Human-Computer Interaction in the Field of Training in Laser Ophthalmic Surgery

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Abstract. The article describes the methods and approaches of human-computer interaction based on a training complex in the field of laser ophthalmic surgery. The possibility of creating educational computer systems for the development of practical skills when performing laser operations for various eye diseases is considered.

1 Introduction

The Government of the Russian Federation approved a plan for implementing the Digital Economy of the Russian Federation program, within the framework of which it is planned to implement projects of artificial intelligence and simulation education in the healthcare sector by 2020. In modern medical education, computer methods are becoming more widespread, including the usage of hardware and software systems for practicing the technical skills of diagnostic and therapeutic manipulations.

The main reasons for the development of this direction in education is the need for more effective implementation of advanced diagnostic and treatment methods, especially surgical and the possibility of practical training without risk to the patient. Also, the advantages of simulation training are that the duration of the educational process is not limited, there is an objective assessment of the student's actions. Modern educational simulation programs use modern technology of multimedia, 3D-modeling, virtual reality, which allows the creation of educational materials with interactive interaction, the ability to use real clinical data. Human-computer interaction provides the development and development of new surgical techniques in electronic form, via the Internet, including virtual models of new tools and operational situations. In this regard, there is a need to create pedagogical technologies that ensure the continuity of the education system and the preparation for professional activities of doctors of various specialties [1].

Simulation training is an essential component in training specialists in accordance with professional standards and rules for the provision of medical care.

The student or doctor must respond to the situation in the same way as they would in real life. The widespread usage of trainings in the field of healthcare was made it possible with the advent of virtual simulators and patient simulation robots. At the simulation lesson, the priority is the learning task, during which all options for the

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course and outcome of the disease under study are considered. Currently, the standard of continuing medical education is adopted - constant training of Continuous Medical Education medical personnel.

Among the medical specialties, specialized courses are distinguished when training is conducted in one or more disciplines. A virtual clinic is the organizational structure of a training center similar to a multidisciplinary hospital. Level of mastered skills: basic; clinical skills, manipulations, operations; high-tech interventions. The contingent of students: students of medical colleges or universities; doctors, employees of law enforcement agencies and the Ministry of Emergency Measures. Simulation centers have a different status from regional to federal, which allows providing training at all stages of patient treatment. The geography of students in simulation centers is the entire Russian Federation, as well as cadets from near and far abroad.

The objectivity of certification on the basis of approved standards for compliance with the criteria and with the documentation and video recording of the process and the results of pedagogical control is conditioned by a single system for evaluating the results of simulation training. It should be noted that in addition to medical personnel, there are IT specialists in the staff list. Also one of the requirements for the activities of simulation centers is participation in specialized conferences, interaction with specialists in the field of artificial intelligence, computer technology, publications in leading scientific publications.

The classification of simulators is based on the practical application and technologies underlying the simulation. Patient dummy is a complex mechanical model of a person, equipped with electronic devices, controlled by computer programs, which are adjusted by instructors Middle-Fidelity Manikin, Instructor Driven Man. The patient simulator robot is the highest class of realistic presentation of the clinical picture. It has a complex electronic-mechanical design, which on the basis of software realistically imitates the patient's response in response to ongoing manipulations and the introduction of medicines. Changes in physiological status are calculated automatically by the program using a mathematical model and do not require monitoring by the instructor. As part of this work, a hardware-software complex for training laser ophthalmic surgery is considered.

2 Related works

Laser ophthalmic surgery, which arose more than 50 years ago, due to the work of such scientists as M.M. Krasnov, S.E. Avetisov, P.I. Saprykin, and their followers, is currently an independent actively developing area in the treatment of many ophthalmic diseases. Constant improvement of laser technology, the creation of a wide range of lasers for various purposes creates the prerequisites for the gradual replacement of a number of instrumental laser operations. More than three million laser ophthalmologic surgeries are performed annually in the world, and a significant proportion of them are in Russian clinics.

Thus, there is an ever-growing demand for specialists in the field of laser ophthalmic surgery. However, the training of medical personnel of this profile is complicated by the fact that the structures of the eye are extremely small, as well as the fact that obtaining tactile surgical skills is impossible without practice.

In 2004, a simple eye model was presented for examination using a pocket ophthalmoscope [2]. The device consisted of a plastic case where a photograph of the retina was located. The hole in the housing imitated a pupil.

At the end of 2007, a model called THELMA (Pao KY, Uhler TA, Jaeger EA) was described. The device was implemented the same principles. The difference was in the implementation of the body of the device in the form of the patient's head, which allowed us to speak of greater realism. Later, in the simulators EYE (Kyoto Kagaku Co., Kyoto, Japan) [3] and Eye Retinopathy Trainer (Rouilly Co., Sittingbourne, UK) implemented as a real-size dummy head with an adjustable pupil, the fundus image quality was significantly improved.

In 2014, a device was proposed in which the image of the retina during examination of a real patient, using a video system, was duplicated on a laptop screen.

The most advanced simulator in the field of ophthalmology at the moment is the virtual ophthalmological simulator of the German company VRMagic Eyesi, first introduced in 2001, and, after that, repeatedly modified. Now Eyesi is an imitation of the workplace of an ophthalmic surgeon: on the operating table, adjustable in height, lies a mask with an eye model, which the learner operates with the tools included in the simulator kit. The instruments that the cadet introduces into the eye become visible through a binocular microscope. Due to high-speed computer graphics in real time, simultaneously with hand movements, an image of eye tissues and their interaction with instruments are generated and transmitted in the field of view of the microscope. During the training intervention, virtual tissues adequately respond to the manipulations of the cadet - the occurrence of bleeding, swelling, rupture, turbidity.

The set of training modules includes a set of instruments for surgery of the anterior and posterior parts of the eye, an endolaser, a phacoemulsifier and a vitreotome with control panels, which allows you to master the work on these modern devices.

The advantages of this development include high realistic simulations, the ability to develop skills for a wide range of surgical interventions, as well as the fact that this is the only currently sold ophthalmic surgery simulation system using virtual reality [4]. A disadvantage can be considered a limited (usually no more than 5 options) set of virtual models of eye structures, as well as high cost. For the Russian consumer, the price of Eyesi varies, depending on the configuration, from 200,000 euros [5].

It should be noted that there is a number of Russian-language publications on the development of virtual laser ophthalmic surgery simulators, but actually working devices, are not yet presented on the world market [6-7-8].

3 Goals of educational process

In the process of teaching laser ophthalmology, students must master a number of basic skills:

• use of equipment for examining a patient;

• correct diagnosis;

• selection of parameters for laser surgery;
• use of equipment for surgical intervention.

When examining a patient, the doctor uses an ophthalmic microscope with a built-in slit lamp. A slit lamp allows to examine the conjunctiva, cornea, iris, anterior chamber of the eye, the lens, vitreous, and also the central parts of the fundus. This equipment is one of the main research tools in ophthalmology. At the same time, the slit lamp has many settings, and to work with it you must have the appropriate knowledge and skills, including practical ones. However, using a real slit lamp for training specialists, expensive equipment, is unprofitable, and not every organization can afford such training method. In addition, the usage of real patients as a “visual aid” is not always possible and convenient.

For the correct diagnosis and choice of treatment methods, theoretical knowledge is needed that can be obtained in the traditional way: by studying literature and looking at illustrative material. However, electronic learning tools allow to:

• significantly increase the number of clinical cases under consideration;
• maximize the process of studying illustrations to the actual conditions of examination of the patient.

To use the laser when operating ophthalmic structures, one must:

• be able to set the appropriate laser exposure settings;
• have tactile laser beam control skills.

Tactile laser control skills are a practical skill that cannot be acquired without training. Figure 1 shows the fundus image after laser coagulation of the “lattice” type; light spots are the results of laser exposure. Depending on the disease, the size of the laser spots and the distance between them can vary in the range of 50-500 microns. In some cases, quite stringent requirements are imposed for observing the dimensions of the “lattice” [8]. In this case, the operation must be performed for some limited time.

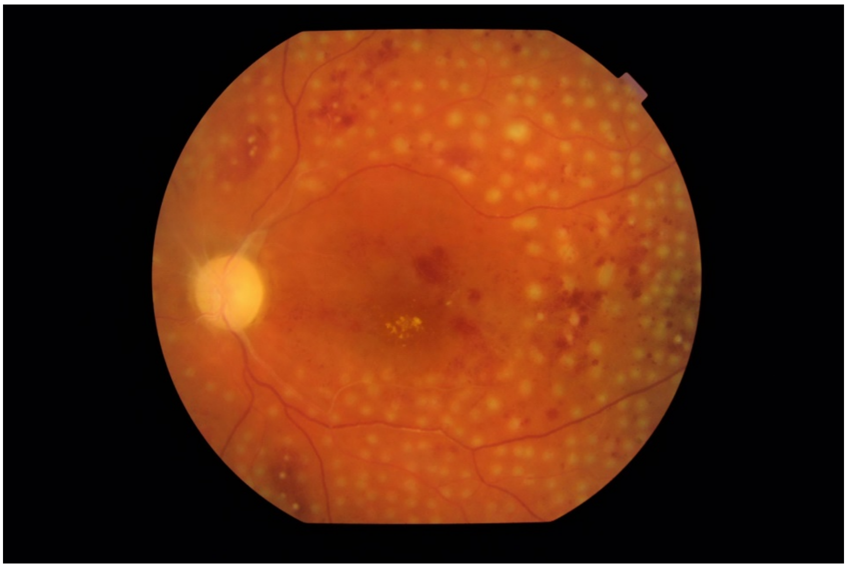

Figure 1. The fundus before and after laser coagulation.

Thus, for high-quality training in the field of laser ophthalmic surgery, it is necessary to create a hardware-software complex that meets a number of requirements:

• equipment should be as close as possible to a real surgical installation;

• Equipment should allow realistic simulation of eye examination and laser surgery;

• the use of any of the controls of the laser microsurgery unit should cause changes that are the same as in this operation. The laser beam must change direction and power, the tissues being operated must change the appearance when exposed to them;

• There should be the possibility of studying theoretical material;

• tasks must be present in the system that allow to gain skills in examining the patient, setting up dianosis, and choosing the parameters of the therapeutic effect;

• tasks must be present in the system, allowing them to develop tactile skills for managing the surgical complex (laser and slit lamp);

• There should be the possibility of assessing the correctness of the fulfillment of all types of tasks.

4 Hardware implementation of the training complex

A modern laser ophthalmic surgery unit usually consists of:

• a surgical microscope with a built-in slit lamp (slit lamp);

• operational laser.

The slit lamp (Figure 2) is used during the examination of the patient and during surgery. On the eyepieces of a slit lamp, an image of various parts of the eye is displayed. The design of the lamp necessarily contains an optical system (binocular microscope) and a lighting system supplemented by a slit diaphragm. The settings of these two systems allow obtaining various images of eye structures.

When implementing the slit lamp simulator, the appearance of the equipment is completely preserved, but instead of the patient, a monitor is placed in the field of view of the microscope, on which the fundus image of the virtual patient is displayed.

The most difficult problem in creating this node was the task of designing a lens system of a virtual microscope, so when projecting an image from a display onto the microscope's eyepieces, suppress the natural graininess of the displays, which is unusual for the microscope image. This problem was solved by selecting an original combination of collecting and scattering lenses. In addition, the distance to the display was selected, which ensured the size of the visible area corresponding to the actual conditions of the operation. When implementing the lens system, the Abbe scheme was taken as the basis: the only image displayed on the monitor is transmitted to the eyepieces of the simulator using a binocular nozzle (Figure 3). All work on the selection of parameters with the assessment of the quality of the resulting image was carried out in consultation with ophthalmologists.

The construction is designed so that it is protected from the influence of external light. It also further standardizes visualization conditions.

Figure 2. Slit lamp

The slit lamp settings knobs are equipped with sensors connected to the host computer. The interface between the sensors and the control computer is built using the Arduino Mega board, based on the ATmega1280 microcontroller, operating at a clock frequency of 16 MHz, having 8 KB of RAM, 16 analog inputs. The slit lamp monitor is also connected to the host computer. Thus, the change in the settings of the

slit lamp is monitored by the control computer, and an image modified in accordance with the current settings of the microscope is fed to the monitor. The same principles apply to virtual laser settings.
The simulator of the operating laser control unit is made on the basis of a touch screen, which corresponds to modern equipment. Figure 3 shows Integre Pro Scan, an integrated laser system from ELLEX (Australia) that uses this technology.
To guide the laser beam in the simulator, a joystick is used, which also corresponds to real equipment (Figure 3).

Figure 3. The integrated laser system of the ELLEX company (Australia)

In addition to the mentioned equipment, a monitor can be added to the training complex, which is used to present text-based training material, descriptions of training and test tasks. This monitor duplicates the image displayed on the eyepieces of the slit lamp, to monitor the tasks from the teacher. In the absence of such a monitor, a simulator of the laser settings control unit can be used for these tasks.

5 Training software

The software of the complex has three levels:

- software that implements the communication of the slit lamp and laser controls with the control computer;
- software visualizing the fundus image and the interaction of the laser beam with the operated tissues;
- software designed to support the training and testing of acquired knowledge and skills.

To write the microcontroller module, which organizes the interface between the sensors and the control computer, the Arduino programming language was used. The module provides reading sensor values through analog ports and transmitting these values to the control computer.

The control computer software is implemented in C ++, the Visual Studio 2015 compiler, using the cross-platform library Boost 1.62. To visualize the image on the eyepieces of the microscope, real photographic images of the fundus of the patients are used, stored in the computer memory in the Jpeg, RGB format (256 gradations in the color channel).

Depending on the settings of the slit lamp simulator received by the control computer, various digital filters are applied to the image, which allow simulating various types of lighting, the degree of magnification, and the configuration of the slit. The output image can be scaled, the brightness is adjustable, there is the possibility of moving the image.

The intensity of each of the three color channels can be changed. This functionality is necessary to set up a virtual operating microscope in relation to the realism of the image obtained in the eyepieces.

The virtual laser beam control module was developed in C ++ (Visual Studio 2015 compiler), using the Microsoft XNA software package for working with the joystick.

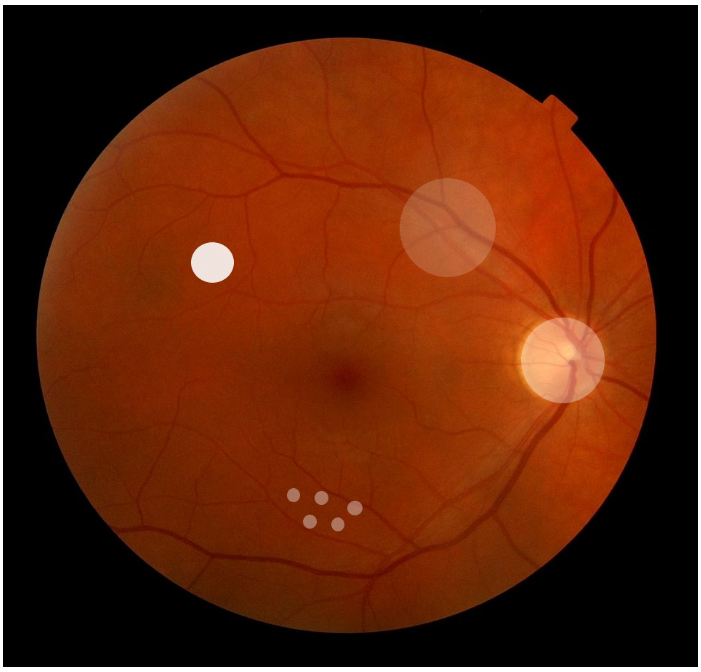

Figure 4. Visualization of traces of laser exposure to tissue

Visualization of the interaction of the laser beam with the operated tissues is achieved by increasing the brightness of the circular region of the image, the center of which coincides with the point of the laser sight. In this case, the brightness increase coefficient has a value greater than 1.0 and varies depending on the wavelength of the laser beam (green, yellow, red - 532, 561, 659 nm, respectively) and the exposure time (0.1-0.5 sec) selected by the student in the laser exposure settings . The diameter of the spot corresponds to the diameter of the laser beam (50 1000 microns, correlated to the size of the visible operating area), also previously indicated by the trainees. Figure 5 shows examples of visualization of traces of exposure of different powers with different values of the diameter of the laser beam.

This type of visualization is intended to assess the accuracy of laser positioning, but does not serve as a criterion for assessing the correctness of the selected parameters of the treatment effect (laser power and beam diameter). The correctness of the choice of parameters of the therapeutic effect is assessed by comparing the optimal parameters laid down in each task with the help of consultants-ophthalmologists and the parameters set on the simulator by the trainee.

6 Building training

Training with the help of the described complex involves the study of theoretical information and the acquisition of practical skills, as well as quality control of the development of the material.

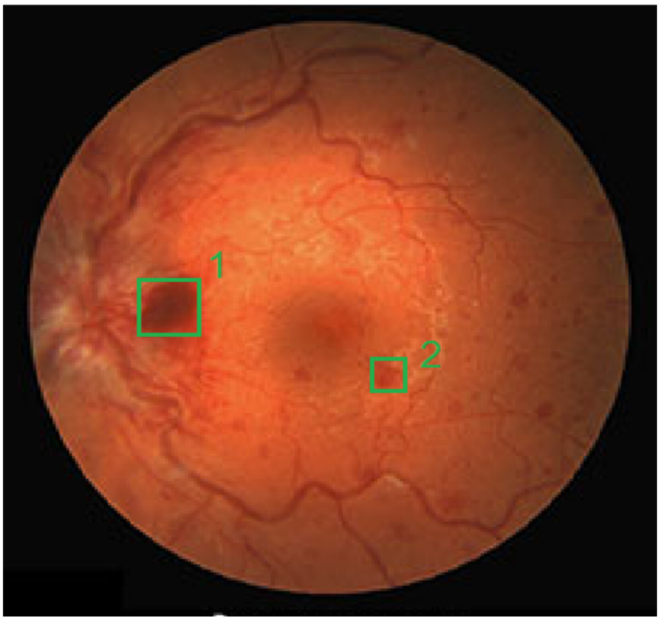

Figure 5. Laser Positioning Job Window

When passing this series of tasks, not only the correct positioning of the sight is evaluated, but also the speed of the task.

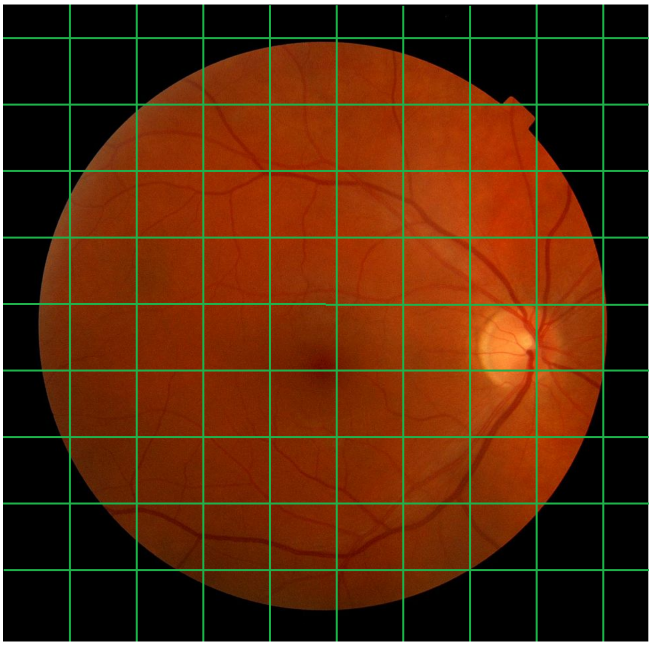

Figure 6. Laser Positioning Job Window

7 Conclusion

In this work, a hardware and software complex designed for the training of laser ophthalmic surgery was described. The described equipment allows a realistic simulation of laser ophthalmological operations in close to real conditions. The use of real clinical cases for modeling the surgery area makes it possible to constantly expand the training material. The complex is intended primarily for training ophthalmologists, but can also be used as part of continuing education courses and accreditation simulation centers.

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