

Real Time Face Tracking for Human-Robot Interaction using MATLAB

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Abstract - This paper intends to detect and track the human face in real time by using MATLAB. Face detection and tracking systems have received increasing interest in the last decade. In the previous research, the webcam sent video frames to OpenCV running on a Windows PC. OpenCV detected a face, it tracked it and calculated its centre's X, Y coordinates. In this research, the detection and tracking of human face are performed using only MATLAB programming. And then the robot is implemented together with Viola-Jones face detection algorithm and it tracks the movement of a face from the video stream by using centre base method. In order to get these functions, the two servo motors are used as actuators for moving the ordinate control system. The performance of this research is successfully tested with both simulation and experimental results.

Keywords: Centre based Tracking, Viola-Jones, Robot, MATLAB, Human Face and Arduino uno

I. INTRODCUTION

In indoor environment, human tracking is beneficial for many uses, for example in surveillance system inside a household, industrial factory [1]. There are also a number of researches being conducted to track moving objects and people. Multiple stereo cameras were used to track motions of multiple people over a wide area in [1] and can perform well in crowded condition. A stereo camera and laser rangefinder are attached to a mobile robot in [2] to track human by using features of human upper body and face detection from the camera and legs data from the laser rangefinder. However, it requires initialization by the user to select who is the person to be tracked. In [3], a human is tracked by a mobile robot which detects his/her face from images obtained by the on-board web camera, takes the picture of him/her and prints it out. Face detection is done by skin-color detection and eye detection, which have possibility of false detection and other objects with similar color and pattern, such as table or wall, can be falsely recognized as a face.

This research intends to control for security, especially, the strong room such as the answer papers storage rooms. Although the CCTV control system can capture the movies, the conycatchers can't be prevented before causing problems. In this paper, interaction between the robot and human are presented. In order to solve these problems, only the MATLAB programming was used for tracking the face and controlling the movement of robot. And then two servo

motors were also used as actuators. The block diagram of the system is expressed in Fig.1.

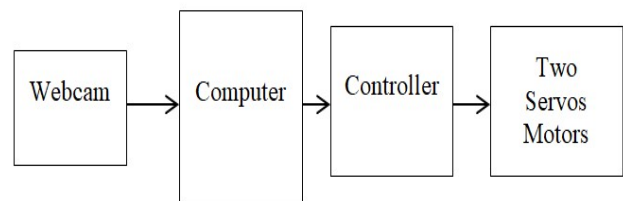


Fig.1. Block Diagram of human face tracker robot

II. RESEARCH AIM AND OBJECTIVES

The main aim of this research is to detect and track the human face in real time with Viola-Jones and centroid based Method.

The objectives of this research are:

- To detect the face locations
- To calculate the center coordinates of the human face
- To control for tracking the robot with webcam

1) Problem statement

With technology advanced, the machine vision becomes essential to the mechatronics areas. There are many problems in industrial applications with machine vision. So in this research, the author intends to improve machine vision based robot application in the application areas.

II. LITERATURE REVIEW

Aswinth Raj had researched "Real Time Face Detection and Tracking Robot using Arduino" in June -13, 2017. The Android application had detected the face and its position on screen; it then decided which direction it should move based on the position of the face so that the face got to the centre of the screen. This direction was then sent to the Arduino via Bluetooth Module.

Krishnachaithanya had done "Real Time Face Tracking Robot with Arduino and Matlab" in Jan-2,2016. In this research, they had used some functions (in Matlab and arduino program) that together make up the Viola-Jones face detection algorithm. They also built a robot that tracked the

movement of a face from the video stream using Matlab and Arduino.

Unknown Author had done "Face Tracking using Arduino", in October 11, 2018. This research had shown how to track faces using Arduino and Python and made the camera follow the face.

But in my research, the controlling program is developed only with MATAB to control the position of the face from the webcam and to track the face based position center based method from bounding box of the Viola- Jones. The set of frames with bounding boxes make up the addition of a bounding box around the face in live video. While adding a bounding box, the coordinates of centroid of the bounding box are also calculated.

III. BACKGROUND THEORY

1) Viola-Jones Algorithm

Viola and Jones's algorithm is used as the basis of our design. As we know there are some similarities in all human faces, we use this concept as a Haar feature to detect face in image. Algorithm looks for specific Haar feature of a face, if these feature are found, algorithm passes the candidate to the next stage. Here the candidate is not whole image but just a rectangular part of this image known as sub window having size 24×24 pixels. As we know there some kind of similarities in human face. We use this concept for making Haar feature. They are composed of two or three rectangles. These features are applied on face of the candidate to find out whether face is present or not. Each Haar feature has a value and this can be calculated by taking the area of each rectangle and then adding the result. Using the integral image concept we can easily find out the area of rectangle.

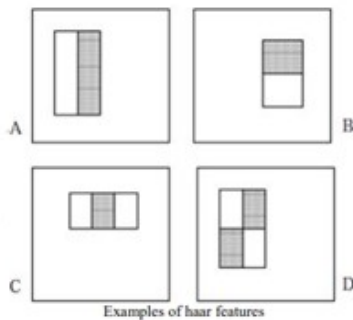


Fig.2. Haar Features

The integral image is defined as the summation of the pixel values of the original image. The value at any location (x, y) of the integral image is the sum of the image's pixels above and to the left of location (x, y) . "Fig. 3" illustrates the integral image generation.

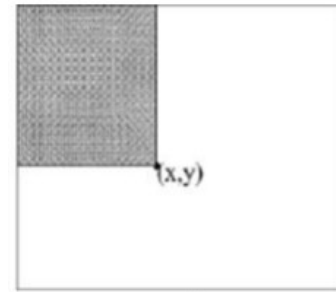


Fig.3. Integral Image

A Haar feature classifier uses the rectangle integral to calculate the value of a feature. The Haar feature classifier multiplies the weight of each rectangle by its area and the results are added together. Several Haar feature classifiers compose a stage. A stage comparator sums all the Haar feature classifier results in a stage and compares this summation with a stage threshold. The threshold is also a constant obtained from the Ada Boost algorithm. Each stage does not have a set number of Haar features. For example, Viola and Jones' data set used 2 features in the first stage and 10 in the second. All together they used a total of 38 stages and 6060 features.

It is possible to eliminate the false candidate quickly using stage cascading. The cascade eliminates candidate if it does not pass the first stage. If it passes then send it to next stage which is more complicated than previous one. If a candidate passes all the stage, this means a face is detected.

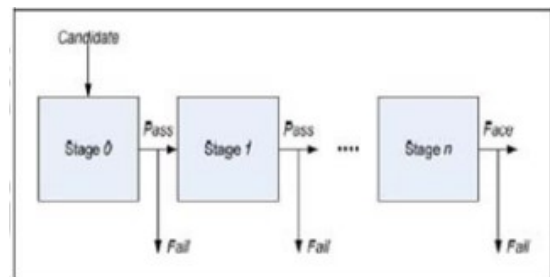


Fig.4. Cascade of stages

2) Hardware components

In this research, the tracking of the face is done with the help of an Arduino Uno microcontroller. Ardiomp is an open source platform with both hardware and software applications. Arduino Uno is used as a buffer. Output pins are used pin 9 and 10 from Arduino Uno. These pins are output pin for two servo motors. PC with MATLAB is directly controls two servo motors through Arduino Uno. And then PC sends input signals to the output pins of Arduino Uno via USB.



Fig.5. Arduino uno

MG995 is a servo motor that is popular for its performance and low price. The motor is used in many applications mainly being robotics and drones. In this research, two MG995 servos are used to track the face with respect to the coordinates from bounding box.



Fig.6. MG995 Servo Motor

In this research, anitech infrared webcam in local market is used to capture the image.



Fig. 7. Webcam

In this research, the hardware circuit is implemented with Arduino Uno, two servo Motors and Computer with MATLAB.



Fig.8. Experiment Setup

IV. METHODOLOGY

In this thesis, there are sections, one is face detection and last is face tracking. In order to detect the face, Viola-Jones is used. The face tracking is done by center base method using the bounding box coordinate from Viola Jones algorithm. Code in Matlab detects a face from every frame of the live video stream and inserts a bounding box around the Region of Interest, which is a face in this case (by detecting some haar features present in the human faces).

1). Face Detection Algorithm

The input video stream is captured using webcam. This video is divided into frames. Each frame is processed for a face.

Viola-Jones algorithm is used to detect a face from a frame from the webcam. And then the coordinates obtained after detecting the face in a frame are compared with the center coordinate with the previous frame.

Viola-Jones algorithm is an object detection technique focusing on the faces in an image or video. It is operative only on frontal faces.

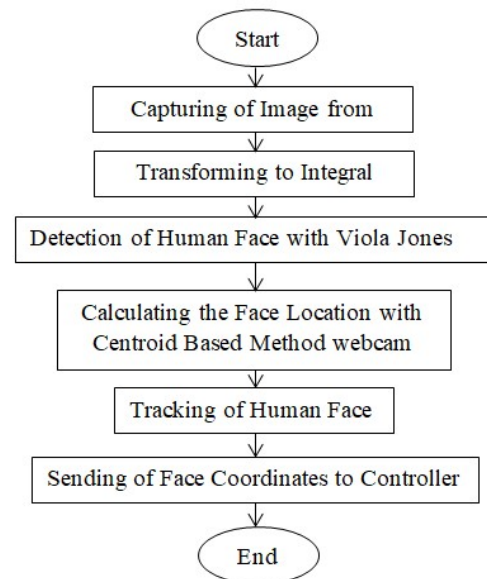


Fig.9.Flow chart of the human face tracking system

2). Centroid based tracking method

The operation of face tracking robot is illustrated as follows:

- Basically, the webcam sends video stream to MATLAB running on a Windows PC.
- MATLAB detects a face; it will track it and calculate the coordinates of centroid of the bounding box.

- The servo motors are controlled depending on these coordinates from MATLAB through the Arduino UNO microcontroller.
- Then Arduino checks that centroid coordinates lie in the center region of the screen after getting the positions of servo motors.

The Arduino controls the movement of the webcam with the help of two servo motors to follow the detected face.

The error values are calculated on the difference from the center point from a set of bounding boxes with the target area. The target location is the surrounding area from the center of the frame (X_c, Y_c). The target area is used to make the target value wider than just one point, so the movement of the actuator is not critical. Small changes from the tracking position often occur, if only using the center point as a target causes the movement of the actuator to be stable.

The Arduino is controlled to set the tilt angles of the webcam by sending serial strings from a computer to the Arduino. Processing gives x and y coordinates of a face in a frame. The plan is to try and keep the x and y coordinates of the face in the center area of the screen by moving the webcam left/right and up/down based on the current x and y coordinates. In order to get this working, processing is needed to change so that it is to send serial commands to the Arduino.

Therefore the coordinates of centroid of the frame are calculated. The centroid coordinates of a face in bounding box are calculated as follow;

$$Bbox = [x \ y \ w \ h]$$

$$Cent \ u = bbox (1) + (bbox (3) / 2)$$

$$Cent \ v = bbox (2) + (bbox (4) / 2)$$

Where bbox is bounding box of a face,

$$bbox (1) = x$$

$$bbox (2) = y$$

$$bbox (3) = w$$

$$bbox (4) = h$$

Where [x, y] determine the upper-left corner location of the rectangle, width and height specify the size. Calculated centroid coordinates with MATLAB are used to control for moving of motors. Arduino operates the two servo motors according to the information from the Matlab. Frame is divided into left and right halves and also top and bottom halves. After finding out where the middle of the face is, this position is compared to the center of the screen. If the centroid falls in the left half, the camera is panned right and if it falls in the right half, camera is panned left and the same with the top and bottom halves and tilting. This process is continuous and tracking is done.

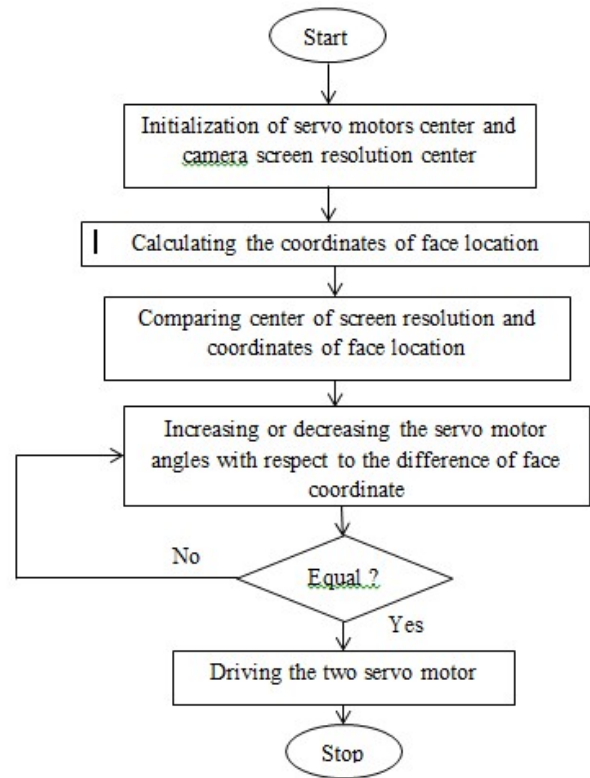


Fig.10. Centre based tracking method for only one frame

V. RESULTS

In this research, only MATLAB is used for processing the images and controlling the motors.

- Viola Jone is used for only detecting the faces
- Center based method is applied for tracking the face
- Screen Maximum Resolution is 640x480
- Center Screen Resolution is 320x240
- Maximum Servo Motor Rotation is 180 Degrees
- Center Servo Motor Rotation is 90 Degrees

```

    14 - wait = 0;
    15 - while (wait < 60)
    16 -     wait = wait + 1;
    17 -     img = getsnapshot(vid);
  
```

Command Window

```

    c1 =
         690

    c2 =
         280
  
```

Fig.11. Center coordinate of a face




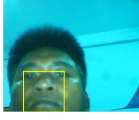
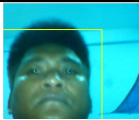
	Real time Captured images	Bounding box of image (bbox)	Center x (c1)	Center y (c2)	Distance for x between center of bounding box and center of screen resolution	Distance for y between center of bounding box and center of screen resolution
1		49 160 269 269	183.5	294	126.5	64
2		151 78 302 302	302	229	8	1
3		73 30 278 278	212	169	98	61
4		58 169 58 58	87	198	233	42
5		32 90 140 140	102	160	218	80

Fig.12 Bounding box coordinates

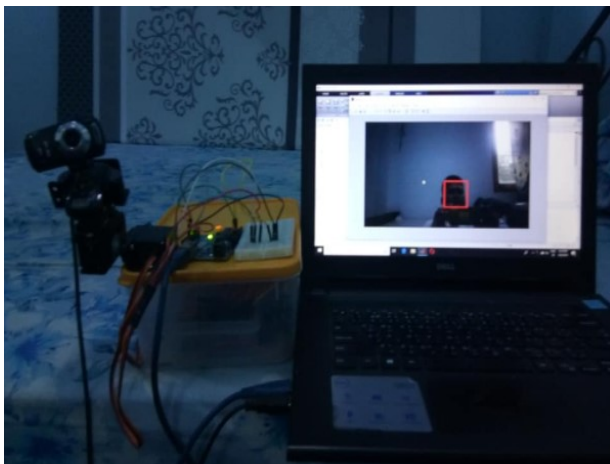


Fig.13. Tracking Result 1

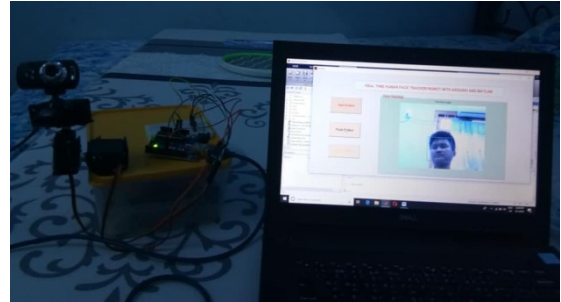


Fig.14. Tracking Results 2

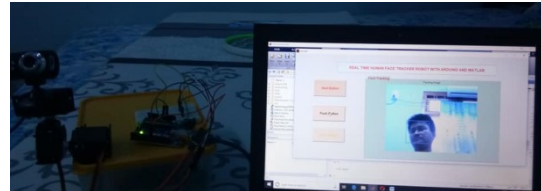


Fig.15. Tracking Result 3

VI. CONCLUSION

Face detection and tracking system is part of image processing applications and its importance as a research area is increasing recently. In this system, centroid tracking algorithm is used for tracking the detected of human face. It relies on the Euclidean distance between existing face centroids and new face centroids between subsequent frames in a video. If there is a face, some calculations are made to determine the coordinates of the center of the face. Notice that the only face coordinates being used are the coordinates in the first array position. If the center of the face is above the center of the screen, the tilt position variable is changed to raise the webcam. The change in the webcam angle is small, but it still tries to get the subjects face closer to the center of the screen. The same general principle is made if the face is below the center of the screen, or to the left or right of the center.

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