Simple Gaze Tracker

SIGB Assignment 1

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Introduction

This is the first mandatory assignment for the course SIGB F2013. In this assignment we'll implement a simple gaze tracker. This will be done in the programming language python with help from the opencv and numpy libraries.

This report is an attempt to document what has been done to make this gaze tracker.

The basic structure for each section will be a short introduction of the goal of the section, followed by the theory behind our approach ending with a description of our actual implementation with visual aids used for documentation. Additionally we will accompany the report with captured videos demonstrating the usage of the eye tracker

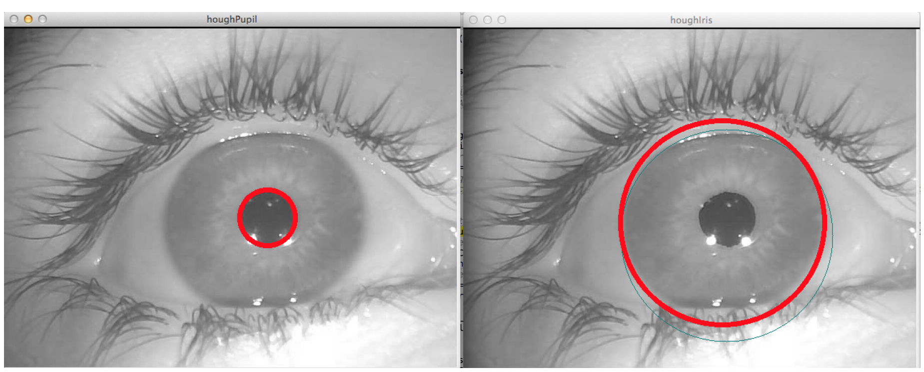


Figure 1: Eye located with hough

Pupil detection

Overall rationale and theory

The eye consists of several distinct features such as pupil, iris, limbus and sclera. The position of these can aid in correctly determining the gaze. Detecting these features is therefore a good starting for a gaze tracker implementation, but it poses some challanges in correctly identifying each component, and filtering away noise.

Of these features one of the easiest to recognize is the pupil, as it is the darkest part of the eye. Furthermore it's good starting point, as it is surrounded by the other eye components. The challenges/noise in locating the pupil is mostly due to glints/reflections of light.

As mentioned, the pupil is the darkest part of the eye. Therefore a good way to find is to find an intensity value which can seperate it from the background. This is called thresholding, and will be explained in the following sections. Following these is a description of a method automatically setting this threshold value, clustering.

Thresholding

Thresholding is a form of point processing used for seperating areas of an image based on intensity in these areas. The desired end result of this method is a binary image with the foreground (object) in one color and the background (everything else) in a different color. This is usually black and white respectively. This will effectively seperate the foreground from the background for us, leaving us with only the contours. In that sense we loose information and granularity in the image, but since we're only interested in position we haven't lost anything important.

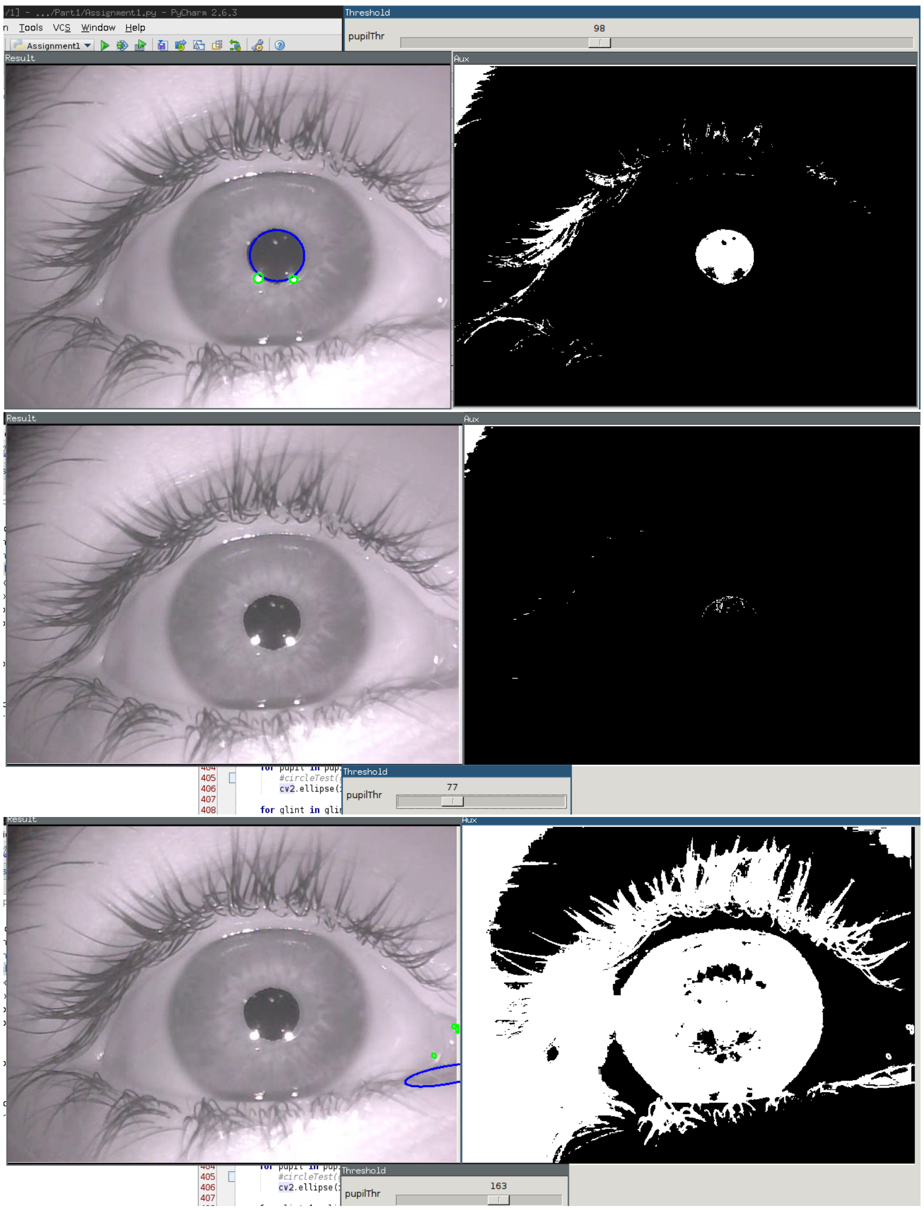
Theory

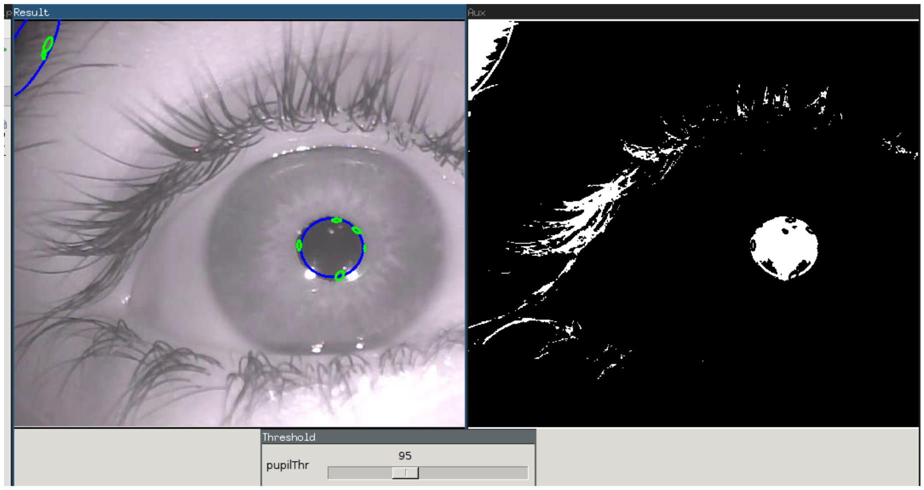
As with all point processing methods the basic theory behind thresholding is applying a calculation to every pixel in the image, effectively changing the value of that pixel. We know that the end result is a binary image, following this each pixel will be transformed into one of two values. We've so far operated on byte images so the max value is 255 and the min value is of course 0. For clarity we will assign each pixel either the min or the max value. Thus thresholding can be expressed as the following with T being the assigned Threshold value and f being the function applied to each pixel:

if f$(x, y) \leq T \quad then\, g(\text{x,y}) = 0$ and if f$(x, y) < T \quad then\, g(\text{x,y}) = 255$

Performing these operations will leave us with an image where only the contours are visible. We can then analyse the properties of these contours to find which one is most likely to be a pupil

Our implementation





K-means clustering

In this section it will be demonstrated how a form of machine learning is applied in order to perform supervised classification in order to semi-automatically set a proper thresholding value

Clustering is the practice of grouping a set of elements into several smaller groups of elements with similar features. It has a wide range of applications within datamining and different types of analysis. Obviously what will be demonstrated here is it's use within image analysis. Clustering isn't a specific algorithm. Rather it's the task we wish to perform in order to achieve our goal. In this assignment we've used the k-means algorithm for this

K-means is a clustering algorithm which can group a number of observations/data points into k number of clusters based on their nearest mean value.

The properties of the k-means algorithm (k groups based on mean intensity) combined with an existing knowledge of the properties of the eye(the pupil is the darkest part) makes it possible to use k-means for setting a threshold value automatically

Theory

The basic idea behind k-means clustering is to iteratively run through a dataset assigning points in their correct cluster based on previously selected values. Initially k points a selected and denoted as a center for it's cluster, c_1, . . . , c_k. These points can be selected on random or based on some guessed distribution. On each run through the dataset every points is examined. For each point the closest c is found, and the point is marked as to belong to this cluster. Once all points have been examined and placed in a cluster, the mean value of each cluster is calculated as c_i_val. Compare the mean value for the cluster with the previously recorded value of c_i_val. If it has changed, another run through is performed. This continues until a desired level of precision is achieved or amount of runs have taken place

When we have done this we have k different threshold values to choose from, given our knowledge of the pupil, we will choose the one with the lowest mean value (c_i_val).

Our implementation

There are a couple of possible caveats for this approach. Firstly there is an element of uncertainty in exactly how the clusters will be distributed. We need therefore to have a high enough k value to be sure to get the right cluster. There is also some uncertainty about whether the pupil always belongs to the darkest cluster. If for instance our k-value is too high, and there exists a darker region in the image (dark spot on the skin for instance) then the value of this cluster will be chosen as a threshold value, and we might miss the pupil

Through trials it was found that 8 is a good value for k