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Person to Camera Distance Measurement Based on Eye-Distance

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Abstract−**This paper presents a novel person to camera distance measuring system based on eye-distance. The distance between centers of two eyes is used for measuring the person to camera distance. The variation in eye-distance (in pixels) with the changes in camera to person distance (in inches) is used to formulate the distance measuring system. The system starts with computing the distance between two eyes of a person and then person to camera distance is measured. The proposed distance measurement system is relatively simple and inexpensive to implement as it does not require any other external distance measuring tools. Experimental results show the effectiveness of the system with an average accuracy of 94.11%.**

Keywords-Eye detection; Eye distance; Person to camera distance.

I. INTRODUCTION

Two widely used approaches for measuring object to camera distance are: contact and non-contact approaches [1]. In contact-based approach, various methods can be used, such as ultrasonic distance measurement [2, 3], laser reflection methods [4, 5]. These two methods use the theory of reflection. If the reflection surface is not uniform, the measuring system generally performs poorly or not at all. On the other hand, image-based measuring systems based on pattern recognition or image analysis techniques [6, 7] generally demand huge amount of storage capacity and high-speed processors. To overcome these problems and difficulties encountered by the existing techniques, an image-based person to camera distance measuring system without complex calculation method is presented in this paper. The system setup and configuration of the proposed method is very simple, consisting of only a single CCD camera. Based on an established relationship between the distance of two eyes in number of pixels and camera to object distance (in inches), the distance of a person from the camera is computed.

The proposed method in this paper is quite different from other existing image processing based person to camera distance measuring techniques which requires additional CCD cameras [8, 9], laser projectors, etc. during the measurements. The distance between two eyes (in pixels) of a person in an image reduces as the person moves away from the camera and vice versa. This property is used to measure the person to camera distance based on a certain eye-distance in real time.

The paper is organized as follows. In Section II, the proposed person to camera distance measurement system based on eye-distance is described. Experimental results and discussions are presented in Section III. Finally the paper is concluded in Section IV.

II. PERSON TO CAMERA DISTANCE MEASURING SYSTEM

A. Eye Distance Measurement

This system forms an image pyramid of the input images and uses a template matching approach for face and eye detection [10]. An image pyramid is a set of the original image at different scales. To locate the face, a mask is moved pixel-wise over each image in the pyramid, and at each position in the image the mask is passed to a function that assesses the similarity of the image section to a face. If the similarity value is high enough with respect to specific threshold, the presence of a face at that location is assumed. From that location, the position and size of the face in the original image is generated [10]. From the detected face eye is detected by forming an image pyramid of the detected

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face images and uses a template matching approach for eye detection. The Euclidian distance between two eyes is computed using the following (1):

$$d_{ep} = \sqrt{(E_{LX} - E_{RX})^2 + (E_{LY} - E_{RY})^2} \quad (1)$$

where (E_{LX}, E_{LY}) and (E_{RX}, E_{RY}) are the center points of left and right eyes respectively and d_{ep} is the distance between two eyes in pixels.

B. Formulation of Person to Camera Distance Measurement Equation

After a comprehensive study conducted over 35 people of both sexes and from different height ranges, it is found that a relation exists between eye distance (in pixels) and person to camera distance (in inches). A sample square of eye distance versus person to camera distance graph of several persons is presented in Fig. 1. From the figure it is noticeable that the square of eye distance versus person to camera distance graph is significantly identical thus it can be generalized for persons of different physical identities. Table I presents collected measured data of three persons on different predefined camera to person distances (in inches).

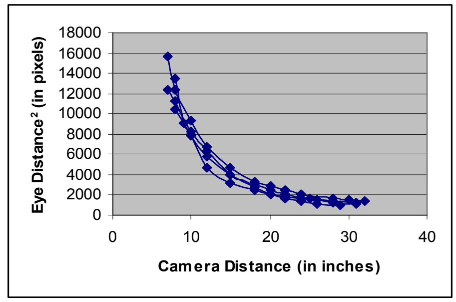


Figure 1. Relation between eye-distance and person to camera distance

TABLE I. SAMPLE MEASURED DATA

Square of eye distance (in pixels)			Person to camera distance (in inches)
Person 1 (Abir)	Person 2 (Wahid)	Person 3 (Robin)	
1228	1150	1225	31
1350	1329	1370	28
1580	1450	1685	25
1900	1959	2034	22
2226	2145	2501	20
2720	2890	3000	18
4000	3986	4005	15
5800	6120	6277	12
7800	7980	8200	10
10400	10350	11211	8
14500	13500	12400	7

Equations (2) and (3) are formulated after a thorough study of the nature of Eye Distance² versus Person to Camera Distance graphs of 35 people, which simulates the graphs in real-time.

$$d_{ep}{}^2 = \frac{MAX_{ed}}{(1 + \frac{d_c - Mid_G}{Mid_G})(\sqrt{d_c - MIN_{ed}} - 1)} \quad (2)$$

$$d_c' = d_c \pm V(2 - \frac{d_{ep}}{MAX_{ed}}) \quad (3)$$

where d_{ep} is the distance between two eyes, MAX_{ed} is the maximum eye distance point, MIN_{ed} is the minimum camera distance point, Mid_G is the mid point of square of eye distance Vs person to camera distance graph , d_c is the primary camera to person distance (with error), d_c' is the corrected camera to person distance and V is the correction weight. Positions of MAX_{ed}, MIN_{ed}, Mid_G points are shown in Fig. 2. These values are generalized considering the data collected of 35 people.

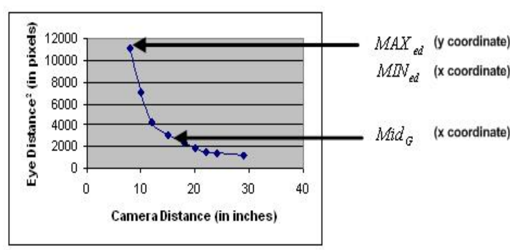
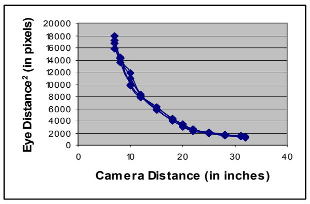
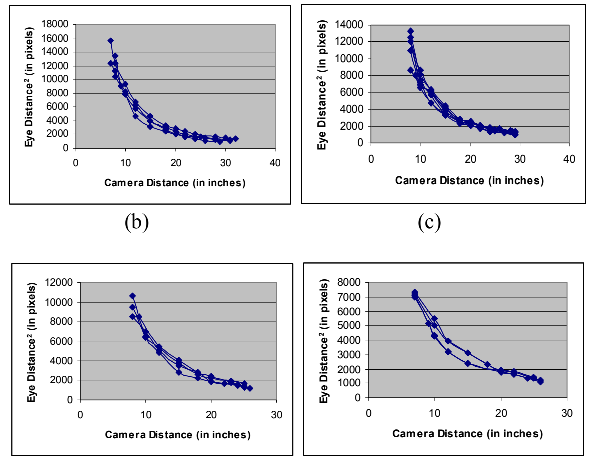


Figure 2. Relation between eye distance and object to camera distance

Before measuring the person to camera distance, the person is trained with different predefined distances from the camera starting from 7 inches and increased up-to 31 inches. During the training session corresponding person to camera distances (in inches) and eye distances are mapped and the MAX_{ed} value of that person (when the person is in the highest distance from the camera) is set by the system. It is also found that there are generally 5 categories of MAX_{ed} values ranging from 16000 to 9500 in which the persons tested have been categorized. Depending on the MAX_{ed} value, the other parameters of (2) and (3) are set according to Table II. Fig. 3 shows the different square of eye distance versus person to camera distance graphs depending on different MAX_{ed} value. The values of Table II are set after analyzing the characteristics of square of eye distance versus person to camera distance graphs of Fig. 3.



(a)



(b) (c) (d) (e)

Figure 3. Square of eye distance versus person to camera distance graph (a) where MAX_{ed} >16000 (b) for 13000< MAX_{ed} <=16000, (c) for 11000< MAX_{ed} <=13000, (d) for 9500< MAX_{ed} <=11000 and (e) MAX_{ed} <=950

TABLE II. INTRINSIC PARAMETER TABLE

MAX_{ed} **Range**	MIN_{ed} **Value**	Mid_G **Value**	**Value of** V	**Sign**
MAX_{ed} >16000	8	23	8	+
13000< MAX_{ed} <=16000	8	20	6	+
11000< MAX_{ed} <=13000	8	18	4	+
9500< MAX_{ed} <=11000	8	15	0	N/A
MAX_{ed} <=9500	7	15	4	-

C. *Person to Camera Distance Measurement*

Person to camera distance measurement is accomplished by calculating the eye distance and then mapping the corresponding person to camera distance from the generalized (2) and (3) with the values of the parameters from Table II after identifying the person along with corresponding MAX_{ed} value of that person. If the person is not identified then the default parameters values are chosen. Fig. 4 shows the complete architecture of the proposed distance measuring system. The person to camera distance measurement algorithm is described bellow:

Step 1. Detect the center of the two eyes and find the Euclidian distance between them [10].

Step 2. If the person is identified then retrieve the MAX_{ed} value of that person from the database.

Step 3. Set the values of MIN_{ed}, Mid_G, V from Table II according to MAX_{ed}, where MAX_{ed} is the maximum eye distance point, MIN_{ed} is the minimum camera distance point, Mid_G is the mid point of Eye Distance^2-Camera Distance graph and V is the correction weight.

Step 4. Calculate primary camera to person distance, d_c from the (4)

$$d_c^{\,2}(d_c - MIN_{ed} - 1) = \left(\frac{MAX_{ed} \times MID_G}{d_{ep}^{\,2}}\right)^2 \tag{4}$$

where d_{ep} is the distance between two eyes.

Step 5. Make correction to the camera to person distance by the following equation

$d_c' = d_c \pm V(2 - \frac{d_{ep}}{MAX_{ed}})$ where d_c is the primary camera to person distance (with error), d_c' is the corrected person to camera distance and V is the correction weight and return d_c'.

Step 6. If the person is not identified, set the default value as MAX_{ed} = 11000 and goto Step 2.

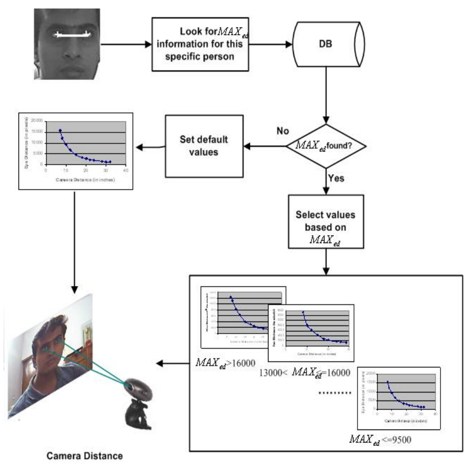


Figure 4. Person to camera distance measurement system architecture

III. EXPERIMENTAL RESULTS

This system uses *A4 Tech PK-336MB* CCD camera for image acquisition [11]. Each captured image is digitized into a 320×320 matrix with 24-bit color. The system captures 30 image frames per second. The system considers every 5th frame captured by camera for further processing. Thus the system processes 6 image frames per second for face area and eye detection [10]. Fig. 5 shows sample system output for two different scenarios. The Eye Distance and Camera Distance fields in Fig. 5 are showing square of eye distance (in pixels) and person to camera distance (in inches) respectively.

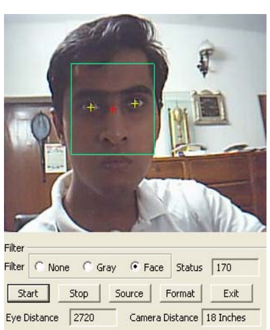


Figure 5. System output on two different scenarios

Accuracy of measurement results using the proposed method are shown in Table III, where real distances, measured distances, and accuracy (for distances from 7 inches to 31 inches) of 35 persons are recorded. Fig. 6 shows the accuracy (%) of the proposed system at different predefined distances. The average accuracy of 94.11% is obtained. Though other conventional measuring results shows slight accurate where error rates range from 1 to 8% [12,13], the proposed system validated its' superiority in terms of simplicity and cost effectiveness.

TABLE III. ACCURACY OF THE DISTANCE MEASUREMENT METHOD

Actual person to camera distance (in inches)	System person to camera distance (in inches)	Accuracy (%)
31	33.8	88.96
28	31	90.25
25	26.7	93.2
22	23	95.45
20	20.3	98.5
18	18.2	96.88
15	14.5	96.66
12	10.71	93.25
10	9.24	92.4
8	8	97.55
7	7.76	92.14

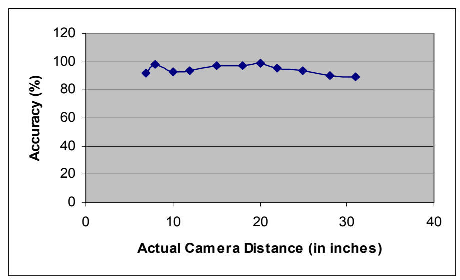


Figure 6. Accuracy (%) of the measured distance with the actual distance

IV. CONCLUSION

In this paper, a simple image-based person to camera distance measuring system is proposed. The proposed method has significant importance because of its lower cost and simpler algorithm for real-time implementation. Because of the simplicity of the proposed approach, hardware-intensive techniques, such as echo detection, additional CCD cameras, laser projector [14], flash lights etc. are no longer required for obtaining a satisfactory person to camera distance measurement. In contrast, the accuracy of the measured face to camera distance method decreases as the user moves away from the camera. Though the current system considers only frontal face view for distance measurement, in the future, we shall consider side face views for improving the accuracy of measurement with a practical potential in the fields of security and robotics.

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