Eye tracking

Students

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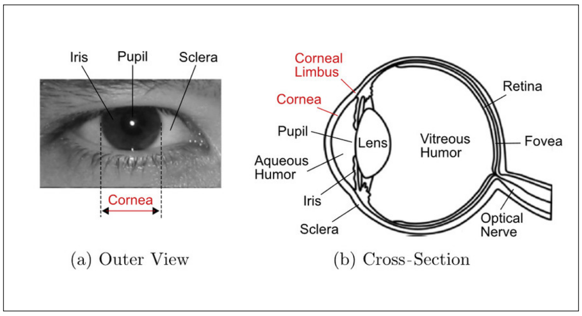
Introduction: Nowadays eye tracking is a widespread application in several fields particularly in medicine, psychology, human-computer interaction and other visual systems. This thesis deals with an eye tracker, where the human eye is tracked using image processing and computer vision algorithms. The task is to localize the pupil diameter and the pupil center. Measuring the pupil center on an image is a prerequisite for gaze tracking. Hence, the accuracy of the measured pupil center is determined to make a prediction of the angular gaze tracking error. To demonstrate the pupil detection a face image is overlayed by a circle around the detected pupils boundaries.

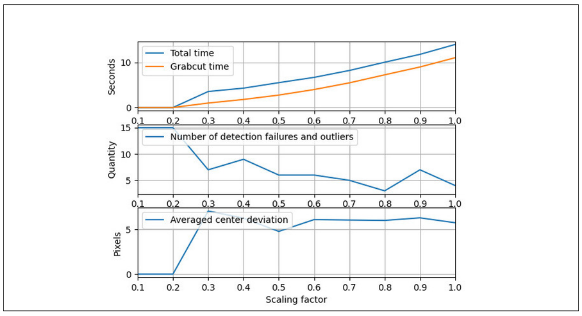
Approach / Technology: In our approach we first use Mediapipe Face Mesh, which is a lightweight application that detects 468 face landmarks, including the rough eye position, with low computational load. The eye landmarks provided are used for segmentation of the eye regions. In a next step we apply a GrabCut algorithm, which extracts the foreground in an image, based on color data of pixels. In our case we use GrabCut to extract the iris shape. We achieve that by creating circular masks on the irises using the rough position of the Face Mesh landmarks. GrabCut then creates a model based on pixel colors with our initial labeling of pixels. Using a minimum cut algorithm GrabCut segments the image along a line, where the color difference between pixels is maximal, into foreground and background. Selected points along the contour of the previously extracted iris shape are used to fit a circle by a RANSAC algorithm. The center of said circle is our pupil center point. Using the relation between the center point and other face landmarks, we determine the current angle of the eye, which is, as desired, independent of head movement relative to the camera.
Furthermore, we measure the pupil diameter using a method called Ray propagation with energy attenuation. This method uses ideas and notions of physics of ray propagation. The algorithm yields a cluster of points near the pupil boundary. The detected points are put through a hierarchical clustering algorithm to filter out undesired points. Finally a circle is fitted over the still remaining points, again using RANSAC.
We also created comprehensive accuracy and time test functions, that allow us to specify which part of the program creates inaccuracies or demand high computing power. This allowes us to refine problematic parts of our programm, which greatly enhanced the capabilities of our application.

Result: In the end our application runs as intended. The application records a video of a human face with approximately 20cm distance to the camera. This video is processed offline and a video of the resulting eyes is generated.
We were able to detect the pupil diameter with an average deviation of 5.14 pixels on an image with the resolution of 2048x1536 pixels. The average deviation of the pupil center is 8.93.pixels which translates to an average deviation of 1.53°.

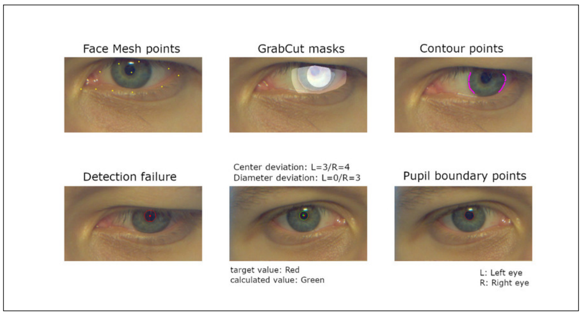
This figure shows a outer view and a cross section of the eye
www.sciencedirect.com/science/article/pii/S1077314211000725



Plots showing the time and accuracy response to downsampling of the Image
Own presentment



Test function that shows the results of the partial functions
Own presentment



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Subject Area
Image Processing and Computer Vision