Development of a method for adjusting the coordinates of the center of attention in the absence of fixation of the head

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Abstract. In this paper, the movement of the pupils is a biometric indicator that analyzes the emotional state of a person. Eyetracking using infrared illumination based on the determination of the displacement vector between the centers of the pupil and the shine of the cornea gives results with high accuracy, provided that the human head is fixed. A method for determining the coordinates of the center of attention in the absence of fixation of the head without using infrared illumination is proposed. The accuracy of determining the coordinates of the center of attention is improved by moving from a coordinate system associated with a fixed head to a coordinate system associated with a moving center of the pupil.

1. Introduction
Today, an important aspect of modernity is safety. For this, organizations are introducing the latest technology. Modern security systems use biometric data [1]. The security systems used are good, but no system can guarantee an absolute result. To approach the maximum reliability of the data, it is necessary to use an integrated approach. This will make the information received more valuable, and its application will become more extensive. The reaction of the pupil in response to the provided stimuli was chosen as a biometric indicator. By registering the time of fixation and the density of the trajectory of the gaze, one can judge the significance of the elements visible to a person [2]. Eyetracking, as a testing method based on tracking the movement of the pupil, allows you to unobtrusively assess the psychophysical state of a person. This method can track the natural reaction of the pupil, which is a subconscious mechanism that is difficult to fake or control [3]. Moreover, the disadvantages of such systems are the use of a large amount of equipment, the use of special glasses, the complex process of projecting the image on the screen, the increased number of images themselves and the use of rigid fixation of the subject’s head [4-6]. In a real video environment, you can increase efficiency by using non-rigid fixation of the head, while maintaining the reliability of the data. For this, it is necessary to develop a technology for adjusting the pupil’s track, which minimizes the displacement of the pupil’s track caused by the movement of the head and body of the test person. This, in turn, will increase the reliability of the data and will allow you to most accurately determine the emotional response that could be lost due to an uncomfortable posture or stress from a rigid fiction of the head during testing. This article describes a method for increasing the accuracy of tracking the pupil’s center of attention regardless of the position and movement of the subject’s head. The aim of the study was to develop a method for increasing the accuracy of tracking the pupil’s center of attention in the absence of rigid fixation of the human head. The following tasks were set: 1. to get a track of attention without distortion (head rotation angle 0º), to get a deliberately distorted track (head rotation by a certain angle), check the correction method at coordinate points.
2. Experimental
The installation mechanism (figure 1) consisted of an optoelectronic system. T7 Astro Camera Astronomical, 1X-100X optical zoom microscope lens. Studies by Kovalenko, V. B. Pavlenko, S. V. Cherny and V. Grekova explain that the minimum time for the formation of an emotion is about 300 milliseconds. On average, emotions last about 600 milliseconds. Thus, in our system, a video camera with a frequency of 30 frames per second allows you to register the formation of emotion. To study the reaction of the pupil to test objects, a helmet was developed that creates a rigid coordinate connection between the camera and the head, but does not limit the rotation of the head. A swivel mechanism with a height adjustment system is mounted on a vertical rack. It is equipped with a frame angle control system. The helmet itself is equipped with a soft layer for the comfort of the subject. The camcorder is mounted separately from the helmet. The installation itself is attached to a fixed table. The frame provides for the regulation of the helmet along the vertical axis with a range of 180 degrees. This allows you to study the center of attention track relative to different shooting planes. The frame is designed to minimize its impact during video recording on the head of the subject. In the occipital part of the frame is an adjustment screw that allows you to loosen or tighten the helmet on the head. Next, using the optoelectronic system, video recording of the movement of the pupil is performed. The internal time of the cameras is synchronized up to hundredths of a second. This allows you to establish the reason for the change in the size of the pupils. In total, more than 100 people took part in the experiment, including full-time and part-time students. Note that of all the results of the study, only those video files were selected on which people blinked infrequently. Because the blinking of the pupil affects its size. The pupil needs some time to restore its size to its original state. With frequent blinking, the video file consists mainly of the time to restore the original pupil size. Therefore, in order to avoid distortion of the obtained results, video files with frequent blinking were not taken into account in the analysis. The distance, for this installation with this monitor, between the test objects and the eye was at least 2.5 two and a half meters. The video process was carried out while minimizing the effect of illumination from the test object (taking into account its color) on the size of the pupils.

![Figure 1. Experimental setup.](image)

To obtain a pupil movement track without distortion, a helmet is put on the subject’s head. The swivel mechanism is set to 0 degrees. Next, using the optoelectronic system, video recording of the movement of the pupil is performed. To obtain a distorted track center of attention track using a rotary mechanism, the subject’s head rotates at a fixed angle from 0 to 15 degrees. Ceteris paribus. Further, the resulting tracks are superimposed on the calibration grid (figure 2 a, b).

3. Result and Discussion
During testing, the subject observed images of black dots on the slide, while tilting the head was not limited by anything. Obviously, a track with a head turn requires adjustment (figure 2a). Correction characteristics are presented in Table 1. Slides with points were shown to the subjects in order, and at
the end of the presentation a slide with all points at the same time (figure 3), with the points shifting relative to each other on the order of 30 minutes (table 1). Graph 1 (figure 2a) shows the pupil movement track, which requires adjustment, and graph 2 (figure 2b) shows the same track after correction.

![Graph 1](before_adjustment.png)

![Graph 2](after_adjustment.png)

**Figure 2.** Pupil movement track before (a) and after (b) adjustment.

When comparing the angular sizes with the obtained pupillograms, shifting the focus of attention by $8^\circ \ 0' \ 30''$ leads to a change in the size of the pupils $\Delta s / s \pm 0.02$. It should be noted that turning the head even 15 degrees horizontally leads to a significant distortion of the center of attention track, which makes it impossible to correctly track the pupil by visual stimulus. After using the method of adjusting the attention track, you can observe the duplication of tracks, due to the fact that in fact the person observed each point twice (first one, and then all at once). This adjustment reflected duplication, and also grouped the tracks relative to the coordinates of the points. This method makes it possible to compensate for the natural movements of the head and body of the subject, affecting the track of the center of the pupil. In this case, the person during the test will think and show a greater emotional response. He will not be distracted by thoughts about a device that affects the mobility of his head. Thus, the method of analyzing the movement of pupils by visual stimulus, even with non-rigid fixation of the head, can give reliable results.
Figure 3. Points for adjustment.

The diameter of Point ᴓ is 6 mm.

Table 1. Angular dimensions.

| distance between points | centimeters | angular dimensions, degrees | distance between points | centimeters | angular dimensions, degrees |
|-------------------------|-------------|-----------------------------|-------------------------|-------------|-----------------------------|
| 1-2                     | 35          | 8°0′30″                     | 7-8                    | 19.5        | 4°28′1″                     |
| 2-3                     | 31          | 7°5′44″                     | 8-9                    | 11          | 2°31′14″                    |
| 3-4                     | 17.5        | 4°0′33″                     | 9-10                   | 12.2        | 2°47′44″                    |
| 4-5                     | 1.5         | 0°20′38″                    | 10-11                  | 10.6        | 2°25′44″                    |
| 5-6                     | 35          | 8°0′30″                     | 11-12                  | 17.7        | 4°3′17″                     |
| 6-7                     | 11          | 2°31′14″                    | 12-13                  | 18.3        | 4°11′32″                    |

4. Methodology
The transition from the center of the visual stimulus to the center of the moving pupil is as follows. At the beginning, in the Image program outlines the pupils and separately the monitor image itself on the cornea (figure 4). The quality of this stage significantly affects the accuracy of the data. Here it is important to most accurately identify the pupil region and separately the image region on the cornea. This will minimize the error in calculating the center of mass of these sections.

Further, in the Image program determines the coordinates of the center of mass of the pupil and the separately selected reflection of the monitor on the pupil. This allows you to make a quality transfer of coordinate data to the grid. Then, the offset is calculated relative to the coordinate of the image of the monitor from the center of mass of the pupil. During the shooting, even if visually it seems that the person was not moving, the pupil’s attention track will still shift. Even a slight fluctuation can affect the interpretation of the results, since the relative amplitude of the graphs is small. Therefore, it is always necessary to calculate the displacement between the center of mass of the pupil and the center of mass of the monitor image on the pupil itself. Visualization of the results was done in Originlab2020. This adjustment allows you to more accurately track the pupil’s attention on visual stimulus even in the absence of rigid fixation the subject’s head.
5. Conclusion
In the course of the study, the following was established. A shift in the focus of attention by 8 ° 0'30" leads to a change in the size $\Delta s / s$ of the pupils $\pm 0.02$. Which is an order of magnitude smaller than the changes introduced by the emotion. Turning on the head on 15 degrees horizontally leads to distortion of the track of the center of attention, which makes correct tracking impossible. The proposed method allows you to minimize distortion by moving from a coordinate system associated with a fixed head to a coordinate system associated with a moving center of the pupil's. In the future, this method can be used in optoelectronic security systems.

Acknowledgments
The study was carried out with the financial support of the Russian Foundation for Basic Research in the framework of the research project 18-47-860018 p_a.

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