Eye Centre Localization Using Low Cost Web Cam

P.Neeraj, Anurag Sharma

Abstract: ***Numerous Computer vision applications uses eye tracking and face recognition. An eye tracker is far better input then other input devices. According to the historical point of view first approach on camera based eye tracking was illustrated by Dodge and Cline in 1901. Eye tracker is all based on the analysis of person's eye movement, attention, feelings and concentration. The main objective is to achieve eye tracking with more precision using low cost web camera. But recent systems which depend on available light to predict eye centre using various algorithms fail to detect eye centre in low resolution or low cost. To achieve this objective software which is used is opencv3.0 and visual studio 2015 with low cost and low resolution camera. To achieve this objective Image gradient is one of the best approaches used to predict eye centre accurately. By following this simple approach function in this paper which has only dot product makes possible to achieve the objective. The position of the maximum of this function is at the point where maximum gradient vectors intersect and thus to the eye's centre. This method helps to detects eye centre localisation of pupil in 99% of the cases in spite of varying contrast pose or illumination.***

Index Terms: ***Eye centre localization, pupil and iris localization, image gradients, feature extraction.***

I. INTRODUCTION

Humans are much like computers they receive inputs from their sensory organs like eyes , ears, skin nose etc. and produce output through their actuators like hand feet mouth etc. The study of sensory body parts of the human body can be used to generate a new concept i.e. eye tracking which construct on the basis of deep perception of situation and build relation between individual eyes and their interest. These concepts use a tool known as eye trackers [1].various applications have been developed on detecting and tracking of human's eye. Eye tracker construct by computing the person gaze point or the area where it is fixed it can be constructed into a 2D or 3D plane and is called as point of regard (POR). By estimating the centre of eye or by localizing eye centre we can manipulate many computer applications. Various computer vision applications like brain computer interface face detection or face matching extensively use eye detection or localisation method [2]. There are number of algorithms which can be used to locate eye centre. Most popular ones are head mounted algorithm and chin rested algorithm which is more precise than head mounted algorithm. In addition to this infrared illumination is used to locate eye centre precisely and to negate corneal reflections.In spite of all these advantages these algorithms produce less reliable results and are miserable in day light and low light. So to overcome these limitations in day light and to produce more reliable results some new methods are used. These methods roughly divided into three parts:- (i) feature based methods, (ii) model based methods , (iii) hybrid methods. In this paper we use feature based method to find the centre of eye. This method helps in localisation of eye centre efficiently, precisely and tracks the centre of eye in low resolution images and videos (real time tracking using webcam).

Figure 1.1: Multi-stage approach for eye centre localisation. A face detector is applied first; based on the face location rough eye regions are extracted (left), which are then used for a precise estimation of each eye centre (middle and right)

In feature based localization of eye centre a step by step scheme is followed. Following are the steps used to implement eye centre localization(i) To define the centre of a (semi-) circular pattern as a point for eye centre localization where the highest degree of the gradient intersect in the image. We use mathematical function which defines the maximum range at the centre of the circular pattern [3]. This mathematical function drives a fast iterative scheme. (ii) After finding the centre of eye we tracked the movement of pupil in the real time using webcam in opencv. Then reviewing the earlier literature about the eye appearance and enhance the hardiness (iii) We use simple post processing techniques to overcome the limitations that arises due to the prominent eyebrows, spectacles, and reflection inside the glasses. The result that obtained using this method is highly accurate for low resolution images and real time tracking of eye movement using low cost webcam.

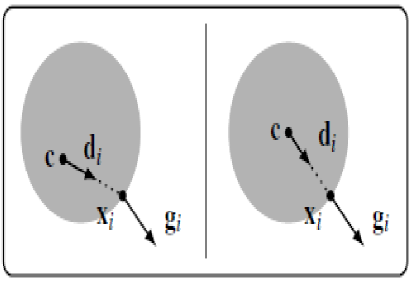

Figure 1.2: Artificial example with a dark circle on a light background, similar to the iris and the sclera. On the left the displacement vector di and the gradient vector gi do not have the same orientation, whereas

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on the right both orientations are equal.

In some paper other author have proposed a new approach using pre-defined sub templates which are segmented in lines like face eyes nose, mouth. First step is to match face with pre-defined face template using correlation and to verify it by comparing it with the acquired image. The recommended approach follows two steps: - first is to design a correlation function with the face properties and other is to find existence of face. These steps are necessary in this approach because it can easily detect the face even in the presence of noise or low light [4]. In this paper the approach which is follows is the multi resolution template to test the similarities of the faces like curves using edge detectors and then combing them to get result and detect faces. This approach is also known as mosaic template because it needs the information about the location of parameters given at the particular resolution point. On adding the subsequent images this approach checks 37 features of the face which are like position of eyes nose, mouth or location of eyebrows and outline of the head with respect to the size and the shape of the face. In conclusion this approach involves fitting curves and edge detection for face detection [5]. In this paper detection of the face is done from the Eigen faces which is the principal component for face detection although these features do not relate to the facial features such as eyes, nose and mouth. The study is based on computational methodology which uses information theory and physiology of the face to get the information accurately. This methodology detects features accurately in spite of different positions of head and identify the face and then identifies various parameters like eyes nose etc. detection of face in 2D makes the calculation easy instead of 3D [6]. In this paper author analyse the value of cheap eye-tracker in which the hardware contains single webcam and a Raspberry Pi device. His main target is to design such device which provides acceptable performance in a low cost or affordable cost [7].

II. LOCALIZATION OF EYE CENTRE

Centre localisation of any circular object can we found by using the vector field analysis of the image gradient. This is also used for localisation of centre of eye. According to the study conducted by Kothari and Mitchell the strong contrast between iris and sclera causes issues in flow field character [8]. They designed a line through the whole image by using the orientation of each gradient vector to create accumulator bin every time this line passes through centre of the eye. Estimated eye centre denoted where these lines intersect and is also called as accumulator bin. However in their approach they did not considered the issues caused by eyebrows, eyelids or glasses. Their approach was only for discrete images and no mathematical formula was used. In this project we are going to use vector field of the image gradient as well as provide a mathematical formulation approach for the vector field characteristics [9]. And we also defined mathematical relationship between the possible centre and orientations of all possible gradients. Suppose possible centre be ‘c’ and at position xi the gradient vector is gi. Then the di which is the normalised displacement vector and have same orientation except sign as the gradient gi (see fig 1.2) the effect of vector field of image gradient can be reduced by using dot products between the normalised displacement vectors (related to fixed centre) and gi gradient vector. An image with pixel positions xi, i 2 f1; Ng, centre c of a circular object in is then given by

$$C^* = \arg\max \left\{\frac{1}{N} \sum_{i=1}^{N} (d_i^T g_i)^2\right\} \quad (1)$$

$$d_i = \frac{x_i - c}{||x_i - c||_2}, \forall i: ||g_i||_2 \quad (2)$$

In order to get equal weight for all pixel positions the displacement vectors di are set to unit length. Linear changes in lighting and contrast the gradient vectors should also be set to unit length to improve robustness. Fig 2.1 shows the calculation of some of products for different centres at which the objective functions will have the strong maximum at the centre of pupil.

By considering gradient vector with sufficient magnitude i.e. ignoring the gradients in homogenous region evaluation complexity can be decreased. Image gradient partial derivative gi is given by

$$g_i = (\partial I(x_i, y_i) / \partial x_i, \partial I(x_i, y_i) / \partial y_i)^T$$

But the other algorithms for evaluation of image gradient do not sufficiently change the behaviour of the objective function [8]

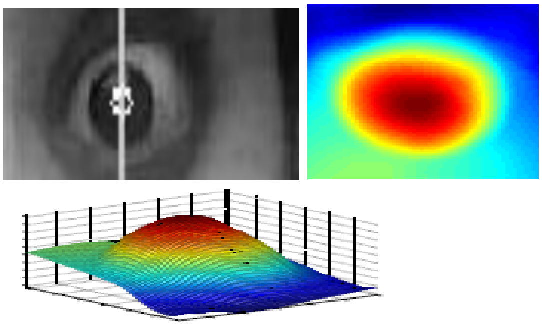


Figure 2.1: Evaluation of (1) for an exemplary pupil with the detected centre marked in white (left). The objective function achieves a strong maximum at the centre of the pupil; 2-dimensional plot (centre) and 3-dimensional plot (right).

A. Prior knowledge and post processing

In some situations the maximum is not well defined and there are some local maxima which give false estimation like dominant eyelids and eyelashes or wrinkles with the combination of low contrast between eyes and sclera which gives illusion of eye centre [10].since we already know this we can create a robust system which can encounter this type of situations. The pupil is basically a dark in maximum cases as compared to the sclera and the skin then w_c weight is for each achievable centre c. Integration of this weight w_c in objective function leads to

$$\arg_c\max \left\{\frac{1}{N} \sum_{i=1}^{N} w_c (d_i^T g_i)^2\right\} \quad (3)$$

Whereas w_c = I_(cx;cy) is the grey value at (cx;cy) of the smoothed and inverted input image I. To avoid the problems that occur due to the bright outliners like reflections of glasses image required smoothed by using e.g. Gaussian filter. The value of objective function does not depend on the changes in the parameters of low cost filter. If the image contains the eye then the result of this squared dot product gives accurate results [11]. On the other side when multistage is applied, which is shown in figure 1.1 In contrary if the image contains different structures such as dark hair growths glasses or hair the reflection of glasses show significant image gradient which is not similar to the image gradient of pupil. Therefore because of this issue the estimation of eye centre is little inaccurate and other structures will always be there that is why we use post processing to overcome these issues in this approach we apply threshold to the maximum value of objective functions, and all of the

image border values that are connected to the image are removed. Then, we calculate the maximum of the remaining values use these for eye centre location [12]. Basically according to the experiments the value of the threshold does not have significant on determining the centre of eye.
Therefore it is better to set this threshold to 90 percent of the overall maximum.

B. Evaluation

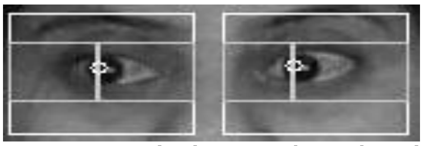
Dissimilarity in the location of the subject, its brightness as well as their posture is to be considered for the localisation of eye centre. Other than this subject may wear spectacles and have some curly hairs near the eyes. In some cases eyes of the subject get closed and goes far away from the camera are not noticeable because of shadow or of reflection of glasses. Moreover the resolution of camera is also very low, because of this reason we apply multi-stage property, in which face is detected initially by using a boosted cascaded face detector this algorithm is already proved as a efficient algorithm the other [13]. On the premise of recognised position of face and anthropometric relations we identify the position of unpleasant eye region on the basis of size of identified face. After this detection of rough eye region the estimation of centres of eye is precisely detected by the desired method to measure the precision of the rough and ready eye centre we measure the accuracy of normalised error, which represent the error which is got by the rough identification of both eye. This calculation is given by [14]. And is defined as:

$$e \leq \frac{1}{d}\max(e_1, e_r) \qquad (4)$$

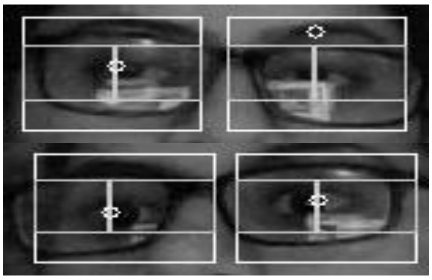
Where e_1, e_r are the Euclidean distances between the predicted and the correct left and right eye centres, and d is the distance between the predicted eye centres. In the eye localisation method has the following characteristics (i) $e \leq 0.25 \approx$ distance between the eye centre and the eye corners, (ii) $e \leq 0.05*2 \approx$ diameter of the iris, and (iii) $e \leq 0.025*2 \approx$ diameter of the pupil. Thus, the method that should be used for eye tracking must not only gives a high performance for $e \leq 0.25$ but also gives the better result for $e \leq 0.05$.small change either less or equal to 0.25 in an error will only illustrate the predicted centre which might be placed within the eye, but this prediction cannot be used in identifying the accurate eye tracking.

III. RESULT

The approximate result of the proposed method is shown in fig3.1.



a) Accurate eye centre localisation with or without glasses



b) In accurate eye centre localisation with glasses

Fig 3.1. eye centre localisation accuracy

It can be seen that the result gives a precise centre prediction not just for overwhelming pupil; in addition to that it gives the precise centre of eyes within the site of spectacles shadows low contrast of hairs. This experiment indicates the solidness and demonstrates that the strategy which followed can follow up successfully with number of issues that happened during eye tracking using low cost webcam. Eye centre identification may be not accurate when eye is not completely opened or there is a more reflection effect on the eye then this will influence the pupil of eye by the noise, therefore the squared dot product is contributed less than the contribution of gradient along the eyebrows or eyelids. Calculated result is shown in fig3.2 measurement of accuracy is shown as e, e_{better} ,e_{avg}. Using equation 4 we get accuracy 99% for pupil localisation without glasses.

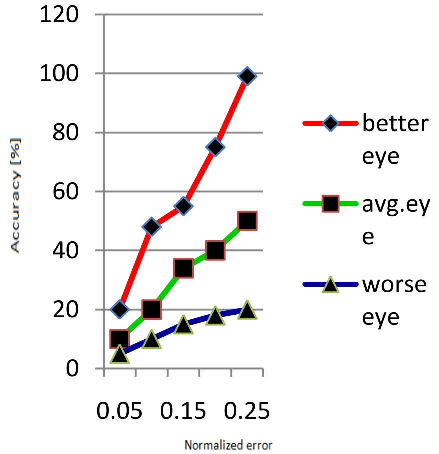


Fig 3.2: Quantitative analysis of the proposed approach. In order to give upper and lower bounds, the accuracy versus the minimum (better eye, ebetter), the maximum (worse eye, e) and the average (avg. eye, eavg) normalised error are shown. Some characteristic values are given explicitly.

After the localisation of both the left and right eye followed the movement of pupil in a real-time webcam as shown in fig3.3

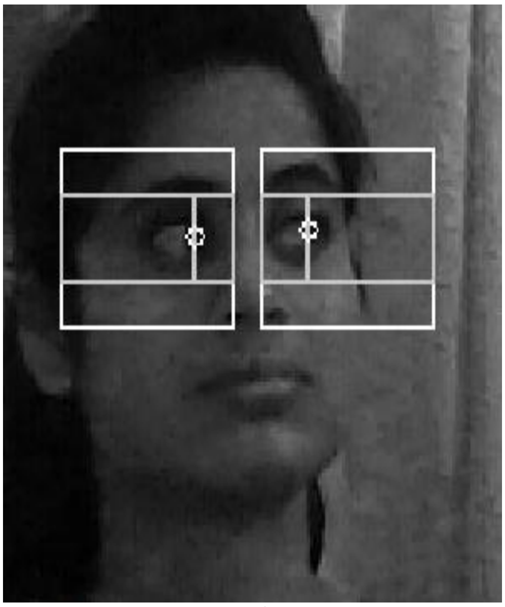


Fig.3.3.:-Tracked movement of pupil in real time using webcam.

IV. CONCLUSION

After a complete research a novel approach for correct eye centre localization is

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recommended based on image gradient which is compatible in all conditions like low resolution, reflections etc. In this calculation of the dot product between the displacements vector of a centre and the image gradient is done.

The position of the maximum of this function is at the point where maximum gradient vectors intersect and thus to the eye's centre. This method gives the invariant result on the changes of scale, pose, contrast and variations in illumination and also measure the accuracy of eye centre localisation without glasses which is 99% for pupil. This research enables future scope in varieties of fields because using this we can recording of eye movements and positions of eye which help to develop application in number of fields like in education, medical, physiological etc.

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