# Hand Gesture Recognition Using Average Background and Logical Heuristic Equations

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## ABSTRACT

This paper introduces a hand gesture recognition algorithm for Human Computer Interaction using real-time video streaming .The background subtraction technique is used to extract the ROI (Region Of Interest) of the hand. Fingertip is detected using logical heuristics equations that are applied on hand contour, convex hull and convexity defects points. A combination between background subtraction and logical heuristic technique that leads to more accurate results is introduced. Experimental results prove that the proposed algorithm improves the finger's tips detection by 52 % compared to the reference model.

## Keywords

Image processing, Hand gesture , Average background , Logical heuristic equation , gesture detection , Computer vision.

## 1.  INTRODUCTION

Gesture recognition is a challenging area in computer vision. At present, many traditional interfaces such as the keyboard or mouse doesn't provide the best interaction between user and computer. Once hand gestures are recognized , it will make the interaction much better for the user .This paper proposes an algorithm to extract foreground hand regions from background using background averaging and extracting contour, the convex hull and convexity defects information to recognize each gesture. There are different techniques that have been used for hand gesture recognition in different fields. Some of the techniques using skin model , colored gloves , data gloves , PCA , Neural Network. All techniques can be divided into the following categories : Hand segmentation techniques , Feature extraction techniques and Gesture recognition techniques. In this paper a few of the works are discussed.

In papers [1-5] skin color model was used to extract hand pixels. This technique eliminates background pixels or any non-skin colored pixels , then extracting hand region from the image. In others [6-7] external aid like colored glove were used by the researchers for a segmentation purpose .Both of the techniques are very robust, but also vulnerable when objects are present with a color similar to the skin or a glove, since the segmentation in color is based. In papers [8-10] data gloves are used , In a paper [8] 14 sensor with a data glove were used to measure inflection points , but accuracy rate was 94%. In the paper [9] data glove package that contains a Bluetooth , 3 accelerometer sensor, and a controller which extract hand gesture features . This paper tests only 3 gestures and the detection speed was very slow. In paper [10] Cyber glove was used to measure angles between fingers , thumb rotation and wrist pitch. This paper test only single gestures. In paper [11] Principal Component Analysis (PCA) was used for feature extraction and pattern recognition with saved images to control a robot in real time. Due to paper results PCA training phase is faster than the neural network based methods which require training database and more computation power.  In paper [12] Background averaging and CAMSHIFT algorithms are used for hand tracking in real time and test only two gestures.

Thus a system that could overcome the difficulties faced by various techniques is proposed. The proposed system can detect five gestures. First , foreground objects can be detected using background subtraction. Second, detection of moving objects contours and selection of the biggest contour to track. Third, detection of convex hull and convexity defects points and applies logical heuristics equations to detect finger tips. Finally, after finger tips detection we can calculate how many fingers are stretched, and gestures are used to control an event like mouse actions can be calculated.

This paper is organized as follows . Section 2 describes the block diagram of the proposed system. Section 3 describes the steps that we follow to extract hand gestures starting from hand segmentation, feature extraction and gesture recognition. Section 4 describes the proposed system results compared to the reference model.          This paper is organized as follows . Section 2 describes the block diagram of the proposed system . Section 3 describes the steps that we follow to extract hand gestures starting from hand segmentation, feature extraction and gesture recognition. Section 4 describes the proposed system results compared to the reference model.

## 2.  PROPOSED SYSTEM MODEL

The proposed system block diagram is given in Fig.1. this model consists of main four main stages : background subtraction using a background averaging algorithm , contour extraction of all moving objects and select the biggest contour , convexity defects calculations and finger tips detection using logical heuristic equations.
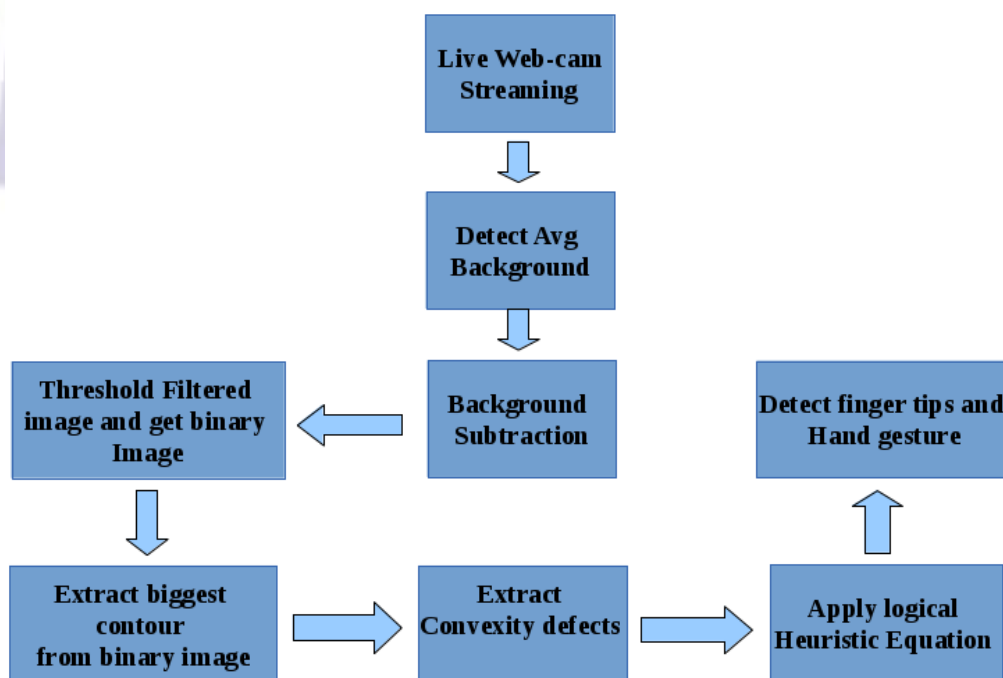


**Fig 1: Block diagram of the proposed system**

In the proposed system five simple gestures are detected. Each gesture can be detected in different orientations , any scaling factor and without training. The samples of five gestures are shown in Fig.2

| Gesture Image | Gesture Meaning |
|---|---|
|  | Zero |
|  | One |
|  | Two |
|  | Three |
|  | Four |
|  | Five |

**Fig.2: Samples of gestures**

## 3.  PROPOSED SYSTEM ANALYSIS

### 3.1.  Hand segmentation

As mentioned previously skin color model can be used to detect hand and face regions but it's not efficient in complex backgrounds. In our system we assume that human face won't move so the hands will be the only movable objects in the foreground scene. Thus , background subtraction will be the best solution to find hand area and track hand movements. To get the best background model an average filter is used [12]. Average filter will create an initial background from the first N frame as shown in Eqn (1), as experiment N = 20

$$Avg_{(x,y)} = \frac{1}{N}\sum_{i=1}^{N} Frame_{(i)_{x,y}} \quad (1)$$

The moving areas are obtained by subtracting the current frame from the average background as shown in Eqn(2).

$$\Delta \left| Avg_{(x,y)} \right| = \left| Frame_{(x,y)} - Avg_{(x,y)} \right| \quad (2)$$

To get better result a threshold filter on the difference image to create a binary image is applied as shown in Eqn (3). Threshold = 50 is used

$$Bin_{(x,y)} = 1, \quad \Delta \left| Avg_{(x,y)} \right| > Th$$
$$Bin_{(x,y)} = 0, \quad \text{otherwise} \quad (3)$$

The updated background is calculated updating the average background's pixels using the equation as shown in Eqn(4) to remove any noise or any static object that was added to the background.

$$Avg_{(x,y)} = \alpha\, Frame_{(x,y)} + (1 - \alpha)\, Avg_{(x,y)}, Bin_{(x,y)} = 0 \quad (4)$$

Coefficient alpha where is used to control speed of updating process in other words controls how quickly the average background is updated by the current frame.Alpha value is between 0 to 1. 0.001 is used to decrease learning speed. The steps of hand extraction are shown in Fig.3 .



| **(a) Background** | **(b) Frame** | **(c) Difference** | **(d) Binary** |

**Fig.3 : Steps of background subtraction**

The contour is a curve that connects all points that surround specific part of an image that has the same color or intensity.

To identify hand gestures we detect contours of all objects that exist in the threshold image as shown in Fig.4a and select the biggest contour that has the biggest calculated area that represent the hand's area as shown in Fig.4b .

To find the contour Suzuki's algorithm [13] is used .we approximate the filtered contour points to another contour that has fewer number of points. The contour approximation is the process of finding key vertex points [14] to speed up calculations and it consumes low memory size .



**(a) Contours of all objects**          **(b) Biggest contour**

**Fig.4**

## 3.2.  Feature extraction

After contour extraction  key features to detect hand gestures should to be  extracted. In experiment it's found that finger tips are good features to detect hand gestures .

To extract finger tips the extracted contour is analyzed to find convexity information .To understand the shape of an object convex hull and convexity defects information can be used.

To extract convex hulls Sklansky's algorithm in paper [15] is used. it is used to calculate the convex hull for given points. It's ideal for hand gesture analysis and it offers complexity O(n) [16].The algorithm has been applied on the image shown in Fig.4b and  the result is shown in Fig.5.

From the convex hull and the original contour convexity defects can be detected which are the holes between contour and convex hull. Fig.6 show start and depth points of each defect where yellow points are start point of defects and red points are the furthest points from contour (depth points).
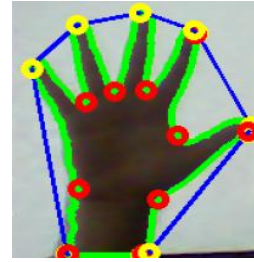
**Fig.5 : Hull Extraction**



**Fig.6 : Convexity defects points**

## 3.3. Gesture recognition

   After convexity defects points detection all points are filtered and  finger tips points are detected using logical heuristic equations [1].This methodology didn't require any training phase . Results are shown in Fig.7
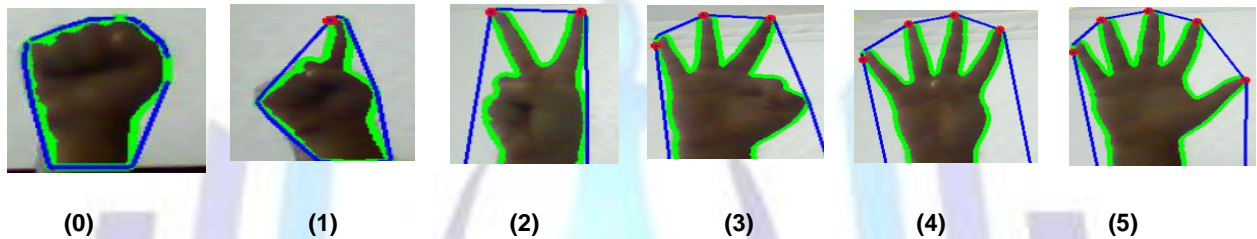


|  (0)  |  (1)  |  (2)  |  (3)  |  (4)  |  (5)  |

**Fig.7: Successfully detected gestures**

## 4.  EXPERMINTAL RESULTS

   The proposed system is implemented in python 2.7 and tested on AMD Quad-Core processor ( FX 4-Core Processor Black Edition, 3.8 GHz).The test video stream was grabbed from a Web camera with a resolution of 320×240.

   There are many techniques for hand gesture recognition. we compared our method with the method proposed in [1] that has used a skin color model and logical heuristics to detect hand gesture . The reference program was tested also under the same  environment to get accurate comparison against the proposed algorithm.

   The proposed method by background subtraction detection is more robust than the reference technique in [1] in a complex background and simple background with low contrast with skin color as shown in Table[1] ,Table[2]  respectively but the two algorithms have the same performance in simple background with high contrast to skin color as shown in Table[3].Each gesture has been tested in different five orientations.

**Table.[1] : Simple Background with low contrast to skin color**

|  | Reference Model [1] | Proposed Model |
|---|---|---|
| zero | 0/5 | 3/5 |
| one | 0/5 | 4/5 |
| two | 1/5 | 4/5 |
| three | 1/5 | 5/5 |
| four | 2/5 | 5/5 |
| five | 3/5 | 5/5 |

**Table.[2] : complex Background**

|  | Reference Model [1] | Proposed Model |
|---|---|---|
| zero | 0/5 | 3/5 |
| one | 0/5 | 3/5 |
| two | 0/5 | 3/5 |
| three | 0/5 | 4/5 |
| four | 0/5 | 5/5 |
| five | 0/5 | 5/5 |

**Table.[3] : Simple Background with high contrast to skin color**

|  | Reference Model [1] | Proposed Model |
|---|---|---|
| zero | 3/5 | 3/5 |
| one | 4/5 | 4/5 |
| two | 5/5 | 5/5 |
| three | 5/5 | 5/5 |
| four | 5/5 | 5/5 |
| five | 5/5 | 5/5 |

We tested every gestures in 5 different postures and get better performance than the proposed method and improve the performance by 52 %.

The only false positive were observed when the background has many objects with different colors that have intensity value lower than hand pixel's intensities as shown in Fig.8
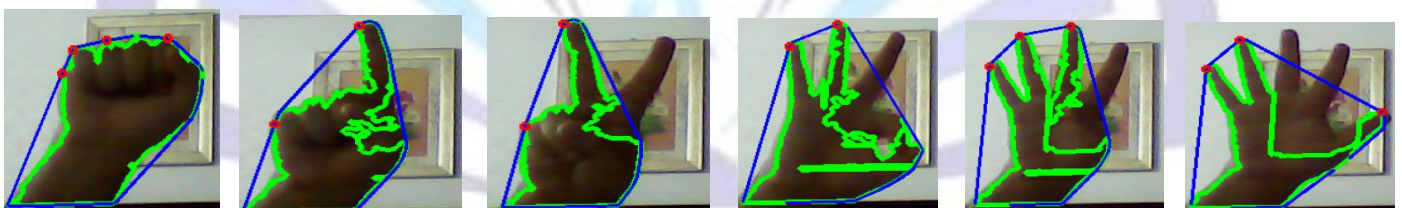


**Fig.8: False Positive**

# References:

[1]- Pulkit Kathuria , Atsuo Yoshitaka , "Hand Gesture Recognition by using Logical Heuristics" , Information Processing Society of Japan (IPSJ), 2012 , pp. 1-7

[2]- J. L. Raheja, K. Das, and A. Chaudhury, "An Efficient Real Time Method of Fingertip Detection", International Conference on Trends in Industrial Measurements and automation (TIMA), 2011, pp. 447-450.

[3]- Manigandan M. and I. M Jackin, "Wireless Vision based Mobile Robot control using Hand Gesture Recognition through Perceptual Color Space", IEEE International Conference on Advances in Computer Engineering, 2010, pp. 95-99.

[4]- Chen-Lan Yen, Wen-Hung Ting and Chia-Chang Li, "Real-time Deformable Hand Tracking System Based on Monocular Camera" , APSIPA 2009

[5]- L. K. Lee, S. Y. An, and S. Y. Oh, "Robust Fingertip Extraction with Improved Skin Color Segmentation for Finger Gesture Recognition in Human-Robot Interaction", WCCI 2012 IEEE World Congress on Computational Intelligence, June, 10-15, 2012, Brisbane, Australia.

[6] - Luigi Lamberti , "Real-time hand gesture recognition using a color glove", ICIAP'11 Proceedings of the 16th international conference on Image analysis and processing , pp. 365-373

[7]- Manar Maraqa, Raed Abu-Zaiter. (2008, Aug.). "Recognition of Arabic Sign Language (ArSL) Using Recurrent Neural Networks," IEEE First International Conference on the Applications of Digital Information and Web Technologies, (ICADIWT 2008), pp. 478-48.

[8]- S. Saengsri, V. Niennattrakul, and C.A. Ratanamahatana, "TFRS: Thai Finger-Spelling Sign Language Recognition System", IEEE, 2012, pp. 457-462.

[9]- J. H. Kim, N. D. Thang, and T. S. Kim, "3-D Hand Motion Tracking and Gesture Recognition Using a Data Glove", IEEE International Symposium on Industrial Electronics (ISIE), July 5-8, 2009, Seoul  Olympic Parktel, Seoul , Korea, pp. 1013-1018.

[10]- J. Weissmann and R. Salomon, "Gesture Recognition for Virtual Reality Applications Using Data Gloves and Neural Networks", IEEE, 1999, pp. 2043-2046.

[11] -Aheja J.L., Shyam R,. Kumar U., Prasad P.B., "Real-Time Robotic Hand Control using Hand Gesture", 2nd international conference on Machine Learning and Computing, 9-11 Feb, 2010, Bangalore, India, pp. 12-16.

[12]- Han-Sung Park, Kang-Hyun ,"Real-Time Hand Gesture Recognition for Augmented Screen using Average Background and CAMshift",The 19th Korea -Japan Joint Workshop on Frontiers of Computer Vision, 30 Jan 2013 - 1 Feb 2013 , pp.18-21 .

[13]- Satoshi Suzuki, KeiichiA be, "Topological structural analysis of digitized binary images by border following", Computer Vision, Graphics, and Image Processing, Volume 30, Issue 1, April 1985, Pages 32-46

[14]- David Douglas & Thomas Peucker, "Algorithms for the reduction of the number of points required to represent a digitized line or its caricature", The Canadian Cartographer 10(2), 112–122 (1973)

[15]- Jack Sklansky, "Finding the convex hull of a simple polygon", Pattern Recognition Letters, vol. 1, Issue 2, pp. 79-83, December, 1982.

[16]- M.M. Youssef, K.V. Asari, R.C. Tompkins, J. Foytik, "Hull convexity defects features for human activity recognition," Applied Imagery Pattern Recognition Workshop (AIPR), 2010 IEEE 39th , pp.1-7, 13-15 Oct. 2010.