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THE PROGRAM DEVICE FOR DETERMINATION OF THE HUMAN PAIN FEELINGS

The program device has been designed for determination of pain feelings on the foundational diameter of pupil of the human eye with the help of the mathematical apparatus that is based on the theorem of Thales about the right triangle inscribed circle.
Key words: pain, pupil of the eye, recognizing algorithm for pupils.

Introduction

The research of the reaction of the human organism to pain is difficult problem that hasn't a complete decision. Nowadays subjective methods of estimation of pain are used in the condition of the clinic. According to their nature they are verbally-sign: visually analog, visually rank, verbally rank scales, further more Mc Hillovskyy questionnaire and others. However patients can estimate their filling, which are caused with the appearance of pain, different ways. It is largely depend from their psycho-emotional conditions [1, 2]. Filling the emotional stress which is often accompanied with excitation, anxiety, fear, depression, patients estimate their pains inadequately: some of them can understate their impact, while others tend to exaggerate [1]. All of this makes difficulties to give the real estimation of pain. That is why considerable attention is allocated to working of the objective methods of diagnosis human body reactions response to painful stimulus-alhometriy, which take into consideration its components: touch, vegetative, psycho-emotional. The benefits of these methods are the possibilities of quantification very important indicator, the reaction of the patient to the external painful stimuli of the different intensity.

Problem

Informative method of studying vegetative human reaction is pupilohrafy – diagnosis of diameter of pupil. Normal diameter rangers from 3 to 8 mm, physiological anisocoria is allowed to 0,8 mm. The pupil can never be absolutely relaxed. It can be constricted and expanded by different external and internal factors. Increased activity of the sympathetic innervation causes dilated pupils while their pupillary indicates increased parasympathetic tone. Psycho-emotional stress, fear, pain stimuli cause mydriasis (symptom Parry Robertson). These clinical data suggest pupilometry importance not only for study konverhentsiyno-accommodative system of the eye, but also to explore the psychophysiological state of patients, the tone of the autonomic nervous system [2,3,4]. Investigated that temporal and amplitude characteristics of pupil diameter changes reflect the features of the regulation of cognitive processes influenced by stress factors and is closely related to the dynamics of cognitive functions in healthy individuals and in patients with affective and behavioral disorders. This allows you to use the analysis of these characteristics in the differential diagnosis of cognitive impairment in patients with neuropsychiatric disorders [3]. The object of our study pupillary reflex was chosen as the most accessible facility, "open" for direct non-invasive study of the central nervous system (CNS). This choice is due to the fact that the reaction of pupils to painful stimuli is unconditioned reflex, intractable control of the cerebral cortex, that is consciousness. At the same time, this is a unique and sensitive indicator of a wide range of physiological processes, depending on the sympathetic-parasympathetic balance. The advantage of the pupilometriya, unlike most traditional methods is not only the realization of the objective and quantitative assessment of the functional state of the autonomic nervous system (ANS), but with the added benefits of screening methods for investigation of psychophysiological status [3,4]. The implementation of this research method using appropriate approaches to quantify the functional state of the SPA, of course, is relevant because aimed solving the important problems of clinical

medicine. Assessment of the individual characteristics of the regulatory processes in the body under stress, pain okulodynamic parameters should be considered promising.

At the same time, even though it is at first glance, availability, registration and mathematical processing of pupillary reflex is very difficult due to the rapidity of reaction and the relatively small size of biological object, eye the pupil. In addition to estimates dynamics of the patient's pupil size, in determining the intensity of the pain stimulus should be considered a constriction of the pupil, her average speed, amplitude of contraction, the expansion of the pupil, the average rate of expansion, the amplitude of the expansion, the total time pupillary reaction.

The stated objective is to develop a software tool that would give an opportunity to register dynamics of the human pupil diameter over time and display the data in a user-friendly way.

Developing an algorithm of the software

To most simple technical implementation of the task, for the video stream featuring eye an electron microscope is widely used. The advantage of this microscope is that it is easy to connect to any computer via USB interface, eliminating the need to use specialized computer. The approach involves the use of computers, general purpose users, so software should not require large computing power.

Video clip that is provided by the electron microscope, consisting of a sequence of frames depicting the eye. Images come from a frequency of 20 frames / c, which allows measure the diameter of the pupil every 500 ms. That's why the running time of the search algorithm should not exceed 500 ms.

To determine the diameter of the pupil of the eye first of all we must make its' search in the video stream; allocate it among the minor objects (other parts of the human eye, shadow, noise, etc.). The pupil of most people is shaped similar to a circle and reflects very little light, if the light direction does not coincide with the direction of the camera. This gives the opportunity to look for it as a dark circle in the image. Also, the pupil is quite different from the iris in brightness on its border - the circle - the value of the gradient is greater than the value of the gradient of the iris. This factor can be used for binarization rate, separation of the dark (pupil) and light (iris) of the eye. Then, to find the circumference of the parameters, it is widely used Hough transform [6]. Unfortunately, the use of Hough transform in this case may not give the desired accuracy. The reason is that the image pupil eyelid may partially overlap, and Hough method is able to find the picture enclosed path only if they are as close to a perfect circle or an ellipse, otherwise error detection increases and the result is inaccurate [7]. In order to improve recognition accuracy pupil algorithm based on the search circle theorem of Thales regarding a right triangle inscribed circle.

The algorithm consists of the following steps:

1. Binarization image (secondary screening for significant objects in the image).

2. Search the basic points of the mask (ie selection of points that are potentially edges of the circle in different quarters).

3. Determination of the center of a circle and its diameter.

Let's examine the each step separately.

1. Binarization image

Binarization is the operation threshold division which gives a binary image (includes only two colors). The goal of operation is to reduce significantly the binarization of information contained in an image. During the initial binarization image has a large number of brightness levels, converted to black and white image pixels which have only two values - 0 and 1.

Binarization image is a very important part of the algorithm as at this step, the division conducted an image into separate zones. Zones with a value of 1 pixel can be as noisy and integer giving the pupil of the eye.

There are many ways threshold image processing, the main of which are:

- Method Oates.
- Method Yani.
- Method medium.
- Binarization with the lower threshold, upper threshold, dual limit.

Methods Oates, Yana and medium are the so-called automatic threshold search methods involving binarization images without user intervention. However, they require additional passes over the image, which slows down the algorithm. Moreover, experiments have shown that these methods are not always effective for this type of image and sometimes give incorrect results.

Binarization with the lower threshold is the simplest type of binarization, which uses only one threshold value:

$$Y(m,n) = \begin{cases} 0, X(m,n) \geq t; \\ 1, X(m,n) < t. \end{cases}$$

(1)

where X and Y are the intensity values of pixels that are given the coordinates of m and n, according to the original and binary images. t - value threshold.

Here all the pixels, whose brightness is less than a threshold value, get the value 1 and pixels that are greater or equal to a given threshold, we obtain a value of 0.

Binarization with the upper threshold is inverse to the lower threshold binarization.

Problems in the selection of areas in which the brightness of pixels can vary in a certain range, using binarization double restriction:

$$Y(m,n) = \begin{cases} 1, X(m,n) \geq t_1; \\ 0, t_1 < X(m,n) \leq t_2; \\ 1, X(m,n) > t_2. \end{cases}$$

(2)

where X and Y are the intensity values of pixels that are given the coordinates of m and n, according to the original and binaryzed images. t1, t2 - value constraints (t1 <t2).

The problem is that the image is always a reflection of infrared illumination (Fig. 1). However, it usually concerns the part of the image that contains the pupil, as light is installed directly on the microscope, which is fixed to the eye. According to that fact we can consider the potential part a reflection of the pupil, and therefore binarization algorithm is used with a double constraint. Given that the glare is brightest part of the image and pupil - the darkest, binarization method accepts a double restriction zones with intermediate brightness pixels as noise and extraneous objects, and areas with high and low luminance pixels are areas in which is the desired circle (pupil).

Options binarization (i) specifies the user depending on the ambient light.

Figure. 1. Single frame video sequence

After the process of binarization image is obtained, which clearly shows where it can be placed desired range (Fig. 2).

Figure. 2. Binary frame from the video stream

Once a zone that may be desired circle, color, you can proceed to the next step of the algorithm.

1. Search the basic points of the mask

If we consider the raster circle with a small radius (Fig. 3), we can see that most of the points that make up its outline, we can identify certain mask.
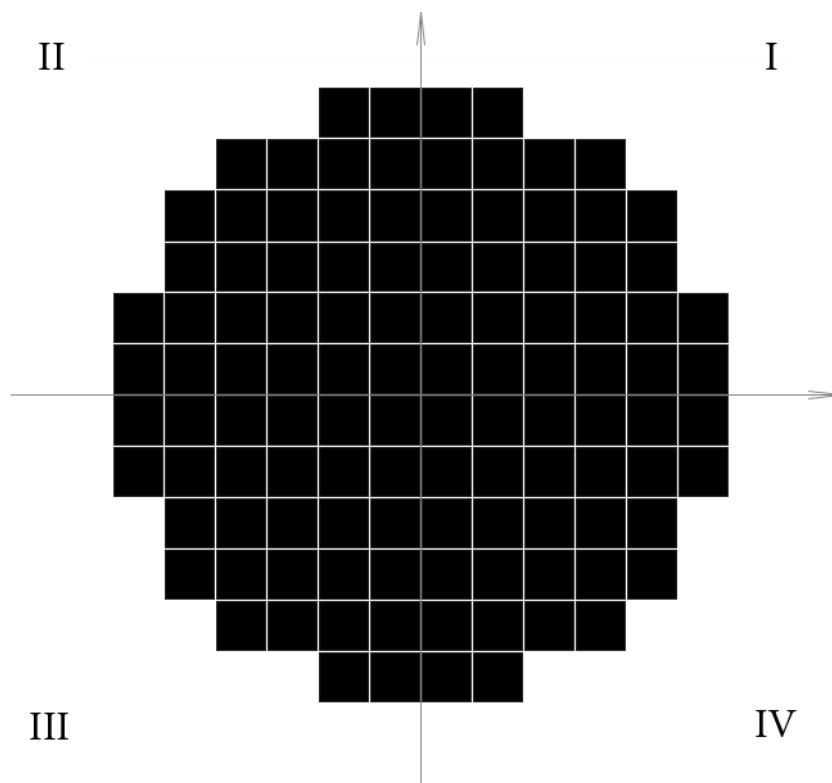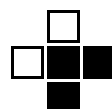

Figure. 3. Scanning range

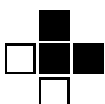For example, to search points of the contour of the wheel, which are in some quarters used by these masks:
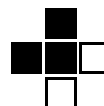
For the first quarter:

For the second quarter:

For the third quarter:

For the forth quarter:

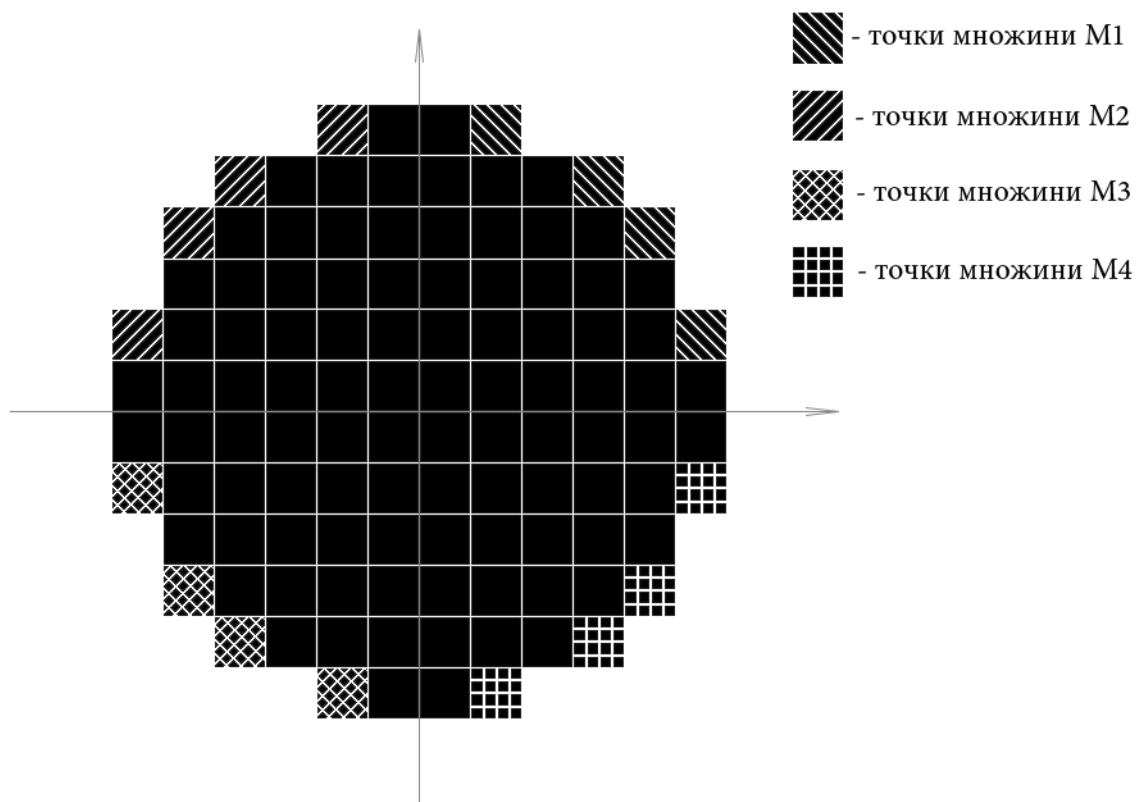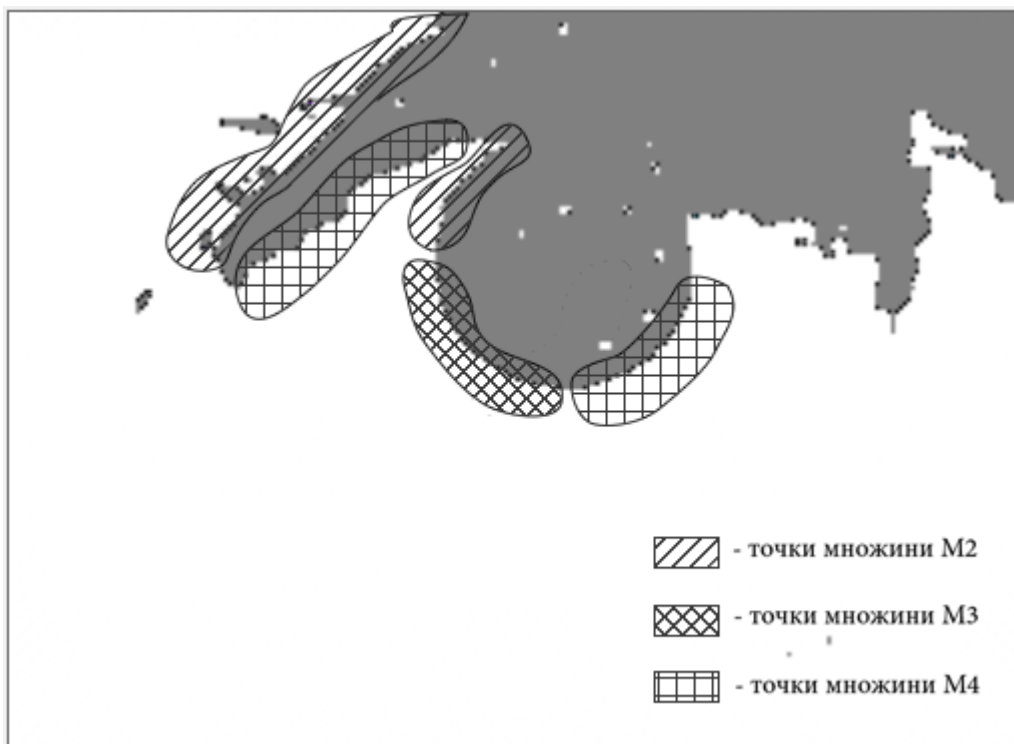After the search of these masks we get four sets of coordinates of points that can be represented as follows:

- точки множини М1

- точки множини М2

- точки множини М3

- точки множини М4

Figure. 4. Points found by mask

In the frame of the video sequence base points are distributed as follows:

1. Figure. 5. The basic point of the frame of the video stream

Determination of the center of a circle and its diameter

To determine the center of a circle and its diameter using an algorithm based on the theorem of Thales. This theorem states that the hypotenuse of a right triangle is inscribed in a circle is the diameter of the circle, and its midpoint is the center of the circle.

Therefore, for each point $P(x,y)$ of the four basic sets are points $P_2(x_2,y_2)$ and those that satisfy the following conditions:

$$\text{if } P(x,y) \in M_1 \begin{cases} P_1(x_1,y_1) \in M_2, \text{ якщо } y = y_1, \ x > x_1 \\ P_2(x_2,y_2) \in M_4, \text{ якщо } y > y_2, \ x = x_2 \end{cases}; \qquad (3)$$

$$\text{if } P(x,y) \in M_2 \begin{cases} P_1(x_1,y_1) \in M_1, \text{ якщо } y = y_1, \ x < x_1 \\ P_2(x_2,y_2) \in M_3, \text{ якщо } y > y_2, \ x = x_2 \end{cases}; \qquad (4)$$

$$\text{if } P(x,y) \in M_3 \begin{cases} P_1(x_1,y_1) \in M_4, \text{ якщо } y = y_1, \ x < x_1 \\ P_2(x_2,y_2) \in M_2, \text{ якщо } y < y_2, \ x = x_2 \end{cases}; \qquad (5)$$

$$\text{if } P(x,y) \in M_4 \begin{cases} P_1(x_1,y_1) \in M_3, \text{ якщо } y = y_1, \ x > x_1 \\ P_2(x_2,y_2) \in M_1, \text{ якщо } y < y_2, \ x = x_2 \end{cases}. \qquad (6)$$

The segment $P_1 P_2$ is the hypotenuse of a right triangle inscribed in a circle. For example, consider a point $P(-4, \ 5)$ (Fig. 6), it shall set M_2. Thus, we find points that satisfy the condition (4). One of the points is $P_1(4, \ 5)$ a set M_1, in which the same coordinate axis Y. Another point is $P_2(-4,-5)$ the set M_3, because P and P_2 equal coordinates of the axis Y. So we form a triangle with a right angle $P_1 P P_2$ and the hypotenuse $P_1 P_2$. The middle of the hypotenuse is the center of the desired circle and its length - its diameter

Figure 6 legend:
- точки множини М1
- точки множини М2
- точки множини М3
- точки множини М4

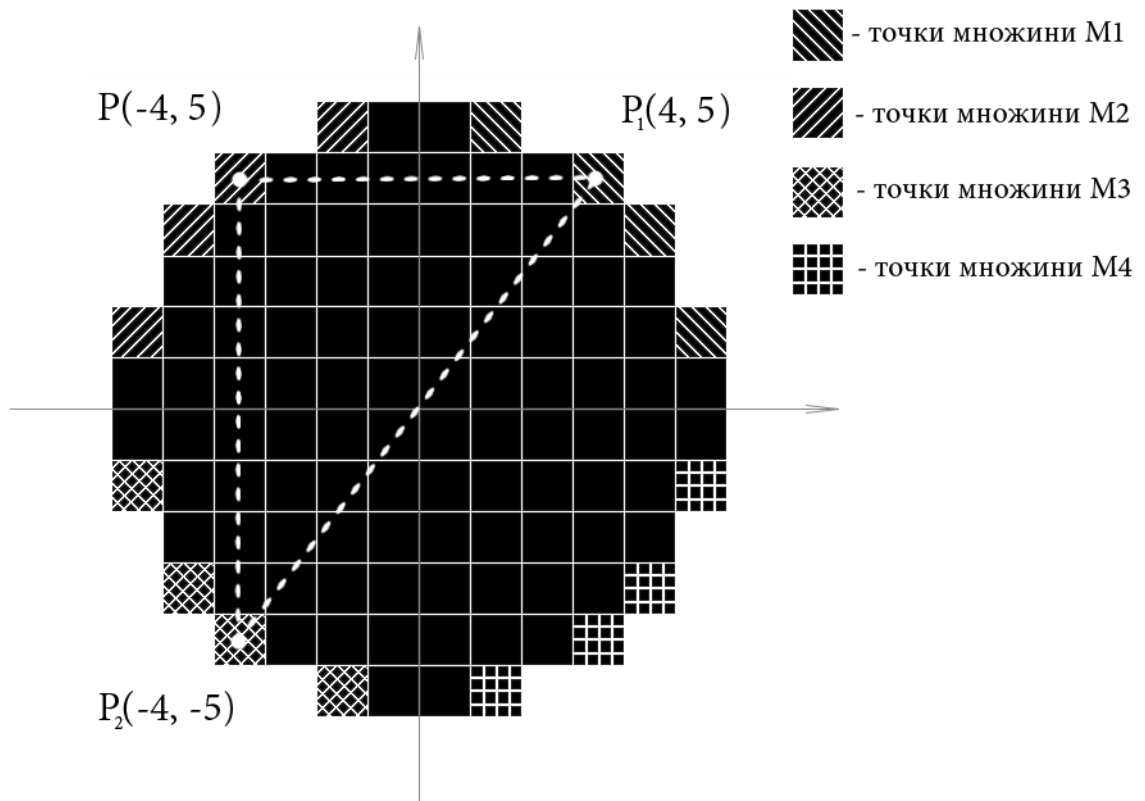Labels on figure: $P(-4, 5)$, $P_1(4, 5)$, $P_2(-4, -5)$

Figure. 6. Example of finding the center of a circle

Thus, sorting through all the basic terms, we obtain a new set of possible centers of the circle and its diameter, besides the desired center of the circle is at the point where the center of the most probable intensity (Fig. 7).
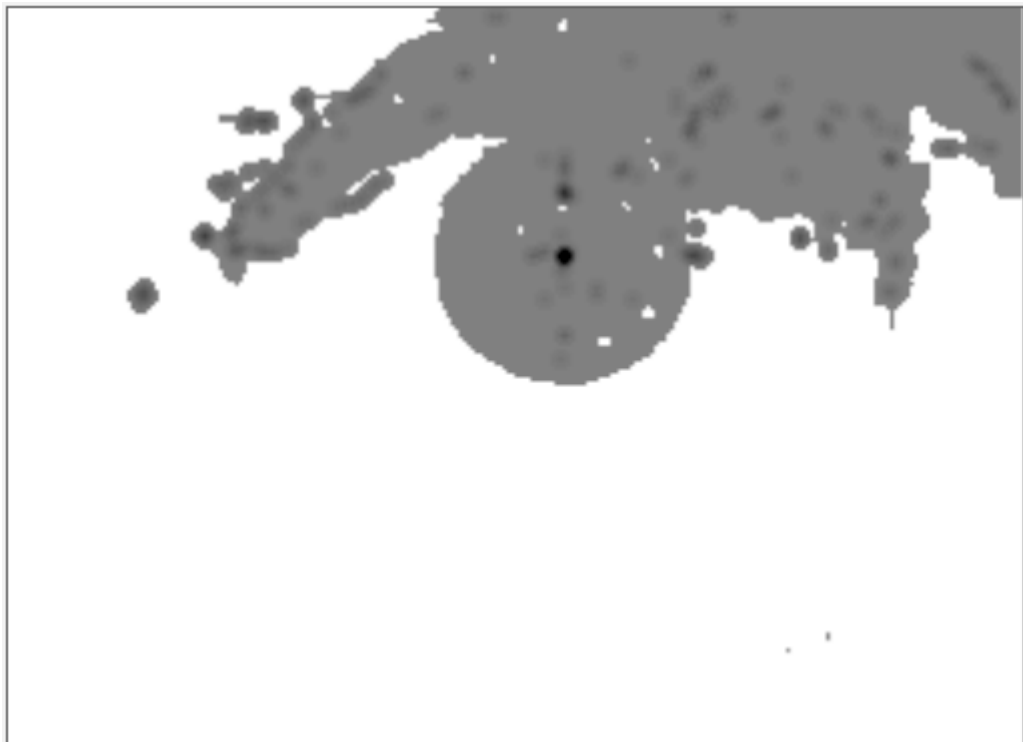

Figure. 7. Saturation probable centers in the frame of the video stream

Program realization

To reduce development time and create more flexible as the software decided to implement it using an object oriented programming language. Also take into account that this software has to be multiplatform that should work in different operating systems and hardware platforms. It was therefore chosen language C # /. NET, which is enough crossplatform. In addition to standard library FCL, software platform .NET Framework, There is a number of classes that allow you to realize the interaction with a microscope at a high level, which greatly speeds up development time. Programming environment using Microsoft Visual Studio 2012 and WPF technology a convenient user interface, shown in Figure 8

The main window is conventionally divided into four areas:

1. Video display area. In the upper right corner of this area are buttons, one of which is designed to invoke a dialog box where you can select a type of providers of video (or video camera). Pressing the second button the user can configure the binarization, a directory for the video stream, and so on.
2. Pupilohram area where displays a graph of the size of the pupil of the eye over time. There is also a button to save pupilohram to adjust its presentation (color curve length of the time axis, etc.).
3. The display area of numerical data, which provide current numerical values of the amplitude deviation and deviation pupilohram diameter, which can be considered that the pain - available.
4. Field management program. It contains the "start / pause" - to start analyzing the video stream and temporary suspension of its possible recovery. The "stop" - for the final closure of registration video stream and save it to your movie by the user.
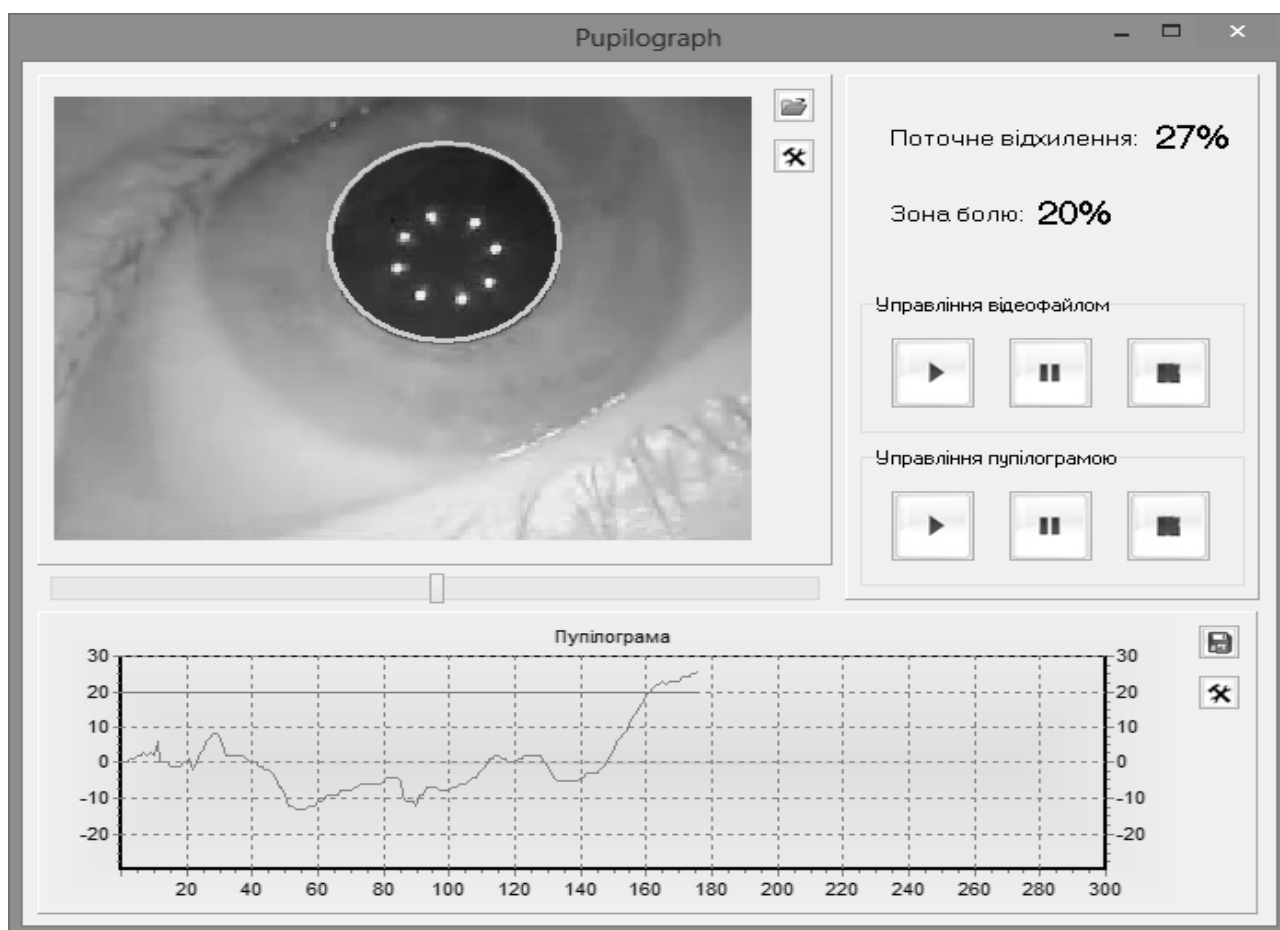

Figure. 8. The main window of the software developed

Prior to using this software tool to securely attach the camera to the microscope eye of the patient and connect it to your computer. Then user (doctor) can activate the program. First of all, it must choose the source of video (or video camera) and, if necessary, depending on the brightness of ambient light, adjust the binarization process by moving the sliders, which are responsible for the parameters t_1 and t_2.. Sign that they are in the correct position is that the program clearly identifies the position and diameter of the pupil.

During the first three seconds of the hardware-software system the analysis of the video stream is and calculate the average diameter of the pupil since it depends on the lighting and emotional state. At the same time pupilohram no information is displayed. The average diameter of the pupil diameter is at rest, and that is in relation to it current deviation calculated diameter (increase) in conditions of stress factors (of the pain stimulus).

The duration and intensity of the growth dynamics of the amplitude pupilohram (mydriasis) and its reduction (pupil constriction) also is assessed.

Conclusions

In a surgical dental clinic the use of practical, effective methods for rapid diagnosis of pain in patients is important. There are many physiological manifestations of stress response of the human body, from which you can determine pain. One of the significant and undeniable symptoms of pain there is a change in the size of the pupil of the human eye. Therefore, due to the analysis of pupil diameter we can evaluate the sensory-perceptual features surveyed patients and to examine the reactivity of the organism as a whole.

An important component of the software to detect and identify changes in the size of the pupil is the image processing algorithm for images of the human eye. In practice we can use different approaches to solving this problem. However, due to the possibility of using standard hardware and software required performance of the method was developed based on the diameter of the pupil of Thales theorem about right-angled triangle inscribed in a circle. Software implementation of this method has led to the construction of an effective tool that can be widely used to determine the presence of pain in humans in various fields of medicine.

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