



Research Paper

Eye centre localisation using low cost webcam

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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, the 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, the software opencv3.0 and visual studio 2015 with low cost and low resolution camera is used. 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 study which has only dot product makes possible to achieve the objective. The maximum position 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.

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INTRODUCTION

Humans are much like computers, they receive inputs from their sensory organs such as eyes, ears, skin nose etc. and produce output through their actuators such as hand feet mouth etc. The study of sensory body parts of the human body can be used to generate a new concept, that is, eye tracking which is constructed 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 (Noureddin et al., 2005). Various applications have been developed on detecting and tracking of human's eye. Eye tracker works by computing the person gaze point or the area where it is fixed and constructing into a 2D or 3D plane which is referred to 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, such as brain computer interface face detection or face matching extensively, use eye detection or localisation method

(B'ohme, et al., 2006). There are number of algorithms which can be used to locate eye centre. The 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 are roughly divided into three parts:- (i) feature based methods, (ii) model based methods and (iii) hybrid methods. In this study, 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).



Figure 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 localisation of eye centre, a step by step scheme is followed. The following are the steps used to implement eye centre localisation: (i) To define the centre of a (semi-) circular pattern as a point for eye centre localisation where the highest degree of the gradient intersect in the image. We used mathematical function which defines the maximum range at the centre of the circular pattern (Zhou and Geng, 2004). 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 hardness (iii) We used simple post processing techniques to overcome the limitations that arises due to the prominent eyebrows, spectacles, and reflection inside the glasses. The result obtained using this method is highly accurate for low resolution images and real time tracking of eye movement using low cost webcam (Figure 2).

In some study, the author have proposed a new approach using pre defined sub templates which are segmented in lines such as 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 involves 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 (Sakai et al., 1969). In this study, the approach which 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

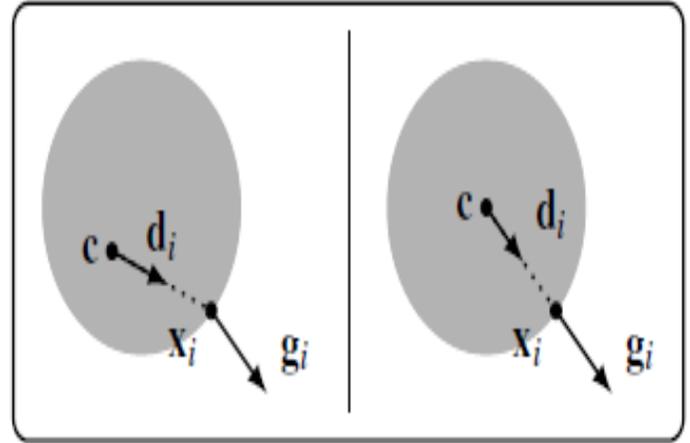


Figure 2: Artificial example with a dark circle on a light background, similar to the iris and the sclera. On the left the displacement vector d_i and the gradient vector g_i do not have the same orientation, whereas on the right both orientations are equal.

template because it needs the information about the location of parameters given at the particular resolution point. In adding the subsequent images, this approach checks 37 features of the face, such as 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 etc. In conclusion, this approach involves fitting curves and edge detection for face detection (Craw et al., 1987). In this study, detection of the face is done from the Eigen face 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 the head and identifies the face and then identifies various parameters, such as eyes, nose etc. Detection of face in 2D makes the calculation easy instead of 3D (Turk and Pentland, 1991). In this study, the authors analysed 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 that provides acceptable performance in a low cost or affordable cost (Fernando et al., 2014).

LOCALISATION OF EYE CENTRE

Centre localisation of any circular object can be found 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 (1996), the strong contrast between iris and sclera causes issues in flow field character. They designed a line through the whole image 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 accumulator bin. However, in their approach, they did not consider 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 (Niu et al., 2006). Also, mathematical relationship between the possible centre and orientations of all possible gradients will be defined. Suppose the possible centre is '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 (Figure 2), the effect of vector field of image gradient can be reduced using dot products between the normalised displacement vectors (related to fixed centre) and gi gradient vector. An image with pixel positions xi, i = 1; N; Ng, centre c of a circular object in is then given by:

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

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

To obtain equal weight for all pixel positions, the displacement vectors di are set to unit length. For linear changes in lighting and contrast, the gradient vectors should also be set to unit length to improve robustness. Figure 3 shows the calculation of some of products for different centres at which the objective functions will be stronger at the centre of pupil.

By considering gradient vector with sufficient magnitude, that is, 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 (Kothari and Mitchell, 1996).

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 (Kroon et al., 2008). Since this is already known, we can create a robust system which can encounter this type of situations. The pupil is basically dark in maximum cases as compared with the sclera and the skin. Then wc weight is for each achievable centre c.

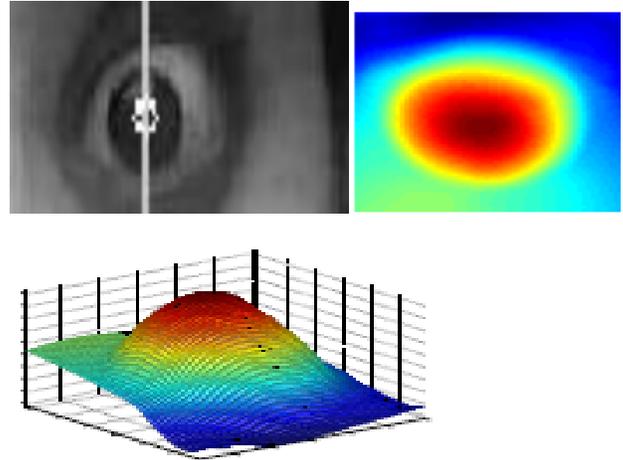


Figure 3: Evaluation of (1) for an exemplary pupil with the detected centre marked in white (left). The objective function achieves a strong maximum at the centre of the pupil; 2-dimensional plot (centre) and 3-dimensional plot (right).

Integration of this weight wc in objective function leads to:

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

Whereas $w_c = I_c(x_c; y_c)$ is the grey value at $(x_c; y_c)$ of the smoothed and inverted input image I. To avoid the problems that occur due to the bright outliners like reflections of glasses, the image needs to be smoothed 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 (Mohamed et al., 2007). On the other hand, when multistage is applied, which is shown in Figure 1, and on the contrary if the image contains different structures such as dark hair growths glasses or hair, the reflection of glasses shows significant image gradient which is not similar to the image gradient of pupil. Therefore, as a result of this issue, the estimation of eye centre is little inaccurate and other structures will always be there; hence, we used post processing to overcome these issues in this approach and apply threshold to the maximum value of objective functions. Thus all of the image border values that are connected to the image are removed. Then, we calculated the maximum remaining values used for eye centre location (Yarbus, 1965). Basically, according to the experiments, the value of the threshold is not significant in determining the centre of eye. Therefore, it is better to set this threshold to 90% of the overall maximum.

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, the eyes of the subject get closed and go far away from the camera and are not noticeable because of shadow or of reflection of glasses. Moreover the resolution of camera is also very low and as a result, we applied multi-stage property, in which face is detected initially using a boosted cascaded face detector. Thus, this algorithm has already proved a more efficient than the other (Viola and Jones, 2004). On the premise of recognised position of face and anthropometric relations, we identified 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 measured the accuracy of normalised error, which represent the error obtained by rough identification of both eye. This calculation is given by Jesorsky et al. (2001). And is defined as:

$$e \leq \frac{1}{d} \max(e_l, e_r) \tag{4}$$

Where e_l, 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. 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.

RESULTS

The approximate result of the proposed method is shown in Figure 4.

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 the number of issues that happened during eye tracking using low cost webcam. Eye centre identification may not be accurate when eye is not completely opened or there is a more reflection effect on the eye, thereby influencing the pupil of the eye by the noise. Therefore, the squared dot product contribution is less than the contribution of gradient along the eyebrows or eyelids. The calculated result is shown in Figure 5; measurement of accuracy is shown as e, e_{better}, e_{avg} . Using Equation 4, we obtain an accuracy of 99% for pupil localisation without glasses.

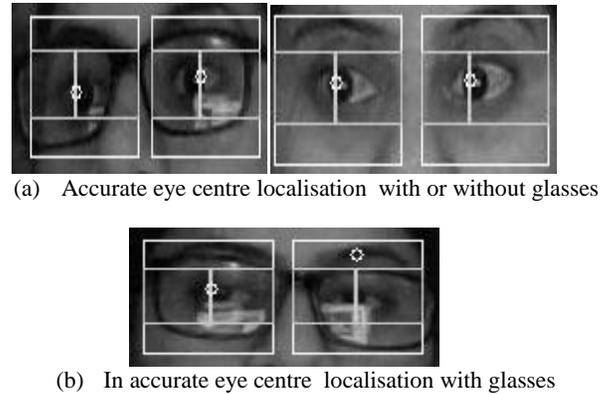


Figure 4: Eye centre localisation accuracy.

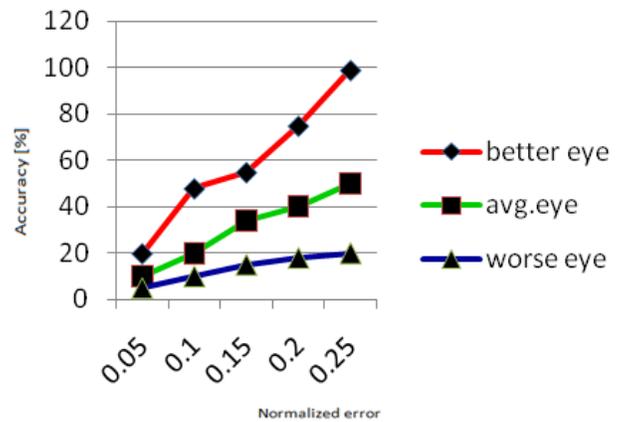


Figure 5: Quantitative analysis of the proposed approach. In order to give upper and lower bounds, the accuracy versus the minimum (better eye, e_{better}), the maximum (worse eye, e) and the average (avg. eye, e_{avg}) normalised error are shown. Some characteristic values are given explicitly.

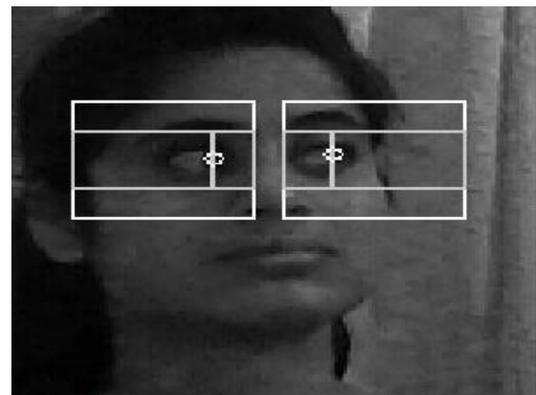


Figure 6: Tracked movement of pupil in real time using webcam.

After the localisation of both the left and right eye, there followed the movement of pupil in a real-time webcam as shown in Figure 6.

Conclusion

After a complete research, a novel approach for correct eye centre localisation is recommended based on image gradient which is compatible under all conditions, such as low resolution, reflections etc. In this study, calculation of the dot product between the displacements vector of a centre and the image gradient is done.

The maximum position 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 measures the accuracy of eye centre localisation without glasses which is 99% for pupil.

REFERENCES

- Böhme M, Meyer A, Martinetz T, Barth E (2006). "Remote eye tracking: State of the art and directions for future development". In Proceedings of the 2nd COGAIN, Turin, Italy. pp. 10-15
- Craw I, Ellis H, Lishman JR (1987). "Automatic extraction of face-features". *Pattern Recognit. Lett.* 5(2): 183-187.
- Fernando V, Vilarino F, Sanchez FJ (2014). "A cheap portable eye-tracker solution for common setups". *J. Eye Mov. Res.* 7: 1-10.
- Jesorsky O, Kirchberg K, Frischholz R (2001). "Robust face detection using the Hausdorff distance" In Proceedings of the 3rd AVBPA, LNCS, Halmstad, Sweden. Springer, pp. 90-95.
- Kothari R, Mitchell J (1996). "Detection of eye locations in unconstrained visual images". In Proceedings of the IEEE ICIP. 3: 519-522.
- Kroon B, Hanjalic A, Maas S (2008). "Eye localisation for face matching: is it always useful and under what conditions?" In Proceedings of the CIVR, Ontario, Canada. ACM. pp. 379-388.
- Mohamed AO, Da Silva MP, Courboulay V (2007). "A history of eye gaze tracking. Hal-00215967, vol. 1.
- Niu Z, Shan S, Yan S, Chen X, Gao W (2006). "2d cascaded adaboost for eye localization", In Proceedings of the 18th IEEE ICPR. 2: 1216-1219.
- Noureddin B, Lawrence PD, Man CF (2005). "A non-contact device for tracking gaze in a human computer interface". *Comput. Vis. Image Underst.* 98(1): 52-82.
- Sakai T, Nagao M, Fujibayashi S (2004). "Line extraction and pattern detection in a photograph". *Pattern Recognit.* 1(3): 233-248.
- Turk M, Pentland A (1991). "Eigen faces for Recognition". *Cogn. Neurosci.* 3(1): 71-86.
- Viola P, Jones M (2004). "Robust real-time face detection". *IJCV.* 57(2): 137-154.
- Yarbus AL (1965). "Eye movements and vision", Original Russian edition published in Moscow.
- Zhou Z, Geng X (2004). "Projection functions for eye detection. *Pattern Recognition*", IEEE. 37(5): 1049-1056.

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