## Diego Torricelli , Silvia Conforto , Maurizio Schmid , Tommaso D'Alessio, A neural-based remote eye gaze tracker under natural head motion, Computer Methods and Programs in Biomedicine, v.92 n.1, p.66-78, October, 2008

### Problem

The presented work provides a method that is robust to light conditions and head location change. Also, initialization of the system is simplified compared to other gaze detection systems.

### Method

1. Blink detection is used to find the location of the eyes. To detect blinks difference of two consecutive frames are calculated, then converted to binary. Morphological open is applied to the result. Resulting clusters in the image are eye candidates; to verify the candidates correspond to real eyes a set of criterias needs to be satisfied: Number of clusters should be two, ratio between cluster size and distance between two clusters should be in a range, the inclination of the line passing through center of the clusters should be between +30° and -30°, size of clusters should not be too different than previously detected eye candidates. The clusters locations are assumed to correspond to eye locations.
2. Edge detection, specifically Sobel operator, followed by a modified version of Hough transform is applied to the eye location to find the iris as a circle.
3. Inner corner of the eye is detected through searching for the most lateral white pixel in a thresholded search window that does not include iris.
4. To detect external corner of the eye ten-level quantization is applied in a search window that starts from the point iris ends. External extremity of the resulting shape is considered to be external corner.
5. It is stated that iris and corners of the eye are tracked in subsequent frames using template matching and sub-pixel approximation, although no details about the mentioned methods are provided.
6. 12 parameters, like distance between iris center and the external corner, are extracted from the iris and eye corner locations. Two different types of neural network, multilayer perceptron (MLP) and general regression network (GRNN), with 12 inputs and 1 output is built to compare the performance of both. The only output represents x or the y value of the gaze on screen meaning two networks are build for each type.

### Dataset

17” screen is divided into 15 zones with 3 rows and 5 columns. Subjects are told to follow a white cursor moving from one zone to another for each trial. During the process, for every zone 7 frames are recorded; 5 of frames are used for training 2 of them are used for validation. Trials are done with different head displacements and lighting conditions. All the images belong to frontal views of the face although it has not been mentioned explicitly.

### Results

GRNN is proved to be a better choice compared to MLP for the stated constraints. Two types of performance values are considered, first one is the angle between the estimated and actual target of the gaze, and second one is the zone hit/miss ratio. The mean zone recognition ratio is found to be 94.7% and mean and standard deviation of the gaze error for X and Y coordinates are 1.4°±1.7° and 2.9°±2.2° respectively.

## Haiyuan Wu , Yosuke Kitagawa , Toshikazu Wada , Takekazu Kato , Qian Chen, Tracking Iris contour with a 3D eye-model for gaze estimation, Proceedings of the 8th Asian conference on Computer vision, November 18-22, 2007, Tokyo, Japan

### Problem

Most of the present methods for gaze detection often confused with the eyelid contours that is occluding iris contour. In the presented work a 3D eye-model with eyeballs, irises and eyelids are designed.

### Method

1. A 3D model for the eye with eye lids is represented. This gaze estimation model consists of eyeball center and radius, iris radius and center, and eyelids which are defined as B-spline curves with 4 control points for each eye.
2. Iris contours are tracked with particle filter utilizing a likelihood function of irises that takes advantage of the iris having lower brightness than its surroundings.
3. Because the brightness difference of eyelid with its surrounding is not as big as like iris only image gradient is used to estimate the likelihood of eyelid.
4. To estimate eye gaze positions of eye corners, both external and internal, are marked manually in the input image, and the eyeball parameters are assumed to be equal to average values of people. Other parameters are acquired using particle filter using video input.

### Dataset

Dataset is collected using markers on the wall where subject is located 2 m far from camera and camera is located 4 m far from wall. There are 9 markers on the wall where the distances between markers are 20 cm. Each subject stared at a marker for 2 seconds in order.

### Results

The mean of difference between estimated and actual eye gaze direction for x direction was observed about 2.5° and for y direction 3.5° using proposed method.

## Hirotake Yamazoe , Akira Utsumi , Tomoko Yonezawa , Shinji Abe, Remote gaze estimation with a single camera based on facial-feature tracking without special calibration actions, Proceedings of the 2008 symposium on Eye tracking research & applications, March 26-28, 2008, Savannah, Georgia

### Problem

Most of the present gaze estimation methods are far from being usable because of their complex calibration procedures and usable only in experimental setups. In this work a method that is applicable to daily life situations are presented.

### Method

1. Gaze direction can be expressed in terms of 2D positions of the eyeball centers, 2D position of iris centers and the radius of the eyeballs. Although iris centers are observable in the images other parameters are not.
2. Face position is determined using Six-Segmented Rectangular (SSR) filter. This filter also provides rough positions of facial features.
3. Using Lucas-Kanade tracker facial features are searched around the previously found rough positions and extracted.
4. By capturing N images of the user, face position and pose can be retrieved using Lucas-Kanade method. Knowing the eye regions in the image, eye regions are divided segmented into three regions which are skin, iris and sclera region. Then this 3 regions are back projected to 3D space meaning estimation of the eye parameters.
5. Once the eye parameters are acquired using the model presented earlier the gaze direction can be calculated by extracting facial features in the given image and finding the iris.

### Dataset

Dataset is collected using 28 markers arranged onto the wall on 4 rows and 7 columns where subject sits 220 cm far from the wall; the camera is placed in front of the wall 20 cm away from it. The subject looked at each marker for 5 seconds in order. Estimation accuracy is computed for five subjects.

### Results

Average estimation error is 5.3° horizontally and 7.7° vertically. Gaze detection was detected with acceptable error rate even if the user was wearing glasses, or subject’s head pose was changed.