The empowerment of biometric systems of psychophysical research

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Abstract. Interest in detecting the psychophysical state of a person according to various biometric data (KGR, pupillography and profiling, etc.) is becoming more widespread every year. The most statistically reliable and resistant to counterfeiting systems are the identification of a person by the iris and face. Biometric identification systems can be combined. This paper presents proposals for improving the existing systems of recognition of the psychophysical state of a person.

1. Introduction
In today's world, special procedures are increasingly used to measure the unique behavioral and physical characteristics of a person. Biometric technologies are considered most often as automated or automatic methods by means of which recognition of the person's face according to his individual characteristics is carried out. The most common method of biometrics is facial and fingerprint recognition. [1] the Standard method of determining emotions, focused on mimic changes is good, but if a person is good at controlling himself, then it is difficult to recognize evil intentions, and sometimes it is too late. The advantage of using pupillography is an unambiguous biochemical uncontrolled reaction of the human body to the heard (seen) information, including changes in the size of the pupil [2]. Terrorists, sadists have a set of preferences, values, pleasures that differ (opposite) from ordinary people. The spatial and temporal resolution of modern digital video cameras allows video shooting with the desired resolution [3]. Been successfully applied to recognition system, the diameter of the pupils of potentially dangerous people, which represents an open threat. In these cases, the pupil identifies people who are in a state of drug or alcohol intoxication. The aim of the work is to expand the capabilities of such systems through the use of recognition of people who pose a hidden threat. In this case, the pupillary response of an individual who has to solve the tasks requires a comprehensive approach that combines several methods.

2. Experimental method
Basic provisions, which should correspond to the means of display and reception of information:
- It is known that for reliable reproduction of a compact object in a digital image, its size must be at least four pixels. In our case, the requirements are tightened. The resolution of the recording camera should not be worse than 5 MPCS. This allows you to reliably monitor changes in pupil size is not worse than 0.1 S.
- The image on the screen should be clear and full color when changing the viewing angle.
- If the test objects are shown from the screens of collective use (receiving information simultaneously by a large number of people), the observation distance can be significant. The brightness of the radiation from the image of useful information should be at least 3000 CD [4].
- The design observation distance should depend on the screen size and the distance between the emitting cluster elements and the gap between the composite screen modules.

- The design observation distance is determined by tests on the results of the change in the greatest distance between the emitting elements of the cluster (screen) and the theoretical angular resolution of the eye, with the pupil diameter and wavelength corresponding to the maximum value of the relative spectral efficiency of the eye.

\[ t = \psi \cdot r_{pr} \]  

\[ \psi = \left(1.22 \cdot \lambda \right) / d \]  

\[ r_{pr} = t \cdot d / \left(1.22 \cdot \lambda \right) \]

where \( r_{pr} \) is the smallest distance from the screen to the observer, at which the emitted elements are indistinguishable separately.

- When changing the viewing angle by ±60°, the brightness of any color should not change more than twice.

Thus, there is an acute problem of taking into account the dependence of pupil size on illumination.

To study the reaction of the pupil in idealized conditions, a helmet was developed, creating a rigid coordinate connection between the video camera and the head (Fig. 1). Rigid coordinate communication facilitates the processing of images received by the camera. At this stage, it is necessary to avoid ambiguous interpretation of the results. For video filming used video camera T7 Astro Camera Astronomical Astronomy Planetary High Speed Electronic Astrophotograph, video mode 30 fps, microscope lens with optical magnification 1X-100X. Images were analyzed in the freely distributed program FiJi-it is an improved and expanded distribution ImageJ, combining many plugins that allow you to conduct a complete scientific analysis of the image.

![Figure 1. Installation for receptions pupillogram.](image)

The helmet is a frame welded from a copper tube. The frame is wrapped with a layer of foam. In the occipital part of the frame there is an adjusting screw that allows you to loosen or tighten the helmet on the head. A person wearing a helmet is located at a distance at which the difference in the illumination of the eye is insignificant. Preliminary selection of the distance was carried out on the basis of measurements of illumination created by monochrome frames, each of which had a different color. The footage was shown from a monitor located at a distance varying from 0.75 to 4 m from the photometric head of the luxmeter. Figure 2 shows a graph of the light produced by the monitor at different distances.
Figure 2. The illumination created by the test object on the photosensitive element of the meter.

The experiments determined the distance at which the stimuli do not contribute to the change in pupil size. In human physiology, retinal illumination is important. The size of the pupil, as well as the level of illumination, is very important to ensure sufficient illumination of the retina and, therefore, to feel the brightness. For this reason, the intensity of illumination of the pupil \( L \) was introduced as a measure of illumination of the retina in the daytime. The value \( L \) is the product of illumination \( E \) on the surface area of the pupil \( S \):

\[
L = S \cdot E
\]  

(4)

It is known that in field conditions the person of rigid coordinate communication of a video camera and the head won't be. In this case, the illumination of the retina will depend on the angle. Therefore, light control (Fig. 2) will be carried out in brightness of skin area near the eye. Let the pupil area \( S_1 \), the average brightness of the pixels included in the selected area of the skin near the pupil (in grayscale) \( I_1 \) be at the illumination of the pupil \( E_1 \). Then, with an unplanned change in the illumination \( E_2 \), the pupil area will become \( S_2 \), the brightness of the skin \( I_2 \). It is known that the transformation of light by the photomatrix is linear. Therefore, the brightness of the pixels is proportional to the illumination of the photomatrix. Then the change in illumination in \( E_2 \mid E_1 = I_2 \mid I_1 \) is taken into account by introducing a correction factor:

\[
k = \frac{I_1}{I_2}
\]  

(5)

Another problem occurs when processing images. The problem of finding a circle is one of the most well-known in image processing. To solve it created a large number of different methods, some of which are applicable in this particular case. At the first stage of experiments it is enough to apply the contouring "manually" what is happening in semi-automatic mode. For images with very poor quality, we used the following algorithm:

1. Trim file. You must select the area of the image that contains the pupil. The selection must be large enough so that the pupil does not leave the selected area on any of the frames. Cropping is necessary, because the files have a high resolution, and the PC will not be able to process it entirely.
2. Run the subtract background command.
3. We carry out masking on the threshold, the most suitable for contouring.
4. Remove outliers (Remove Outlier). The radius defines the area (uncalibrated, that is, in pixels) used to calculate the median. The threshold determines how far the pixel must deviate from the median to be replaced, in raw (uncalibrated) units.
5. If you are satisfied with the result, then in each of the above items the action is automatically applied to the entire stack by pressing "OK".

Getting oculogram occurs in several stages:

1. Uploading an image to ImageJ;
2. "Masking" is performed, i.e. setting the boundaries of the pupil;
3. Next, you need to build a graph of the coordinates of the center of mass of the time in the program Origin.

![Graph showing measurement results of the relative changes of pupil diameter using different methods](image)

**Figure 3.** The measurement results of the relative changes of pupil diameter using different methods (two of the ejection - outline on the slides in a moment of blink)

Comparing the result of contouring with different methods, you can choose the most accurate result. Based on statistical analysis and as can be seen from the graphs (Fig.4) the closest results are obtained by a semi-automatic method based on the developed algorithm. The standard deviation of the normalized values $\overline{S_i} = 1.0049 \pm 0.0461$; $\overline{S(S)} = 1.0125 \pm 0.0677$; $\overline{I(I)} = 1.037 \pm 0.1999$. It can be seen from the graphs that at constant illumination the method of measuring the relative change in the pupil area by the level of gray is the least sensitive to changes in the pupil size. Selection of contours manually and in semi-
Automatic mode gives almost the same result. In this case, the error of contouring is an order of magnitude less than the change in the area of the pupil.

3. Approbation of the method

Approbation of the method was carried out when registering the pupillary response in response to viewing test objects. As test objects we used images exposed by Internet users to the public access. The distance between the monitor and the eye is 2.5 m. the intensity Level of emotionally colored video files, on a scale from 1 to 10, does not exceed 4, where 10 is the strongest emotion that can be. The control of illumination was carried out by the skin tone of the test subject (in the gray scale, normalized by the average value), Fig.4. For confidence in interpreting pupillages in each frame followed the line of sight. For this purpose, the image of the monitor reflected in the pupil was isolated on the obtained video frames. Then the center of mass of the selection was monitored in each frame and its coordinates were determined. The coordinates of the center of mass of the reflection of the monitor in the pupil and measured in each frame, the pupil diameter used to build pupilllage and oculogram.

![Figure 4. Control of the stability of the illumination of the eye surface](image)

4. Conclusion

In the course of the work, the main results can be considered: the introduction of a correction factor for unplanned changes in illumination; the development of a method to track the coordinates of the center of attention. Method of registering the waves of attention are based on synchronous recording of pupilllage and oculogram (not swinging saccades). The method can be used as a selective indicator of the presence of low-intensity reactions to specific test objects, provided that the stimulus is significant for the individual. The possibility of specifying the element of the test object to which the emotional reaction occurred.

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References

- [1] https://habr.com/ru/post/126144/ Modern biometric identification methods
- [2] Lanata, A., Armato, A., Valenza, G., and Scilingo, E. P. (2011). “Eye tracking and pupil size variation as response to affective stimuli: a preliminary study,” in 2011 5th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) (Dublin: IEEE), 78–84.
- [3] Andreassi George. L. Psychophysiology: human behavior and physiological response. - Psychology of the press, 2010.
- [4] GOST R 52870-2007 Means of display of information of collective use. Requirements for visual display of information and methods of measurement
- [5] de Gee J. W., Knapen T., Donner T. H. Decision-related pupil dilation reflects upcoming choice and individual bias //Proceedings of the National Academy of Sciences. – 2014. – T. 111. – №. 5. – C. E618-E625.
- [6] Gulyaev P.Yu., Gulyaev I.P., Milyukova I.V., Cui H.Z. In-situ selfpropagating-hightemperature-synthesis controlled by plasma // Bulletin of Ugra state University. 2012. № 2 (25). C. 28-33.
- [7] Gulyaev P.Yu., Gulyaev I.P., Milyukova I.V., Cui H.-Z. Temperature measurements for Ni-Al and Ti-Al phase control in SHS Synthesis and plasma spray processes // High Temperatures – High Pressures. 2015. Т. 44. № 2. C. 83-92.
- [8] Garkol’ D.A., Gulyaev P.Y., Evstigneev V.V., Mukhachev A.B. A new high-speed brightness pyrometry method to investigate self-propagating high-temperature synthesis // Combustion, Explosion, and Shock Waves. 1994. Volume 30. Issue 1. pp 72-76. DOI:10.1007/BF00787888
- [9] Development prospects of SHS technologies in Altai state technical university/ V.V. Evstigneev, P.J. Guljaev, I.V. Miljukova, at al // International Journal of Self-Propagating High-Temperature Synthesis. 2006. T. 15. № 1. C. 99-104.
- [10] Gulyaev I.P., Ermakov K.A., Gulyaev P.Yu. New High-Speed Combination of Spectroscopic And Brightness Pyrometry For Studying Particles Temperature Distribution In Plasma Jets // European researcher. 2014. № 3-2 (71). C. 564-570.
- [11] Dolmatov A.V., Gulyaev I. P., Imamov R. R. Spectral pyrometer for temperature control in thermosynthesis // Bulletin of Yugra state University. 2014. № 2 (33). P. 32-42.
- [12] Gulyaev I. P., Gulyaev P. Yu., Jordan VI resolution virtual temperature control devices of particles in the plasma flow at total spectrum // polzunovskii almanac. 2008. №. 2. C. 13-14.