Ministry of Education and Science of the Russian Federation
Federal Independent Educational Institution
«NATIONAL RESEARCH TOMSK POLYTECHNIC UNIVERSITY»

Research School of Chemistry & Applied Biomedical Sciences
Program/specialty 12.04.04 «Biotechnical systems and technologies»

MASTER'S THESIS

Topic of the work
Разработка программного комплекса для оценки и реабилитации двигательных расстройств при поражении центральной нервной системы **Development of a software package for the assessment and rehabilitation of motor disorders in lesions of the central nervous system**

UDC: 004.415.2:004.946:616.831

Student

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Tomsk – 2020

Planned program learning outcomes

Код результата	Результат обучения (выпускник должен быть готов)	Требования ФГОС, критериев и/или заинтересованных сторон
Профессиональные компетенции		
P1	Применять глубокие специальные естественнонаучные, математические, социально-экономические и профессиональные знания в инновационной инженерной деятельности при разработке, производстве, исследовании, эксплуатации, обслуживании и ремонте современной биомедицинской и экологической техники	Требования ФГОС (ОК-2, ОПК-2), Критерий 5 АИОР (п. 5.2.1), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P2	Ставить и решать инновационные задачи инженерного анализа и синтеза с использованием специальных знаний, современных аналитических методов и моделей	Требования ФГОС (ОПК-1, 3; ПК- 1 – 4), Критерий 5 АИОР (п. 5.2.2), согласованный с требованиями международных стандартов EUR-ACE и FEANI
P3	Выбирать и использовать необходимое оборудование, инструменты и технологии для ведения инновационной практической инженерной деятельности с учетом экономических, экологических, социальных и иных ограничений	Требования ФГОС (ОК-9, ПК-10, 14, 18). Критерий 5 АИОР (пп. 5.2.3, 5.2.5), согласованный с требованиями международных стандартов EUR-ACE и FEANI
P4	Выполнять комплексные инженерные проекты по разработке высокоэффективной биомедицинской и экологической техники конкурентоспособной на мировом рынке	Требования ФГОС (ОК-2, 3; ПК-5 – 11, 14), Критерий 5 АИОР (пп. 5.2.3, 5.2.5), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P5	Проводить комплексные инженерные исследования, включая поиск необходимой информации, эксперимент, анализ и интерпретацию данных с применением глубоких специальных знаний и современных методов для достижения требуемых результатов в сложных и неопределенных условиях	Требования ФГОС (ОК-2, 3; ОПК-5, ПК-1 – 4). Критерий 5 АИОР (пп. 5.2.2, 5.2.4), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P6	Внедрять, эксплуатировать и обслуживать современное высокотехнологичное оборудование в предметной сфере биотехнических систем и технологий, обеспечивать его высокую эффективность, соблюдать правила охраны здоровья и безопасности труда, выполнять требования по защите окружающей среды	Требования ФГОС (ОПК-1, 2), Критерий 5 АИОР (пп. 5.2.5, 5.2.6), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
Универсальные компетенции		
P7	Использовать глубокие знания в области проектного менеджмента для ведения инновационной инженерной деятельности с учетом юридических аспектов защиты интеллектуальной собственности	Требования ФГОС (ОПК-2; ПК-14, 15). Критерий 5 АИОР (п. 5.3.1), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P8	Владеть иностранным языком на уровне, позволяющем активно осуществлять коммуникации в профессиональной среде и в обществе, разрабатывать документацию, презентовать и защищать результаты инновационной инженерной деятельности	Требования ФГОС (ОК-1), Критерий 5 АИОР (п. 5.3.2), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P9	Эффективно работать индивидуально и в качестве члена и руководителя команды, состоящей из специалистов различных направлений и квалификаций, с делением ответственности и полномочий при решении инновационных инженерных задач	Требования ФГОС (ОК-3, ОПК-3; ПК-3, 12, 13), Критерий 5 АИОР (п. 5.3.3), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P10	Демонстрировать личную ответственность, приверженность и готовность следовать профессиональной этике и нормам ведения инновационной инженерной деятельности	Критерий 5 АИОР (п. 5.3.4), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P11	Демонстрировать глубокие знание правовых социальных, экологических и культурных аспектов инновационной инженерной деятельности, компетентность в вопросах охраны здоровья и безопасности жизнедеятельности	Критерий 5 АИОР (п. 5.3.5), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*
P12	Самостоятельно учиться и непрерывно повышать квалификацию в течение всего периода профессиональной деятельности	Требования ФГОС (ОК-2, 4; ОПК-4), Критерий 5 АИОР (п.5.3.6), согласованный с требованиями международных стандартов *EUR-ACE* и *FEANI*

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Program/specialty 12.04.04 «Biotechnical systems and technologies»

APPROVED BY
Head of the Program
_____ _____ F.A.Gubarev
(Signature) (Date)

ASSIGNMENT
for the Master's Thesis completion

In the form:

Master's Thesis

For a student:

Group	**Full Name**
9DM8I	Skopchenko Evgeny Maksimovich

Topic of the work:

Разработка программного комплекса для оценки и реабилитации двигательных расстройств при поражении центральной нервной системы **Development of a software package for the assessment and rehabilitation of motor disorders in lesions of the central nervous system**	
Approved by the order of the Head (date, number)	

Deadline for completion of the Master's Thesis:	

TERMS OF REFERENCE:

Initial data for work: *(the name of the object of research or design; performance or load; mode of operation (continuous, periodic, cyclic, etc.); type of raw material or material of the product; requirements for the product, product or process; special requirements to the features of the operation of the object or product in terms of operational safety, environmental impact, energy costs; economic analysis, etc.).*	The object of the research: development of a software package for the assessment and rehabilitation of motor disorders in lesions of the central nervous system Subject matter of the research: central nervous system disorders The results of this study can be used to rehabilitate patients with impaired motor functions of the upper and lower extremities, up to the full or partial restoration of fine motor skills and large motor motility
List of the issues to be investigated, designed and developed *(analytical review of literary sources in order to elucidate the achievements of world science and technology in the field under consideration, the formulation of the problem of research, design, construction, the content of the procedure of the research, design, construction, discussion of the performed work results, the name of additional sections to be developed; work conclusion).*	• Writing a review of the literature and analysis on the topic; • Research of existing developments in this area, planning the creation of software • Completion of equipment and software for creating a software package • Creation of a software package for the rehabilitation of motor disorders in augmented reality; • Research of results and their interpretation; • Assessment of the possibility of further development of this path

	• Feasibility study; • Industrial and environmental safety.
List of graphic material *(with an exact indication of mandatory drawings)*	
Advisors on the sections of the Master's Thesis	
Chapter	**Advisor**
Section «Financial Management, Resource Efficiency and Resource Saving»	Associate professor, Menshikova Ekaterina Valerievna
Section «Social Responsibility»	Associate Professor, Mikhail Vladimirovich Gorbenko

Date of issuance of the assignment for Master's Thesis completion according to a line schedule	

The task was issued by the Scientific Supervisor and Technical Advisor:

Position	Full Name	Academic degree, rank	Signature	Date
Associate Professor, SSMU	Tolmachev Ivan Vladislavovich	Candidate of Technical Sciences		
Associate Professor, TPU	Gubarev Fedor Alexandrovich	Candidate of Physical and Mathematical Sciences		

The assignment was accepted for execution by the student:

Group	Full Name	Signature	Date
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ASSIGNMENT FOR SECTION
«FINANCIAL MANAGEMENT, RESOURCE EFFICIENCY AND RESOURCE SAVING»

To the student:

Group	Full name
9DM8I	Skopchenko Evgeny Maksimovich

School	RSCABS	**Division**	
Degree	Master	**Educational Program**	12.04.04 Biotechnical systems and technologies

Input data to the section «Financial management, resource efficiency and resource saving»:	
1. *Resource cost of scientific and technical research (STR): material and technical, energetic, financial and human*	– Salary costs – 375012 rubles – STR budget – 773725 rubles.
2. *Expenditure rates and expenditure standards for resources*	– Electricity costs – 3487 rubles.
3. *Current tax system, tax rates, charges rates, discounting rates and interest rates*	– Labor tax – 14,71 %; – Overhead costs – 13,79%;
The list of subjects to study, design and develop:	
1. *Assessment of commercial and innovative potential of STR*	– comparative analysis with other researches in this field;
2. *Development of charter for scientific-research project*	– SWOT-analysis;
3. *Scheduling of STR management process: structure and timeline, budget, risk management*	– calculation of working hours for project; – creation of the time schedule of the project; – calculation of scientific and technical research budget;
4. *Resource efficiency*	– integral indicator of resource efficiency for the developed project.
A list of graphic material *(with list of mandatory blueprints):*	
1. *Competitiveness analysis* 2. *SWOT- analysis* 3. *Gantt chart and budget of scientific research* 4. *Assessment of resource, financial and economic efficiency of STR* 5. *Potential risks*	

Date of issue of the task for the section according to the schedule	3.02.2020

Task issued by adviser:

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Group	Full name	Signature	Date
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ASSIGMENT FOR THE SECTION
«SOCIAL RESPONSIBILITY»

For the student:

Group	Full name
9DM8I	Skopchenko Evgeny Maksimovich

School	RSCABS	**Department**	
Level of education	Master's degree	**Program/Specialty**	12.04.04 Biotechnical systems and technologies

Initial data to the section «Social responsibility»:	
1. *Characteristics of the object of study (substance, material, device, algorithm, method, working area) and its areas of application*	*Development of a software package for the assessment and rehabilitation of motor disorders in lesions of the central nervous system using video capture.. Video capture can be used to accurately determine the coordinates of the location of the hand and fingers.* *The workplace is located in a laboratory room equipped with a computer, a work desk, laboratory equipment, lamps for lighting the working area.*
The list of issues to be investigated, designed and developed:	
1. Legal and organizational safety issues: *1.1. Special legal norms of labor legislation.* *1.2. Organizational arrangements for the layout of the working area.*	*Special legal norms of labor legislation (medical examination of employees, safety instructions, provision of personal protective equipment).* *Requirements for the organization of the workplace.*
2. Industrial safety: *2.1. Analysis of harmful and dangerous factors that can be created by object of study.* *2.2. Analysis of harmful and dangerous factors that may arise in the laboratory during research.*	*2.1 Analysis of harmful factors, which in turn can have a negative impact on humans. These include:* *2.1.1. microclimate of the working room;* *2.1.2. illumination of the working area;* *2.1.3. noise level at the workplace;* *2.1.4. increased level of electromagnetic radiation.* *2.2 Analysis of identified hazards:* *2.2.1 electrical safety*
3. Ecological safety:	*The facility does not affect the environment.* *Disposal of equipment.*
4. Safety in emergency situations: *4.1. Analysis of probable emergencies that may occur in the laboratory during research.* *4.2. Justification of measures to prevent emergencies and the development of procedures in case of an emergency.*	*Legal and organizational security issues:* *• layout of the working area;* *• modes of work and rest.*

Date of assignment for the section on a linear schedule	3.02.2020

Assignment was issued by an advisor:

Position	**Full name**	**Degree**	**Signature**	**Date**
Associate professor	Mikhail Vladimirovich Gorbenko	Candidate of Technical Sciences		

Assignment was accepted for execution by the student:

Group	**Full name**	**Signature**	**Date**
9DM8I	Skopchenko Evgeny Maksimovich		

ABSTRACT

Final qualifying work 53 p., 13 fig., 15 tab., 12 sources., 8 appendices.

Keywords: motor impairment, augmented reality, Leap Motion controller, Epson Moverio BT-300 glasses.

The object of study is motor impairment.

Objective: development of a software package for the assessment and rehabilitation of motor disorders in lesions of the central nervous system.

In the process of the study were carried out: analysis of the literature on this topic, selection and creation of the program.

As a result of the study, a software package was developed for the rehabilitation of motor disorders in augmented reality.

Scope: Neurology (stroke, multiple sclerosis).

Economic efficiency / significance of work: mobility in use.

Definitions, symbols, abbreviations, normative references

The following abbreviations are used with the corresponding decodings:

- PC - personal computer
- AR – augmented reality
- VR – virtual reality
- Soft – Software
- OS - operating system

Content

Introduction

Currently, augmented reality technologies have reached a high level of development even before the introduction of AR in all spheres of life. However, the real potential of augmented reality is tremendous. We must admit that AR is seen more as a marketing "toy", as yet another marketing ploy that replaced the advertised 3D glasses in glossy magazines. However, the real potential of augmented reality is huge. AR is able to completely transform our entire world, making it more convenient, safe and interactive. AR is a kind of "bridge" between the real and virtual worlds. This is its main advantage over fully virtual reality (VR). AR in its essence requires contact with reality. It does not replace, but complement it. This eliminates the possible psychological dangers of using this technology in education, starting from a very young age. [1]

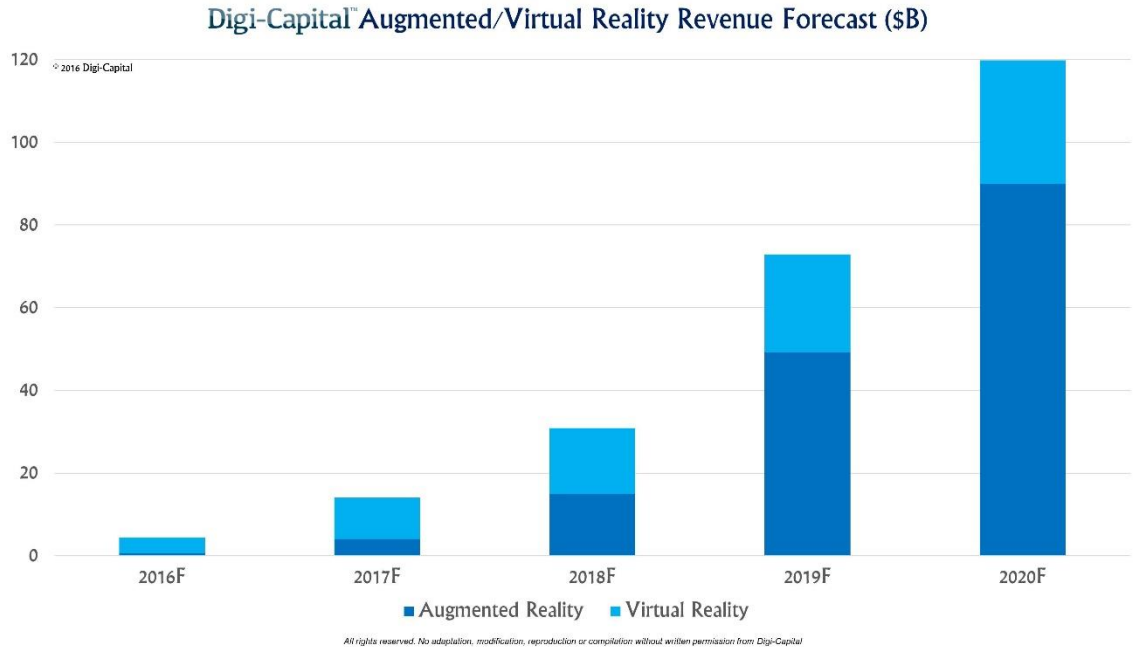

Figure 1. Augmented / virtual reality usage statistics.

Currently, augmented reality is widely used in various fields, such as the media, medicine during operations and rehabilitation of patients after a stroke, military technologies, for example, augmented reality is built into the pilot's helmet so that he can see the world around him, supplemented with necessary information in the AR glasses for the convenience and ease of use of the aircraft, without being distracted by individual devices on the panel. [3]

The basic and comprehensive idea is to define the tasks and their purpose, and then improve them using augmented reality. Some of the presented products have already taken their place in the market and are used in hospitals. Others are in their earlier stages. [1]

Purpose and tasks

Purpose:

Creation of a software package for the rehabilitation of motor disorders in augmented reality.

Tasks:

1. Analysis of modern rehabilitation methods using virtual and augmented reality technologies and preparation of requirements for the software complex.
2. Software prototyping.
3. The implementation of several types of rehabilitation methods based on augmented reality glasses.

1. Literature review

1.1 Augmented Reality.

Augmented reality is a technology of adding, introduction into real life and a three-dimensional field of human perception of virtual information, which is perceived as an element of real life. With quality content, a person erases the line between reality and the artificially created world. Reality is expanding (or supplementing) by introducing virtual information into it. [2].

Thus, in the creation of augmented reality in real time, objects are placed in real time using special software and gadgets, such as:

- Augmented reality glasses (“smart glasses”)
- Map-case.
- Smartphones with AR function and other gadgets.

The world of augmented reality has the following properties:

- Combines virtual and real.
- Interacts in real time.
- Works in 3D.

To create augmented reality, the following devices are used: a processor, display, camera, and position-determining electronics such as an accelerometer, GPS and a compass. A touchscreen smartphone, for example, has the necessary kit so that the owner of the gadget plunges into the world of augmented reality [2,3].

Augmented reality applications work as follows:

- A special mark is used.
- The tag is read by a mobile device or computer.
- A layer of additional information is displayed on the screen.

One of the ways to complement reality is the use of AR-tags (special tags), which are able to encrypt a large amount of information. Augmented reality tag technologies can be divided into:

- marker;
- markerless (based on the coordinates of the user's location).

The marker is usually a surface with a special image. The type of pattern may vary and depends on the image recognition algorithms. There are various types of represented markers, they can have geometric shapes of simple shapes (for example, a circle or a square) and objects in the shape of a rectangular parallelepiped or, for example, people's faces. However, the surface that is used as the output device for a special image is usually static, which means that any movement of an augmented reality object is possible only with special algorithms, which in turn will reduce the accuracy of the location of the object, as well as increase the need for computing power for its location in augmented reality. An alternative to a static image is interactive displays: multi-touch tables, interactive whiteboards, display cases or walls [6,8]

Markerless technologies are based on recognition algorithms, with the help of which a virtual “grid” is superimposed on the surrounding landscape and captured on camera. Software algorithms analyze the “grid”, find reference points (marker), and based on the information about the position of the marker in space, the program can accurately project a virtual object onto it, from which the effect of its physical presence in the surrounding space will be achieved. Using additional graphic filters and high-quality models, a virtual object can become practically real and difficult to distinguish from other elements of the interior or exterior. [6, 8]

Conclusion

An analysis of the literature in the field of stroke and after stroke rehabilitation showed that this topic is acutely social. Despite the development of medicine, diagnostic and rehabilitation techniques and technologies, acute cerebrovascular diseases remain diseases with a high percentage of mortality and disability. The early start of rehabilitation increases the chances of restoring motor function, as well as the psycho-emotional state. The introduction of modern information technologies should help doctors and patients to achieve maximum results in the shortest possible time.

The application of virtual and augmented reality technologies can be traced in various fields, such as pilot training, construction and tourism. One of the promising areas is medicine, which has a wide range of applications of these technologies. The ability to teach students using simulators in a virtual environment or three-dimensional visualization of educational material using augmented reality. The use of modern technologies in the rehabilitation of patients with disorders of the musculoskeletal system and fine motor disorders can improve the quality of therapy.

2. Materials and methods

2.1 Types of methods for assessing motor dysfunction.

There are at least 2 ways to evaluate neurological disorders:

- Moving pegs into a container with holes.
- Gorbov-Schulte test.

Implementation of the Gorbov-Schulte test in a virtual environment is much simpler and more practical than “Moving pegs into a container with holes.”

The Gorbov-Schulte estimation method is one of the most popular tests for assessing the speed of attention switching. It is given by psychologists to conclude suitability for professions that require increased concentration and quick response, such as air traffic controllers and train drivers. The red-black Gorbov-Schulte tables are a modified version of the single-color Schulte tables, which are a square divided into 49 cells. Cells are numbers in random order - from 1 to 25 black, and from 1 to 24 red. Colors can be set in various ways. [9]

For example:

1	21	2	6	12	7	7	12	21	23	21	15	19	9
20	5	17	8	22	13	18	2	11	12	14	5	10	19
19	11	12	8	23	3	19	3	25	6	8	13	17	16
17	24	24	10	10	13	5	10	3	9	17	1	18	18
21	2	11	18	6	22	3	6	8	22	7	4	24	14
4	9	25	4	15	9	23	20	4	23	24	20	2	22
15	1	16	14	20	14	16	1	7	15	16	13	5	11

Figure 2. Tables (text color / cell background color).

2.2 Leap Motion Sensor.

The Leap “Motion capture” sensor is a key object in this work. The sensor is used for virtual capture of hands and the creation of their 3D-models on a PC. The sensor uses two monochrome infrared cameras and three infrared emitters. The cameras “scan” the space above the table surface with a frequency of up to 300 frames per second and transfer the received data to a computer, where they are processed by proprietary software. Despite the apparent similarity with Microsoft Kinect, these devices are still different (Kinect uses a color video camera and depth sensors).

Leap Motion should be placed behind the keyboard or in front of it for the convenience of using a motion sensor. As a result, Leap Motion has a rather small size and a wide scanning area, which occupies a small space near the keyboard.

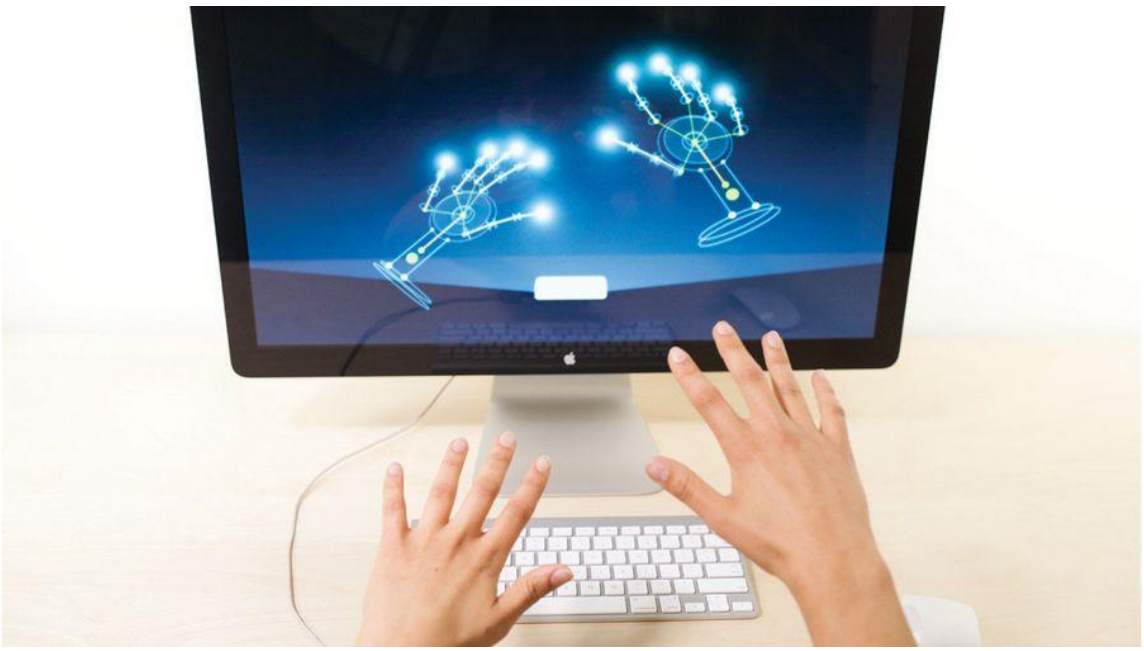

Figure 3. Received data on a PC from a Leap Motion sensor.

The controller works with a computer running Windows, all it takes is download the Airspace utility. Necessary software package is downloaded from the official site. In order for the “Leap Motion” motion sensor to work together with AR glasses or a VR helmet, the developer provides instructions for this. With MacOS, the device also interacts freely, but some hardware problems may occur. In this case, you just need to reconnect the device to the system and wait until it is recognized.

The scanning technology of a moving object is not revolutionary and is actively used in modern computer animation. There are similar products for home user. At the heart of specialized software and conventional webcams or cameras that work in the infrared. Microsoft's Kinect is the most famous and popular similar project. But this controller is positioned mainly as a game. In the recent past, there were attempts to create a controller for controlling a PC however, without the ability to recognize many objects, like Leap Motion. [11]

The setup is automatic. If you need to adjust specific parameters for yourself, you need to the utility settings or use the special Demo from the Airspace Store. There you can see how hand recognition occurs, and adjust sensitivity.

Sensor Features:

• Interface - USB 2.0

• OS - Windows 7/8, Mac OS X 10.7, Linux

• Dimensions, mm - 13 × 13 × 76

• Mass - 45 g

Based on the characteristics and capabilities of the sensor, it is safe to say that the sensor is portable, ultra-convenient to use and the best choice among competitors in the market. [10]

2.3 Augmented reality Epson Moverio BT-300.

Technical characteristics of augmented reality glasses Epson Moverio BT 300:

• time of continuous work - 6 hours;

• light sensor;

• OS - Android, version 5.1;

• wireless connectivity - Bluetooth, WiFi;

• display - Si-OLED;

• built-in memory - 16 GB;

• processor - Intel Atom;

• processor frequency - 1.44;

• sound - Dolby Digital Plus;

• front camera - 5 megapixels;

• additional functions - compass, headset, accelerometer, GPS;

• wireless transmission standard - WiFi Miracast;

• RAM - 2 GB;

• memory card - up to 32 GB;

• perceived image - 40 inches from 2.5 meters - 320 inches from 20 meters;

• contrast characteristics - 100 000: 1;

• screen resolution - 720 HD Ready.

Figure 4. Virtual reality glasses Epson Moverio BT-300.

Si-OLED screen technology is a development of which was applied to Epson Moverio glasses. It enables you to achieve a high level of contrast and provide the colors with the necessary saturation. The technology to make the unused parts of the screen transparent, and the projected image is harmoniously combined with objects of the surrounding world.

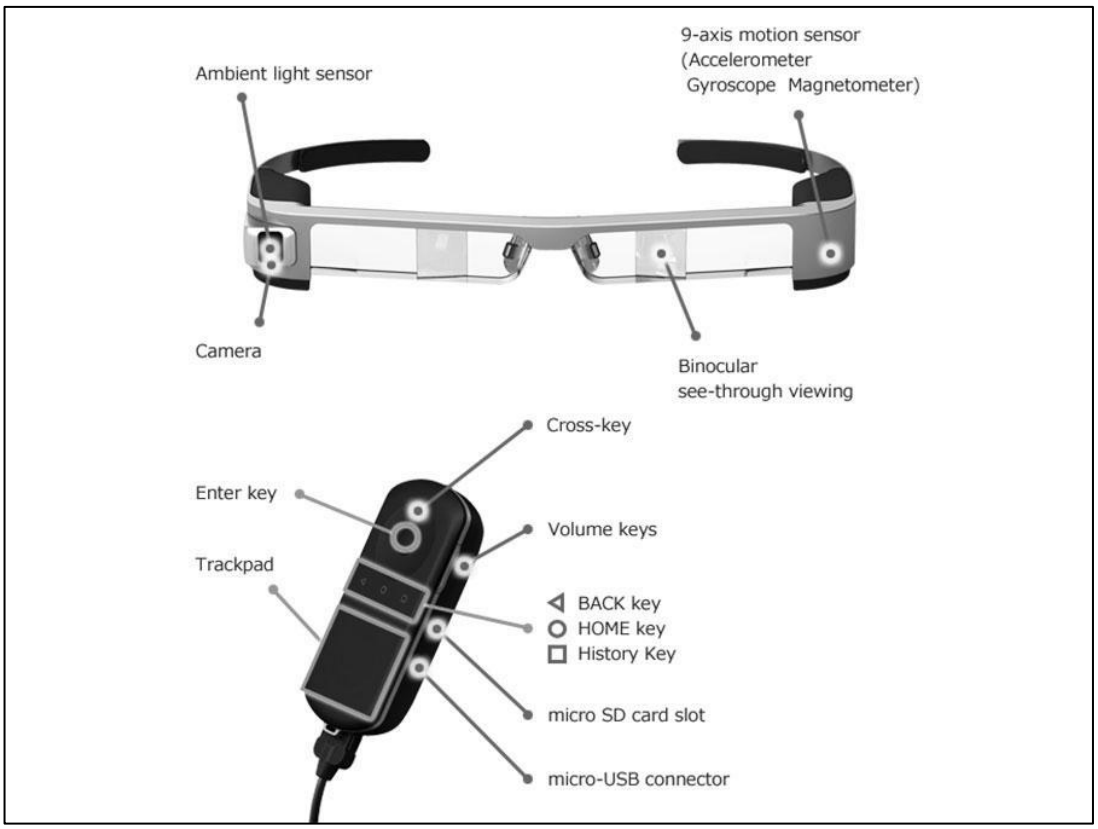

Figure 5. The control panel.

Points are controlled using the remote control (switching on, navigation in the OS interface, settings and other functions). [12]

2.3.1 Augmented reality in medicine.

Example of the use of augmented reality glasses is surgery, where an individual anatomical model of the patient's organs according to the results of computed tomography studies. During the operation, the Epson Moverio BT-200 and specially developed Android-based software superimpose the created anatomical 3D model on the real organ in the surgical field. A doctor who uses glasses can selectively turn off some layers for example, remove the organ model, leaving only the outline and blood vessels. The system monitors not only the position of the organ, but also the position of the surgeon himself, constantly adjusting the picture in accordance with position in space and the deformation of the patient's organ. In addition, solutions with augmented reality showed excellent results in visualization in the field of maxillofacial surgery. [13;4]

2.4 Choice of the environment for the research.

The choice of environment for use in research certainly fell on "Unity" it is free and easy to use. The Unity editor has a simple Drag & Drop interface that is easy to configure, consisting of various windows, so you can debug the application directly in the editor. The engine supports two scripting languages: C# and JavaScript (modification). Previously, there was support for Boo (a dialect of Python), but it was removed in the 5th version. Calculations are performed by the PhysX physics engine from NVIDIA. [5]

The main advantages of Unity are the presence of a visual development environment, cross-platform support and a modular system of components. The disadvantages include the appearance of difficulties when working with multicomponent circuits and difficulties when connecting external libraries.

"Unity" also has a large ready-made database of ready-made scripts, items and other settings with which you can easily necessary scenario for events. Using "Unity", most of the objects and tasks for the application were created. To create

scenes, you only need to select an object and determine its physical parameters [5, 6].

2.5 General requirement.

Application and selection of component devices should be carried out taking into account the following general requirements:

- reliability of devices in operation;
- minimum costs for their operation;
- long service life;
- wide scope;
- minimum cost;
- required performance;

The design of the entire system is determined by mobility universal use by doctors as well as the possibility the application by ordinary citizens.

In this case, you must adhere to the following basic rules:

- Devices should not have a wider measuring range than is really necessary for a specific task.
- The sensitivity of the device must by the needs of control. Sensitive devices are usually very difficult to operate, more expensive and require more qualified service.
- The accuracy of the instrument must be maintained for a long time.
- The application and system should be relatively simple so that their maintenance does not require highly qualified employees. [2]

3. Result.

As a result of the work done, the software package for the rehabilitation of motor disorders in augmented reality was performed using the following materials and methods:

•Development environment	Unity
• Method for assessing motor dysfunction	Gorbova-Schulte
• Motion capture sensor	Leap motion
• Augmented reality glasses	Epson Moverio BT-300

- Epson Moverio BT-300 OS — Android
- PC OS — Windows 10

To start rehabilitation and launch the application:

1. Connect the Leap Motion sensor to the included PC.
2. Cress and enable augmented reality glasses, then launch applications through the remote control.
3. Starting the application.

Based on the outcome of the task, from the beginning of the to the complete restoration of motor functions, we will be able to evaluate the progress of recovery and the progress this process.

3.1 The discussion of the results.

Based on the goal, literature data and hardware and technical equipment, work was carried out to implement additional scenarios in the application for the rehabilitation of patients with varying severity.

3.2 Conclusion.

Despite the development of medicine and diagnosis, stroke remains one of the most common cardiovascular diseases, leading to death and disability. Many rehabilitation techniques have been developed that help and accelerate patient recovery.

Augmented and virtual reality technologies are rapidly developing, which allows them to be used in almost all areas of human activity. The use of AR technology in rehabilitation can help both patients and doctors, accelerating recovery several times.

Combining various technologies, it is possible to achieve even greater results. Development and use of special gloves that can respond to objects in a virtual environment giving tactile feedback. Exoskeletons that help with fine motor activities can help restore motor function.

Technical tools for creating augmented and virtual reality also become more functional with improved technical characteristics. Which contributes to the development of more complex software.

4. Financial management, resource efficiency and resource Saving

4.1 Assessment of the commercial potential and prospects of conducting research from the standpoint of resource efficiency and resource conservation.

4.1.1 Potential consumers of research results.

In this research work, a software package is being developed for the rehabilitation of motor disorders in augmented reality. The results obtained during the work, allow to rehabilitate motor disorders of patients. As a general field of application of the research results, the target consumer is hospitals and special neurological centers where they provide treatment for people with motor impairment disorders. Neurological diseases are common throughout the world and the need to address the field of rehabilitation of motor disorders is also in demand around the globe. Moreover, Russian medicine is interested in introducing modern technologies in all spheres of life and in one of the most important areas - the sphere of medicine. In addition, the development may be of interest to ordinary citizens as a basis for the further development of the application or as a layout. Thus, we can conclude that the main market segment is represented by medical institutions (50%), neurological centers (20%), private clinics (15%), medical universities (10%) and ordinary citizens (5%) in quality base for other programs. This article is a confirmation of the technical solutions described in the release of the qualification work substantiating the economic necessity and expediency of performing scientific and technical research.

The objectives of the section include: determining research results, competitiveness analysis of technical solutions, performing SWOT analysis, calculating the budget of scientific and technical research.

4.1.2 Competitiveness analysis of technical solutions.

To describe the quality of the new development and its prospects in the market, which allows us to decide on the feasibility of investing in a research project, we use an analysis of competitive technical solutions.

An analysis of competitiveness goes between rehabilitation based on:

1. Augmented reality;

2.Virtual reality;

3.Surgery

The analysis of the scorecard is presented in Table 5. The position is evaluated on a five-point scale, where 1 is the weakest position, and 5 is the strongest. The weight of indicators in total should be 1. Analysis of competitive technical solutions is determined by the formula:

$$C = \sum W_i \cdot P_i,$$

Where *C* is the weighted average of the quality indicator and the prospects of scientific development;

W_i – indicator weight (in fractions of a unit);

P_i – weighted average value of the i-th indicator;

Rehabilitation based on augmented reality was chosen as the main method in this master's dissertation. This method allows recovery to be carried out most efficiently and has greater potential compared to other non-invasive recovery methods (Pf).

Competitors usually apply the methods of Virtual Reality (Pi1) and surgical intervention, which depends on the degree of damage to the neural connections. From which it follows that with small and medium lesions, surgical intervention within the restoration of limb motility is rather a technology of the 20th century (Pi2).

Table 1 - Evaluation card for comparing competitive technical solutions (developments)

Evaluation criteria	**Criterion weight**	**Points**			**Competitiveness** Taking into account weight coefficients		
		P_f	P_{i1}	P_{i2}	C_f	C_{i1}	C_{i2}
1	2	3	4	5	6	7	8
Technical criteria for evaluating resource efficiency							
1. Energy efficiency	0.05	5	5	2	0.25	0.25	0.1
2. Reliability	0.2	4	3	2	0.8	0.6	0.4
3. Safety	0.15	5	5	2	0.75	0.75	0.3
4. Functional capacity	0.1	4	3	3	0.4	0.3	0.3
5. Measurements accuracy	0.2	5	4	2	1	0.8	0.4
Economic criteria for performance evaluation							
1. Development cost	0.07	3	4	2	0.21	0.28	0.14
2. Scientific developments market penetration rate	0.2	4	3	1	0.8	0.6	0.2
3. Methodology perspectives	0.3	4	3	2	1.2	0.9	0.6
Total	**1**	**34**	**30**	**30**	**5.41**	**4.48**	**2.44**

As we see after the analysis of competitiveness, the highest competitiveness scores are observed for our AR (Cif) project and in total are equal to 5.41; while for points VR (Ci1) the total points are equal to 4.48 and rehabilitation through surgery (Ci2) 2.44. AR technology receives a greater amount of points for resource efficiency, security and accuracy of the data received.

4.1.3 SWOT Analysis.

Table 2- SWOT Matrix

Strengths of the research project: C1. Claimed technology efficiency. C2. High functional development power. C3. Lower production cost compared to other technologies. C4. Easy to learn software. C5 Qualified staff.	**Weaknesses of the research project:** S1. Lack of an engineering company capable of building turnkey production S2. Lack of ergonomics S3. Long delivery of components S4. Relatively expensive components
Capabilities: B1. The emergence of additional demand for a new product B2. Reduction of customs duties on materials used in scientific research B3. Increase the cost of competitive development	**Threats:** U1. Lack of demand U2. Developed competition of production technologies U3. Introduction of additional state requirements for product certification U4. Untimely financial support of scientific research by the state.

The second stage is to identify the strengths and weaknesses of the research project to external environmental conditions. This compliance or non-compliance should help to identify the degree to which strategic change is needed.

Table 3 - Interactive matrix of the project

Project Strengths						
		C1	C2	C3	C4	C5
Project Features	B1	+	+	+	–	–
	B2	+	–	+	–	–
	B3	+	–	–	–	–

An analysis of interactive tables is presented in the form of recording highly correlated strengths and capabilities:

- B1B2C1C3

Table 4 - Interactive matrix of the project

Weaknesses					
		S1	S2	S3	S4
Project Features	B1	+	–	–	–
	B2	–	–	+	–
	B3	–	–	–	0

An analysis of interactive tables is presented in the form of recording highly correlated strengths and capabilities:

- B2S3

Table 5 - Interactive matrix of the project

Project Strengths						
		C1	C2	C3	C4	C5
Project Threats	U1	–	–	+	–	–
	U2	–	–	–	–	–
	U3	+	–	+	–	–
	U4	+	–	+	–	+

An analysis of interactive tables is presented in the form of recording highly correlated strengths and capabilities:

- U1U3U4C1C3

Table 6 - Interactive project matrix

Weaknesses					
		S1	S2	S3	S4
Project Threats	U1	+	+	–	+
	U2	–	0	–	+
	U3	+	–	–	–
	U4	+	–	–	–

An analysis of interactive tables is presented in the form of recording highly correlated strengths and capabilities:

- U1S1S2S4
- U1U2S4

Table 7 - The resulting SWOT matrix. Having compiled and analyzed the interactive project matrices, we will compose the final matrix of the SWOT analysis (Table 2).

	Strengths of the research project: C1. Claimed technology efficiency. C2. High functional development power. C3. Software and hardware accuracy C4. Easy to learn software. C5 Qualified staff.	**Weaknesses of the research project:** S1. Lack of an engineering company capable of building turnkey production S2. The need for a number of components for the program S3. Long delivery of components S4. Uniformity of use of the program
Capabilities: B1. The emergence of additional demand for a new product B2. Reduction of customs duties on materials used in scientific research B3. Increase the cost of competitive development	• The emergence of demand and a reduction in customs duties will make development cheaper, which means that the functional capacity of the device can be improved at the same cost • The development implementation strategy, like any other, is cyclical in time and requires either an acute shortage or an acute need for use. To increase the number of sales and implementation, first you need demand, with which we understand that the growth of industrial development entails a number of diseases and disorders, including motor ones. Also, toughening for drivers and medical workers for health forces enterprises to use accurate methods for measuring	• Reducing customs duties on components, will expand the choice of delivery method, which will reduce the time for their delivery • Given the territorial affiliation of the project and its further improvement, namely increasing mobility. We can confidently believe that with due attention the project is being implemented in the Russian army and medical institutions of the country. Which eliminates almost all problems points

	tremor and accuracy of hand movements (for example, surgery). It is important to note that a good product does not need advertising, you just need to put it on the market. Competitors stimulate the development of the project. If initially the project does not have any benefit for society, then any advertising will not save him.	
Threats: U1. Lack of demand U2. Developed competition of production technologies U3. Introduction of additional state requirements for product certification U4. Untimely financial support of scientific research by the state.	• Lower production cost and cost-effectiveness of the technology will increase demand, as well as minimize losses when introducing additional requirements for certification and untimely financial provision • Development, constant supply of new ideas and improvements will reduce risks and consolidate local positions.	• Lack of an engineering company as the main problem of the project. A marketing campaign should solve this problem. The search for potential clients and their public recall in the space of state hospitals and private hospitals will create a favorable environment for organizing any level of production

Thanks to the SWOT analysis, we can conclude that the strength of the project is its simplicity and accuracy of the assessment, which will expand the range of capabilities, as well as reduce the impact of threats on the implementation of the project. But the uniformity of the program and an expensive set of components can greatly complicate the delivery to the market.

4.2 Research Planning

4.2.1 The structure of work within the framework of scientific research.

Planning a set of proposed works is carried out in the following order:

- determination of the structure of work within the framework of scientific research;
- identification of participants in each work;
- setting the duration of work;
- building a schedule for research.

For each type of planned work, an appropriate position of performers was established.

In this section, a list of stages and works within the framework of the scientific research was compiled, the distribution of performers by type of work was carried out (Table 8).

Table 8 - a list of stages, works and distribution of performers.

Main stages	№ job	Work Content	Position performer	Duration, working days	Start date/Date of completion
Research Direction	1	Research Direction	Supervisor Engineer	7	1.02.2020 – 7.02.2020
	2	Drafting and approval of technical specifications	Supervisor	7	1.02.2020-7.02.2020
	3	Work scheduling by date	Supervisor	3	8.02.2020-10.02.2020
	4	Selection and study of materials on the topic	Engineer	5	10.02.2020-15.02.2020
Theoretical and experimental research	5	Writing a theoretical part	Engineer	6	15.02.2020-20.02.2020
	6	Evaluating the effectiveness of the results and determining the appropriateness of development work	Supervisor	3	20.02.2020-22.02.2020
	7	Component Check	Engineer	2	24.02.2020-25.02.2020
Development work					
Development of technical documentation and design	8	Development of a program algorithm in C#	Engineer	22	25.02.2020-20.03.2020
	9	Scene implementation in Unity3D	Supervisor Engineer	16	21.03.2020-9.04.2020
Production and testing of the layout (prototype)	10	Checking the interaction of all components	Supervisor Engineer	15	9.04.2020-25.04.2020
	11	Lab testing layout	Supervisor Engineer	10	25.04.2020-6.05.2020
	12	Evaluation of the results	Supervisor	16	6.05.2020-23.05.2020

Total duration of working time – 112 days

A Gantt chart, or harmonogram, is a type of bar chart that illustrates a project schedule. This chart lists the tasks to be performed on the vertical axis, and time intervals on the horizontal axis. The width of the horizontal bars in the graph shows the duration of each activity.

Table 9. A Gantt chart

№	Activities	Participants	T_c, days	Duration of the project											
				February			March			April			May		
				1	2	3	1	2	3	1	2	3	1	2	3
1	Research Direction	Skopchenko E.M Tolmachev I.V	7												
2	Drafting and approval of technical specifications	Tolmachev I.V	7												
3	Work scheduling by date	Tolmachev I.V	3												
4	Selection and study of materials on the topic	Skopchenko E.M	5												
5	Writing a theoretical part	Skopchenko E.M	6												
6	Evaluating the effectiveness of the results and determining the	Tolmachev I.V	3												

	appropriateness of development work														
7	Component Check	Skopchenko E.M	2												
8	Development of a program algorithm in C#	Skopchenko E.M	22												
9	Scene implementation in Unity3D	Skopchenko E.M Tolmachev I.V	16												
10	Checking the interaction of all components	Skopchenko E.M Tolmachev I.V	15												
11	Lab testing layout	Skopchenko E.M Tolmachev I.V	10												
12	Evaluation of the results	Tolmachev I.V	16												

Skopchenko E.M - Tolmachev I.V -

4.2.2 Research and Development Budget.

The costs required for the implementation of the project include:

- Material costs;
- Costs of special equipment for scientific research;
- The basic salary of the performers of the topic;
- Additional salary performers topics;
- Contributions to extra-budgetary funds (insurance contributions);
- Overhead.

4.2.2.1 Calculation of material costs.

Table 10 - Material costs.

Name	Unit of measurement	Amount		Price per unit., ruble.		Material costs (C_m), ruble.	
		HP	N	HP	N	HP	N
Ballpoint pen	Ruble.	1	1	15	15	15	15
Paper Packaging (A4)	Ruble.	0,5	0,5	350	350	175	175
Total:				365	365	190	190

Total item “material costs” - 380 rubles.

4.2.2.2 Calculation of costs for special equipment for scientific research.

The cost of special equipment includes all costs associated with the acquisition of programmers, microcontrollers and other peripherals. The cost of special equipment is determined according to the current price lists (Table 11).

Table 11 - Calculation of the budget costs for the purchase of special equipment for scientific work

№	Name of equipment	Number of pieces of equipment	Unit price, rubles.	The total cost of equipment, rubles
1.	USB wire	1	150	150
2.	Leap Motion Controller	1	12150	12150
3.	Epson Moverio BT-350	1	117000	117000
Total:				129300

Total under the item “costs for special equipment” - 129300 rubles.

4.2.2.3 Electricity costs.

On average, a personal computer runs for about 6 hours. As practice shows, the actual consumption of electricity by the average system unit, regardless of the values on the power supply (even 1000 watts), varies from 100 to 180 $Wh \cdot$ h in normal use (Internet surfing and other simple computer processes) , and up to 350 $Wh \cdot$ h with a significant load on the machine (this is work in resource-intensive programs, connecting additional equipment).

Therefore, taking into account the fact that the load on the PC reached low to high, the average value of electricity consumption will be (100 $Wh \cdot$ h + 180 $Wh \cdot$ h + 350 $Wh \cdot$ h) / 3 = 210 $Wh \cdot$ h. The approximate cost of electricity for a monitor is up to 40 $Wh \cdot$ h. The result is: 210 $Wh \cdot$ h + 40 $Wh \cdot$ h = 250 $wh \cdot$ h.

Multiplying the obtained value by 6 hours and adding the cost of electricity to the computer in the off state, the remaining 19 hours - about 4 W x 18 h = 72 W, we

find the required amount of PC electricity consumed per day - 6 h x 250 $Wh \cdot$ h + 72 W = 1,572 kW, which is 47,16 kW per month.

The tariff in the Tomsk region is 2.39 rubles / kWh.

Accordingly $\frac{2{,}39 \text{ rubles}}{0{,}46 \text{ kW}} = 5{,}19\ rub\ in\ h$, when the computer is on

Payment the total period of work for electricity will be $5{,}19\ rub * 6h *$ 112 days $= 3487{,}6$ rub

4.2.2.4 The main salary of performers.

The article includes the basic salary of employees directly involved in the implementation of the Scientific and Technical Task (including bonuses, surcharges) and additional salary:

$$S_{\text{sl}} = S_{\text{main}} + S_{\text{ov}},$$

Where S_{main} – basic salary;

S_{ov} – additional salary (12–20 % from S_{main}).

According to TPU data, the salary for an assistant professor of a department with a PhD degree is 35120 rubles without a regional coefficient. (DC = 1.3)

The main salary (S_{main}) of the head of the company is calculated according to the following formula:

$$S_{\text{main}} = S_d \cdot \text{T}_\text{p},$$

Where S_{main} – basic salary per employee;

T_p – the duration of the work performed by the scientific and technical worker, days;

S_d – average daily salary of an employee, rubles;

The average daily wage is calculated by the formula:

$$S_d = \frac{C_m \cdot \text{M}}{F_d},$$

Where C_m – monthly salary of an employee, rub.;

M – number of months of non-vacation work during the year:

when you leave at 24 work day M = 11.2 months, 5-day week;

when leaving at 48 workers days M = 10.4 months, 6-day week;

F_d – actual annual fund of working hours of scientific and technical personnel, workers days.

Table 12 - the balance of the working day

Working hours	**Supervisor**	**Engineer**
Calendar number of days	365	365
The number of days off – weekend – holidays	 52 13	 52 13
Loss of working time – Vacation – absenteeism	 48 10	 48 10
Valid annual work time fund	242	242

Monthly employee salary:

$$S_{\text{main}} = S_{\text{тс}} \cdot \left(1 + k_{\text{p}} + k_d\right) \cdot k_{\text{tp}},$$

Where S_{tr} - salary at the tariff rate, rubles.;

k_p – premium coefficient of 0.3 (i.e. 30% of S_{tr});

k_d – the coefficient of surcharges and allowances is approximately 0,2 – 0,5;

k_{tp} – regional coefficient equal to 1.3 (for Tomsk).

Table 13 - Calculation of basic wages

Performers	Category	$k_т$	S_{tr}, rub.	k_p	k_d	k_{tp}	C_m, rub	S_d, rub.	$T_{p,}$ rub. Day.	$S_{main,}$ rub.
Supervisor	PhD	–	35120	0,3	0,2	1,3	68484	2943	77	226611
Engineer	–	1	17890	0,3	0,2	1,3	34885	1499	99	148401
Total S_{main}										375012

Total under the article “Basic salary”– 375012 rubles.

4.2.2.5 Additional salary.

The costs of the additional wages of the theme performers take into account the amount of additional payments provided for by the Labor Code of the Russian Federation for deviation from normal working conditions, as well as payments related to the provision of guarantees and compensations.

The calculation is carried out according to the following formula:

$$S_{\text{add}} = k_{\text{add}} \cdot S_{\text{main}},$$

Where k_{add} - the coefficient of additional wages (at the design stage is taken equal 0,12 – 0,15).

S_{add} (supervisor) = 27193,3 rubles.

S_{add} (engineer) = 17808,1 rubles.

Total item “additional wages" – 45001,4 rubles.

4.2.2.6 Deductions extrabudgetary funds.

This expense item reflects mandatory deductions according to the norms established by the legislation of the Russian Federation to the state social insurance (FSI), pension fund (PF) and medical insurance from the costs of employee wages.

The amount of contributions to extra-budgetary funds is determined on the basis of the following formula:

$$S_{\text{ex}} = k_{\text{ex}} \cdot (S_{\text{main}} + S_{\text{add}}),$$

Where k_{ex} – rate of deductions for payments to extrabudgetary funds (27,1).

Table 14 - Contributions to extrabudgetary funds.

Performer	**Basic salary, rub.**	**Additional salary, rub.**
Supervisor	226611	27193,3
Engineer	148401	17808,1
Coefficient deductions to extrabudgetary funds	k_{ex} = 0,271	
Total		
Supervisor	68781	
Engineer	45042,6	

Total for the article "Contributions to extrabudgetary funds" – 113823,6 rubles.

4.2.2.7 Overhead.

Overhead costs take into account other expenses of the organization that are not included in the previous items of expenditures: printing and photocopying of research materials, payment of communication services, electricity, postal and telegraph expenses, reproduction of materials, etc. Their value is determined by the following formula:

$$S_{\text{ov}} = (\text{sum of articles} 1 \div 6) \cdot k_{\text{ov}},$$

Where k_{ov} – overhead factor.

The value of the coefficient of overhead costs can be taken in the amount of 16%.

S_{ov} = 106720,74

Total item “Overhead costs” – 106720,74 rubles.

4.2.2.8 Budgeting a research project.

The calculated value of the research work is the basis for the formation of the project cost budget, which, when forming the contract with the customer, is protected by the scientific organization as the lower limit of the cost of developing scientific and technical products (Table 18).

Table 15 - Calculation of the cost budget of the scientific and technical assignment

Title of the article	Amount, rub.	Share of costs,%
1. Material costs of the scientific and technical assignment	380	0,05
2. The cost of special equipment for scientific (experimental) work	129300	16,71
3. Electricity costs	3487,6	0,45
4. The costs of the basic salary of performers	375012	48,47
5. The costs of additional wages performers topic	45001,4	5,82
6. Contributions to extrabudgetary funds	113823,6	14,71
7. Overhead	106720,74	13,79
8. The budget of the costs of the scientific and technical assignment	773725,34	100

4.2.3 Assessment of the effectiveness of scientific work.

The effectiveness of this development lies in the fact that there are almost few analogues of this application, and the effectiveness and interest in medicine is quite high.

Thus, the goal is achieved, the tasks are solved.

According to the analysis of the competitiveness of technical solutions, it is obvious that the development is more promising than the existing work and has prospects for further development.

A SWOT analysis allows you to draw conclusions about the project's strengths, ways to expand the range of capabilities, as well as narrow the range of threats and vice versa.

A list of stages was compiled and performers distributed. A research schedule was developed, which includes 12 stages of training, which took 77 days for the leader and 99 days for the engineer.

The budget for scientific and technical research was calculated, the total amount of expenses amounted to 773725,34 rubles.

Conclusion

In this final qualifying work, a software package for rehabilitation working in augmented reality was developed and put into practice. The program algorithm is written in C #. Scenes are made in Unity, the connection between scenes is also carried out in Unity using scripts. The program is visual and very easy to learn. In the future, it is planned to improve the design by reducing the size and increasing the mobility of the entire installation. As a result, we can say that the goal of the final qualification work was fully achieved.

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Appendix A

(Required)

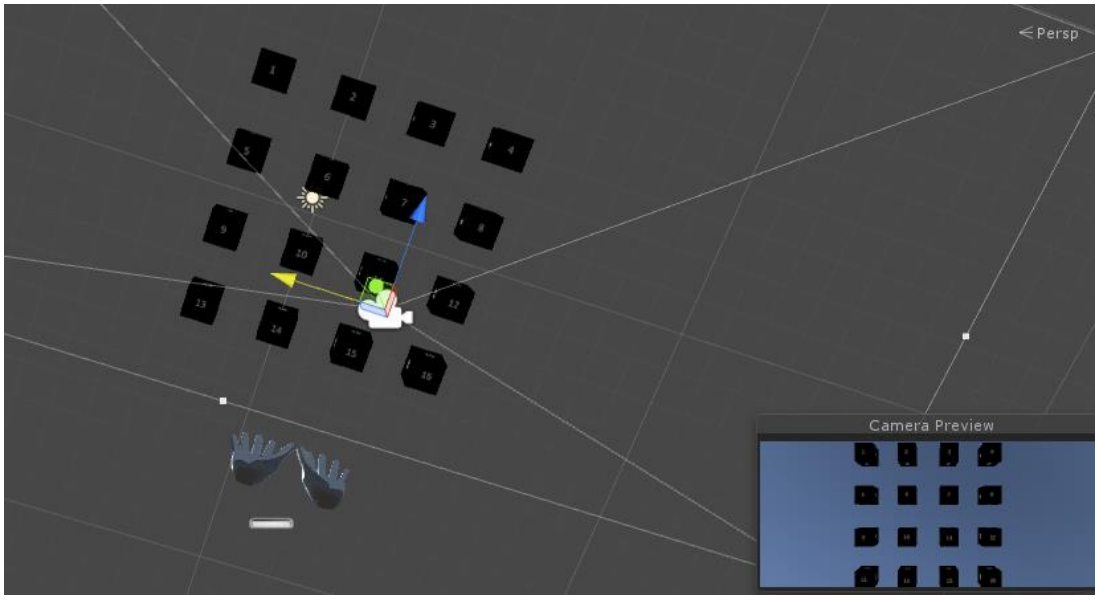

Figure A.1 Base scene.

Appendix B

(Required)

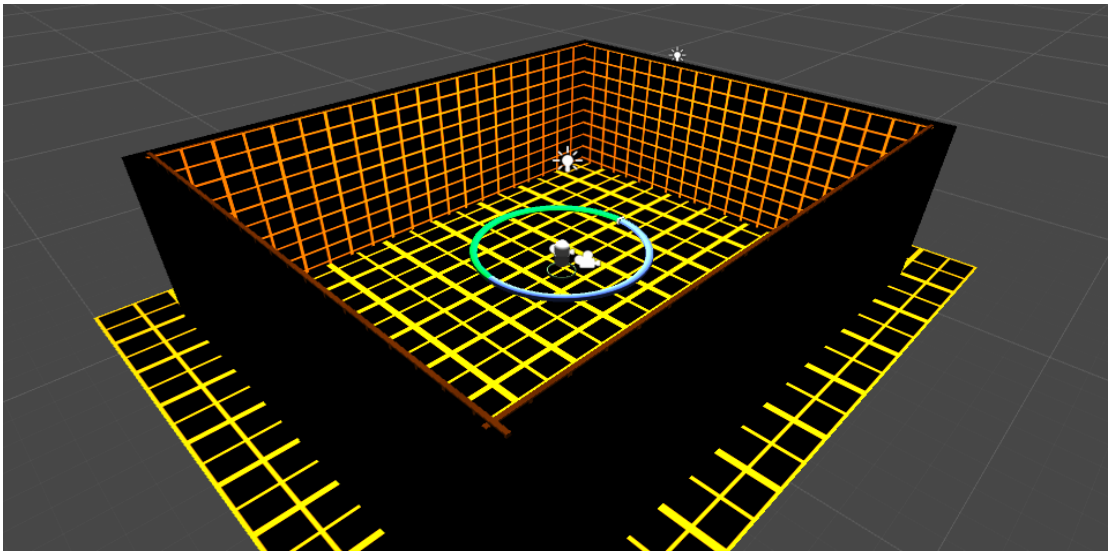

Figure B.1 Room scene.

Appendix C

(Required)

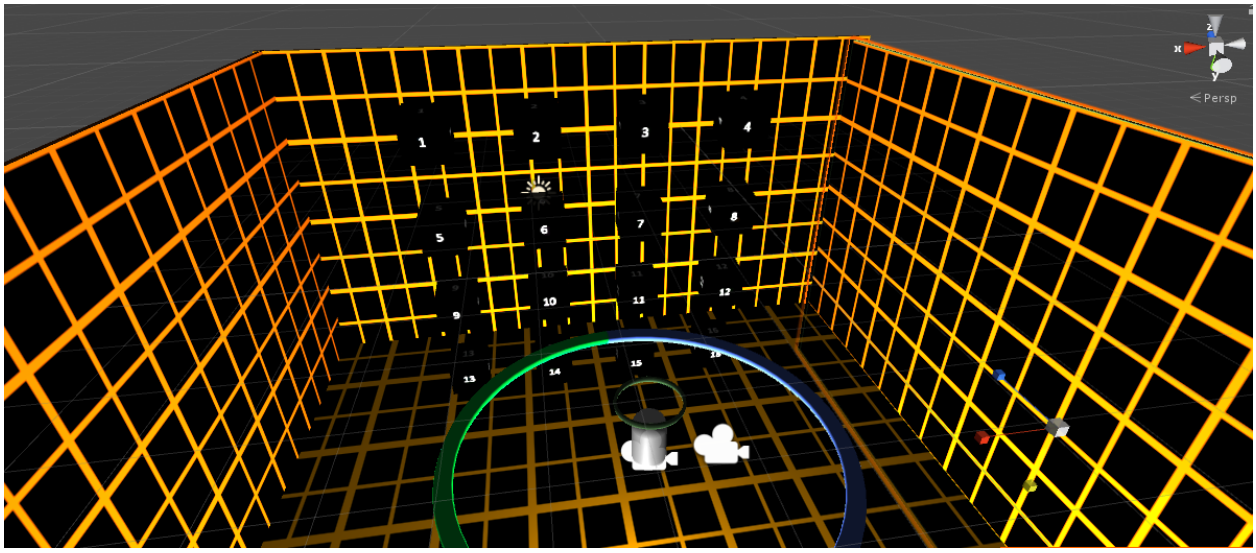

Figure C.1 United scene.

Appendix D

(Required)

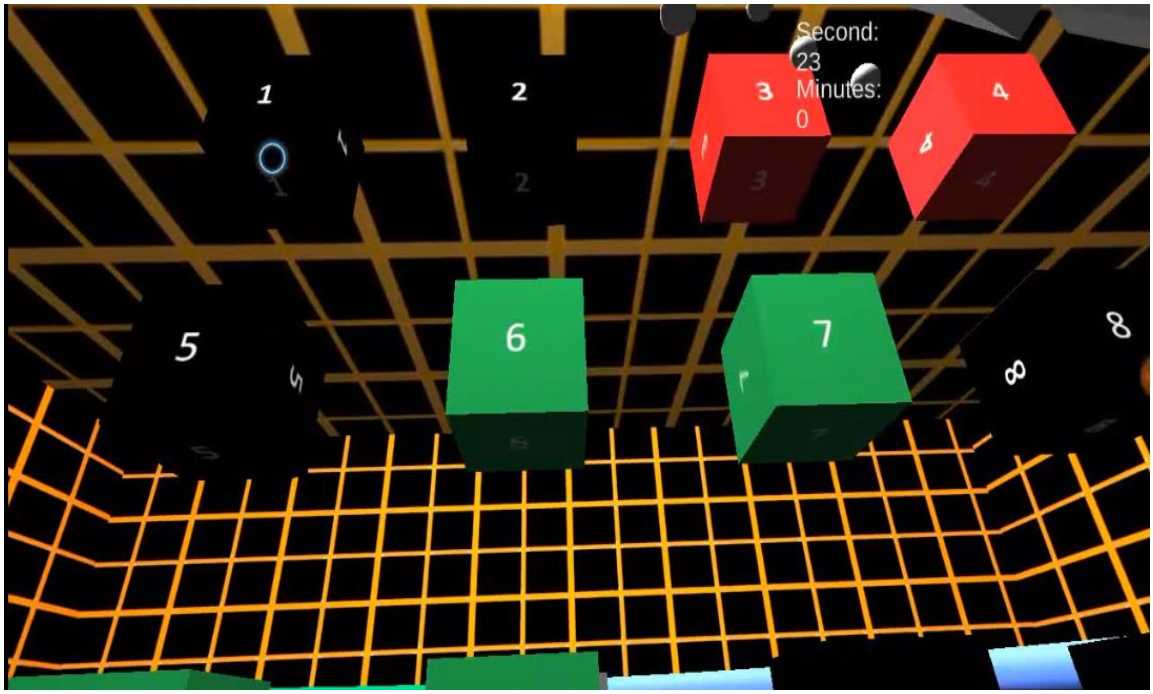

Figure D.1. Application for augmented reality glasses, inside view.

Appendix E

(Required)

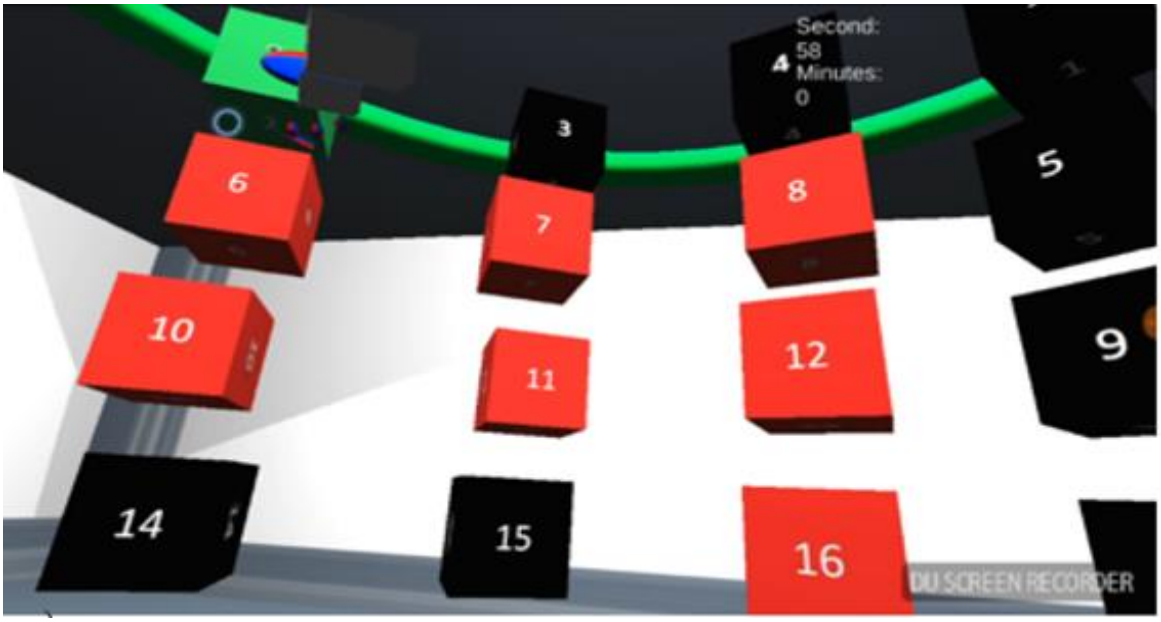

Figure E.1 Application for augmented reality glasses, inside view (accuracy).

Appendix F

(Required)

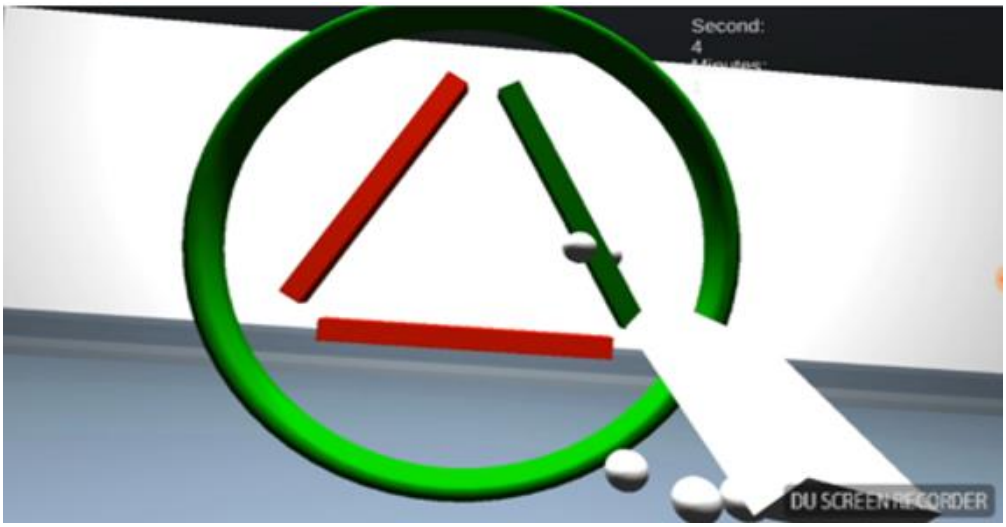

Figure F.1 The second type of work is based on the "static movement of the hand".

Appendix G

(Required)

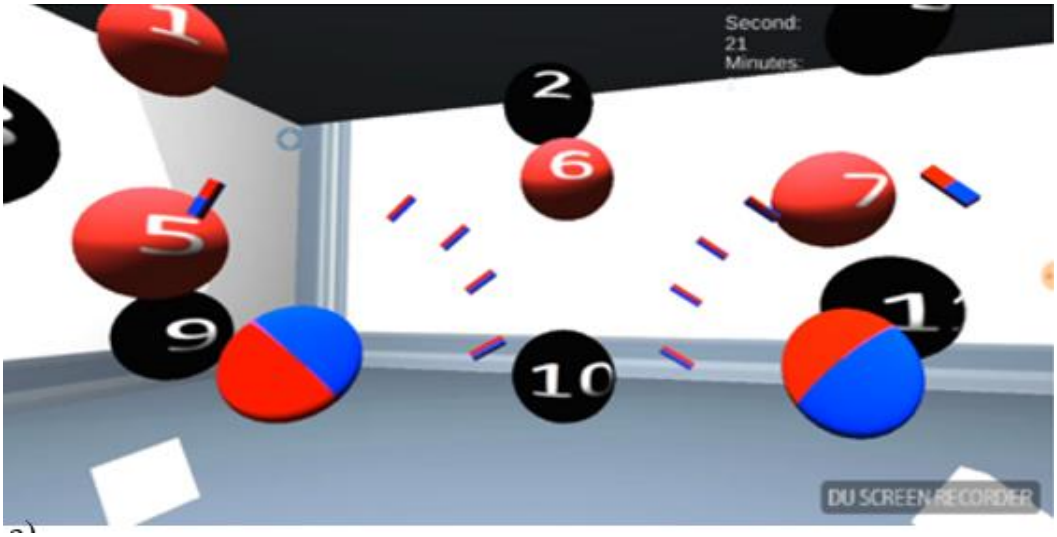

Figure G.1 The third type is the movement of the brush based on the “statodynamics”.

Appendix H

(Required)

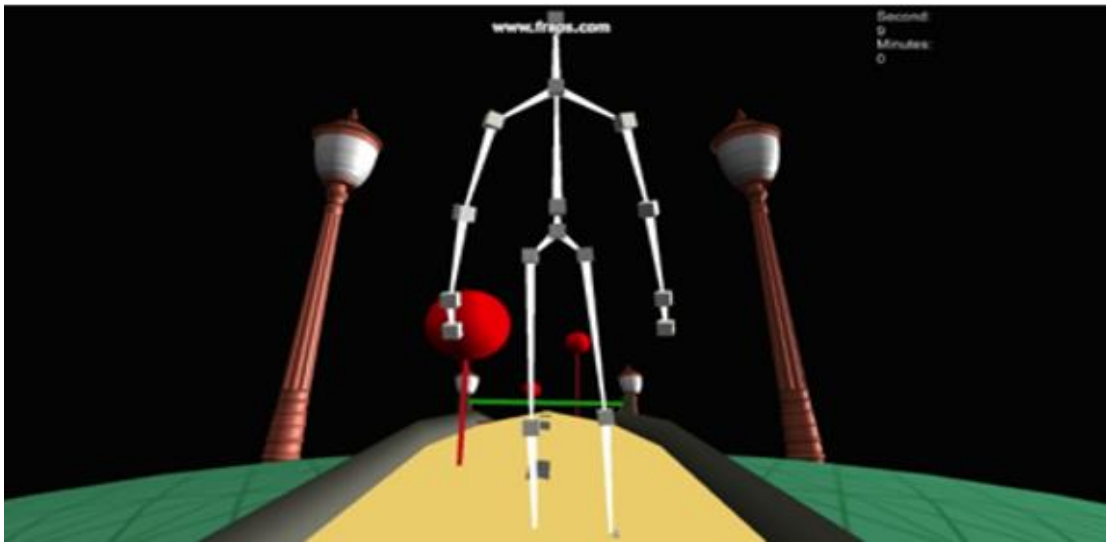

Figure H.1 The last type of task is based on balance passing obstacles.