Augmented reality in ophthalmology: development of a software interface for interaction with a virtual reality headset

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Abstract. This work is devoted to the application of augmented reality in the field of ophthalmology. The paper presents information on image formation and discusses modern technologies used in diagnostics. For a visual demonstration of the possibilities of augmented reality, an application was implemented that allows a person to interact with a virtual reality headset and study the anatomy of the human eye using 3D models. The goal of the project is to develop a training software tool for human interaction with a virtual reality headset for use in the field of ophthalmology. The object of the research is the processes occurring in information systems during the functioning of augmented reality applications. The subject of the research is the functioning of augmented reality applications in the field of ophthalmology.

1. Introduction
A person with physiological double vision perceives all objects of the real world in the zone of optimal stereopsis, and the sense of depth is determined by the magnitude of disparity. The image seen by the left eye is different from the image seen by the right eye. Due to this, our brain is able to restore the depth of the observed scene [1].

All evidence from evolutionary biology indicates that binocular vision serves to enable very accurate depth discrimination. Complex mechanisms for maintaining binocularity, present even in predatory animals of different lineages, demonstrate the adaptive value of depth perception based on two eyes [1].

Charles Wheatstone defined the stimulating conditions necessary for depth perception in 1838 and integrated geometric relationships describing the lines of sight of two movable, horizontally separated eyes. Because of the separation, each eye sees the world from a slightly different angle. Thus, if you fix some point in space (hold a pencil) and alternately close each eye, the difference in views becomes apparent [2].

In my work, we propose a development that is based on the use of binocular architecture in virtual reality glasses and will improve the work of future surgeons.

2. Augmented reality in medicine
Augmented reality is a collection of real objects and programmable ones. Any household items, body parts, and text can act as real objects. It is important to remember that for an accurate image to be captured, the subject must be static for the camera to recognize. Otherwise, you will receive a damaged or unstable image on the headsett.
There are two groups of Virtual Reality headsets: headsets that use a smartphone display to present an image and headsets that have their own display. The first group includes such popular gadgets as Google Daydream and Samsung Gear VR, as well as many other analogues. The second group includes Microsoft VR Gaming, Oculus Rift, Sony Playstation VR and others. A significant difference between these groups is not only the type of display used, but also the presence of sensors, controllers for the second, as well as a significant difference in the price category of goods.

The VR headset display is less than 15 cm from the eyes. However, between the human eye and the screen there is a collecting lens and that allows you to perceive the image remotely and not lose orientation in space.

Virtual reality technologies play an important role in telemedicine from remote diagnostics to sophisticated tele-interventions. 3D computer graphics pioneered the development of virtual reality technology several decades ago. The main goal is to create images with virtual objects or complete scenes in an almost photorealistic manner. To achieve this goal, two main components are required: appropriate algorithms for calculating the visual appearance of a virtual scene to be visualized - rendering, and physical devices (in most cases, graphic displays) to present the resulting images to the user.

An extensive collection of rendering techniques have been developed over the past decades. They mainly simulate the interaction of light with the geometry of virtual objects, which can be represented as a collection of surfaces (surface rendering) or as volumetric models (volume rendering). To achieve real-time performance for large objects, various specialized accelerators have been developed and are readily available today, even for personal computers. The level of realism can be significantly increased through the use of texture mapping methods, which make it possible to paint the presented surfaces with detailed photographic images.

The results of these rendering algorithms are presented on a video monitor. Since stereoscopic vision is a fundamental prerequisite for realistic immersion in a virtual scene, considerable effort has gone into the development of stereoscopic display systems. The basic technique of these devices is to present the scene from a slightly different perspective to each eye. The easiest way to achieve this separation is to use polarized glasses, which selectively filter the images that appear on the screen. A different resolution is provided by head mounted displays, with a separate screen for each eye. New technological developments based on the construction of special display screens or holography promise to eliminate the need to carry special equipment while maintaining a completely stereoscopic representation of the scene. Typical resolution for commercial stereoscopic displays is around 1200 × 500 pixels, while cheaper head-mounted displays provide much poorer resolutions at around 400 × 200 pixels.

Graphical Guided Surgery is a typical application where virtual objects (data from the preoperative image and anatomical objects extracted from them) and real objects (patient and surgical instruments) must be combined into single unified scene requiring augmented reality techniques[3]. For the first time in medical history, on April 14, 2016, Shafi Ahmed, a cancer surgeon, performed an operation using a virtual reality camera at the Royal London Hospital. Everyone could follow through two 360-degree cameras as the surgeon removed the cancerous tissue from the patient's intestines.

Using of VR makes it possible to expand the level of vision both for educational purposes[3] and in the long term for carrying out operations with binocular virtual reality glasses [4]. This will increase the effectiveness of student learning, as well as contribute to a deeper study of the anatomy of the eye.

3. Materials and methods

3.1 The Main modules
The application contains three main modules: target, application module and content. For the application to function a label is needed - some object that is fundamental. The essence of the label is that the programmed image will be based on it. That is, if the quality of the selected object is low, then the resulting display of the model will be unstable. Labels are divided into 5 levels. This indicator depends on the number of nodes of the contour connections.
Level 1 is an indicator of 0 or 1, it signals that the quality of displaying an object for this label will be very low, since it has a small number of objects.

Level 2 is indicator 2; it differs from the previous one by a slight increase in image contrast, but is still unsatisfactory.

Level 3 is indicator 3; it indicates a satisfactory quality of the mark and (creates additional contour connection nodes).

Level 4 is an indicator of 4, it corresponds to a greater number of used marks and already at 45% of the mark hitting the scan area - the corresponding volumetric image is displayed correctly.

Level 5 is an indicator of 5, it is considered a reference, and even with a 30% hit of the mark in the scanning area, the volumetric image will be displayed even in not the best lighting [5]. In Figure 2 you can see the target that was used to display the normal anatomy of the eye.

Figure 1. Block diagram of AR application development

Figure 2. Level 5 target mark used for the normal eye anatomy model in the app
The second main module of the application is the application module. It performs the function of recognizing the label, combining and transferring the image from the camera to the VR headset - Xiaomi MI VR 2 [6]. For the development of the application used the programming language C#. The main framework that was used in software development was a cross-platform framework for software development in the C# programming language - Unity 3D.

The main class in the application is the Main Cam class. Its purpose is to capture an image from a camera device, image processing and tag recognition. The Concat class combines the recognized image and displays the combined image on the headset - augmented reality[7].

The third module is content. The content is modelled 3d eye models: normal eye anatomy and various pathologies. 3D models are made in Autodesk 3ds Max environment. The models were compiled into packages and imported into the Unity 3D development environment. After integrating all three main modules, we get an augmented reality application that recognizes the disease by tags and displays the corresponding 3D model on the VR headset. An example of how the application works is shown in Figure 3 and Figure 4. The development was introduced at the Department of Ophthalmology for teaching students.

![Figure 3. Normal eye anatomy model](image1)

![Figure 4. Cataract eye model](image2)
The main feature is that the use of a VR headset expands the level of vision and improves the perception of pathology [8]. At the same time, the use of VR eliminates the load on the cervical spine during prolonged viewing under a microscope, now the picture can be seen before the eyes. Example of the displaying eye-model on VR-headset is presented on the Figure 5.

![Eye model view in VR-headset](image)

**Figure 5.** Eye model view in VR-headset

### 3.2 Application testing

System testing was done by the user, that is, according to the black box model. It meant the first test build on Android with a high quality tag and final 3D model. System testing resulted in established defects with different priorities:

1. The speed of target-mark recognition is more than 5 seconds.
2. The position of the model is not fixed when rotating the head.
3. Application camera response with significant braking.
4. The target-mark recognition radius is less than 1.5 meters.
5. The quality level of the target is below 4.

After correcting some of the defects, a repeated testing was performed - regression. Its purpose is not only to make sure that the defect no longer manifests itself and has already been fixed, but also to verify that these changes did not affect the operation of other modules.

Summing up the testing, it is worth noting that testing was carried out, within which the most critical defects were identified and corrected. The application is ready to use and all functionality meets the requirements.

### 4. Conclusion

The general architecture of the augmented reality software was developed. In addition, it was designed, developed and tested software with a graphical interface for recognizing real objects and teaching on the example of normal eye anatomy and various pathologies. The application functionality meets the following requirements:

- the application transfers the image to the VR-headset;
- when you hover over a mark, the corresponding 3D model appears;
- it is possible to add more than 10 labels and corresponding 3D models;
- the tag is recognized at a distance of up to 1.5 meters;
- when rotating the head, the image of the model does not disappear;
- mark level 4 or more;
- application launch time no longer than 10 seconds;
- response time of head movement in the headset in real time.

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