# Synthesis of the General Structure and Algorithm of Controlling the Functions of a Mobile Photo-Ophthalmoscope


Alexander Gushchin[1], and Yuri Mukha[2]

[1] The Volgograd State Medical University, Department of Biomedical Technique and Technologies, Volgograd, Russia
ag@v1.ru

[2] The Volgograd State Technical University, Department of Computer Engineering, Volgograd, Russia
muxaup@mail.ru



**Abstract.** This paper is about the development of a PO – a mobile device for direct examination of the eye fundus, in which a shifting mirror, a lens unit, a photo sensor, a microprocessor and an interface part are added to the currently known ophthalmoscope for direct ophthalmoscopy. The device can work in such modes as the mode of ophthalmoscopy, when the optical circuit of the device fully corresponds to the scheme of the traditional ophthalmoscope and in the mode of photo fixation, when the sliding mirror briefly blocks the main optical axis of the device, directing the rays reflected from the investigated eye fundus not to the eye of the researcher, but to the photosensor. This makes possible to make a photograph of the observed picture of the fundus. The device provides for the possibility of adjusting the optical scheme of photographic fixation to the clinical refraction of the researcher so that the routine use of the device as little as possible differs from the use of a traditional manual ophthalmoscope. In addition, in the hardware and software complex of the photo-ophthalmoscope (PO), the functions of storing and transmitting the received information are provided, as well as a software interface for integrating the device into the local network of the medical institution. There provided the detailed information on the development of a general scheme of the device, on the development of a diagram of the optical part of the instrument, and on the development of the structure of the integrated software for the PO.



**Keywords:** ophthalmoscopy, ophthalmoscope, photographic registration, algorithm, built-in software algorithms.


## 1 Introduction

The method of direct ophthalmoscopy is now widely used by ophthalmologists to examine the condition of the eye fundus (retina) of the eye and its optical media [1, 2]. To use this method, various models of hand-held mobile ophthalmoscopes are currently being mass-produced [3]. The important task is to record the picture of the eye fundus observed with such devices with the purpose of archiving, measuring the observed objects, evaluating the long-term dynamics of pathological changes, and determining the success rate of the therapy [4].

The known types of handheld mobile photo-ophthalmoscopes (PO) proposed in the world literature [5] are a mechanical combination of an ophthalmoscope and a digital camera, and differ in that they do not have the possibility of a direct examination by the researcher of the fundus of the subject. Instead, the researcher observes the picture of the fundus through a small LCD-screen of a digital camera. Such a method of image transmission is associated with a significant decrease in its usefulness for the researcher, since the amount of visual information that can be displayed on a small-sized LCD screen is much less than the amount of information obtained by direct examination of the fundus [6].

So, the overall goal of this work is to realize the possibility of automatic documentary photographic recording of the results of a study performed with the help of a hand-held mobile ophthalmoscope.

This goal is achieved by adding to the ophthalmoscope optical, electromechanical and electronic components, which are the hardware base of the software, which makes it possible to photograph the visible picture of the fundus.

## 2 Synthesis of the General Structure of PO

At the first stage of the work, a synthesis of the graphical representation of the general structure of the hardware-software complex of the PO in the form shown in Fig. 1 [7] was carried out.

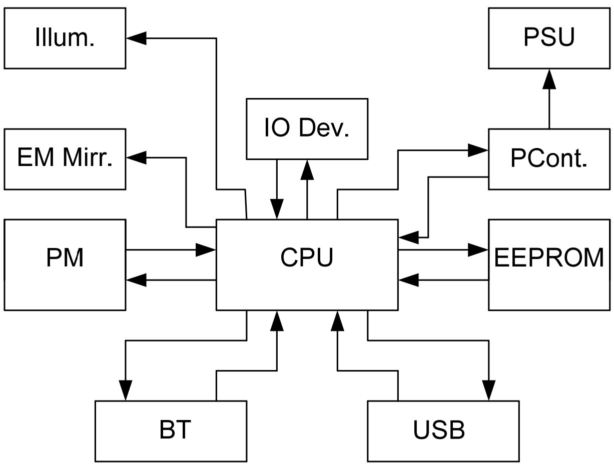


**Fig.1.** Detailed structural diagram of the PO

In Fig. 1, the central processor (CPU) is the main component of the device. When user press the button switches on the IO device (IO Dev), the processor performs the actions specified by the firmware of the device. It controls the position of the mirror (EM Mirr) and brightness of fundus illuminator (Illum) in accordance with the user-selected operating mode of the device (ophthalmoscopy or fundus photo). In photographic mode CPU receives information from CCD sensor (PM), process it, store it in the EEPROM memory and transfer for further processing on a PC over a wired (USB) or a wireless (BT) interface channels. Also, the processor through the power controller (PCont) monitors the level of the battery's charge and gives a low-charge warning signal to the indicator on IO device.

## 3 The Optical Subsystem of PO

The structure of the optical scheme of the PO, which combines both the possibility of direct observation and the fixation of the image, can be represented as follows (Fig. 2).

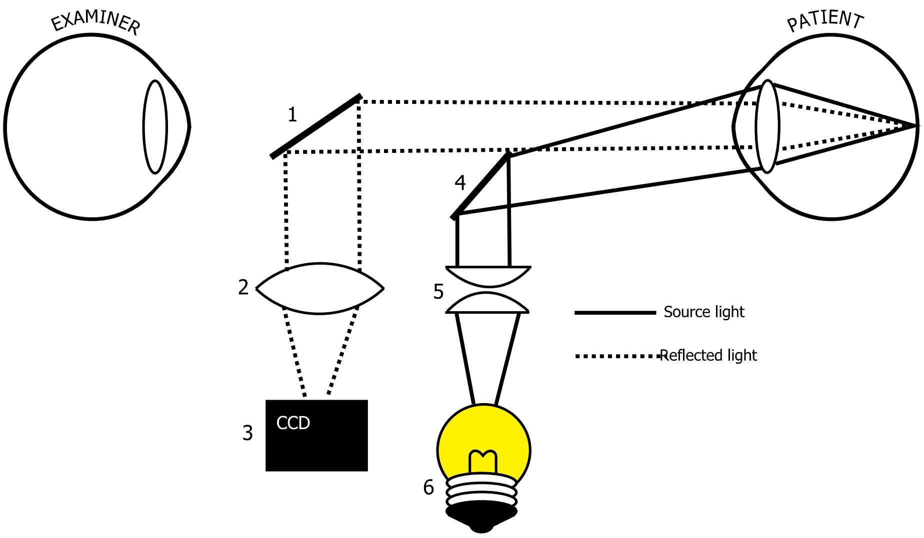


**Fig. 2.** The optical scheme of the PO (1 – movable mirror in the position for direct inspection, 2 – photo lens; 3 – CCD sensors array; 4 – illumination mirror; 5 – illumination condenser; 6 – fundus illuminator)

It is proposed to use the Tessar scheme [8] as an optical scheme of the photo lens (2). This choice is due primarily to the widespread use of compact photographic devices based in this manner. Also, in comparison with other optical schemes, Tessar that makes it possible to achieve an optimal ratio of the image's price / quality / geometric dimensions in order to reduce the cost and simplify the design and mass production of the PO [9].

The CCD matrix [10, 11] diagonal size is 1/2.5" and a length to width ratio of 2.31 / 1.75 mm. The relative aperture of the diaphragm is determined by the ratio 2.8 / 5.6, where 5.6 is the back focal length of the lens, expressed in millimeters. Based on the available data and formulated requirements, the Camera Module 12C VGA from Carl Zeiss, which is used in Nokia N73 and Nokia N73-1 mobile phones [12], can be considered the best choice for use in these conditions. It is assumed that the length of the head of the ophthalmoscope, with the moving mirror, the CCD sensor, the objective and the focusing drum, will not exceed 25 mm, so that the increasing dimensions of the photo-ophthalmoscope head do not cause a significant reduction in the viewing angle for the ophthalmologist during direct examination of the patient's fundus.

# 4 The Structure of the Firmware of PO

## 4.1 The General Structure of the Firmware

The general block diagram of the firmware of the device is shown in Fig. 3.

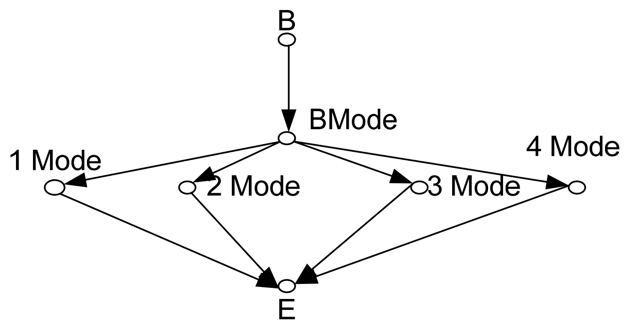


**Fig. 3.** The graph of the general structure of the PO (B – beginning; BMode – mode switch; 1Mode...4Mode – operation modes; E – end)

Based on the created block diagram describing the algorithm of the manual PO, the main structural elements of this scheme were analyzed [13, 14].
Functions of the built-in software: initialization at power-on; IO sensors polling; processing operator actions (drives of electromechanical nodes of the photo-ophthalmoscope; Automation of the process of transmission of received images); Safely turn off the device.

## 4.2 Initialization of PO

The structure of the algorithm for the initialization procedure of the device when it is turned on is shown in the graph (Fig. 4):

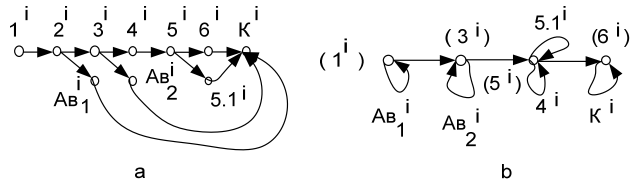


**Fig.4.** The graph of the procedure for initializing the device (index I): a – source; B – optimized by the method of block-functional distributions (i-initialization mode) [16].

The first step is to check the status of the sliding mirror. To continue to work with the device, the software must check the position of the sliding mirror. This mechanism provides 2 states, which corresponds to the on and off states of mirror position sensors. It is supposed to use 2 contact sensors, when triggered, the processor will stop supplying power to the electromagnet in order to stop the movement of the mirror. Proceeding from this, we get two working positions of the mirror:

1) Mirror is down – the starting point;
2) The mirror is raised and is at the end point.

### 4.3 User Input Processing

The keypad polling procedure is the main control procedure of the processor. After the main control program is switched on and loaded, the device goes into the button response mode. The structure of this section of the program is presented on the graph (Fig. 5).

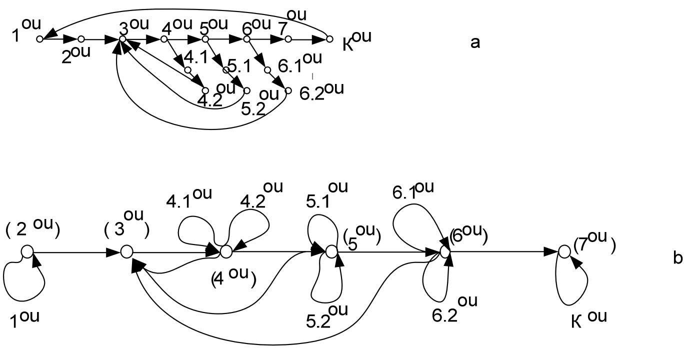


**Fig. 5.** The graph of the procedure of querying the keyboard in the control process (OU index): a – the source; B – optimized by the method of block-functional distributions (OU-control mode) [16].

The device constantly polls the buttons, waiting to receive a response at any time. The frequency of polling buttons will be determined by the frequency of the used processor. The graph (Fig. 6) shows the structure of the algorithm describing the process of controlling the survey.

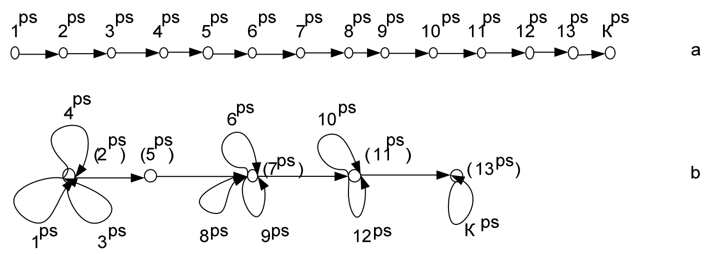


**Fig. 6.** The graph of the algorithm of the procedure of querying the keyboard during the survey (PS index): a - the source; B - optimized by the method of block-functional distributions (PS- fundus photographic mode) [16].

After pressing the "Shot" button, voltage is applied to the electromagnet, which moves the mirror. The time for raising the mirror will vary from 0.2 to 0.6 seconds. Such a time interval may depend on the level of charge of the battery, and hence on the voltage output from it. So, because of the lowering of the voltage level received from the battery in 20% of the rated value, the time of the mirror rise can increase by 0.5 seconds.

After lifting the mirror, the device goes directly to the image capture procedure.

1. The initial adjustment values for a particular CCD sensor are loaded.
2. The processor needs to assess the average light level of the CCD sensor.
3. Next, it`s need to evaluate the exposure values. We expect to set the shutter speed in the range from 0.15 to 0.35 seconds. This time will be enough for the camera exposure in the operating conditions of our device.
4. At the next stage, the necessary level of increase in the power of the illuminator is calculated to balance the lack of illumination level of the room. However, the power is calculated only if the level of illumination is not sufficient.
5. The received parameters are saved, and the system switches to the mode of reading the illumination values from the CCD sensor x.
6. And further, proceeding from the illumination of the environment, the program increases the power of the illuminator to the calculated value, if necessary.
7. The procedure for exhibiting the matrix begins.

8 ... 9. After the shutter is closed, the power of the illuminator is reduced to the initial value.

10. After the shutter is closed, the information is read from the matrix into the operative memory of the device.
11. Next, the image is converted to a color image.
12. After converting the original image from the matrix to a color one, the white balance correction is performed.
13. Ultimately, the image is converted to the format we selected. In our case, the JPEG format is sufficient and optimal for us [15].

### 4.3 Switching Off the PO

The graph (Fig. 7) shows the algorithm of switching off the PO.

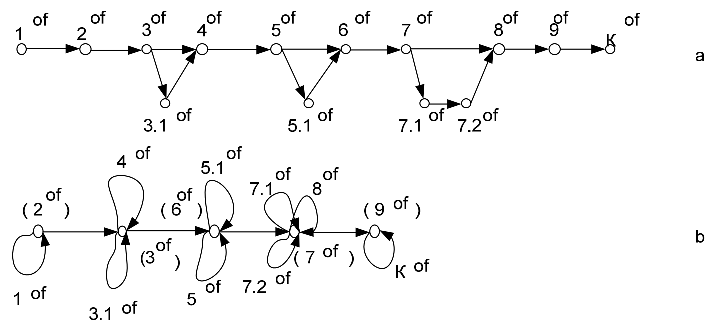


**Fig. 7.** The graph of the algorithm of the procedure of switching off the PO (index OF): a – initial; B – optimized by the method of block-functional distributions (OF – switching off mode) [16].

1. Even before turning off the device, the software must perform a number of procedures. If the operator turned off the device, this does not mean that the device should immediately shut down. So, you need to finish processing the pictures taken earlier, which are in the RAM of the device, and also transfer them to the PC, if there is a connection or save the received images to a flash card.
2. The software needs to find out whether there is a file in the RAM or not.
3. In case there are still files in the memory, the processor should postpone the shutdown until there is no image file in the RAM. The processing time of the images will depend on the level of CPU utilization, that is, the number of images not processed. If, there are no such files in memory, the program can proceed to the next stage of disconnection.
4. In the next step, the program should check whether the transfer of processed files has ended on a flash card or PC. To do this, the program must check whether all the processes of transferring files with images have been completed.
5. If the processor is transferring images to external or removable media, you must first wait for the transfer process to complete. The time for transferring the image from the internal memory to another medium can vary widely. This will depend on several factors.
6. After completing the above tasks, the processor should check the status of the sliding mirror.
7. If there is an activated start point sensor (mirror is omitted), the device can proceed to the next shutdown stage. In the event that the sensor that fixes the initial position of the mirror is not involved, the program turns on the electromagnet and returns the mirror to the starting point.

8 ... 9. At the final stage of the processor, it is necessary to stop the indication, and also to terminate the power supply of the device.
Thus, a synthesis of the general structure, the optical part and the integrated software of the mobile photo-ophthalmoscope-the original device that combines all the functions of traditional ophthalmoscopes for direct ophthalmoscopy with the functions of photographic fixation of the user's observed eye-fund picture was performed.

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