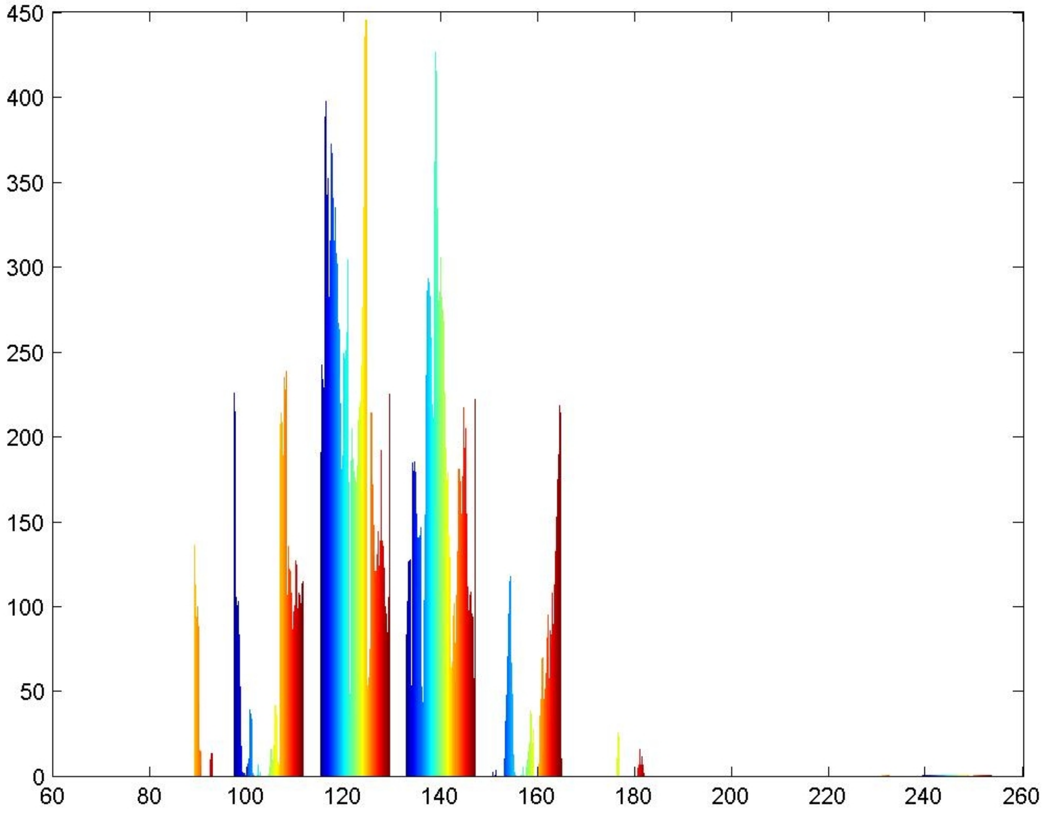


Figure 3.10 (e). YCbCr Image Of Hand And Its Histogram

3.3 Tracking And Pattern Recognition

After exhaustive trials ,we found that red colour could be extracted from the image using the following threshold values on the YCbCr images :-

$$160 < Cb < 175$$

$$105 < Cr < 140$$

A new output image is created, which is of the same size as the YCbCr image. The default values in the new image are set to 0. Using the above mentioned threshold values, the region containing the colour red in the YCbCr image is overwritten with the value 1 in the new output image. All further tracking and implementation is done with the help of this newly created image.

The total numbers of pixels having intensity level as 1 in the new output image are found using a summing function. This is done in order to control the play and pause functions of the media player.

Similarly, using another inbuilt function, the coordinates of the centroid of the region having intensity level as 1 is found. The movement of this centroid helps in controlling the volume functions of the media player.

The functions are performed using the following algorithm :-

- When the finger is brought closer to the laptop's webcam, the total number of red pixels as compared to background pixels increases. This indicates the music player to pause the current file.

- When the finger is taken away from the laptop's webcam, the total number of red pixels as compared to background pixels decreases. This indicates the music player to continue playing the current file.

- When the finger is moving towards the left, the centroid of the region containing the red marker moves correspondingly. This indicates the music player to increase the volume.

- When the finger is moving towards the right, the centroid of the region containing the red marker moves correspondingly. This indicates the music player to decrease the volume.

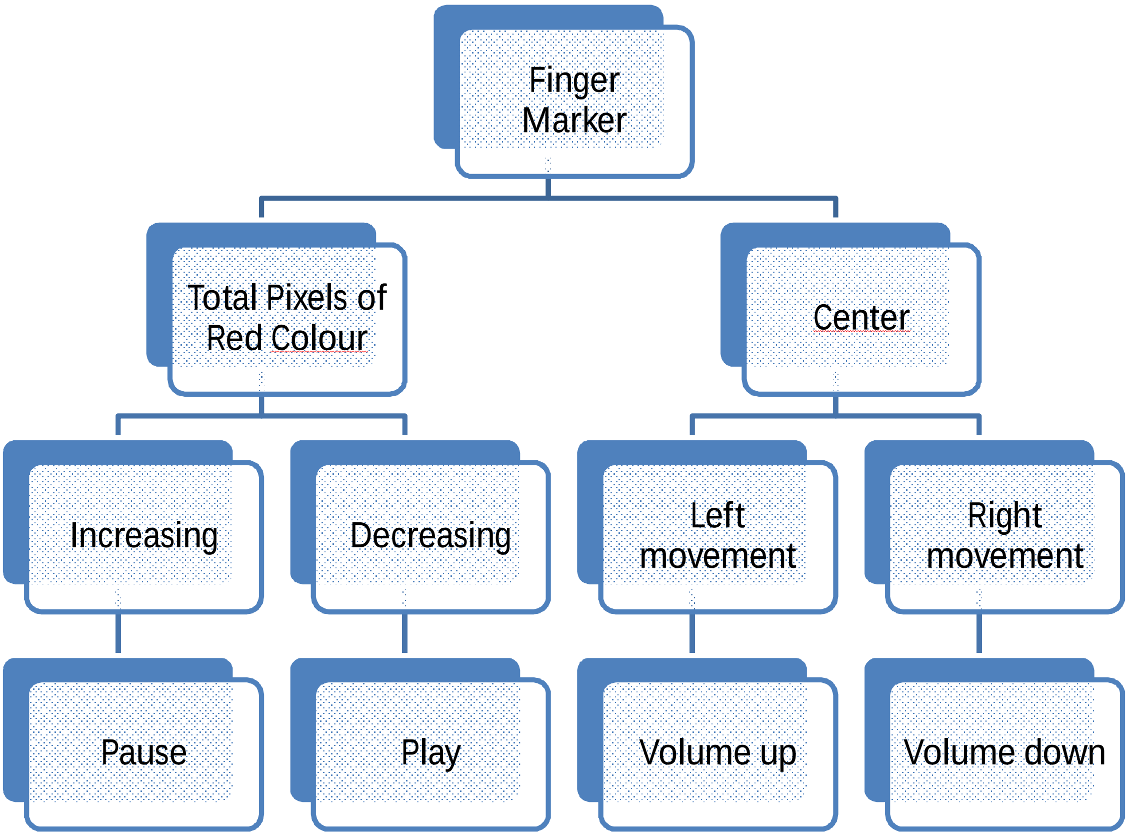


Figure 3.11. Design flow of the Tracking and Pattern Recognition Algorithm

CHAPTER 4

IMPLEMENTATION AND DESIGN

4.1 Design Flow

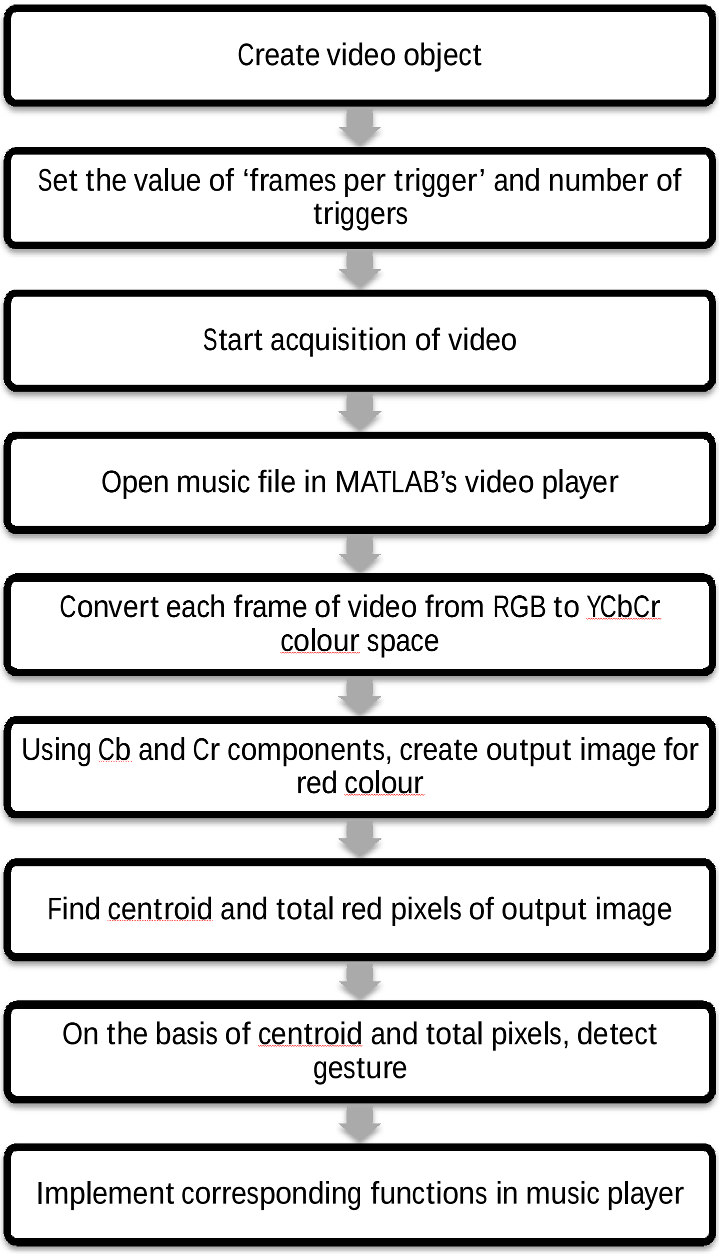


Figure 4.1. Algorithm for Proposed Technique

4.2 Algorithm

4.2.1. Software Used :- MATLAB R2013a Student Version

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. Developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java,Fortran and Python.

4.2.2. Prototype Mechanism :-

Step 1 :- Create a video object and set values for the number of triggers and frames per trigger.

```
vidobj = videoinput('winvideo',1);

set(vidobj,'FramesPerTrigger',1);

set(vidobj,'TriggerRepeat',inf);

triggerconfig(vidobj,'manual');

start(vidobj);
```

Step 2 :- Open the inbuilt media player in MATLAB R2013a using the following commands. Open a media file to play.

```
h=actxcontrol('WMPlayer.OCX.7', [0 0 500 550], m);
```

```
[filename pathname] = uigetfile('*.*','Please select a file');
h.URL=[pathname filename];
h.controls.play;
```

Step 3 :- Initialise the volume of the player and set it to zero.

```
set(h.settings,'volume',i);
figure;
i=0;
```

Step 4 :- Start image acquisition.

```
    trigger(vidobj);
    frame=getdata(vidobj);
```

Step 5 :- Convert each frame acquired from the webcam from RGB colour space to YCbCr colour space.

```
    image_ycbcr=rgb2ycbcr(frame);
```

Step 6 :- Extract the luma and croma components from the YCbCr image.

```
image_y=image_ycbcr(:,:,1);

image_cb=image_ycbcr(:,:,2);

image_cr=image_ycbcr(:,:,3);
```

Step 7 :- Create an output image of the same size as the YCbCr image acquired.

Initialise all the pixel values of this output image to zero

```
[r c d]=size(image_ycbcr);

output_image_g=zeros(r,c);
```

Step 8 :- Utilise the threshold values (which were found after exhaustive trials) for the extraction of the red marker area from the YCbCr image

Create a binary output image by allocating pixel value 1 to the red area.

```
if((image_cb(i1,i2)>160)&&
                (image_cb(i1,i2)<175)&&
                        (image_cr(i1,i2)>105)&&
```

```
                                (image_cr(i1,i2)<140))

        output_image_g(i1,i2)=1;
```

Step 9 :- Find the center of the region having pixel value 1 using an inbuilt MATLAB function.

```
[r_cent_g c_cent_g]=centroid1(output_image_g);
```

Step 10 :- Calulate the total number of pixels having intensity 1 from the binary output image.

```
total_pix=sum(sum(output_image_g));
```

Step 11 :- Set the controls of the media player using the values of total pixels and center pixel coordinates.

(a) When the finger is brought closer to the laptop's webcam, the total number of red pixels as compared to background pixels increases.

```
if (total_pix>100)

        h.controls.pause;

        disp('Media Paused');
```

(b) When the finger is taken away from the laptop's webcam, the total number of red pixels as compared to background pixels decreases.

```
h.controls.play;

disp('Playing');
```

(c) When the finger is moving towards the left, the center of the region containing the red marker moves correspondingly.

```
if (c_cent_g>(120))

        disp('Volume Up');

        i=i+7;
```

(d) When the finger is moving towards the right, the center of the region containing the red marker moves correspondingly.

```
if (c_cent_g<(400))

        disp('Volume Down');

        i=i-3;
```

4.3 Results

We have implemented a real-time version of hand gesture recognition system, using an ordinary workstation with no special hardware beyond a video camera input and a red colour band. The technique works well under different degrees of background complexity and illumination conditions. The proposed method is implemented by using an optimized Matlab code. The experimental results are illustrated in Table 1. The vertical column shows the next gesture whereas the horizontal column depicts the previous gesture. The table shows the accuracy of transition from one gesture in the vertical column to the other in the horizontal column. We have tested four different moving gestures from different angles and under different illumination conditions. The transition from one gesture to another was tested 100 times for each gesture. The recognition rate for this system was found to be 97.5 per cent. The error matrix obtained for transitions between different gesture movements is tabulated in Table 2. The darkest region indicates least error (less than 5 per cent) and the brightest one represents the maximum error which is only in one case.

Table 4.1. Recognition Results For Different Gestures

Present Gesture	Next Gesture			
	RIGHT	LEFT	CLOSE	FAR
RIGHT	96	92	88	93
LEFT	94	97	90	90
CLOSE	78	83	99	95
FAR	92	89	87	98

Table 4.2. Error Matrix For Different Gestures

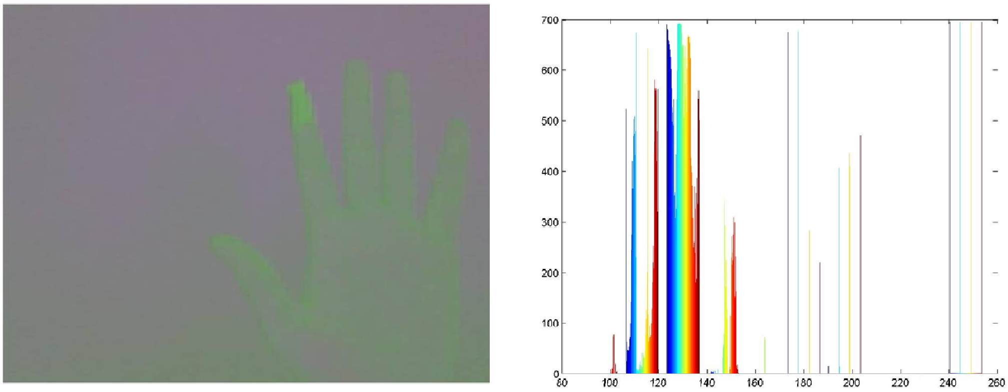
Previous Gesture	Next Gesture			
	Right	Left	Close	Far
Right	0.04	0.08	0.12	0.07
Left	0.06	0.03	0.10	0.10
Close	0.22	0.17	0.01	0.05
Far	0.08	0.11	0.03	0.02

	.21-.25
	.16-.20
	.11-.15
	.06-.10
	.00-.05

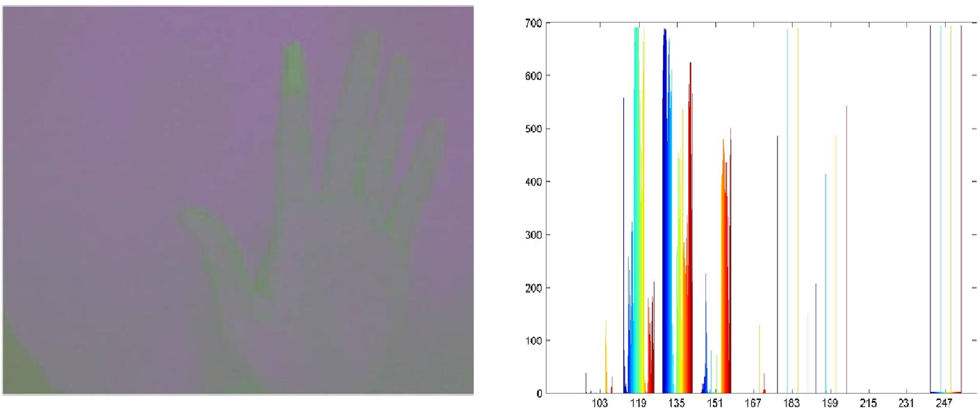
The proposed approach is applied to control the various functions of a music player. The efficiency achieved is 97.5 per cent. Also, orientations of hand at different angles were tested to ensure that system is robust and is able to detect the gesture with different orientations.

Four different angles each at different distance from the webcam were taken to check the adaptability of the system. The results showed that the system was able to recognize the gesture with no deterioration in the actual efficiency. Along with the testing of different orientations of the hands, we also tested our system under different illumination conditions. Images having different degrees of brightness, contrast and saturation were captured. It was found that the efficacy of the system was sustained even after changing the illumination conditions and there was no significant change on the recognition rate of the system.

Furthermore, we tried to combat one of the main challenges of gesture recognition system viz. the background complexity. The system was put to trial under different background complexities. The results portray that the system was able to recognize the performed gesture efficiently even with different backgrounds. Figure 8 shows images and histograms of hand under different background conditions.



Brightness 0
Contrast 32
Saturation 64



Brightness 46
Contrast 37
Saturation 42

Figure 4.2. Histograms of YCbCr Images under Different Illumination Conditions

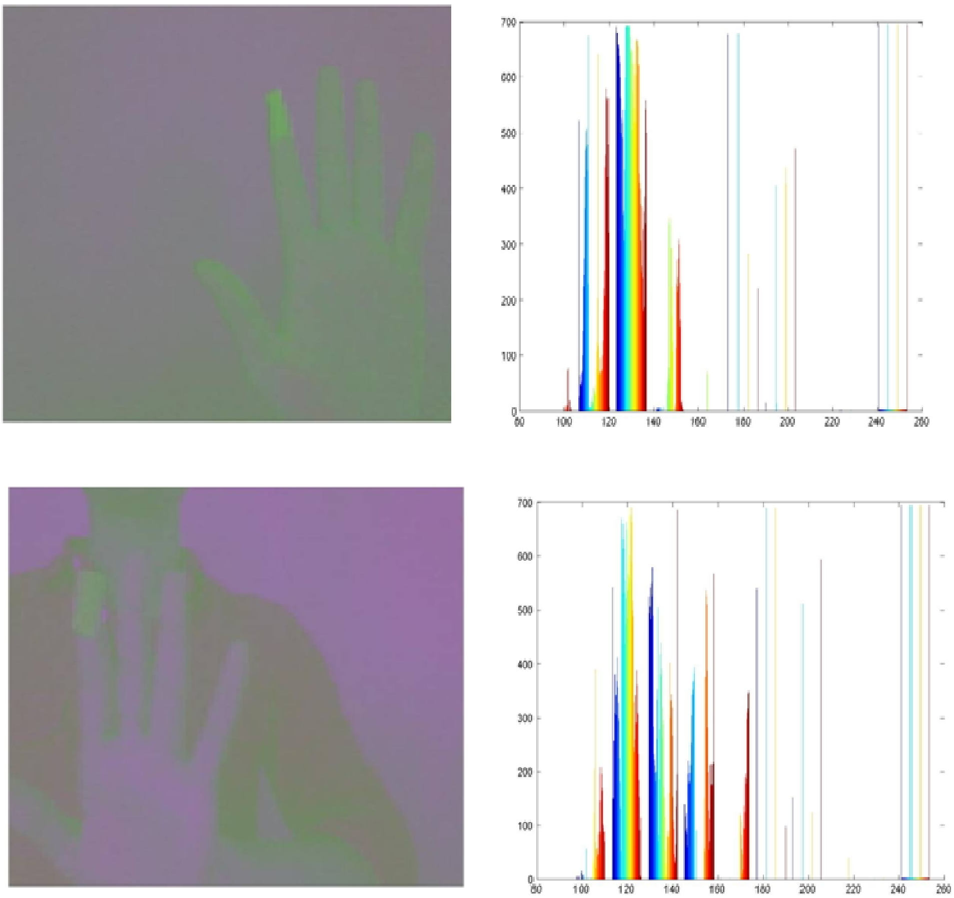


Figure 4.3. Histograms of YCbCr Images with Different Backgrounds

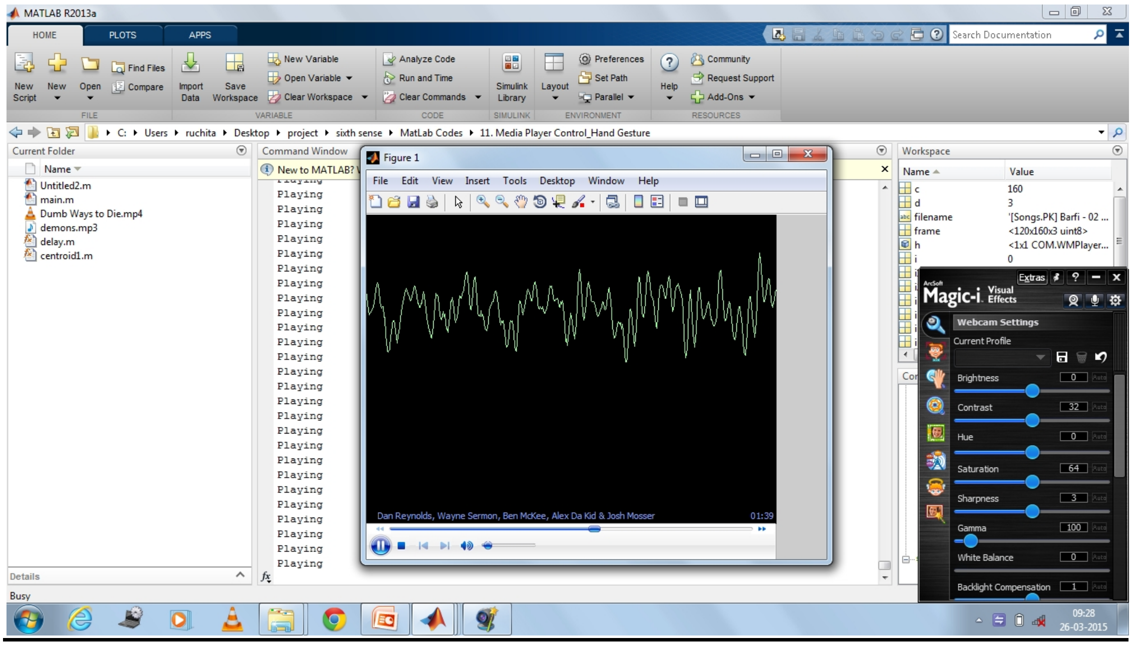


Figure 4.4 (a). Media being Played

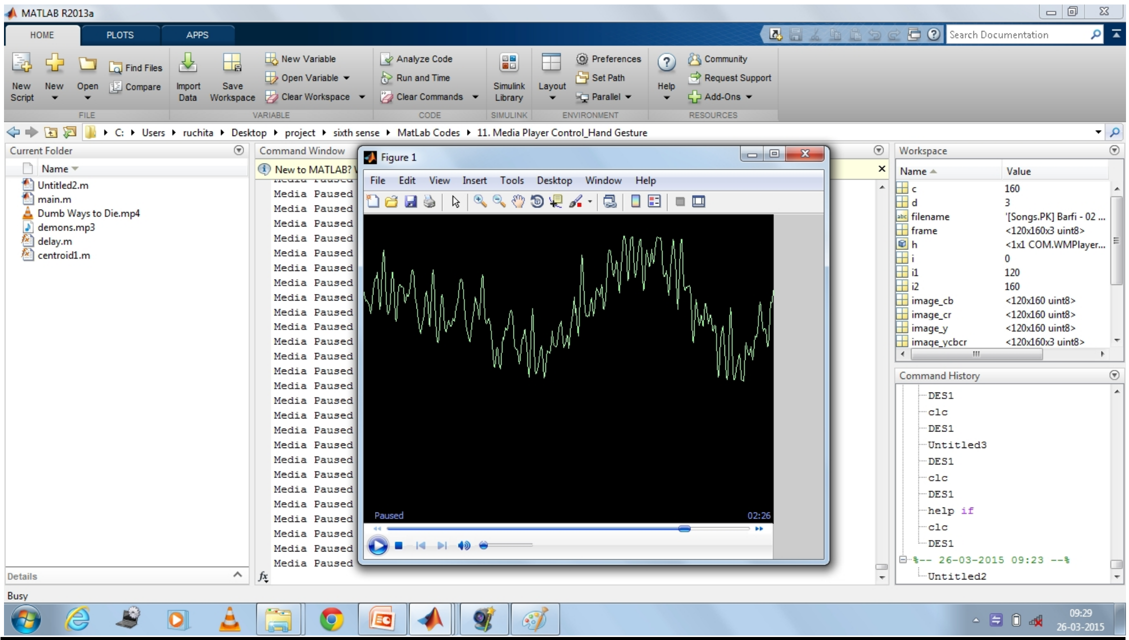


Figure 4.4 (b). Media being Paused

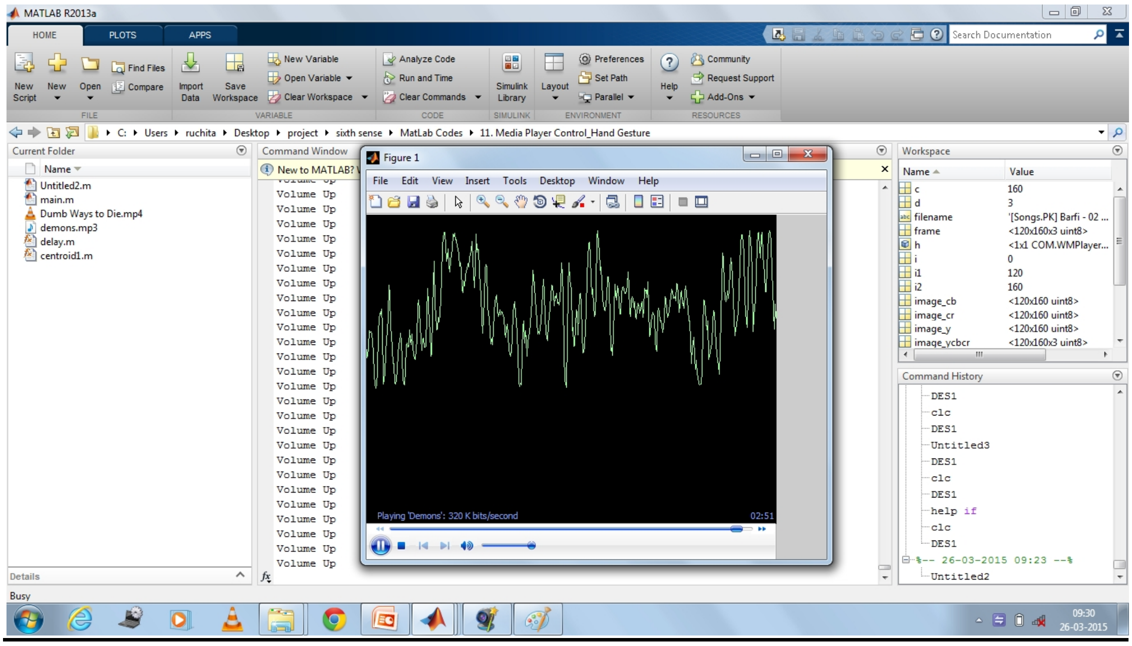


Figure 4.4 (c). Media being Played with Increasing Volume

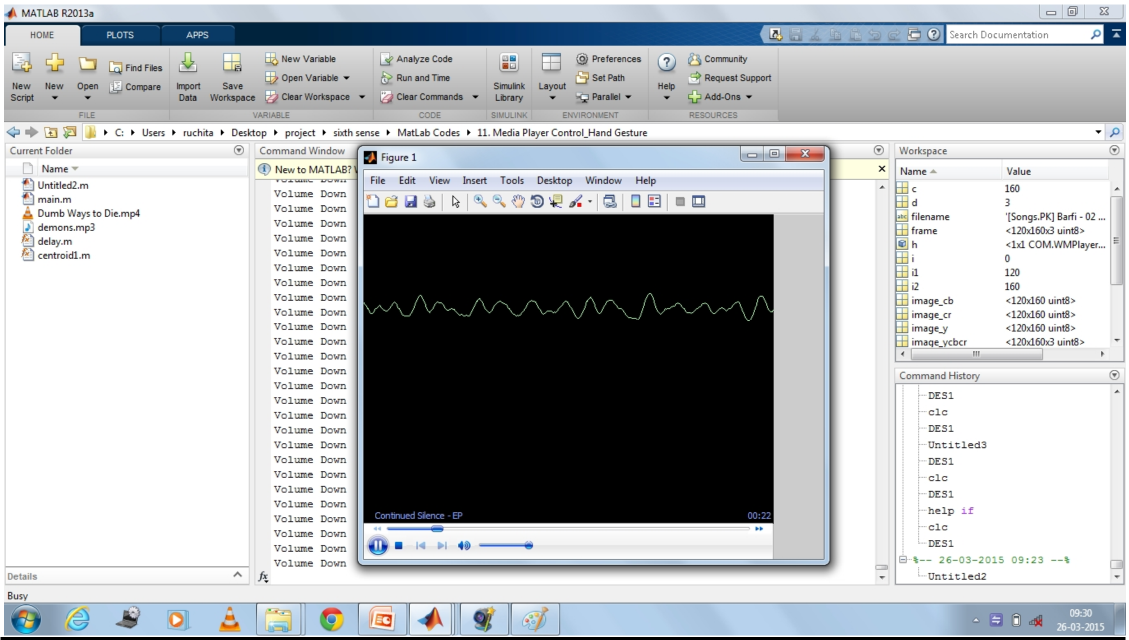


Figure 4.4 (d). Media being Played with Decreasing Volume

Conclusion and Future Scope

In our work we have explored the area of hand gesture recognition to enhance the interface between human computer interactions. A resilient system was developed which used vision based approach to work with the dynamic gestures in real time. The prototype architecture of the application comprises of a webcam which tracks the movement of the hand; uses a suitable colour model so that the desired information can be extracted; and then on the basis of number of pixels and center analyzes the variations in the hand locations, and finally recognizes the gesture. The experimental results show that the technique works well under different degrees of background complexity and illumination conditions with an overall success rate of 97.5 per cent.

A lot of future work is possible in order to increase the adaptability of a gesture recognition system. The gesture recognition accuracy can be further improved by collection of additional gesture information. Moreover, multi stage gestures can also be introduced along with two handed gestures which would further increase the efficacy of the proposed hand gesture recognition systems.

References

[1] Feng-Sheng Chen, Chih-Ming Fu, Chung-Lin Huang, "Hand gesture recognition using a real-time tracking method and hidden Markov models," Elsevier -Image and vision computing, 2003, pp. 745–758.

[2] William T. Freeman, Michal Roth, Orientation histograms for hand gesture recognition, Mitsubishi Electric Research Laboratories TR94-03.

[3] Hervé Lahamy and Derek Litchi, "Real-time hand gesture recognition using range cameras," International Journal of Innovative Research & Development, 2013.

[4] Mohamed Alsheakhali, Ahmed Skaik, Mohammed Aldahdouh, Mahmoud Alhelou, "Hand gesture recognition system," 9th International Conference on Information, Communication and Signal Processing (ICICS), 2011.

[5] S. Nagarajan et al "Static hand gesture recognition for sign language alphabets using edge orientation histogram and multi class SVM," International Journal of Computer Applications, 2013, pp. 28-35.

[6] Hassan Ahmed, Todd C. Alexander, Georgios C. Anagnostopoulos "Real time, static and dynamic hand gesture recognition for human-computer interaction".

[7] Radhika Bhatt, Nikita Frenandes and Archana Dhage, "Vision based hand gesture recognition for human-computer interaction," International Journal of Engineering Science and Innovative Technology, 2013.

[8] Sauvik Das Gupta, Souvik Kundu, Rick Pandey, Rahul Ghosh, Rajesh Bag, Abhishek Mallik, "Hand gesture recognition and classification by discriminant and principal component analysis using machine learning techniques," International Journal of Advanced Research in Artificial Intelligence (IJARAI), 2012, pp. 46-51.

[9] Jayashree R.Pansare, Sharavan H.Gawande, Maya Ingle, "Real-Time Static Hand Gesture Recognition for American Sign Language (ASL) in Complex Background", Journal of Signal and Information Processing, 2012, pp 364-367.

[10] Rajesh Mapari, Dr.Govind Kharat, "Hand Gesture Recognition using Neural Network", International Journal of Computer Science and Network, 2012.

[11] Md. Atiqur Rahman, Ahsan-Ul-Ambia, Md. Aktaruzzaman, "Recognition of Static Hand Gestures of Alphabet in ASL", IJCIT, 2011.

[12] J.L. Raheja, R. Shyam, U. Kumar, P.B. Prasad, “Real-Time Robotic Hand Control using Hand Gesture”, 2nd international conference on Machine Learning and Computing, Bangalore, India, 2010, pp. 12-16.

[13] B. Dorner, "Hand shape identification and tracking for sign language interpretation", Looking at people workshop, Chambery, France, 1993, IJ-CAI.