International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 7, Number 2 (2014), pp. 89-97

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Real Time Face Selection and Tracking Based Camera Motion Control System

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Abstract

This paper describes the design and implementation of a architecture that can continously monitor and track selected face in real time by controlling camera motion around. Dection and tracking of face has been an significant and dynamic investigation domain because it provides many application, primarily in video coding, video surveillance, biometry or Video Identity Resolution. But detection and tracking of face in real time is a composite issue with numerous feasible applications. The objective of this project is to implement an real time camera motion control system to detect and track selected human face. The detection of face includes cascade classifiers and harr features. One of the detected face will be selected using mouse click option and matching is done in each frame by difference algorithm. The system is integrated with a frame-by-frame Kalman tracker in order to locate face region in each frame. Experimental result demostrate that the system able to track selected face in real time with horizontal rotation angle -360 to +360 degree with maximum rotation speed 5 degree per second. Implementation was done in real time with minimum computational endevour, thus suitable for low cost application.

Keywords: Adaboost learning algorithm, Face Detection, OpenCV, Kalman Filter, SAD algorithm, Camera Motion.

1. Introduction

Continuous monitoring and surveillance system is playing an important role in security whereby the recent demand for installation of security camera system had been increased dramatically. However, increasing of camera installation in both indoor and outdoor environment such as streets, parks, building, and stores arise problem of deciding position, direction, and visual angle of camera [1]. In order to cover all the area by minimum of camera and at the same time used to track the activity done by a selected user, we propose realtime face selection and tracking based camera motion control system used in continuous tracking of selected user by a single camera. Besides of a better activity recording based on target can be done throughout this system, the system also has advantage in making the low-cost smart doll become more user interactive as the doll will always face to the user.

2. Methodology

Fig. 1 shows the overview of the system and it is being initialized by input capture image from webcam to the computer for further image processing. Face detection will be based on Haar-like feature and thus detect the face and calculate its position in capture frame. Through the combination of control theory to artificial intelligence, logic controller is applied into this system. USB is used as serial communication between the computer and microcontroller. Digital signal will send to microcontroller and it used as control signal for neck mechanism to make the proper adjustment using hardware actuator.

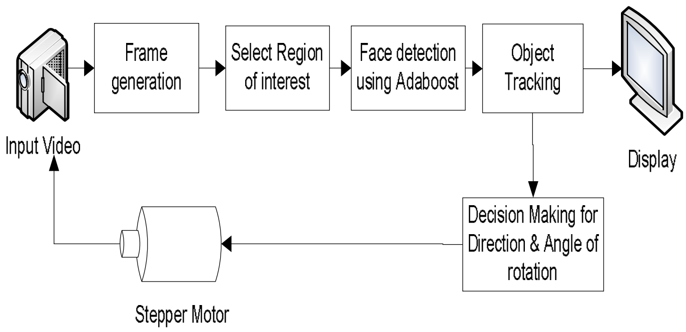

Fig. 1: System Overview.

2.1 Detection Using Haar-Like Features

Haar-like features have scalar values that represent differences in average intensities between two rectangular regions. They capture the intensity gradient at different locations, spatial frequencies and directions by changing the position, size, shape and arrangement of rectangular regions exhaustively according to the base resolution of the detector [2].

Fig. 2 shows the example of Haar-Like feature sets. Haar-feature said to be present if subtracting the average dark-region pixel value from average light-region pixel value is above a threshold (set during learning). AdaBoost combines many weak classifiers to create one strong classifier [3]. Object detection via Haar-like Features with Cascade of Boosted Classifiers.

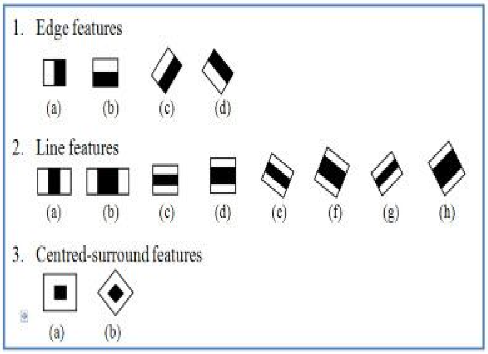

Fig. 2: Examples of Haar-Like Feature Sets.

2.2 Adaboost Learning Algorithm

Adaboost is a simple learning algorithm that selects a small set of weak classifiers from a large number of potential features. In our system, a variant of Adaboost is used both to select a small set of features and train the classifier. Our boosting algorithm is basically the same as P. Viola's algorithm [5] [6].The final strong classifier is a weighted linear combination of T weak classifiers.

Fig. 3 and fig.4 show the single step in haar feature filtering in face detection. The most important characteristic of the Viola-Jones framework is that the Haar like features can be computed rapidly at all scales in constant time by using the integral image [4].

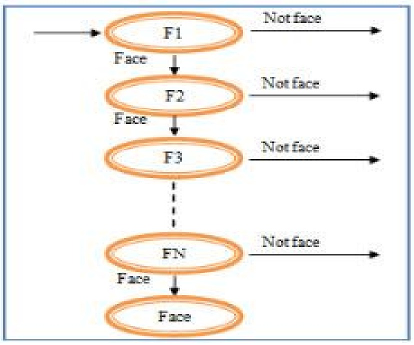

Fig. 3 Chain of single feature filter in frontal face detection

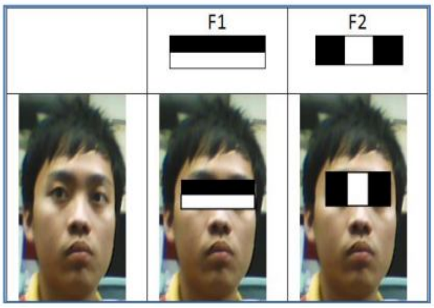

Fig. 4: Chain of single haar-like feature filter in frontal face detection.

2.3 Matching Algorithm

Sum of absolute differences (SAD) is a widely used as simple algorithm for measuring the similarity between image blocks. It works by taking the absolute difference between each pixel in the original block and the corresponding pixel in the block being used for comparison. These differences are summed to create a simple metric of block similarity.

The sum of absolute differences may be used for a variety of purposes, such as object recognition, the generation of disparity maps for stereo images, and motion estimation for video compression.

2.4 Tracking Using Kalman Filter

The Kalman filter is useful for tracking different types of moving objects. It was originally invented by Rudolf Kalman at NASA to track the trajectory of spacecraft. At its heart, the Kalman filter is a method of combining noisy (and possibly missing) measurements and predictions of the state of an object to achieve an estimate of its true current state. Kalman filters can be applied to many different types of linear dynamical systems and the "state" here can refer to any measurable quantity, such as an object's location, velocity, temperature, voltage, or a combination of these[7].

3. Design and Implementation

Fig. 5 shows the process flow chart of the whole system and it is begun with grab frame to get the input capture image from webcam and further processing in the computer. The capture image will undergoes selection processes to select region of interest i.e face region. Upcoming frame undergoes face detection algorithm, Haar-Like Feature comparison. If there are any face detected, face matching process is done using SAD algorithm in current frame with the region of interest selected from the previous frame. Once the face is matched in frame, it starts to track the face in further frames using Kalman Filter.

In our face tracking algorithm, the estimated instantaneous face center position and face size are fed into a simple linear Kalman filter. The Kalman filter is used to smooth the temporal trajectories of the face center position and size. A new frame of the image sequence is acquired and processed at each instant **.** We can describe the face motion on the image plane with the state vector at instant. Assuming a sufficiently small sampling interval, we can write the system model of the linear Kalman filter as follows:

$$\boldsymbol{h_k} = \boldsymbol{h_{k-1}} + \boldsymbol{v_{k-1}} + \boldsymbol{\zeta_{k-1}} \tag{1}$$

$$\boldsymbol{v_k} = \boldsymbol{v_{k-1}} + \boldsymbol{\eta_{k-1}} \tag{2}$$

Where $\boldsymbol{h_k} = (\boldsymbol{x_k}, \boldsymbol{y_k}, \boldsymbol{\sigma_k})^{\boldsymbol{t}}$ is the position and size of a face at instant $\boldsymbol{t_k}$ and $\boldsymbol{v_k} = (\boldsymbol{v_{x,k}}, \boldsymbol{v_{y,k}}, \boldsymbol{v_{\sigma,k}})^{\boldsymbol{t}}$ is moving velocity, $\boldsymbol{\zeta_{k-1}}$ and $\boldsymbol{\eta_{k-1}}$ are zero-mean, white, Gaussian random processes modeling the system noise. The evolution of the system's state can be modeled as follows:

$$\boldsymbol{s_k} = \boldsymbol{\phi_{k-1}} \boldsymbol{s_{k-1}} + \boldsymbol{w_{k-1}} \tag{3}$$

$$\boldsymbol{\phi_{k-1}} = \begin{bmatrix} 1&0&0&1&0&0 \\ 0&1&0&0&1&0 \\ 0&0&1&0&0&1 \\ 0&0&0&1&0&0 \\ 0&0&0&0&1&0 \\ 0&0&0&0&0&1 \end{bmatrix} \qquad 4)$$

$$\boldsymbol{w_{k-1}} = \begin{pmatrix} \boldsymbol{\zeta_{k-1}} \\ \boldsymbol{\eta_{k-1}} \end{pmatrix} \tag{5}$$

Where $\boldsymbol{s} = (\boldsymbol{x_k}, \boldsymbol{y_k}, \boldsymbol{\sigma_k}, \boldsymbol{v_{x,k}}, \boldsymbol{v_{y,k}}, \boldsymbol{v_{\sigma,k}})^{\boldsymbol{t}}$ is a state vector at instant $\boldsymbol{t_k}$ is the time-invariant state transition matrix.The measurement model of the Kalman filter becomes as follows:

$$\boldsymbol{z_k} = \boldsymbol{H_K} \begin{pmatrix} \boldsymbol{h_k} \\ \boldsymbol{v_k} \end{pmatrix} + \boldsymbol{\delta_k}, \boldsymbol{H_k} = \begin{bmatrix} 1&0&0&0&0&0 \\ 0&1&0&0&0&0 \\ 0&0&1&0&0&0 \end{bmatrix} \tag{6}$$

Where $\boldsymbol{\delta_k}$ is a zero-mean, white, Gaussian random process modeling the measurement noise.H is the time-invariant measurement matrix. The Kalman filter equations are characterized by the state covariance matrices $\boldsymbol{p_k}, \boldsymbol{p'_k}$, and the gain matrix $\boldsymbol{k_k}$.$\boldsymbol{p'_k}$ is the covariance matrix of the k-th state estimate $\widehat{\boldsymbol{s_k}}' = \boldsymbol{\phi_{k-1}} \widehat{\boldsymbol{s_{k-1}}}$ predicted by the filter immediately before obtaining the measurement $\boldsymbol{z_k}$. $\boldsymbol{p_k}$ is the covariance matrix of the k-th state estimate $\widehat{\boldsymbol{s_k}}$ computed by the filter after integrating the measurement $\boldsymbol{z_k}$ with the prediction $\boldsymbol{s_k}'$. The covariance matrices are a quantitative model of the uncertainty of $\boldsymbol{s_k}'$ and $\boldsymbol{s_k}$. Finally, $\boldsymbol{k_k}$ establishes the relative importance of the prediction and the state measurement. Let $\boldsymbol{Q_k}$ and $\boldsymbol{R_k}$ be the covariance matrices of the noise processes $\boldsymbol{w_k}$ and $\boldsymbol{\delta_k}$. The Kalman filter equations are as follows:

$$P'_K = \phi_{k-1} P_{k-1} \phi^t_{k-1} + Q_{k-1} \,, \tag{7}$$

$$K_k = P'_k H'_k (H_k P'_k H^t_k + R_k)^{-1} \tag{8}$$

$$\widehat{s_k} = \phi_{k-1} \widehat{s_{k-1}} + K_k (z_k - H_k \phi_{k-1} \widehat{s_{k-1}}) \tag{9}$$

$$P_k = (I - K_k) P'_K (I - K_k)^t + K_k R_k {K_k}^t \tag{10}$$

Microcontroller PIC16F877A is one of the PICMicro family microcontroller which is popular at this moment, start from begineer untill all professionals. Because very easy using

PIC16F877A and use FLASH memory technology so that can be write-erase untill thousand times. The superiority this Risc Microcontroller compared to with other microcontroller 8-bit especially at a speed of and his code comperession. PIC16F877A have 40 pin by 33 path of I/O. As per movement of face, the MCU will generate control signals. These signals are used to vary the speed and direction of stepper motor and thus further making position adjustment of camera.Control signals for stepper motor M:

- **M-A < 0** → M moves clockwise with 5^0
- **M-A > 0** → M moves counter-clockwise with 5^0.

Fig. 6: PIC16F877A microcontroller.

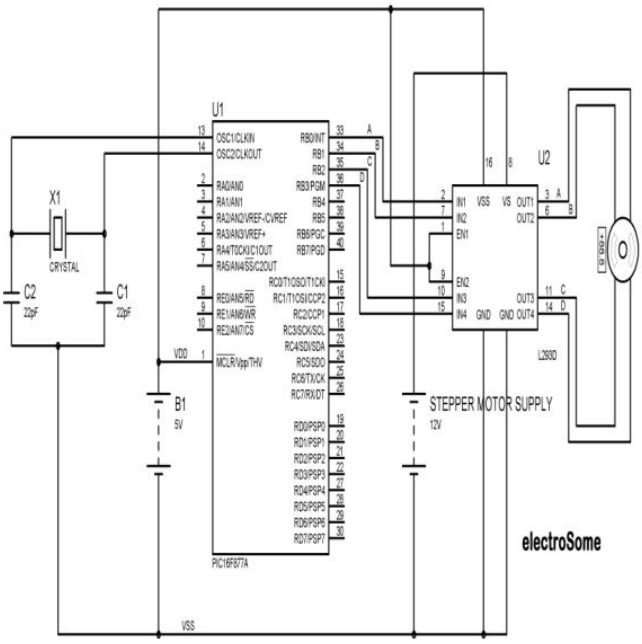

Fig. 7: Stepper Motor Control system.

4. Result

Performance evaluations have been done on centroid calculation of face and degree of angle rotation of camera. In order to make sure tracking face always at the centre of frame, the microcontroller output value will make the camera position by controlling the stepper motor.

4.1 Expected output

Fig.8 show the proper adjustment of mechanical control system in horizontal direction.

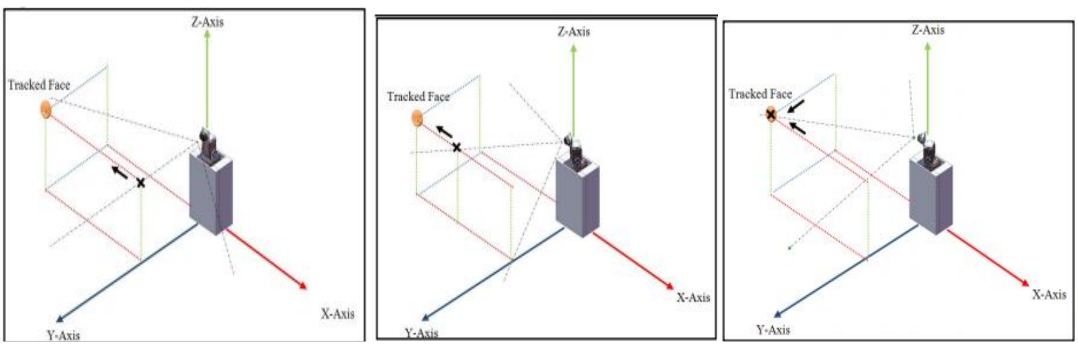

Fig. 8: Adjustment Steps in Horizontal Displacement.

4.2 Experimental Output

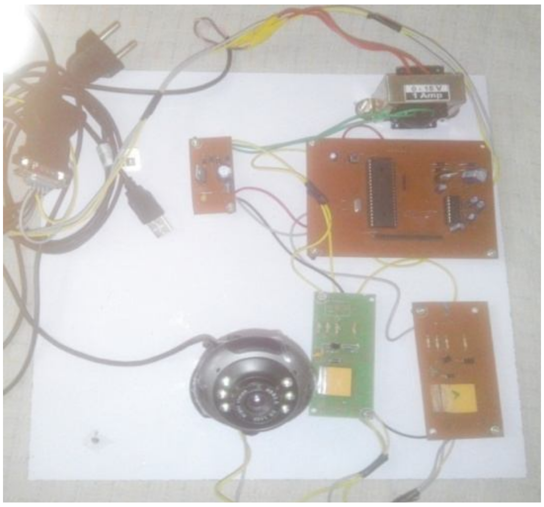

Fig. 9: Complete experimental setup in real time.

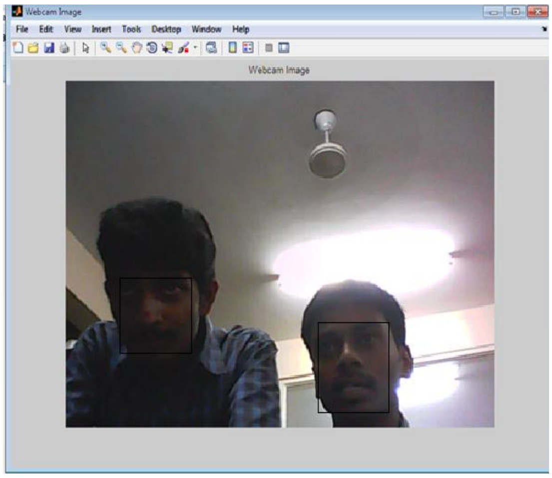

Fig. 9: Multiple Face Detection using haar like features and cascade clasifiers

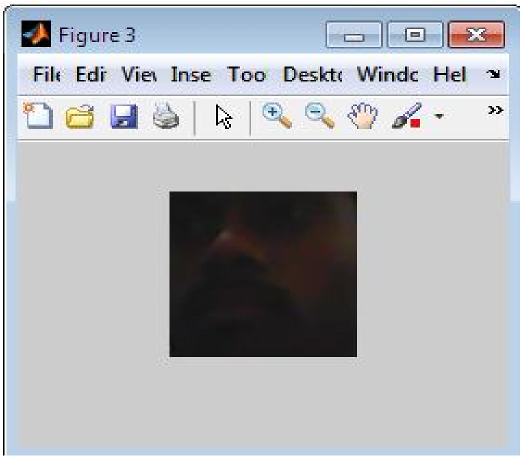

Fig. 10: Face selected using mouse click option

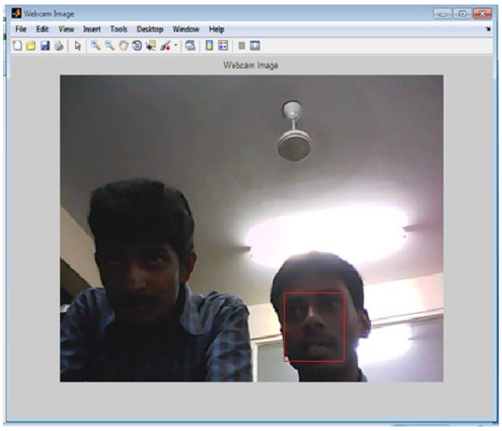

Fig. 11: Face matching is done by difference algorithm

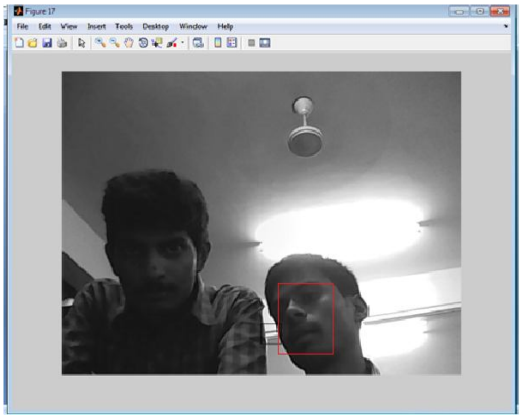

Fig. 12: Tracking Selected Face by kalman filter tracker

5. Discussion and Conclusion

Moving camera will blur the captured image and further brings difficulties in image processing. Besides, the distance between face to camera will significantly affects the performance of the system. Difference in distance between the camera and face will result in the difference in the change of error even with the same horizontal displacement speed. This makes the system even more difficult to be controlled.

Vigorous experiments and fine tuning shows that the system is able to work up to expectation when the distance between face and camera is more than 50 cm or the rotation speed of camera is more than 15 degree per second. Hence, distance of 50 cm and 5 degree per second for maximum rotation speed are used as the testing threshold parameter for this system. Finally the response of the system in this condition is optimized to roughly 1.5 seconds needed in completely moving the camera to move the tracked face into the centre of frame. From the above obtained result, the overall system is stable as the bounded input yields a bounded output.

Development of facial tracking based head movement control system is begun by a simple real time selected face tracking in software further enhancement to wide tracking region by combination of hardware and software. Exploration of haar-like face detection algorithm, Kalman filter for face tracking and control signals for camera control showed that this model is able to improve and enhance the overall monitoring system.

6. Acknowledgment

I would like to articulate my profound gratitude and indebtedness to my project guide RAVIKAUMAR.A.V(Asst. Prof. Dept. of ECE. SJBIT) who is always being a constant motivation and guiding factor throughout the project time in and out as well. It has been a great pleasure for me to get a opportunity to work under him.

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