A SYSTEM FOR EYE MOVEMENT TRACKING

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Abstract: The goal of this project is to design the real-time eye movement tracking system, realise it and perform measuring on several subjects to verify its functionality and precision. The eye movement tracking system consists of a camera attached to the camera holder mounted on subject´s head. The camera captures the eye of the subject and the measuring software detects the iris. The software then calculates the location the subject is looking at using the input video of the eye, the calibration results and the head movement measuring device.

Keywords: Camera holder design, eye detection, eye tracking system, image processing, OpenCV

1 INTRODUCTION

The tracking of the eye movement is a technique that enables us to gather large amount of information about the subject. Eye tracking technologies in today's society have a wide scale of applications used in many fields, ranging from medical research, security, sensors to marketing and advertising.

The eye movement tracking system is designed to be able to detect where the subject was looking during the test measuring and give the result of the test in a graph or a video output. The basic test involves system calibration, reading part, watching the picture and solving an easy maze. There are many possibilities of how to track the eye movement, for this project a single-camera system was chosen. The camera attached to the 3D printed camera holder scans the left eye of the subject and the measuring software then detects the position of the iris. Point of regard is then calculated using calibration results, real-time image processing result and the head movement correction. [1]

2 CAMERA HOLDER

To ensure the system's precision, the eye must be captured from the stable point in front of it. To provide a camera standing in the same position at all times, the camera holder has been designed. The design was drawn in SolidWorks and printed on 3D printer at school. The holder consists of four main parts: the forehead support, frontal extension and two clips for attaching the elastic band. The whole construction is shown on Figure 1.

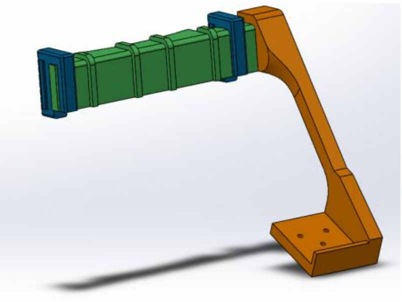

Figure 1: Camera holder model (left), Camera and its holder - application in video recording session (right)

The base of the whole construction is the forehead support. It includes grooves for attaching other parts and a curved front for stabilization and comfort of the tested subject, which is also achieved by a small pillow that is glued on it. The frontal extension is attached by adhesive onto the forehead support. Its bottom includes the camera attachment with three holes in it to secure the camera by screws. Securing the whole holder to the subject´s head is done by two clips glued to the forehead support as well. They are equipped with an elastic band that is supposed to go around the head.

3 VIDEO PROCESSING

Video processing consists of several parts such as iris detection, calibration, head movement correction and test evaluation software. The camera that was used to detect the eye is a web camera created by A4tech, type PK-910H, with Full HD 2 Mpx scanner, it captures video in up to 1920 × 1080 pixels resolution, with the maximum of 30 fps (frames per second) and supports auto focus. It is connected to the computer by USB 2.0.

The iris detection software is written in C/C++ programming language via Visual Studio and libraries of OpenCV. Visual Studio is an integrated development environment for Microsoft. It is used for computer programs, web sites and applications. Open CV (Open Source Computer Vision) is a library of programming functions focused on real-time computer vision. While the video runs real-time, the frames from the camera are processed separately as single pictures.

To simplify the work with the video, the image is first mirrored to create a mirror-like environment. The following operation divides the RGB picture into three separate matrixes, each including one colour channel. The application then processes the red channel matrix because the eye is the most distinguishable there, thanks to the best contrast proportions compared to the other channels.

Then the image is filtered to blur the homogenous areas using the normalized box filter. It smoothens the image and it also reduces less significant edges. A linear box filter is a spatial linear filter in which each pixel in the resulting image has a value equal to the average value of its neighbouring pixels in the input image. It is a form of low-pass filter that reduces noise. To find the edges in blurred image the Canny algorithm is used. The Canny algorithm reduces the amount of data that needs to be processed, accurately finds the edge points in the centre of the edge and prevents the image noise to create the false edges.

From the image of the edges it is easy to detect the circle that defines the iris by using Hough circle transformation. It finds circles in imperfect images by finding the circle "candidates" by "voting" procedure in the Hough parameter space. Candidates are obtained as local maxima in accumulator matrix, which is explicitly constructed for computing the transform. The parameters which define the found circle are *x* and *y* position of the circle centre and the circle radius. X and y coordinates are saved for further processing. Thanks to Hough transforms ability to detect a circle even when it is not fully visible, it is able to identify the eye when it moves in any direction (see Figure 2, left).

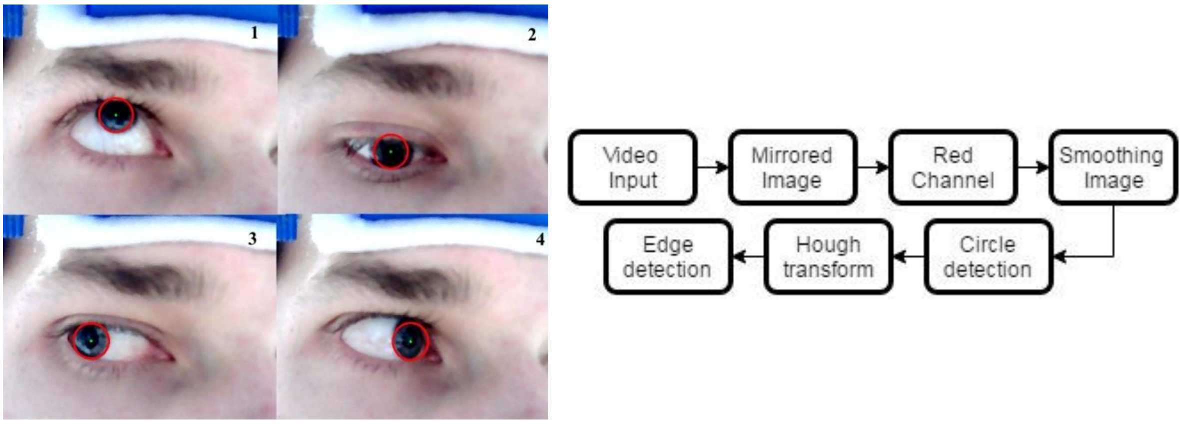

Figure 2: Detection during the eye movement (left) - up (part 1), down (part 2), left (part 3) and right (part 4) direction; Eye detection algorithm (right).

Using this whole method, the program is able to detect the eye in real time as a result of the first stage of the process. The video of the subject's eye, taken by the camera mounted in the camera holder, is processed and evaluated by the algorithm and prepares the project for further point of regard finding. For the eye detection algorithm see Figure 2 (right).

The second stage processes the eye centre positions during the time and compares them with calibration process results. The calibration process is based on test subject's full cooperation. One by one he looks at the points placed all over the screen of the calibration program. With each focus of his sight at the concrete point, the subject marks it by clicking on it with the mouse, at the same time he looks at it. The positions of the acquired points are then compared with the position coordinates of the eye, captured by the eye position detection software, at the same time exactly. This way the point of regard is found.

To prevent mistakes caused by head movement there is homogeneous transformation based on the data gained from the accelerometer and the gyroscope. This way it is possible to detect the change in 3D space and to recalculate it into changes in 2D. The homogeneous transformation matrix $\mathbf{T_i}$ (see equation 1) consists of information about translation (*T* positions in the matrix) and rotation (*R* positions in the matrix).

$$\mathbf{T_i} = \begin{matrix} R & R & R & T \\ R & R & R & T \\ R & R & R & T \\ 0 & 0 & 0 & 1 \end{matrix} \quad (1)$$

After detecting the point of regard while incessantly concerning the head movement, the testing of the subject may begin. The test is meant to consist of a reading part, watching the picture part and possibly an easy maze. The test will be repeated with several test subjects to compare the functionality and reliability of the method. The output of the testing will be a graph, a heat map or possibly a video recording of the computer screen with the exact point of regard changing in time. The whole process is captured in Figure 3.

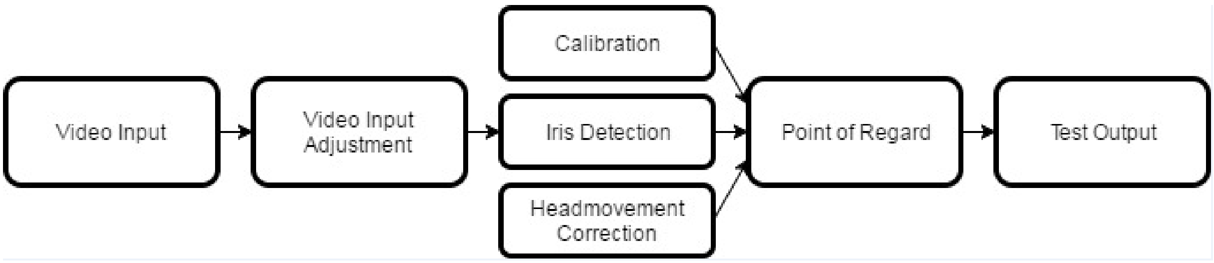

Figure 3: Eye tracking algorithm

4 SUMMARY

The goal of this project is to design a functional eye movement tracking system. It will include the camera, camera holder with rubber bands for head fastening, head movement measuring device, video processing software, point of regard calibration software and testing application with several possible outputs. The system uses one camera to capture the image of the eye. The project is a cheap version of the commercially used devices.

While writing this paper the camera holder is done and the eye detection is fully functional. The software for calibration is partially functional and its prepared for head movement correction data input. Testing application is being developed as well.

REFERENCES

[1] URBANOVÁ, L. A system for eye movement tracking, Brno: BUT FEEC, 2016. 30 p. Semestral thesis supervisor Assoc Prof Jan Mikulka. [cit. 12. 3. 2017].