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

Research School of Chemical and Biomedical Technologies
Direction of training 12.04.04 «Biotechnical systems and technologies»
Department of Electronic Engineering

MASTER'S THESIS

Topic of the work
Разработка программного комплекса для реабилитации двигательных функций (Development of software for the rehabilitation of motor functions)

UDC 004.42:616-009.2

Student

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Tomsk – 2019

Planned program learning outcomes

Код результата	Результат обучения (выпускник должен быть готов)	Требования ФГОС, критериев и/или заинтересованных сторон
Профессиональные компетенции		
Р1	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*
Р2	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
Р3	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
Р4	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*
Р5	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*
Р6	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		
Р7	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*
Р8	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*
Р9	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*
Р10	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*
Р11	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*
Р12	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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Direction of training 12.04.04 «Biotechnical systems and technologies»
Department of Electronic Engineering

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**
1DM7I	Shorokhov Daniil Igorevich

Topic of the work:

Разработка программного комплекса для реабилитации двигательных функций (Development of software for the rehabilitation of motor functions)	
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.).*	1. Unity 3D software development environment. 2. Markerless video capture sensor Leap motion. 3. Glasses augmented reality Epson Moverio BT-300. 4. Matlab program. 5. An expert group of neurologists to formulate medical system requirements. In the process of research, it is necessary to provide a biological feedback between the system and the patient. This goal can be achieved using contactless controllers. This method can be used in medical institutions to examine patients with neurological diseases.
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,*	To accomplish the task, it is necessary to investigate a number of questions: 1) Methods of rehabilitation of patients with neurological disorders. 2) The use of virtual and augmented reality in rehabilitation. 3) Requirements for the developed system for BFB training.

construction, discussion of the performed work results, the name of additional sections to be developed; work conclusion).	4) The choice of software for the implementation of a software application. 5) Development of scenarios for biofeedback training for rehabilitation. 6) Visualization and mathematical analysis of the obtained data. 7) Feasibility study 8) 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»	Senior Lecturer, Department of Social and Human Sciences Potekhina Nina Vasilyevna
Section «Social Responsibility»	Associate Professor of General Technical Disciplines 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
Assistant professor	Gubarev Fedor Aleksandrovich	Candidate of Technical Sciences		
Assistant professor	Tolmachev Ivan Vladislavovich	Candidate of Medical Sciences		

The assignment was accepted for execution by the student:

Group	Full Name	Подпись	Дата
1DM7I	Shorokhov Daniil Igorevich		

ASSIGMENT FOR THE SECTION
«FINANCIAL MANAGEMENT»

For a student:

Group	Full name
1DM7I	Shorokhov Daniil Igorevich

School	Research School of Chemical and Biomedical Technologies	**Department (SEC)**	Electronic engineering
Level of education	Master's degree	**Direction of training/Specialty**	12.04.04 Biotechnical systems and technologies

Initial data to the section "Financial management, resource efficiency and resource saving":	
1. *The cost of scientific research resources: material, energy, financial, informational and human*	Salary of the head - 33664 rub. Salary of the student - 21,760 rub. The cost of material resources is determined on the basis of open prices.
2. *Norms and standards of resource usage*	Additional salary 13%; Overhead costs 16%; District coefficient of 30%.
3. *The used tax system, rates of taxes, deductions, discounting and lending*	The ratio of deductions for payment in extra-budgetary funds 30%.
The list of issues to be investigated, designed and developed:	
1. *Pre-project analysis*	Description of the potential consumer; SWOT analysis; Ishikawa Chart.
2. *Initiation of the project*	Definition of the working group of the project, building a tree of project goals.
3. *Planning research projects*	Formation of the work plan; Gantt chart development; Budgeting the cost of the project; Risks register compilation.
4. *Determination of the potential effect of a research project.*	Determination of the potential effect of a research project.
List of graphic materials *(with exact indication of required drawings)***:**	
1. *SWOT matrix* 2. *Ishikawa chart* 3. *Tree of goals* 4. *The calendar schedule of the research project* 5. *The budget of the research project* 6. *Key risk reduction measures*	

Date of assignment for the section on a linear schedule	

Assignment was issued by an advisor:

Position	Full name	Degree	Signature	Date
Senior Lecturer, Department of Social and Human Sciences	Potekhina Nina Vasilyevna			

Assignment was accepted for execution by the student:

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1DM7I	Shorokhov Danill Igorevich		

ASSIGMENT FOR THE SECTION
«SOCIAL RESPONSIBILITY»

For a student:

Group	Full name
1DM7I	Shorokhov Daniil Igorevich

School	Research School of Chemical and Biomedical Technologies	**Department (SEC)**	Electronic engineering
Level of education	Master's degree	**Direction of training/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 software for the rehabilitation of motor functions of patients with neurological diseases.
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 activities in the layout of the working area.*	Special legal norms of labor legislation: Medical examination of employees (Art. 213 of the Russian Federation Labor Code); Psychiatric examination (Part 6, Article 213 of the Russian Federation Labor Code); Safety Instruction (Decree No. 1/29 of January 13, 2003); Provision of personal protective equipment (Article 221 of the Russian Federation Labor Code). Requirements for the organization of the workplace (GOST 12.2.032-78).
2. Production 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.* *2.3. Justification of measures to protect the researcher from the effects of dangerous and harmful factors.*	Harmful production factors: 1) Insufficient light level in the working area 2) Excess noise 3) Increased electromagnetic radiation 4) Increased air temperature in the workplace Hazardous production factors: 1) Electric current exposure 2) Mechanical injury
3. Ecological safety: *3.1. Analysis of the impact of the object of research on the environment.* *3.2. Analysis of the "life cycle" of the object of study.*	There are no estimated sources of environmental pollution resulting from the implementation of the proposed design and technological solutions. When using the

3.3. Justification of measures to protect the environment.	equipment, the hydrosphere, atmosphere and lithosphere can be damaged. Therefore, in order to avoid this, the equipment disposal procedure is necessary.
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.*	When developing and operating a designed solution, the most possible emergency is fire. The list of measures to reduce the threat of possible emergencies.

Date of assignment for the section on a linear schedule	

Assignment was issued by an advisor:

Position	Full name	Degree	Signature	Date
Associate professor of general technical disciplines	Mikhail Vladimirovich Gorbenko	Candidate of Technical Sciences		

Assignment was accepted for execution by the student:

Group	Full name	Signature	Date
1DM7I	Shorokhov Danill Igorevich		

Abstract

Master’s Thesis contains 92 pages, 29 figures, 21 tables, 42 references, 1 appendix.

Key words: augmented reality, biofeedback, leap motion, rehabilitation, neurological diseases, matlab, stroke.

The object of the study is a system for BFB trainings.

The purpose of this work is development of a system for BFB training in augmented reality for the rehabilitation of patients with neurological diseases, and the implementation of BFB training scenarios for the developed system, as well as the creation of a program for visualization and mathematical analysis of data from sensors.

As a result of the research, a virtual environment for training was created, training scenarios for rehabilitation were developed, and a program for visualization and mathematical analysis of sensor data was created.

The main design, technological and technical and operational characteristics: laboratory conditions of operation.

Degree of implementation: using the system in the laboratory to assess the quality of human movements at SSMU and TPU.

Scope: medical centers, private clinics, public clinics, as well as practicing doctors working with neurological diseases, orthopedics and sports medicine.

Economic efficiency of work allows to save research time, labor-intensiveness, and reduce equipment maintenance costs and device cost.

Definitions, designations, abbreviations, normative references

References to the following standards are used in this work:

GOST 12.1.006-84 “SSBT. Electromagnetic fields of radio frequencies. Permissible levels at workplaces and requirements for monitoring”

GOST 12.1.003-83 “SSBT. Noise. General safety requirements”

GOST 12.0.003-74 “SSBT. Dangerous and harmful production factors. Classification”

GOST 12.1.019-79 “SSBT. Electrical safety. General requirements and nomenclature of types of protection”

GOST 12.1.006-84 “SSBT. Electromagnetic fields of radio frequencies. Permissible levels at workplaces and requirements for monitoring”

GOST R 22.0.02-94 “SSBT. Safety in emergency situations. Terms and definitions of basic concepts”

GOST 12.2.032-78 “SSBT. Workplace when working sitting. General ergonomic requirements”

The following abbreviations are used in this paper:

BFB - biofeedback.

The following terms are used in this paper:

Moverio BT-300 - augmented reality glasses;

Leap Motion - non-contact touch controller for tracking movements of human hands

Unity is a software tool for developing applications and games.

Matlab is a high-level language and interactive environment for programming, numerical calculations and visualization of results.

Contents

Introduction

Constant stress, various chronic diseases, sedentary lifestyles of people, as well as the modern pace of life are factors that contribute to the development of diseases associated with the human nervous system. The older the person, the higher the risk of such diseases. However, it should be noted that in recent years neurological diseases have become younger. [1]

Neurological diseases are directly related to problems of maintaining balance, coordination of movements, walking of a person, since such diseases significantly affect the human nervous system. Since they can cause varying degrees of damage to the vestibular apparatus. In the modern world, the problems listed above are very important, since a person needs to work with various mechanisms, drive a car, manage any technological or production processes. And damage to the human nervous system can be very detrimental in such conditions.

In this paper, it is important to understand what are neurological diseases. Neurological disorders are diseases of the peripheral and central nervous systems, which implies diseases of the spinal cord, brain, peripheral and cranial nerves, the autonomic nervous system, nerve roots, neuromuscular nodes and muscles. Such disorders include epilepsy, Alzheimer's disease and other types of dementia, vascular diseases of the brain, including stroke, Parkinson's disease, migraine and other types of headache, multiple sclerosis, brain tumors, neuroinfections, traumatic disorders of the nervous system, such as brain injuries, and neurological malnutrition disorders. [2]

Rehabilitation of patients with similar diseases to this day is an important issue. Since neurological diseases are quite common, their clinical manifestations are nonspecific, and they are difficult to diagnose and treat. There is no single, universal way to rehabilitate patients. For each patient, depending on the nature of his illness and individual characteristics, a rehabilitation complex is selected, which includes a different number of methods. These methods come from various

fields of medicine: physiotherapy, physiotherapy, psychotherapy, drug therapy and others. [3]

The use of virtual and augmented realities allows in practice to study the functioning and interaction of all components simultaneously, which are responsible for the system of maintaining the balance of the human body and the coordination of its movements. For this purpose, for example, virtual or augmented reality glasses and 3D input devices (markerless motion capture) are used, which provide user feedback. Virtual/Augmented Reality is a three-dimensional feedback environment that is created by computer means. This technique, "immersing" the patient in a virtual environment, allows him to become more involved in the rehabilitation process, thereby increasing the total effectiveness of rehabilitation methods. Although virtual / augmented reality is used relatively recently in medicine, its use along with other methods in the rehabilitation of patients with neurological diseases can give a good result. [4]

The purpose of this work: To develop a software package for the rehabilitation of motor functions in patients with neurological diseases.

Tasks:

- Description of neurological diseases;
- Analysis of rehabilitation methods already used in clinical practice;
- Description of requirements for the developed complex;
- Development of rehabilitation training scenarios;
- Creation of software modules based on the developed scenarios for the rehabilitation of motor functions;
- Development of a method of visualization and mathematical analysis of data received from the controller;
- Testing the developed method with the participation of patients.

Chapter 1. Literature review

1.1 Relevance

The development of computer technology leads to the fact that it gradually more and more is being introduced into medical institutions, improving existing methods, equipment and, accordingly, adding something new. So in the field of rehabilitation of neurological diseases for a long time there is a large number of applied techniques. Hundreds of millions of people in the world suffer from neurological disorders. In Russia, for example, according to statistics, one of the most frequent causes of disability and death is stroke. Of those who managed to overcome the disease, no more than 20% return to full-fledged life, primarily due to the speed of recovery of cognitive and motor functions of the central nervous system. [5]

In general, the complex of rehabilitation measures depends on the nature of the neurological disorders in each individual patient. The following methods for rehabilitation are proposed, which can be included in this complex: physiotherapy exercises that train residual motor functions (exercises that are effective in eliminating the effects of gravity, for example, under water or using antigravity suits) are especially effective; speech rehabilitation performed by a speech therapist; teaching various methods of communication with others (in patients with speech disorders); learning to perform everyday household procedures; neuropsychological correction with the development of preserved cognitive abilities; psychotherapy with the use of methods of psychological influence, which are aimed at overcoming depression, low self-esteem, anxiety, etc.; drug treatment (nootropic drugs, drugs that reduce muscle tone, light psychostimulants, antioxidants, calcium antagonists, etc.); methods of reflex therapy and physiotherapy; Spa treatment; occupational therapy; neurosurgical interventions that are aimed at stimulating the activity or suppressing the pathological activity of certain structures of the central nervous system. [3]

It can be concluded that for rehabilitation, in most cases, a set of techniques is used, and not a single one. The above-mentioned methods in one way or another carry out vestibular rehabilitation, which represents the acceleration of compensation of the function of the vestibular system, as well as the creation of conditions for the earliest adaptation to its damage.

In recent years, there has been an active development of virtual and augmented reality technologies, as well as the introduction of these technologies in various spheres of human life. In the rehabilitation of patients with neurological diseases, this method allows you to “immerse” the patient in a virtual environment, returning him a sense of balance, allowing you to carry out a number of exercises and exercises for the vestibular apparatus. This allows you to speed up the rehabilitation process. The maximum effect of the presence of the user in the virtual space and feedback with him are possible through the use of virtual or augmented reality glasses and a 3D input device (marker-free motion capture system). [4]

The use of virtual or augmented reality in conjunction with already existing methods (for example, drug treatment and physical therapy) will ensure good rehabilitation results and improve the condition of patients.

1.2 Neurological diseases

1.2.1 Parkinson’s disease

Parkinson's disease is a progressive disorder of the nervous system that affects the movement and coordination of human limbs. Symptoms develop gradually, sometimes starting with a little noticeable tremor of one hand. The disease is usually accompanied by tremor, but the disorder also causes stiffness or slowed down movements.

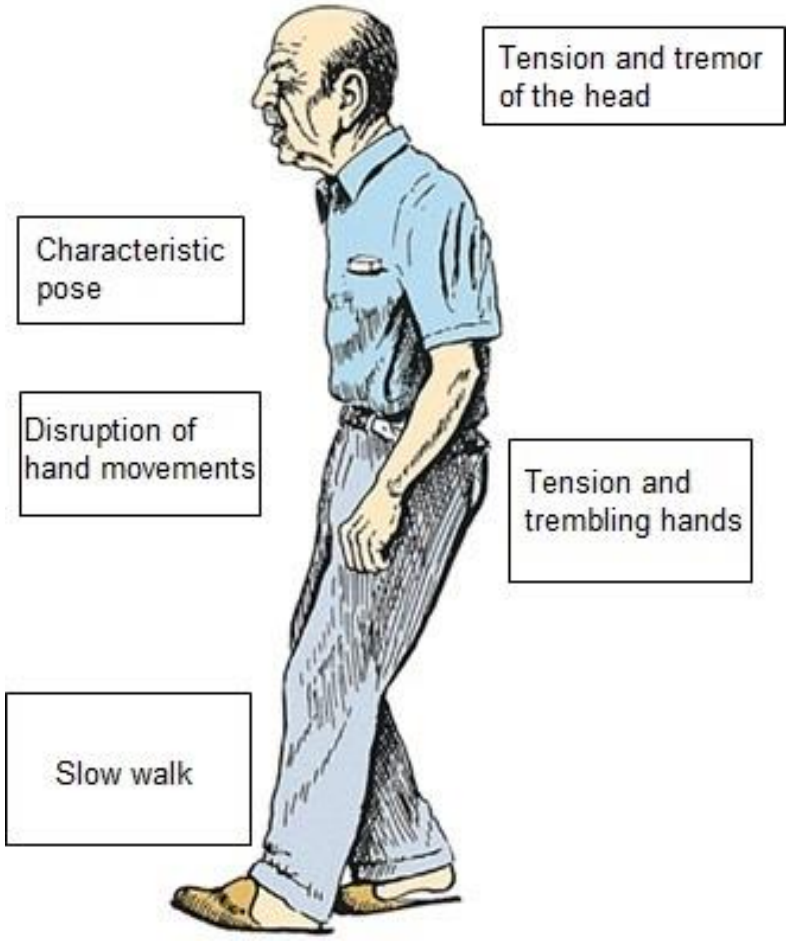


Figure 1 - The main external symptoms of Parkinson's disease

In the early stages of Parkinson's disease, a person’s faces may show little emotion or nothing at all. Hands cannot swing when walking. Speech may become soft or slurred. Symptoms of Parkinson's disease worsen over time. And although Parkinson's is not curable, medications can significantly improve your symptoms.

The signs and symptoms of Parkinson's can be different for everyone. Early signs may be mild and go unnoticed. Symptoms often begin on one side of a person’s body and usually become worse on this side, even after the symptoms begin to affect both sides. [6]

- Signs and symptoms of Parkinson's disease may include:
- Tremor of the limbs;
- Slow motion (bradykinesia);
- Speech impairment;
- Muscle stiffness;
- Impaired posture and balance;
- The deterioration of unconscious, automatic movements;
- Difficulties with fine motor skills.

The cause of Parkinson’s disease is unknown, but several factors seem to play a role, including:

Genetic predisposition. Scientists have identified specific genetic mutations that can cause Parkinson's disease. But they are rare, except in rare cases where many members of the family suffer from Parkinson's disease. However, some gene variations seem to increase the risk of Parkinson's disease, but with a relatively small risk of Parkinson's disease for each of these genetic markers.

Environmental triggers. Exposure to certain toxins or environmental factors may increase the risk of late Parkinson's disease, but the risk is relatively small.

Loss of nerve cells in the part of the brain called the black substance cause Parkinson's disease. It plays an important role in the regulation of motor function, muscle tone, the implementation of the statokinetic function by participation in many autonomic functions: respiration, cardiac activity, vascular tone. [7]

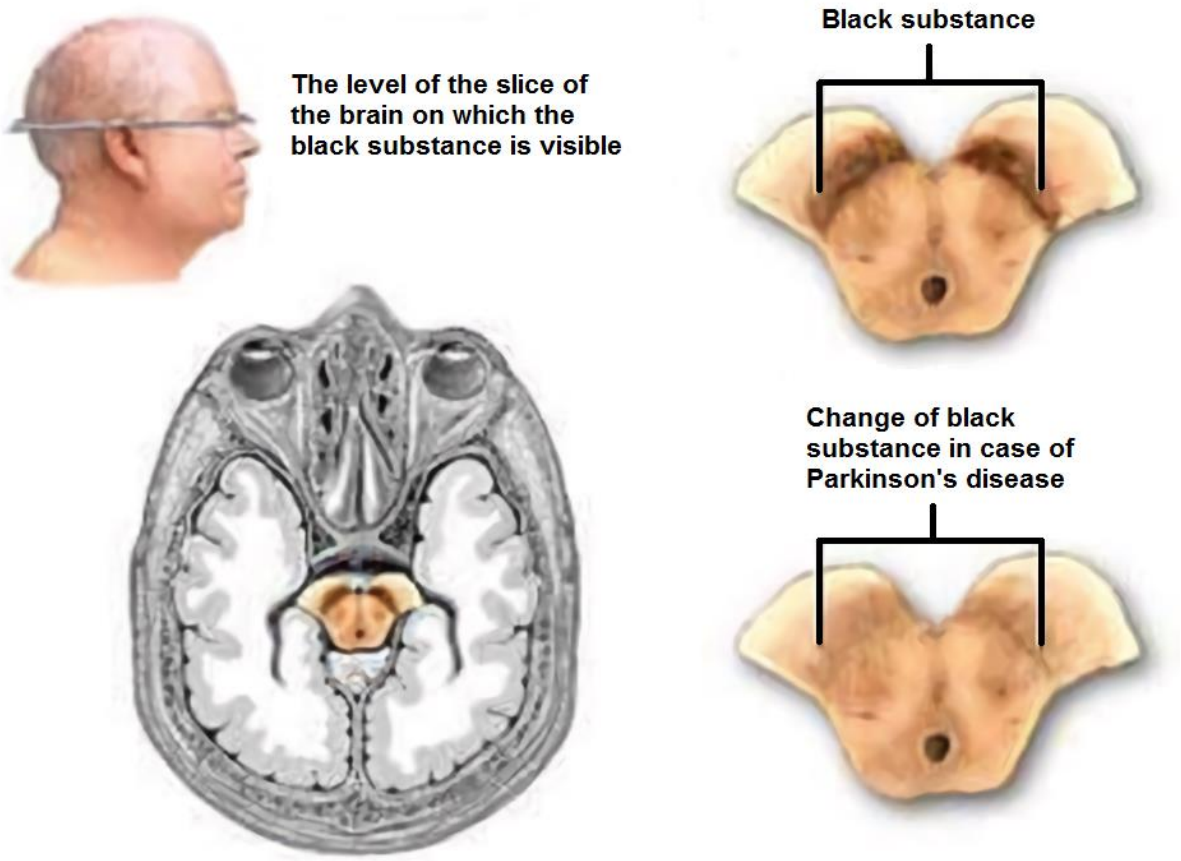


Figure 2 - Black substance change

Such chemical as dopamine is produced in this part of the brain by nerve cells. Dopamine operates as an intermediary between the nervous system and the parts of the brain which help control and coordinate body movements.

In case when nerve cells die or get damaged, the amount of dopamine in the brain decreases. What means that the part of the brain that controls the movement cannot work as usual, causing the movement of the person to become abnormal and slow.

Loss of nerve cells can be called a slow process. Symptoms of Parkinson's disease usually begin to develop only when about 80% of the nerve cells in the black substance are lost. [8]

1.2.2 Stroke and its consequences

What is a stroke? A stroke is a severe disruption of the blood supply to the brain, which is characterized by the appearance of neurological symptoms (focal or/and cerebral). As a result of a stroke, brain cells are deprived of oxygen and begin to die, and the abilities controlled by the affected areas of the brain, such as memory and muscle control, are lost. [9]

There are two types of stroke: ischemic and hemorrhagic. A hemorrhagic stroke occurs when a rupture of a blood vessel occurs in the human brain. Although this is the least common of the two types of stroke, it most often leads to death. Ischemic stroke occurs when the arteries of the human brain are blocked or narrowed, resulting in a significant decrease in blood flow (ischemia). About 80 percent of all strokes are ischemic strokes. [10]

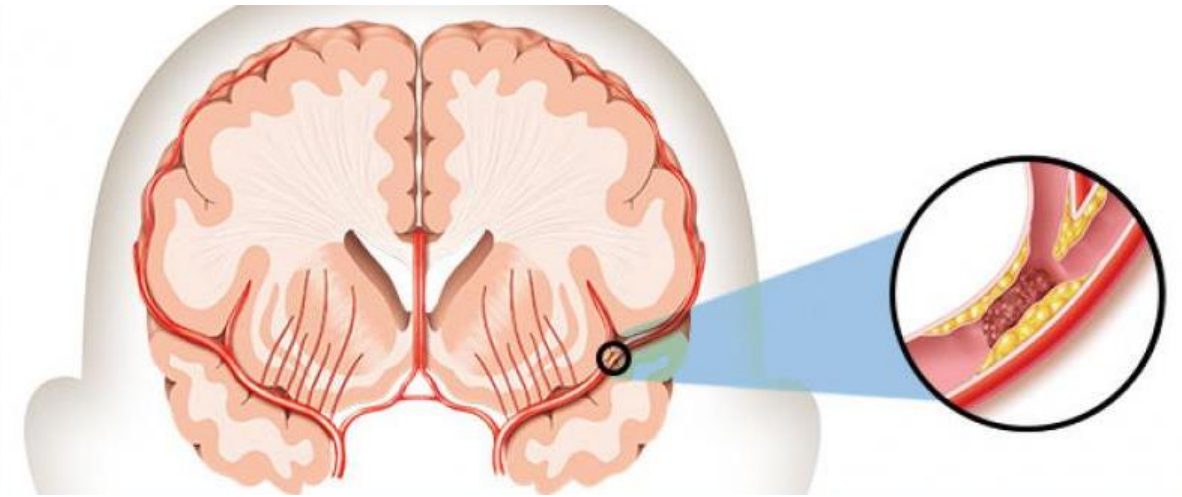


Figure 3 - Disruption of the blood supply to the brain

According to statistics from the Federal State Statistics Service, human cerebrovascular diseases rank second in the structure of mortality from circulatory system diseases (39%), as well as the total mortality rate of the population (23.4%). Of those people who managed to overcome the illness, no more than 20% return to full-fledged life. [11]

There are groups of people, the so-called “risk groups,” in which the likelihood of a stroke is particularly high. People belonging to risk groups should especially carefully monitor their health. Risk factors for stroke include:

Arterial hypertension (high blood pressure). Cerebral vessels can withstand high pressure, but if the pressure rises continuously, the walls of the vessels begin to lose their elasticity, and the risk of rupture increases.

Heart diseases. Various cardiac arrhythmias can provoke the formation of blood clots, thereby increasing the risk of stroke.

Increased cholesterol. Cholesterol plaques on the vessels is another factor in their possible blockage and development of stroke.

Diabetes. One of the consequences of this serious disease is a change in the structure of the blood vessel walls. They become thin and fragile, which increases the risk of their breaks.

Aneurysms of cerebral vessels. These specific formations have thinner walls than the vessel itself, on which the aneurysm originated. As a result, there is always a risk of rupture of the aneurysm and subsequent hemorrhagic stroke.

Blood clotting disorder. Changes in the composition of the blood, its "thickening", can cause the formation of clots that can cause blockage of blood vessels, including in the brain.

Obesity and lack of moderation in food consumption. Improper diet can cause high cholesterol levels.

Smoking, alcohol abuse. These bad habits lead to a violation of the integrity of blood vessels and increase blood pressure. Both can cause a stroke. [12]

A stroke usually affects only one half of the brain. The movements and sensations of one side of the body are controlled by the opposite side of the brain. This means that if a stroke struck the left side of the human brain, then there will be problems with the right side of the body. If a stroke struck the right side of the brain, problems will arise with the left side of the body. Changes that may occur after a stroke on either side of the brain include the following:

- Dysarthria

Dysarthria is a problem of motor speech. This means that a person cannot coordinate the movements of the mouth to form sounds or words.

- Dysphagia

Dysphagia is a problem with swallowing, usually caused by weakness or loss of sensation in the tongue, lips, throat, or palate.

- Problems with memory

The emergence of memory problems. This can lead to difficulties with saving and recalling information.

- Cognitive disorders

Problems with memory, thinking, attention, or learning.

- The problem of endurance

A person cannot perform tasks or activities for a long period of time.

- Abnormal muscle tone

This is a neurological problem that makes a person's movements intermittent and slow.

- Problems with coordination

Possible impairment of hand and eye coordination. Upon reaching an object, a person’s hand may fluctuate or may jump over an object.

There are other changes that can occur with a person having a stroke. But within the framework of the developed software for the rehabilitation of motor functions, the last listed items are important, such as abnormal muscle tone, problems with coordination of movements and the problem of endurance. [13]

1.3 Rehabilitation of patients with neurological diseases

1.3.1 Medical physical culture

The main objectives of medical rehabilitation are to prevent the occurrence of various diseases and injuries, speed up recovery processes and increase their effectiveness, reduce disability, increase the level of adaptation of a disabled person to living conditions.

One of the main sections of medical rehabilitation is physiotherapy exercises (kinesitherapy) - a natural biological method of complex functional therapy. It is based on the use of the main function of the body - movement. Movement is the main form of existence of the human body: it affects all manifestations of the body's vital activity from birth to death, all body functions and the formation of adaptive-adaptive reactions to a wide variety of stimuli. [14]

In this regard, the movement can act as a specific, and non-specific irritant, causing the reaction of both the whole organism and its individual organs or systems. Human motor function is extremely difficult. Movement is provided by interrelated processes occurring in the internal environment of the body at the cellular, organ and system levels, with the consumption and formation of energy and contribute to the manifestation of tonic, trophic, compensatory, normalizing or destructive effects.

Regular, purposeful and strictly dosed use of various motor reactions contributes to the strengthening of the biological mechanism of protective and adaptive reactions, specific and nonspecific resistance of the organism to various influences.

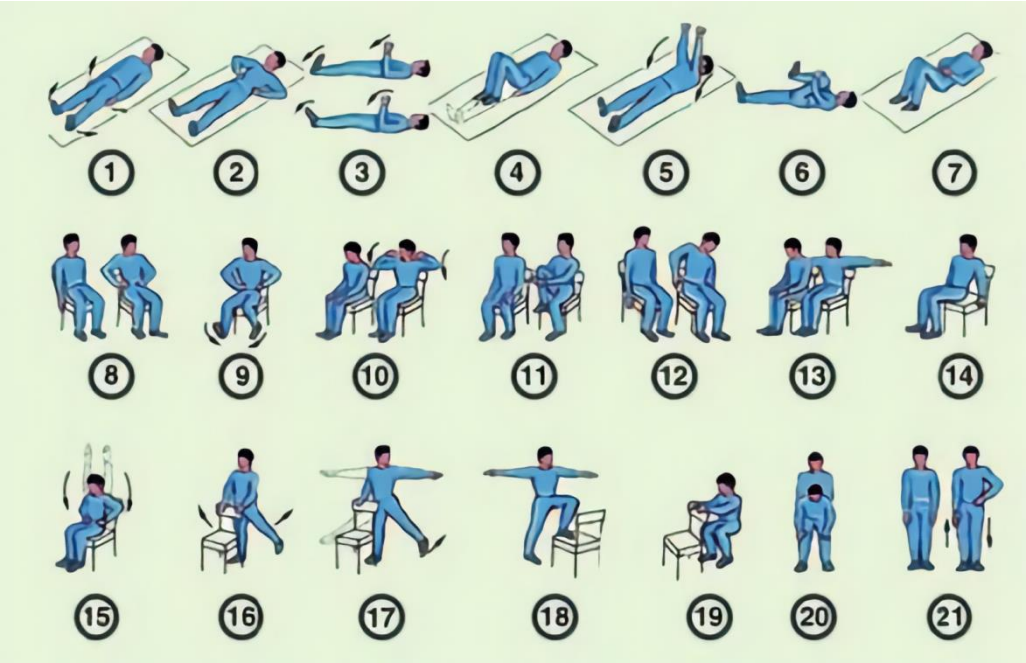


Figure 4 - An example of a set of exercises in Parkinson's disease [15]

1.3.2 Physiotherapy treatment

Physiotherapy is a science that studies the effect on the human body of preformed and natural physical factors, and also develops methods for their use for disease prevention, medical rehabilitation and rehabilitation treatment. [16]

In practice, physical factors are included in early recovery rehabilitation programs. Physical factors are used as monotherapy already in the early period of rehabilitation treatment and during rehabilitation for a number of neurological diseases. For example, patients with radicular and reflex manifestations of dorsopathies with acute pains are prescribed cryotherapy, medicinal electro-ultraphonophoresis of anesthetics, electrostatic massage, and interference currents. UFI, UHF procedures, for example, are carried out to relieve pain, stimulate reparative processes, and improve blood circulation.

From the goals of treatment, contraindications and indications depends on what effect physical factors will apply: local, general and/or segmental-reflex. For modern physiotherapy, the most promising is the use of combined techniques, as well as the creation of comprehensive programs of rehabilitation and rehabilitation.

As a result of this approach, the complementarity and potentiation of the clinical effects of each of the physical factors occurs. As a result, there is an increase in the effectiveness of treatment, reduction of recovery time, prevention of complications and recurrence of the disease. Important is the sequence of procedures performed during the rehabilitation, and respect for the time intervals between them.

The following methods are used: direct current electrotherapy (galvanization, drug electrophoresis); electrotherapy by constant impulse currents (electrosleep); alternating current electrotherapy (transcutaneous electrical stimulation); high-frequency electrotherapy (darsonvalization, UHF - exposure, inductothermia); magnetic therapy (low-frequency magnetic therapy, pulsed high-intensity magnetic therapy); electric fields (infitatherapy); light therapy (infrared radiation, ultraviolet radiation); ultrasound (high frequency ultrasound).

1.3.3 Manual therapy

The term "manual therapy" refers to the treatment of diseases of the spine and pathogenetically associated with visceral, spinal and cerebral disorders using manual exposure. [17]

The structural and functional unit of the spine is a motor segment consisting of the bodies of two adjacent vertebrae, an intervertebral disc, arcuate processes, ligaments of the corresponding muscles, nerves and vessels.

The function of the motor segment of the spine is determined by a genetically determined stereotype, which is closely associated with all systems of the human body, including the internal organs. Disturbance at any level may result in a functional blockade of the motor segment, or a reversible restriction of mobility in the motor segment of the spine within its normal physiological function, resulting from a changed interposition of the intra-articular connective tissue elements, as a rule, due to reflex periarticular articulation.

All these changes are recorded in the short-term, and later in the long-term memory, forming a new motor stereotype, which in the early stages of the disease allows almost completely to compensate for the functions disturbed by the disease.

For the treatment of patients with diseases of the musculoskeletal system to be effective, it is imperative to "recode" the pathological motor stereotype formed as a result of a disease of the spine or joints, which adapts the patient to the disease (but not to a healthy lifestyle) into a normal one that promotes the patient's quick recovery. This can be achieved by simultaneously acting on the motor segment of the spine and using articular mobilization and manipulation techniques directed at once to all pathogenesis links (elimination of the functional blockade of the joint, effects on muscles, ligaments, fascia, neurovascular formations of the spinal motor segment, intervertebral disk).

Mobilization and manipulation techniques include special targeted techniques that allow you to:

- eliminate abnormal tension in muscles, ligaments, capsules of joints;
- improve arterial blood flow, venous and lymph outflow;
- correct the posture and function of internal organs.

1.3.4 Psychotherapy

Psychotherapy is a system of therapeutic effects on the psyche of the human body, as well as through the psyche on the body. The widespread and effective use of psychotherapy is due to two clinical prerequisites:

1) Direct use of the therapeutic action of psychotherapy in a wide range of diseases, in which the etiopathogenesis of mental factors is assigned a decisive or rather significant role.
2) The therapeutic and prophylactic value of psychotherapy, given the psychosocial reactions to somatic, including nervous diseases, their consequences, the impact of specific somatic disorders on the individual's psychological functioning, his behavior.

Goals, objectives, and the choice of methods of psychotherapy is determined by the individual clinical characteristics of the patient and his illness:

- personal characteristics of the patient;
- the role of psychological factors in the etiopathogenesis of a specific disease;
- nosological affiliation of the disease.

The clinical approach to the conduct of psychotherapy activities, in addition to the above, involves the choice of methods of psychotherapy that will correspond to the various organizational forms in which psychotherapy is carried out, i.e. institutions of stationary, semi-stationary, ambulatory, sanatorium types. [18]

Nowadays, the biopsychosocial model of the disease is gaining increasing recognition in health care and medicine. The biopsychosocial model of the disease raises the question of the relationship between the biological, social and psychological effects in the treatment of various diseases.

1.3.5 Medical preparations

One of the methods of rehabilitation therapy of neurological patients is the use of drugs. As part of the treatment and rehabilitation complex, drug therapy occupies a special place. In the course of rehabilitation treatment of diseases of the nervous system, drug therapy should be carried out regularly, by scheduled repetitive courses.

Drugs are a targeted aid, providing the most favorable conditions for carrying out such rehabilitation activities as therapeutic gymnastics and massage, physiotherapy, professional retraining, etc.

The use of medications in patients with the consequences of stroke, traumatic brain injury, epilepsy, parkinsonism takes a particularly prominent place. With these diseases, long-lasting for months and years, pathogenetic drug therapy is an indispensable condition for the success of the patient rehabilitation process.

The purpose of prescribing drugs in the rehabilitation treatment of neurological patients may be different.

Etiotropic treatment is carried out to influence the cause of the disease. For example, the use of antirheumatic drugs (with cerebral vessels rheumaskulitis).

Pathogenetic therapy is carried out to eliminate the main disorders in the body caused by the disease, and to replace with chemicals that are injected in the body in patients with deficiencies. For example, the appointment of funds that improve neuromuscular conduction (with diseases of the peripheral nervous system), or the introduction of levodopa (with Parkinson's disease).

Symptomatic treatment is prescribed to eliminate individual symptoms of the disease. For example, the use of muscle relaxants to reduce muscle spasticity, the use of hypnotic drugs for sleep disorders, etc. [19]

1.3.6 Virtual and augmented reality

Virtual reality is a unique tool in the rehabilitation of patients with neurological diseases. Since various methods of its use are possible, and various rehabilitation programs can be customized and changed, adapting to a specific patient if necessary. It provides “immersion” of the patient in a virtual environment, allowing for various physiotherapy exercises, exercises, actions that are not available in the hospital. Indeed, for a patient, what is happening on the screen of virtual reality glasses begins to be perceived as real. Physical therapy plays a key role in the rehabilitation of patients with neurological diseases. Physical therapy in rehabilitation is usually aimed at strengthening and retraining the muscles in order to restore the lost functions of the limbs and improve the quality of life. The use of augmented or virtual reality has been little studied, but initial studies show that their use can greatly help patients. The introduction of game and competitive elements can also make rehabilitation interesting and not boring, which should additionally motivate patients to perform the tasks assigned to them.

Figure 5 - CAREN system [20]

For example, scientists from the Dutch company Motek Medical have developed an innovative augmented reality system that allows doctors to analyze the balance, movement and coordination. [21]

CAREN or Computer Assisted Rehabilitation Environment is a rehabilitation environment supported by a computer. CAREN system consists of a platform that allows you to move with 6 degrees of freedom, it can turn up, down, left and right. The foundation is a treadmill surrounded by real-time motion capture cameras, motion tracking data is synchronized with the visual environment and sound. The patient is asked to go down the track, drive the boat, go through the airport or any other typical place without fear of injury and without restrictions on the monitoring specialist. [20]

The Polish company Virtual Reality Rehabilitation uses for the rehabilitation of patients various technical devices, such as Kinect, Wii, Leap Motion. Based on Kinect, they developed their own SeeMe application. SeeMe is a PC-based, innovative, comprehensive, doctor-controlled system of exercises and diagnostics. SeeMe is designed to help the rehabilitation process and track patient progress. It improves coordination, balance, muscle strength, range of motion, reaction time,

memory - the number of different applications increases with the updates of their system. [22]

Figure 6 - Visualization of the rehabilitation process with the help of the program SeeMe [22]

SeeMe differs from most other video capture systems in several aspects: no markers, wires or monochromatic backgrounds are required; the system uses motion detection, not just color recognition, thereby eliminating the need for special colored gloves; the system does not need calibration before each session; A unique feature of the SeeMe system is that client performance can be monitored “online” and the parameters of virtual tasks can be changed even in the middle of the game. Thus, the task can be made simpler or more difficult according to the work of the subject. Results, including movement time, success rate and virtual game parameters, are saved and can be easily restored. [23]

The main advantage of the SeeMe system is the ability to adapt it to the individual needs, goals and scientific interests of patients and doctors who use this system.

Examples of tasks are shown in Figure 7. [24]

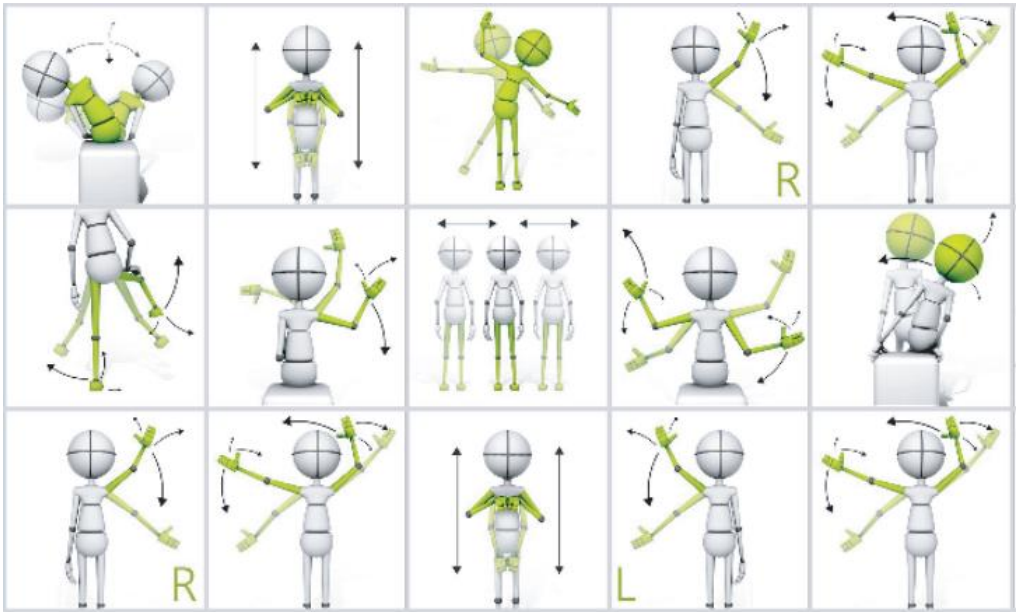


Figure 7 - Examples of tasks for the SeeMe system [24]

The same methods are used in the Spanish company VirtualRehab, where, based on Kinect, they create games for the rehabilitation of patients with neurological diseases. VirtualRehab is a product that allows you to treat various functions in the following pathologies: neurodegenerative diseases (multiple sclerosis, Parkinson's disease, Alzheimer's disease), neuromuscular disorders (dystrophy, myopathy, amyotrophy and neuropathy), neurovascular disorders / injuries (stroke and traumatic injuries brain), as well as to train the mobility of the elderly. [25]

VirtualRehab is the very first virtual rehabilitation software that is classified as a medical device, registered as class I, and obtained a CE mark that complies with the regulatory system of the European Union directives on medical devices.

Figure 8 - VirtualRehab system [25]

The question of the overall effectiveness of the use of virtual and augmented realities in the rehabilitation of patients with neurological diseases can be answered quite positively. For example, the essence of a rehabilitation experiment [26] was that the patient under study was in a chair in front of the screen and at the same time manipulated his healthy hand. At the same time, the screen depicted how the patient performs the same manipulations, but with a different, in this case damaged, hand. To obtain the greatest effect, the color of the patient's clothes on the screen was modulated in accordance with real clothing. During classes, the patient performed with a healthy hand those actions that he could not perform in reality with a damaged hand, but since he saw on the screen how the injured limb was involved in this process, he thereby received positive reinforcement in the form of the visual effect of his activities.

The next stage of rehabilitation included the imitation of the actions of the injured limb, which were reproduced on the screen. This means that the screen shows the manipulations that are performed with a healthy hand, and the patient had to try to repeat these actions with his injured hand. In the process of completing the assignment, the patient could, how to observe his progress in imitation, and not see the actions that his injured hand performs. Tasks were presented in the game material - moving the balls to the target, catching the balls.

Experts recorded all the results and changes in the neurological and mental status of patients using clinical scales. According to the results of work with this method, the authors noted high productivity, since the reduction potential of patients who survived stroke increased by 20-23%, in addition, a significant improvement in cognitive processes, such as involuntary and voluntary attention, was demonstrated. A decrease in the intensity of emotional maladjustment in the form of anxious and depressive experiences was noted. The authors of the article separately note the high motivation of patients for rehabilitation exercises with virtual reality, since in addition to visual appeal they have a personal focus on each specific patient, imitating their appearance, behavioral patterns, etc.

Another article [27] describes three patients, two men and a woman (called conditionally ML, LE, and DK) who were in the chronic phase after a stroke. These three patients participated in the training program for two weeks. They had to perform tasks on agility on real objects and exercises in virtual reality. The use of virtual reality suggested improving coordination, speed of movement and muscle strength. The patient's motor functions of ML were most disturbed at the beginning of rehabilitation, but as a result, his coordination and the speed of the movements of the fingers showed an improvement. LE improved fractionation and range of motion of the fingers. DK showed the best result, showing an improvement in the coordination of movements and strength of the thumb, the speed of movement of the fingers and their fractionation.

In another case [28], 25 people participated in the study at 3–20 days after their cerebral stroke. 18 patients formed a control group that were comparable in severity of stroke, age and time period after a stroke with the main group of patients. In the main group of subjects, markerless interactive rehabilitation system of augmented reality with real-time biofeedback Nirvana was used, and a standard rehabilitation program was implemented in the control group. Against the background of rehabilitation in the main group of patients, there was a decrease in the neurological deficit on the NIHSS scale by 39.1% versus 24.4% in the control group. In addition, in the main group, there was a statistically significant decrease

in anxiety, apathy, and improvement in psychomotor functions. It was also noted in patients in the main group increased motivation for rehabilitation compared with the control group.

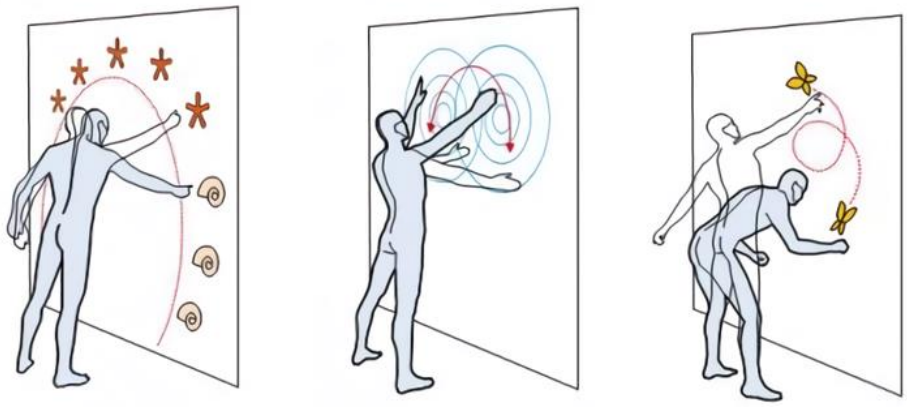


Figure 9 - System for rehabilitation called Nirvana [29]

Another article describes the use of virtual reality and the Leap Motion controller for the rehabilitation of stroke patients. Twenty-six patients with acute stroke were assigned to an experimental group, which was trained in virtual reality, along with the usual vocational rehabilitation, and a control group, which received only regular rehabilitation. The Wolf motor function test (WMFT) was used to assess the motor function of the affected upper limb; Functional magnetic resonance imaging was used to measure cortical activation. After four weeks of treatment, the motor functions of the affected upper limbs were significantly improved in all patients, and the improvement in the experimental group was significantly better than in the control group. The execution time of the action in WMFT has significantly decreased in the experimental group. These results confirmed that learning virtual reality based on Leap Motion was a promising and possible additional rehabilitation intervention that helps to restore motor functions. [30]

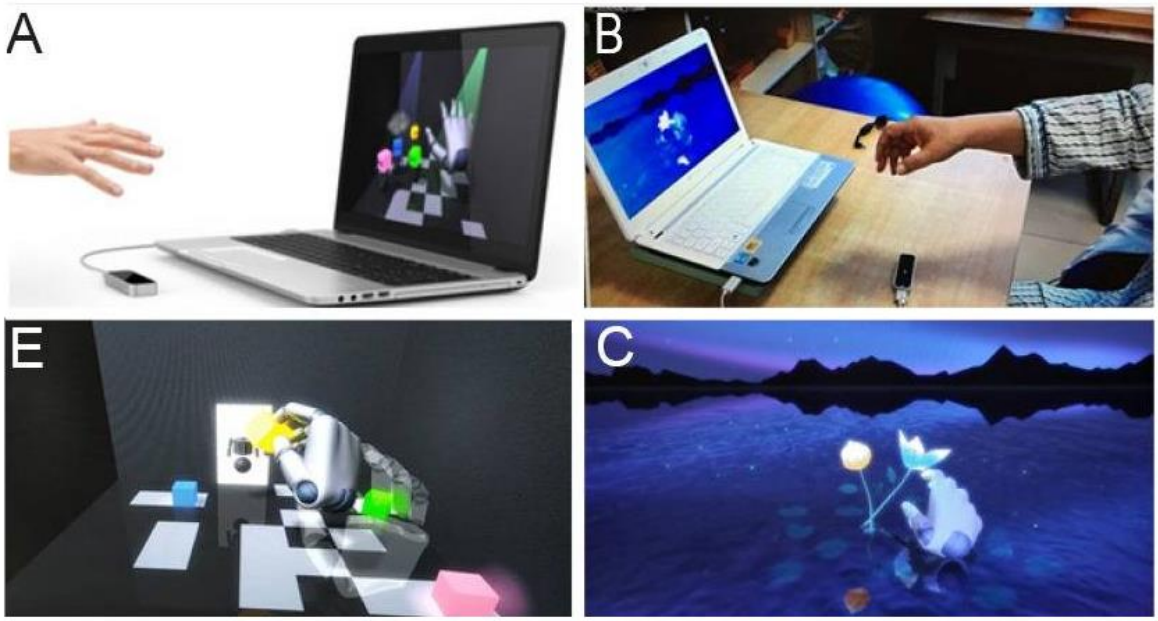


Figure 10 - Exercises using Leap Motion [30]

Why is it necessary to use Leap Motion for physiotherapy trainings? Over the past few years, technology has increased dramatically in the field of rehabilitation. This is made possible by the availability of technology. Sensors in healthcare are becoming more common, and their ability to detect even the smallest movements has recently made them very attractive. Sensors are capable of automation, large-scale monitoring and measurement of health related parameters. They are able to diagnose, treat, and monitor patients and provide clinicians with early warning signs for potential problems. They can also provide more objective feedback than the clinician, who subjectively indicates how the patient's body is in space. In particular, Leap Motion is well suited for use in the rehabilitation process. And the augmented reality allows to provide “immersion” of the patient into the virtual environment in order to accelerate the adaptation and restoration of the patient’s organism in the arising conditions, albeit virtual. [25]

The use of augmented reality is due to the fact that it gives us reactions that affect the behavior during the registration of physiological and kinematic responses. Augmented reality provides feedback that allows you to transfer the complexity of the physical world into a controlled laboratory environment. Virtual reality gives us the opportunity to move away from reductionism to the measurement of natural movement in natural complex environments. In general,

augmented reality allows us to create a synthetic environment with precise control of a large number of physical variables, communication with the patient in real time, control and coordination of incentives, modification of incentives and responses that depend on the physical capabilities of the patient, as well as the safety of the testing and learning environment. [31]

As a result, after reviewing the literature on the use of virtual and augmented realities for rehabilitation, the following requirements were formulated for the system developed for BFB training:

- The feedback signal should be formed on the basis of a change in the spatial coordinates of the hands;
- The BFB training scenario should be customizable;
- There must be a record of file with coordinates;
- Hand position data is receiving wirelessly;
- Visualization of the virtual environment in the form of a scene with objects of interaction;
- The implementation of the interaction model of the patient's hands with virtual objects;

Chapter 2. Materials and methods

2.1 Biofeedback Method

The method of biofeedback (BFB) is a non-invasive and non-drug priority treatment method in rehabilitative medicine, it's finding extensive variations in its application. The method of biofeedback is based on the fact that with the help of various sensors (visual, tactile, acoustic, electromyographic, electrocardiographic, etc.) information is taken from the patient's body, which is then converted into visual and/or audio feedback signals. The BFB interface is for the patient a "mirror" that reflects the physiological processes occurring inside his body and allows him, analyzing feedback signals about the current state of a particular physiological function of the body, to learn to directly control his body. BFB therapy allows the patient to be involved in the process of his own rehabilitation and motivate him to achieve positive results. [32]

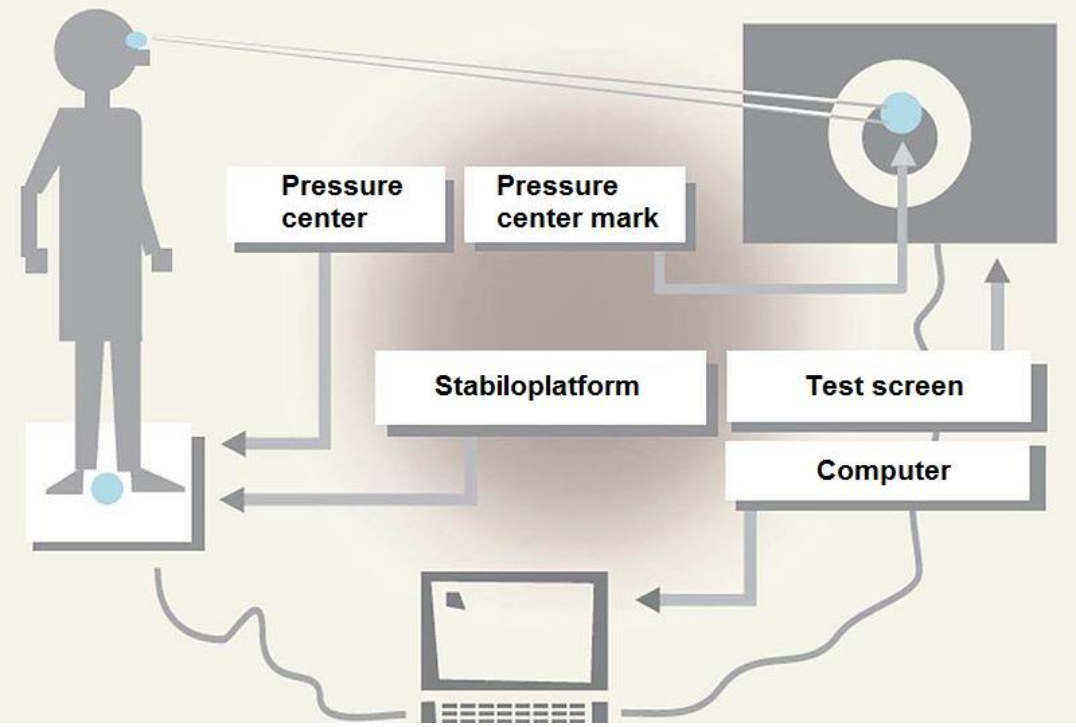


Figure 11 - Artificial feedback using the support reaction [33]

The advantages of this method are conventionally divided into two categories: advantages compared with other methods and advantages from the patient's point of view. The first category includes:

- No side effects, since the biofeedback method is not medicamentous;
- Lack of external influence on the patient;
- Individual approach to therapy, depending on the patient;
- Intensive patient involvement in the rehabilitation process;
- Reducing the need for drugs;
- Prolonged preservation of patient self-regulation skills;
- Impact on the main types of dysfunctions of the body's regulatory systems (humoral, nervous, immune), and not on individual diseases.

The second category can be attributed:

- Complete painlessness for the patient;
- High level of efficiency;
- Accessibility and simplicity of the method;
- Gamification of the method and, as a consequence, patient involvement;
- Ability to combine BFR training with other methods;
- Non-invasive.

2.2 Augmented reality

Augmented reality is a world consisting of objects and subjects, which is created by technical means and transmitted to a person through sensations such as hearing, smell, sight, touch. Augmented reality can mimic both impact and reaction to impact. In order to create a convincing complex of sensations of reality, computer synthesis of reactions and properties of augmented reality occurs in real time.

Also for this, virtual reality objects should behave as close as possible to the actual behavior of similar items. Human interaction with these objects occurs in

accordance with the real laws of physics, for example, gravity, reflection, collision with objects. [34]

The main difference between augmented reality and virtual reality is that augmented reality only introduces individual virtual elements into the perception of the real world, and virtual reality reflects the new artificial world. It can be said that the difference is only in the method of displaying the virtual environment for a person, therefore information about virtual reality is also relevant for augmented reality, which allows a person not to lose control of himself in the real world.

Augmented reality is one of the most promising technologies of the 21st century. Applications are almost everywhere: from the gaming industry to medicine. In today's world often use smartphones to create augmented reality. This use allows you to overlay virtual 3D models on maps, landscapes, layouts, etc; display a map of the area, the names of the surrounding shops; characteristics of a particular subject - the range of possibilities is limited only by the imagination of the developers of such applications.

Figure 12 - An example of using a smartphone to create augmented reality [35]

In addition to smartphones for these purposes, use of augmented reality glasses, which provide greater comfort, since there is no need to hold them in their hands, and a wide range of possibilities. Modern glasses have high performance

and excellent image quality, providing the best immersion in the created augmented reality. That is why in this work used augmented reality glasses.

Figure 13 - An example of using augmented reality glasses [36]

2.3 Augmented reality glasses Epson Moverio BT-300

In this work, we used Epson Moverio BT-300 augmented reality glasses. The use of augmented reality glasses allows you to combine a virtual environment with the real world, thereby simultaneously seeing what is happening in the real world and on the interactive screen. This is their main difference from virtual reality glasses, in which there is a total immersion in virtual reality.

Glasses and remote control are wired. Outside it has a trackpad, three standard Android buttons and a joystick, and inside is a quad-core Intel Atom processor with a frequency of 1.44 GHz, 2 GB of operational memory and 16 GB of internal memory, ensuring stable operation of even complex applications. As well as a battery capable of supporting the work of the gadget for six hours. In glasses, there are only screens, a large number of sensors (GPS, compass, gyroscope, accelerometer, 5 megapixel camera). Epson Moverio BT-300 provides HD Ready 720p resolution.

One of the main advantages of the Moverio BT-300 is its low weight, because their battery and hardware are included in a separate module. Another plus is that glasses do not need to be connected to other devices - a PlayStation game console or a personal computer; everything you need to work is already inside. Epson Moverio BT-300 runs on the Android 5.1 operating system.

Among the shortcomings it is worth noting the difficult work with the text - typing messages from the trackpad is difficult and time consuming. Part of the problem can be solved using voice input. [37]

Figure 14 - Augmented reality glasses Epson Moverio BT-300

2.4 Unity software tool

The virtual environment is implemented using the Unity Engine software tool. Unity Engine is an application and game development tool that runs under Windows, Linux, Android OS, iOS, WebGL operating systems. [38]

Unity editor has a simple and intuitive interface, easily customizable and consisting of various windows, which allows you to debug the application directly in the editor. Supported scripting languages: C #, JavaScript and Boo.

The Unity project is divided into scenes, or levels, which are files that contain separate virtual environments with their objects, scripts, and settings.

These levels can contain not only objects, but also empty objects, that is, those without models. In turn, objects consist of a set of components with which scripts already interact. Objects have names, and two or more objects with the same name are allowed. An object can have a label and a layer on which it should be displayed. For example, any object should have a Transform component that stores the coordinates of the location, rotation, and size of the object along all three planes.

The advantage of the Unity editor is the support of the physics of solids and tissue, as well as the physics of the Ragdoll type - “rag doll”. The editor has an object inheritance system - this means that the child objects will repeat all changes in the rotation, position and scale of the parent object. Scripts in the Unity editor are attached to objects as separate components.

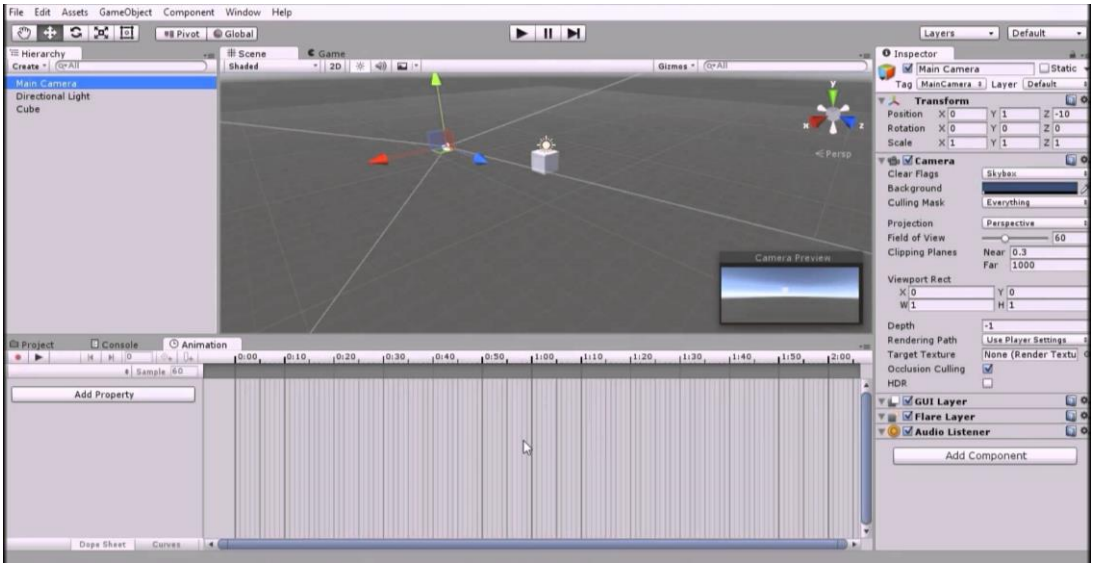


Figure 15 - Interface of Unity Engine

2.5 Leap Motion controller

Leap Motion is a technology that captures movement for interaction between a person and a computer. The device itself, based on the Leap Motion technology, is a small-sized USB device connected to a personal computer, which is positioned upwards by the working part, creating a 3D interaction area with a volume of approximately 227 cubic meters. [39]

Figure 16 - Example of working Leap Motion [40]

The Leap Motion controller allows you to track the movements of both hands and all ten fingers as they move in the air between the personal computer and the user. This controller has a fairly small size - 7.5 centimeters in length and 3 centimeters in width. The front panel of the controller case has a glass coating in order to ensure the efficient operation of the sensors. The rear panel of the controller housing is rubberized in order to prevent it from sliding on the working surface.

Figure 17 - Inside the Leap Motion controller [41]

From a hardware point of view, the Leap Motion controller is pretty simple. The device consists of two cameras and three infrared LEDs. These LEDs emit infrared light with a wavelength of 850 nanometers, which is outside the visible light spectrum. The USB controller reads the sensor data into its local memory and performs any necessary image resolution settings. This data is then transferred via USB to the Leap Motion tracking software on a personal computer. [41]

2.6 Matlab software package

Matlab (short for “Matrix Laboratory”, in Russian pronounced “Матлаб”) is an application package for solving technical computing problems and the same programming language used in this package. The package is used by more than a million engineers and scientists, it works on most modern operating systems, including Linux, Mac OS, Solaris (since version R2010b, Solaris support has been discontinued) and Windows. [42]

Matlab is widely used in areas like:

- computational biology, etc.
- signal processing and communication;
- control systems;
- image and video processing;
- financial engineering;
- automation of testing and measurement;

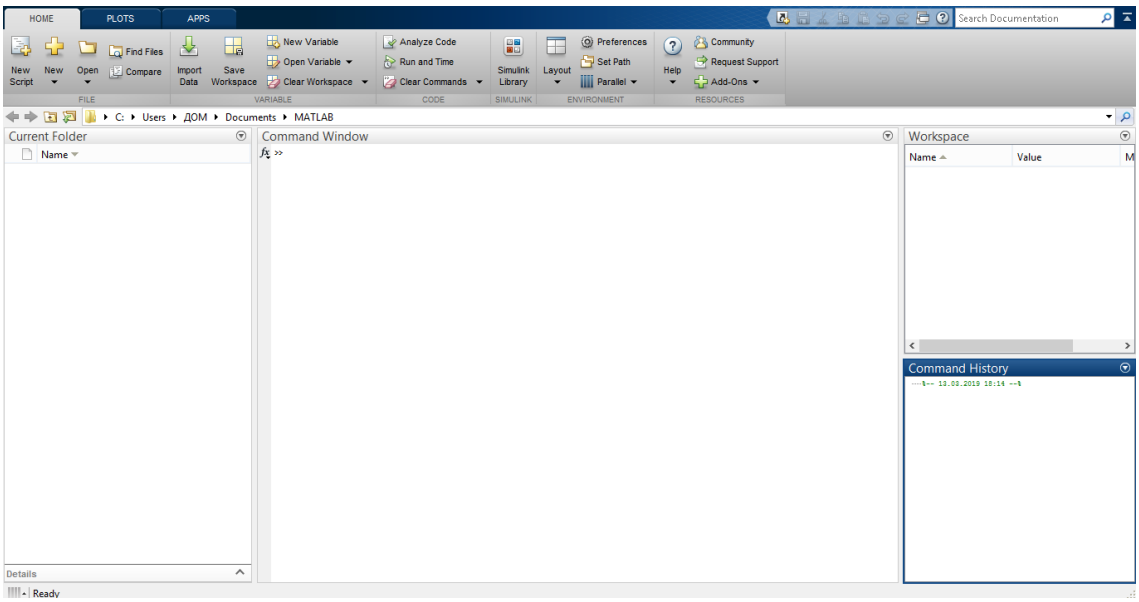


Figure 18 - Interface of Matlab

The MATLAB language is a high-level interpreted programming language that includes matrix-based data structures, a wide range of functions, an integrated development environment, object-oriented features, and interfaces to programs written in other programming languages.

Programs written in MATLAB, there are two types - functions and scripts. Functions have input and output arguments, as well as their own workspace for storing intermediate results of calculations and variables. Scripts use a common workspace. Both scripts and functions are saved as text files and compiled into native machine code dynamically. There is also an opportunity to save so-called pre-parsed programs - functions and scripts processed into a form convenient for machine execution. In general, such programs run faster than usual, especially if the function contains commands for plotting graphs.

Disadvantages:

- Slow and overloaded with operators, commands, functions, language, the main purpose of which is to improve the visual perception.
- Narrowly directed. There is no more software platform where MATLAB would be useful.
- The high cost of software. If you are not a student, either get ready to empty your pockets or cross the line of law. And even if the student - the price is decent.
- Low demand. Despite the great interest in MATLAB in almost all areas, only a few actually use it and legally.

Advantages:

- The language is easy to learn, has a simple and clear syntax.
- Huge possibilities. But it is rather the advantage of the whole product.
- Frequent updates, usually noticeable positive transformations occur at least a couple of times a year.
- The software environment allows you to convert it into “fast” code in C, C++.

Chapter 3. Results

As part of the master's thesis, three scenarios were developed for the training of fine motor skills using the Leap Motion controller. In the process of performing tests, a number of indicators can be assessed, such as: resting tremor, intentional tremor of movements, accuracy of movements, maintaining balance when receiving sensory visual incentives.

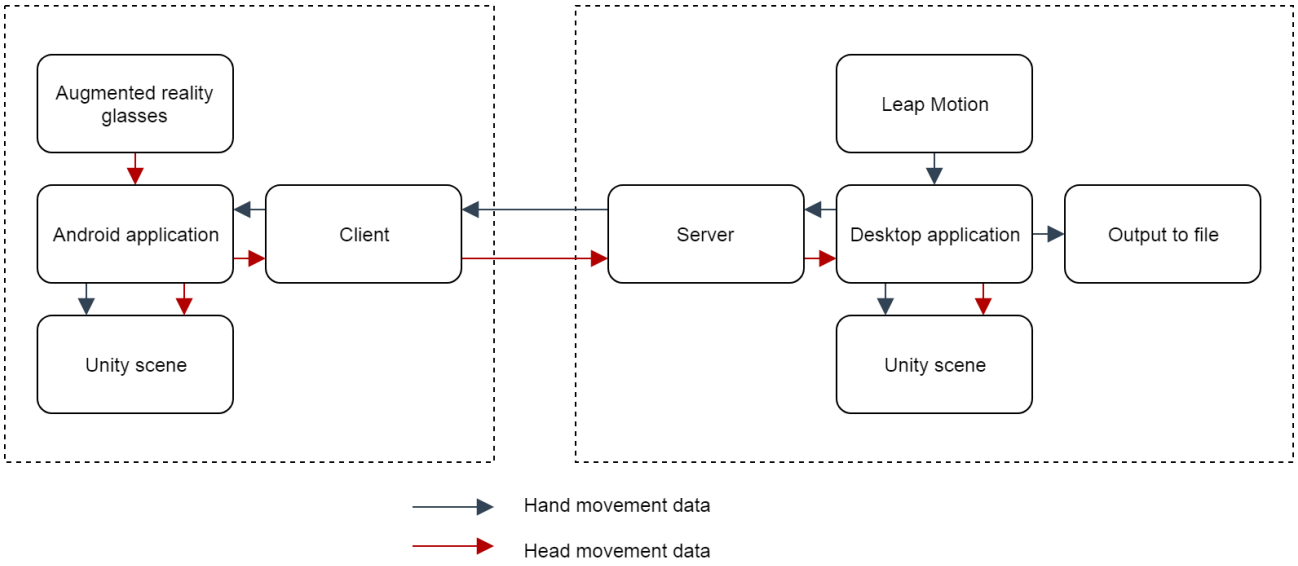


Figure 19 - Block diagram of the program complex for rehabilitation

In the first scenario, the Gorbov-Schulte test was implemented under conditions of augmented reality, and the design of the environment was implemented. The patient must first click on the red cubes in ascending order, and then black in descending order. Then they light up in green.

Figure 20 - Gorbov-Schulte test

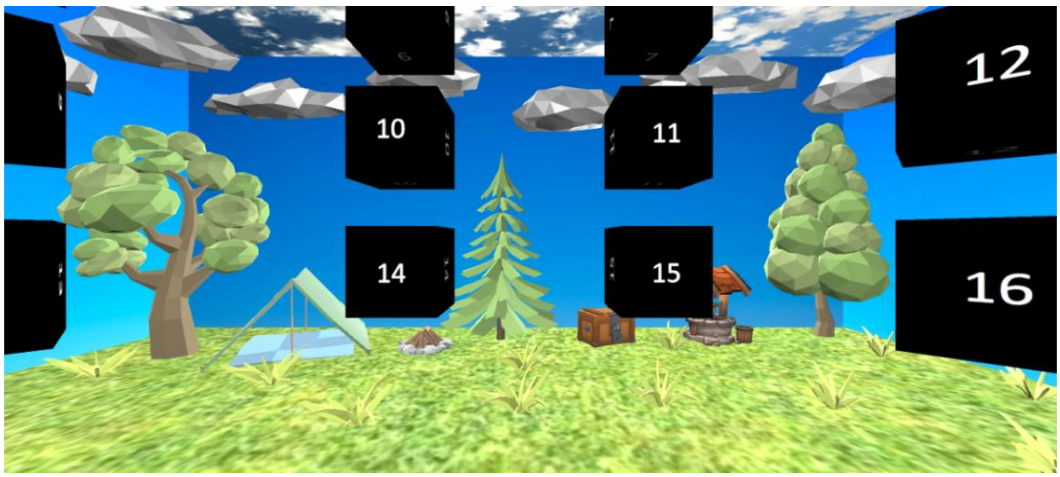


Figure 21 - First-person view in the first scenario

In the second scenario for Leap Motion, the patient sees in front of him a circle within which there is a triangle. The task is that he needs to draw the figures. With correct delineation of figures, they light up in green. The design of the environment was also carried out.

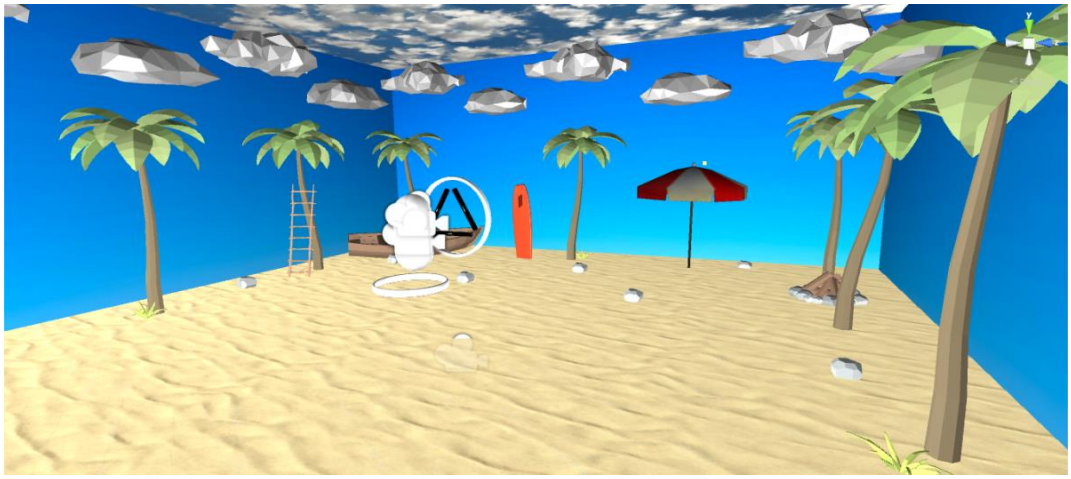


Figure 22 - Drawing geometric shapes test

Figure 23 - First person view in the second scenario

The third scenario is a variation of the Gorbov-Schulte test. The patient observes in front of him the balls, which must be caught by hand and squeezed. The degree of compression at which the ball disappears can be adjusted, thereby adapting the scenario to the individual parameters of the patients. Environment design is not currently implemented.

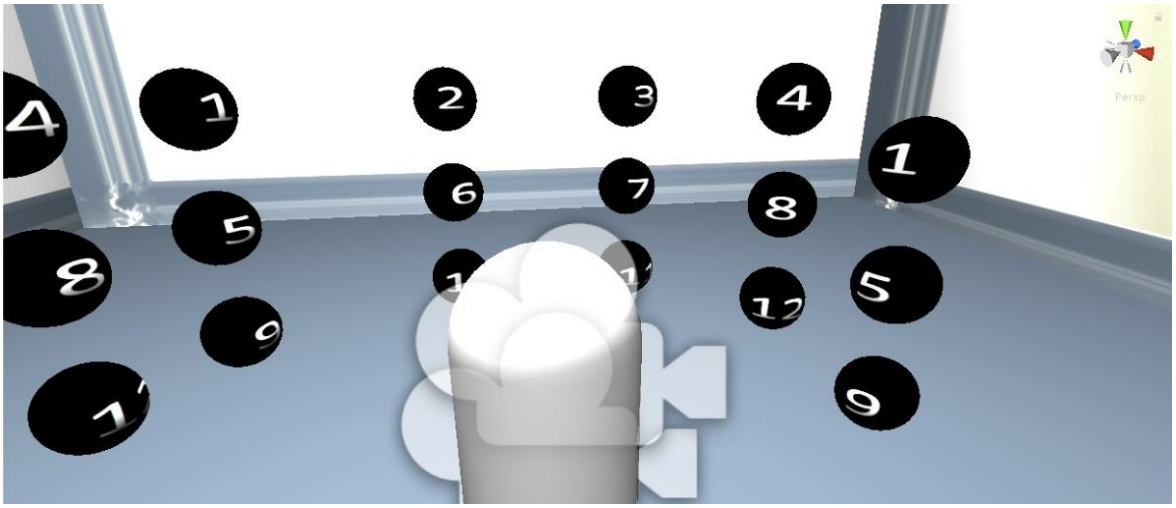


Figure 24 - The third scenario using Leap Motion

After the test, the program writes the coordinates (x, y, z) of the left and right palm, as well as the index fingers of both hands into separate CSV files. They can be used for further analysis. Therefore, it was decided to implement, on the basis of Matlab, a program for visualizing the data obtained from the controller, and its mathematical analysis. In the final version of the program was implemented:

- Two-dimensional plotting;
- Three-dimensional plotting;
- Plotting of smoothed graphs using a moving average filter with a custom coefficient;
- Fourier transform;
- Calculation of mathematical parameters.

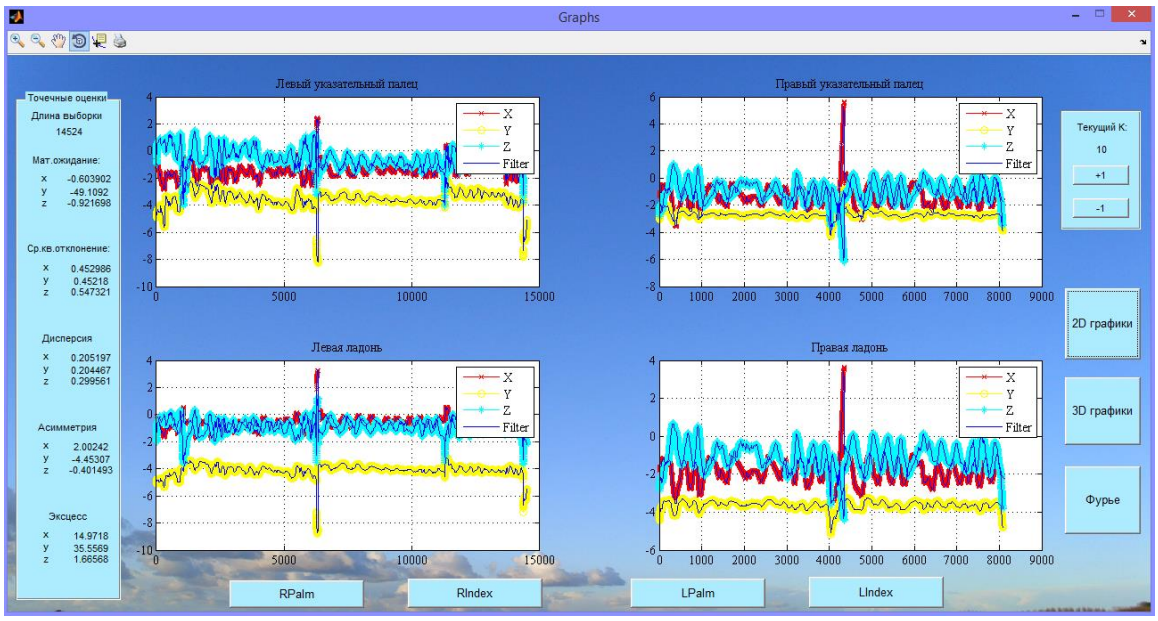


Figure 25 - Two-dimensional plotting

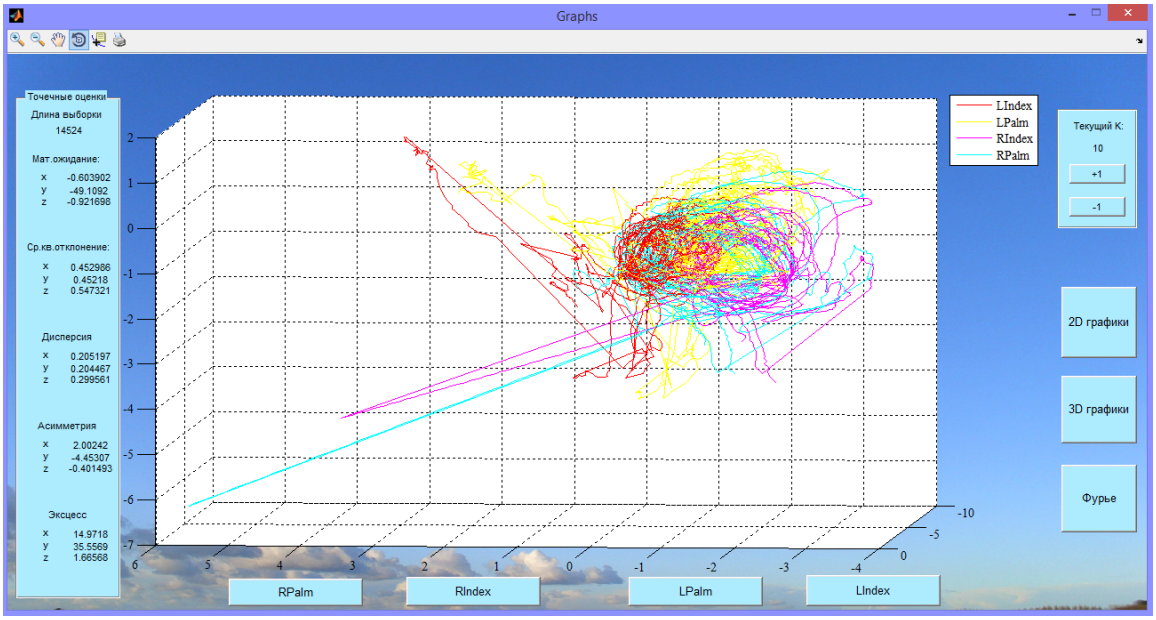


Figure 26 - Three-dimensional plotting

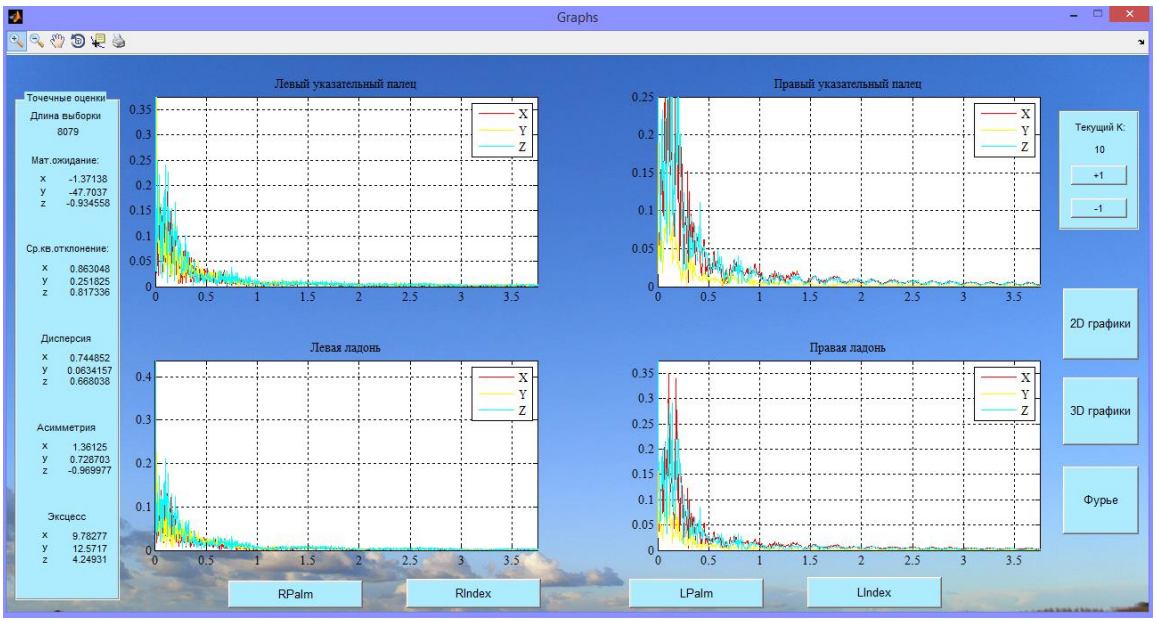


Figure 27 - Fourier transform

The method was tested. The study was conducted at the Department of Neurology and Neurosurgery and the Department of Medical and Biological Cybernetics of the Siberian State Medical University. The sample size was 12 people with ischemic cerebral stroke in the basin of the middle cerebral artery. The choice of nosology is justified in terms of the high prevalence of the disease and the degree of motor disability of patients. Patients in the acute period of ischemic stroke completed a 10-day course of motor rehabilitation with the use of augmented reality technology. The duration of the one training was 60 minutes. The effectiveness of the method can be assessed by reducing the transition time to the most accurate task execution and increasing the period of time before the onset of severe fatigue, which is characterized by a decrease in accuracy rates. As a result, accumulated data on the parameters of the movement of patients in the process of performing the developed tasks.

Chapter 4. Financial management, resource efficiency and resource saving

4.1 Pre-project analysis

4.1.1 Potential consumers of research results

The purpose of this section is to determine the prospects and success of a research project, the development of a mechanism for managing and maintaining specific design decisions at the implementation stage.

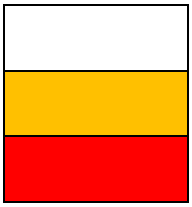
In the course of this work, various ways of rehabilitation of patients with neurological diseases were investigated, including methods of using virtual / augmented reality, and a software package was developed for the rehabilitation of motor functions in augmented reality using the Leap Motion non-contact motion capture system.

Target market is a market with segment, where the developed project will be sold. And the market segment is a specially allocated part of it, which refers to various groups of consumers, which are characterized by common features. To begin with, we can distinguish the general area of application of the development - the medical field, since the study uses medical equipment. This equipment will be used for research and rehabilitation of patients, therefore, a narrower area is medical institutions (hospitals, clinics, research centers, etc.). Studies are aimed at patients with neurological diseases, therefore, will be applied in the neurological departments of medical institutions. More specifically, rehabilitation is aimed at patients whose neurological diseases are associated with disorders of the vestibular apparatus and coordination of movements.

Map of market segmentation is presented in table 1.

Table 1 – Map of market segmentation

	Scope of application	
	Research	Diagnostics
Individuals		
Scientific research centers		
Medical institutions		



Segment is not developed

Segment is poorly developed.

Segment is developed

The main segment is the medical research centers, on which this development is oriented. A more specific area of application is SSMU. In the future, the most attractive segments for this development are institutions that provide medical services, which are, hospitals and clinics.

4.1.3 SWOT analysis

SWOT analysis is a very common method that assesses together the external and internal factors that influence the development of a company. This method is an analysis of the strengths and weaknesses of the organization, as well as threats from the external environment and opportunities. Weaknesses and strengths relate to the internal state of the company, and threats and opportunities to the external environment of the company.

Table 2 – SWOT matrix

	Strengths of a research project: S1. Highly qualified and trained staff S2. Equipment flexibility S3. Demand for market development S4. Novelty and relevance of development S5. The small size of all equipment S6. Relatively low cost compared to competitors S7. Budget financing S8. Usage of lightweight glasses	**Weaknesses of a research project:** W1. Low knowledge of this method W2. The presence of a small delay in the video stream with glasses W3. The presence of errors in the system of motion capture W4. The physiological difficulties of some patients in using with the system
Opportunities: O1. Financial support from outside O2. Increasing the cost of competitive developments O3. Active implementation of these technologies O4. Improvements in equipment parameters	Additional financial support will allow us to hire highly qualified personnel who can later customize the system for individual parameters. And the novelty and relevance will ensure the active implementation of this technology.	Additional funding will allow a better study of the method, and as a result, it is better to adapt the system for patients. And the active introduction of technology will attract attention to it and accelerate the process of improving technology.
Threats: T1. Actively developing competitive technologies T2. The emergence of additional state requirements for equipment T3 Insufficient project funding T4 Drop in demand for this technology	Due to the novelty and relevance of development, competitive technologies are actively emerging on the market. And because of this, the demand for the technology being developed may fall. Due to lack of funding, it will be difficult to provide highly qualified personnel.	Due to the high competition of technology, there may be a low demand for development. And the low level of knowledge of this technology may lead to insufficient financing of the project under development.

After analyzing the strengths and capabilities of a research project, we can say that first of all it is necessary to search for additional funding for the project, which will enable more active implementation and study of technologies, as well as provide highly qualified personnel.

After reviewing the weaknesses of the project and the possibilities, it is possible to come to the same conclusion, a strategy is needed to find additional funding for the project, which will improve the technologies of the developed system, which will have a positive effect on the patients on whom the development is aimed.

Such strengths as novelty, relevance and relevance of the development will minimize the threats associated with the lack of demand for this technology and the search for additional funding.

As a result, for a greater minimization of threats, it is first of all necessary to improve the weaknesses of the project related to the lack of knowledge of the method and measurement errors. Just the emergence of additional cash funding and highly qualified staff will help overcome these weaknesses.

4.1.4 Ishikawa diagram

Ishikawa's cause-effect diagram is a graphical method for analyzing and building causal relationships, a tool for systematically determining the causes of a problem and the subsequent graphic representation.

The construction of the diagram starts with the formulation of the problem area / topic, which is the object of analysis and is applied to the central horizontal arrow of the diagram. Then factors / groups of factors affecting the object of analysis are identified..

Ishikawa diagram for the developed virtual environment is shown in figure X.

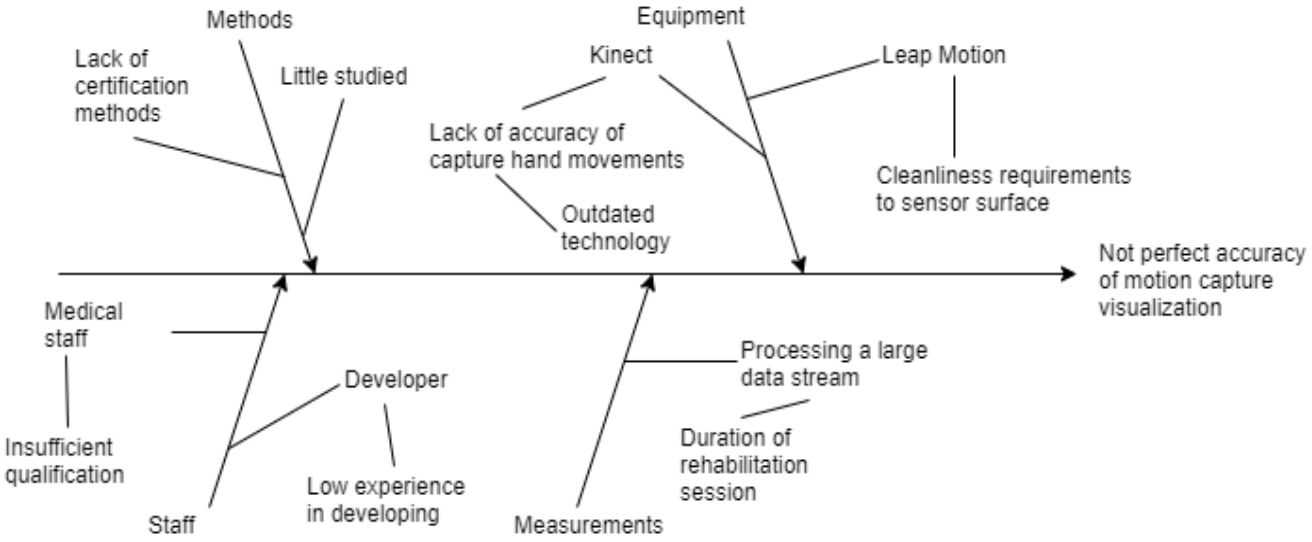


Figure 28 - Ishikawa diagram

Based on the Ishikawa diagram, we can draw the following conclusions about the most influential factors: to eliminate the problem of not perfect accuracy of motion capture visualization, first of all, it is necessary to adjust the duration of rehabilitation sessions, which will reduce the amount of data; keep controllers clean; and in the future, replace one of the controllers with a more modern one to improve the quality of the received data.

4.2 Initiation of the project

Pre-project analysis showed that SSMU is the main segment, and competent use of the project's strengths and capabilities will minimize threats and level down weaknesses. Therefore, the goal of the project being developed is to create a software package for the rehabilitation of patients with neurological diseases, for example, the consequences of a stroke, Parkinson's disease. The result of the project will be a working software package that has been tested.

First of all, it is needed to define a project working group. The data is shown in table 3.

Table 3 – Project working group

№	Full name	Role in the project	Function	Labor hours, h
1	Shorokhov Daniil Igorevich	Project performer	Execution of the project	67
2	Tolmachev Ivan Vladislavovich	Project head / Project performer	Coordination of the project performer / Execution of the project	7
3	Gubarev Fedor Aleksandrovich	Project head	Verification of project stages	1
4	SSMU	Project customer	Formation of the project objectives, the adoption of the final project	1
Total:				76

Table 4 – Objectives and outcome of a research project

Project goals:	Development of software for the rehabilitation of motor functions.
Expected results of the project:	Fully working system for rehabilitation and a program for analyzing the data received, as well as the conducted approbation of the project.
Criteria for acceptance of the project result:	Acceptance is made first by the heads of a research project, and then by the SSMU.
Requirements for the project result:	Requirements:
	Performance of the created complex
	Presence of several rehabilitation scenarios
	Ability to connect to any computer
	The need to use both controllers

The objectives of the project, the structure of the project and the organization of the project participants can be described by interrelated hierarchical (tree-like) structures in which the relations between the components can be established: goals - parts of the project - participants, etc.

The tree of goals is shown in the figure X.

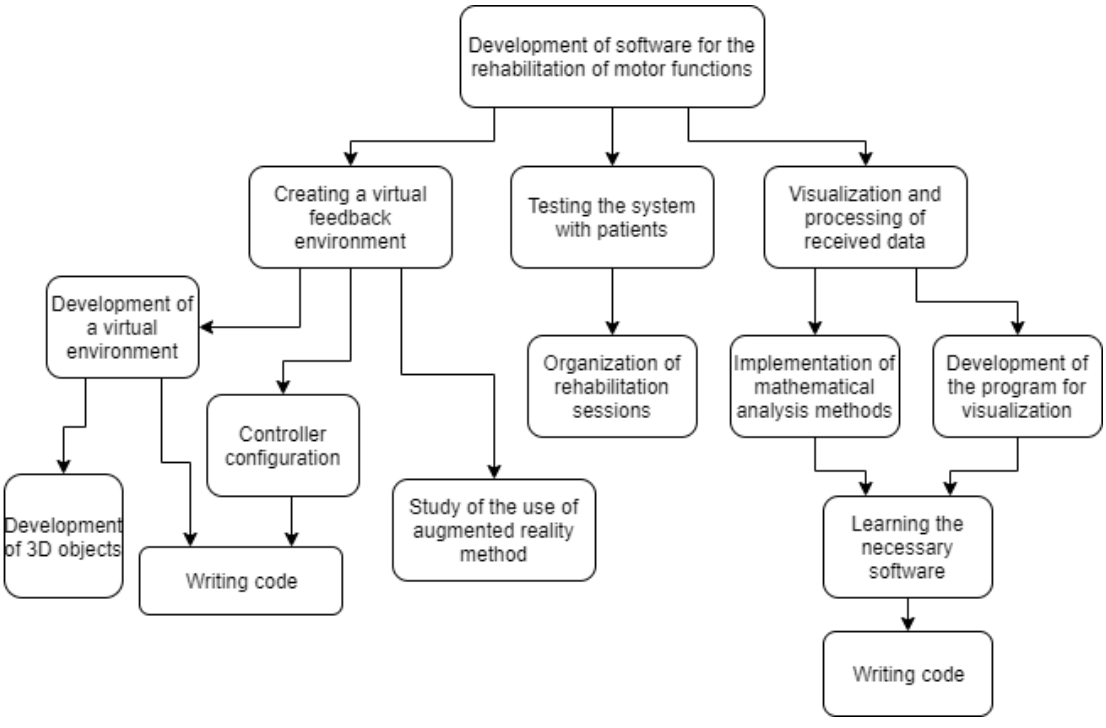


Figure 29 - Tree of goals

4.3 Planning research projects

4.3.1 Plan of the project

In this section, we need to make a list of the stages and works in the framework of the research, and share between participants.

Table 5 – The list of stages, works and the distribution of performers

Main stages	№	Content of work	Position of the performer
Development of technical specifications	1	Drafting and approval of technical specifications	Tolmachev I.V.
Choosing the direction of project	2	Selection and study of materials on the research topic	Shorokhov D.I.
	3	Choosing the direction of research	Tolmachev I.V.
	4	Scheduling work on a research topic	Tolmachev I.V.
Theoretical studies	5	Search for information on various alternative devices	Shorokhov D.I.
	6	Systematization of the received information	Shorokhov D.I.
	7	Analysis of the received information	Shorokhov D.I.
	8	Selection of the most suitable equipment for research	Tolmachev I.V., Shorokhov D.I
	9	Learning how to work with this equipment	Tolmachev I.V., Shorokhov D.I.
	10	Creation of software for research	Shorokhov D.I.
Practical researches	11	Testing system by developers	Tolmachev I.V., Shorokhov D.I.
	12	Data analysis	Shorokhov D.I.
	13	Drawing up a training program for the rehabilitation system	Shorokhov D.I .
	14	Testing the method with patients	Tolmachev I.V., Shorokhov D.I.
	15	Evaluation of the effectiveness of the developed training program	Tolmachev I.V., Shorokhov D.I .
Registration of the project results	16	Drawing up a final version of the project	Shorokhov D.I.
	17	Verification of completed project by the supervisor	Tolmachev I.V., Gubarev F.A.

4.3.2 Determination of the labor intensity of project

Use the following formula to determine the expected value of labor intensity:

$t_{\text{ожі}} = \frac{3t_{\min i} + 2t_{\max i}}{5}$, where

$t_{ожі}$ – expected labor intensity of some work;

$t_{\min i}$ – the minimum possible labor intensity of some (optimistic assessment: assuming the most favorable set of circumstances);

$t_{\max i}$ – the maximum possible labor intensity for some work (pessimistic assessment: assuming the most unfavorable set of circumstances).

Once calculated $t_{ожі}$, calculate the duration of each work in working days:

$T_{\text{р}_i} = \frac{t_{\text{ожі}}}{\text{Ч}_i}$, where

$T_{\text{р}i}$ – the duration of one work;

$t_{\text{ожі}}$ – expected labor intensity of doing one work;

Ч_i – the number of performers doing the same work at the same time.

4.3.3 The development of schedule for the project

To develop a schedule for conducting a scientific study, a Gantt chart will be used - a horizontal ribbon chart in which the work on the topic is represented by long segments, characterized by dates of the beginning and end of work.

For the convenience of plotting, the duration of each of the stages of work from working days should be translated into calendar days. To do this, use the following formula:

$T_{кi} = T_{рi} \cdot k_{кал}$, where

$T_{кi}$– the duration of the i work in calendar days;

$T_{рi}$ – he duration of the i work in working days;

$k_{кал}$– calendar factor.

The calendar factor is determined by the following formula:

$$k_{кал} = \frac{T_{кал}}{T_{кал} - T_{вых} - T_{пр}}, \text{ where}$$

$T_{кал}$ – number of calendar days per year;

$T_{вых}$ – number of days off per year;

$T_{пр}$ – number of holidays per year.

$$k_{кал} = \frac{T_{кал}}{T_{кал} - T_{вых} - T_{пр}} = 1{,}22$$

All calculation results are listed in the table below.

Table 6 – Temporary indicators of the project

Type of work	Labor intensity									Duration of work in working days T_{pi}			Duration of work in calendar days T_{ki}		
	t_{min}, human days			t_{max}, human days			$t_{ожі}$, human days								
	Tolmachev	Shorokhov	Gubarev	Tolmachev	Shorokhov	Gubarev	Tolmachev	Shorokhov	Gubarev	Tolmachev	Shorokhov	Gubarev	Tolmachev	Shorokhov	Gubarev
Drafting and approval of technical specifications	2	-	-	2	-	-	2	-	-	2	-	-	2.44	-	-
Selection and study of materials on the research topic	-	10	-	-	20	-	-	14	-	-	14	-	-	17.08	-
Choosing the direction of research	1	-	-	1	-	-	1	-	-	1	-	-	1.22	-	-
Scheduling work on a research topic	1	-	-	1	-	-	1	-	-	1	-	-	1.22	-	-
Search for information on various alternative devices	-	2	-	-	3	-	-	2.4	-	-	2.4	-	-	2.93	-
Systematization of the received information	-	6	-	-	8	-	-	6.8	-	-	6.8	-	-	8.3	-
Analysis of the received information	-	4	-	-	5	-	-	4.4	-	-	4.4	-	-	5.37	-

Continuation of table 6

Selection of the most suitable equipment for research	1	4	-	1	5	-	1	4.4	-	0.5	2.2	-	0.61	2.67	-
Learning how to work with this equipment	1	4	-	1	6	-	1	4.8	-	0.5	2.4	-	0.61	2.93	-
Creation of software for research	-	6	-	-	8	-	-	6.8	-	-	6.8	-	-	8.3	-
Testing system by developers	1	2	-	1	3	-	1	2.4	-	0.5	1.2	-	0.61	1.46	-
Data analysis	-	4	-	-	6	-	-	4.8	-	-	4.8	-	-	5.86	-
Drawing up a training program for the rehabilitation system	-	3	-	-	6	-	-	4.2	-	-	4.2	-	-	5.12	-
Testing the method with patients	1	4	-	1	5	-	1	4.4	-	0.5	2.2	-	0.61	2.68	-
Evaluation of the effectiveness of the developed training program	1	3	-	1	4	-	1	3.4	-	0.5	1.7	-	0.61	2.07	-
Drawing up a final version of the project	-	10	-	-	20	-	-	14	-	-	14	-	-	17.08	-
Verification of completed project by the supervisor	1	-	1	1	-	1	1	-	1	0.5	-	0.5	0.61	-	0.61

Table 7 – The calendar schedule of the research project

№	Type of work	Performers	$T_{k,}$ cal.day	$T_{k,}$ cal.day	$T_{k,}$ cal.day	Duration of work								
						March			April			May		
						1	2	3	1	2	3	1	2	3
1	Drafting and approval of technical specifications	Tolmachev I.V.	2.44	-	-									
2	Selection and study of materials on the research topic	Shorokhov D.I.	-	-	17.08									
3	Choosing the direction of research	Tolmachev I.V.	1.22	-	-									
4	Scheduling work on a research topic	Tolmachev I.V.	1.22	-	-									
5	Search for information on various alternative devices	Shorokhov D.I.	-	-	2.93									
6	Systematization of the received information	Shorokhov D.I.	-	-	8.3									
7	Analysis of the received information	Shorokhov D.I.	-	-	2.67									
8	Selection of the most suitable equipment for research	Tolmachev I.V., Shorokhov D.I.	0.61	-	2.93									
9	Learning how to work with this equipment	Tolmachev I.V., Shorokhov D.I.	0.61	-	8.3									
10	Creation of software for research	Shorokhov D.I.	-	-	1.46									
11	Testing system by developers	Tolmachev I.V., Shorokhov D.I.	0.61	-	5.86									
12	Data analysis	Shorokhov D.I.	-	-	5.12									
13	Drawing up a training program for the rehabilitation system	Shorokhov D.I .	-	-	2.67									

Continuation of table 7

14	Testing the method with patients	Tolmachev I.V., Shorokhov D.I.	0.61	-	2.68									
15	Evaluation of the effectiveness of the developed training program	Tolmachev I.V., Shorokhov D.I .	0.61	-	2.07									
16	Drawing up a final version of the project	Shorokhov D.I.	-	-	17.08									
17	Verification of completed project by the supervisor	Tolmachev I.V., Gubarev F.A.	0.61	0.74	-									

Shorokhov D.I. - Gubarev F.A. - Tolmachev I.V. -

4.3.4 Budget of the project

When planning a scientific and technical research budget, a reliable and complete reflection of all types of expenses that are associated with its implementation should be provided. In the process of budgeting a scientific and technical study, the following grouping of expenditures by items is used:

- material costs of scientific and technical research;
- depreciation;
- the basic salary of the performers of the project;
- additional salary for the performers of the project;
- payments to extra-budgetary funds (insurance payments);
- overhead.

4.3.4.1 Calculation of the material costs of the project

This item of expenditure includes the cost of all materials that are used in the development of the project. The calculation will be made for all performers.

Table 8 – Office expenses

Name	Unit of measurement	Amount		Price, rub		Material costs, ($З_м$), rub.	
		Tolm.	Shor.	Tolm.	Shor.	Tolm.	Shor.
Packed paper (Size A4)	Rub.	1	1	250	250	250	250
Ball pen	Rub.	2	2	20	20	40	40
Total:		**3**	**3**	**270**	**270**	**290**	**290**

This item of expenditure includes the cost of special equipment that was necessary for scientific research.

Table 9 – Expenditure on component parts

№	Name of component part	Amount	Price, rub.	Total price, rub
1	Leap Motion	1	7500	7500
TOTAL:				7500

Total «material costs» - 8080 rub.

4.3.4.2 Depreciation

Depreciation is the process of periodically transferring the initial value of an asset or intangible asset to production, commercial or general business expenses, depending on how this asset is used.

There are several depreciation methods, but the simplest is linear depreciation. We use the classifier of fixed assets for depreciation groups, approved by Government Decree No. 1 of 01/01/2002 for calculating depreciation. The total data are given in table 10.

Table 10 – Depreciation

№	Name of device	Useful life, years	Initial cost, rub.	Depreciation, rub.
1	Augmented reality glasses Epson Moverio BT-300	5	60000	3000
2	Computer	3	45000	3750

Total «depreciation» - 6750 rub.

4.3.4.3 Basic salary

This item of expenditure includes the salary of the head and the student, as well as a monthly payment of 12–20% of the salary. The salary of the head is 33664 rubles, excluding the regional coefficient. For an engineer, the salary is 21760 rubles, excluding the district coefficient. (DC=1.3)

Thus, basic salary is calculated according to the following formula:

$З_{зп} = З_{осн} + З_{доп}$, where

$З_{осн}$ – basic salary;

$З_{доп}$ – additional salary.

$З_{осн} = З_{дн} \cdot T_p$, where

$З_{осн}$ – basic salary of one performer;

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

$З_{дн}$ – average daily salary of employee, rubles.

Average daily salary is calculated according to the following formula:

$$З_{дн} = \frac{З_м \cdot М}{F_д}$$, where

$З_м$ – monthly salary of an employee, rubles;

M – the number of months of work without vacation during the year (with a vacation of 24 working days M = 11.2 months, 5 days a week; with a vacation of 48 working days M = 10.4 months, 6 days a week);

$F_д$ – valid annual fund of working time of scientific and technical personnel, work days.

Table 11 – Working day balance

Indicators of working time	Tolmachev	Shorokhov	Gubarev
Calendar number of days	365	365	365
The number of non-working days - weekend - holidays	66	66	66
Loss of working time - vacation - absences due to illness	56	56	56
Valid annual working time fund	243	243	243

Monthly salary of an employee:

$З_м = З_{тс} \cdot k_р$, where

$З_{тс}$ – salary at the tariff rate, rubles;

$k_р$ – district coefficient equal to 1.3 (in Tomsk).

Table 12 – Calculation of the basic salary

Performers	$З_{тс}$, rub.	$k_р$	$З_м$, rub.	$З_{дн}$, rub.	$Т_р$, work days.	$З_{осн}$, rub.
Tolmachev	33664	1,3	43763	1873	7	13111
Shorokhov	21760	1,3	28288	1211	67	81137
Gubarev	33664	1,3	43763	1873	1	1553

Total «Basic salary» - 95801 rub.

4.3.4.4 Additional salary

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

The calculation is made according to the following formula:

$З_{доп} = k_{доп} \cdot З_{осн}$, where

$k_{доп}$ – coefficient of additional salary (at the design stage it is 0.12 - 0.15).

Total «additional salary» - 12454 rub.

4.3.4.5 Payments to extra-budgetary funds

This item of expenditure reflects obligatory deductions, according to the standards established by the legislation of the Russian Federation, to the state social insurance, pension fund and medical insurance from the costs of workers.

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

$$З_{внеб} = k_{внеб} \cdot (З_{осн} + З_{доп}), \text{ where}$$

$k_{внеб}$ – coefficient of deductions for payment to extra-budgetary funds, equal to 30% (0.3).

Table 13 – Payments to extra-budgetary funds

Performer	Basic salary, rub.	Additional salary, rub.	Payments to extra-budgetary funds, rub.
Tolmachev	13111	3704	5044
Shorokhov	81137	10548	27505
Gubarev	1553	202	526

Total «Payments to extra-budgetary funds» - 33075 rub.

4.3.4.6 Overhead

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

$$З_{накл} = (\text{sum of items } 1 \div 5) \cdot k_{нр}, \text{ where}$$

$k_{нр}$ – overhead factor.

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

Total «overhead» - 25772.8 rub.

4.3.4.7 The budget of the research project

This item of expenditure considers the total budget of expenditures of this research project, which is calculated as the sum of all previous items of expenditure.

Table 14 – The budget of the research project

Name of item of expenditure	Sum, rub.	Share of expenses, %
1. Material costs of the project	8080	4,46
2. Depreciation	6750	3,73
3. Basic salary	95801	52,89
4. Additional salary	12454	6,88
5. Payments to extra-budgetary funds	33075	18,26
6. Overhead	24982	13,79
Total:	182122	100

The total expenditure budget amounted to - 181122 rub.

4.3.4.8 Risks register

Risk is the possibility of the occurrence of some adverse event that entails the occurrence of various kinds of losses. A unified risk classification project does not exist. We can single out the following main groups of risks inherent in almost all projects: political, economic, social, technological, environmental, financial, organizational, marketing, personnel, technical.

First, it is necessary to determine the main risk groups of the project, to describe what each risk group consists of.

Table 15 – Risks identification

№	Name of risk	Description of risk
1	Political	No risks
2	Economic	Economic problems among the people and, as a consequence, the inability to pay for sessions
3	Social	Patients will have difficulties while interacting with the rehabilitation system
4	Environmental	Harmful effects of equipment on the environment
5	Technological	Violation of the technology of rehabilitation sessions
6	Financial	Lack of finance for rehabilitation and support sessions
7	Organizational	Difficulties with the organization of the venue for rehabilitation sessions
8	Marketing	The novelty of the method, and, therefore, patients may be afraid of unfamiliar augmented reality
9	Personnel	Shortage of highly qualified staff for maintenance
10	Technical	Equipment failure

Then it is necessary to carry out an assessment of the probability of risk on the scale of the probability of risk and the scale of assessment of the level of losses.

Table 16 – Risk probability estimate

№	Name of risk	Risk probability estimate (low, medium, high)
1	Political	Low
2	Economic	Medium
3	Social	Medium
4	Environmental	Low
5	Technological	Medium
6	Financial	Low
7	Organizational	Low
8	Marketing	High
9	Personnel	Low
10	Technical	Low

Table 17 – Loss assessment

№	Name of risk	Loss assessment (low, medium, high)
1	Political	Low
2	Economic	High
3	Social	Medium
4	Environmental	Low
5	Technological	High
6	Financial	High
7	Organizational	High
8	Marketing	Medium
9	Personnel	Medium
10	Technical	High

After that, it is necessary to fill in a matrix of probability of risks and losses, as well as to develop basic measures for risk reduction, where:

- Red area - high risk;
- Yellow area - significant risk;
- Blue area - moderate risk;
- Green area - minor risk.

Table 18 – Key risk reduction measures

№	Name of risk	Risk reduction measures
1	Political	No need
2	Economic	Reducing the cost of services, benefits and discounts.
3	Social	Develop instructions for patients on how to conduct rehabilitation sessions, give them a rest.
4	Environmental	To study equipment recycling methods in case of equipment failure.
5	Technological	Develop instructions for the doctor about how to conduct rehabilitation sessions.
6	Financial	Conduct presentations on the relevance and need for development to obtain funding from SSMU.

Continuation of table 18

7	Organizational	Conduct presentations on the relevance and need for development to obtain premises for rehabilitation sessions by the management of SSMU.
8	Marketing	Develop a brochure describing the method of augmented reality, its merits and absolute safety.
9	Personnel	Development of detailed manuals on the use and configuration of equipment.
10	Technical	To carry out maintenance of equipment, to clean from dust and dirt.

Thus, the existing risks for this research project were considered, and the measures listed above were developed to reduce the existing risks.

4.4 Determination of the potential effect of a research project.

Rehabilitation of patients with neurological diseases is an important issue. Since these diseases are quite common, their clinical manifestations are not specific, and they are difficult to diagnose and treat. It is also worth noting that such diseases are getting younger every year. This development will help in the rehabilitation of patients with neurological diseases. At the same time, gamification of the method will help to involve patients more strongly in the rehabilitation process, thereby making it easier, both for patients and for the doctor. Therefore, it can be said that the developed project meets the social needs and goals of society and has good social efficiency.

Since this development will be used and tested first of all within the framework of SSMU, all expenses are covered by the university itself, and also provide a room for research. Conducting research data within a large university

will attract interest and additional funding from outside. This suggests that this research project is characterized by excellent efficiency.

Thus, the goal was achieved and the tasks were solved. In this section, potential consumers of the results of this study were identified, a SWOT analysis was performed, and the Ishikawa diagram was constructed. In addition, research planning was done (71 days, 5 stages, 17 works), the research subjects were identified (3 people), and work plan was built. In addition, the budget for the project was calculated (181122 rubles). Existing risks for this research project were reviewed, and measures to reduce existing risks were developed. The work was carried out a qualitative assessment of the effectiveness, and also revealed the high social significance of the study, as it is aimed at patients with neurological diseases, which are very common.

Chapter 5. Social responsibility

Introduction

The object of research in this paper is a system for the rehabilitation of motor functions of patients with neurological diseases, which is characterized by computer work using Leap Motion controller, and Epson Moverio BT-300 augmented reality glasses, held indoors. In the course of this work, methods for the rehabilitation of patients were studied, as well as sets of exercises and tasks for a rehabilitation system developed for personal computers. From this we can conclude that it is necessary to organize a workplace at the computer in accordance with the regulations. The working area will be the space corresponding to a small room, up to 2 meters high. All research and work is carried out in an educational institution in the laboratory for computers.

5.1 Legal and organizational safety issues

5.1.1 Special legal norms of labor legislation

Most of the work that is performed in production is directly related to the presence of dangerous and (or) harmful production factors. When applying for a job, the hired employee is informed about this, and this is also indicated in the employment contract. And, accordingly, the employer is also obliged to acquaint not only with such working conditions, but also to teach safety measures, safe work methods, conduct on-the-job training, provide labor protection training, and periodically check the employee's knowledge on labor protection requirements.

In accordance with art. 221 - 225 of the Russian Federation Labor Code in the conditions of dangerous and (or) harmful production factors, the employer should provide the workers with all the necessary first aid share.

It is also envisaged to undergo a medical examination for workers who perform work in conditions with hazardous and (or) harmful production factors, which is specified in article 213 of the Russian Federation Labor Code. And in employment, and in the process. In the order of the Ministry of Health and Social Development of the Russian Federation of 12.04.2011 No. 302n. procedure for conducting a medical examination is specified. The requirements of this document provide that a medical examination should be carried out once a year, or twice a year. It depends on the type of activity of the worker in production, as well as on the presence of specific harmful factors.

According to Part 6 of Article 213 of the Russian Federation Labor Code for workers whose work is connected with sources of increased danger (for example, the influence of adverse production factors and harmful substances), as well as for those working under conditions of increased danger, a mandatory psychiatric examination should be carried out at least once 5 years. According to the resolution of the Ministry of Labor of the Russian Federation and the Ministry of Education of the Russian Federation No. 1/29 dated January 13, 2003 "On Approval of Training Procedures on Labor Protection and Examination of Knowledge of Labor Protection Requirements of Employees of Organizations", in addition to medical examinations labor protection, as well as training in providing first aid to affected people.

5.1.2 Organizational activities in the layout of the working area

The working area refers to the space up to 2 meters from the floor level, or the site where there is a place of temporary or permanent stay of the production worker. In other words, the work zone is the main and primary link of production, and from this it follows that it is very important to rationally organize a work zone. A workplace is a place of temporary or permanent stay of production workers in the course of their employment. The organization of the workplace is a complex of

measures for equipping the workplace with objects and means of labor, as well as their placement in a specific order.

The organization of service workplace means providing it with items, means of labor, as well as services that are necessary in order to carry out the labor process. The main purpose of the workplace organization is to achieve cost-effective and high-quality performance of the production task in terms that have been strictly established, based on the full use of working time, equipment, application of modern labor methods using the least physical effort, creating favorable and safe conditions for work. From the specifics of production depends on the influence of other factors on the organization of jobs. Such as: the ratio of elements of physical and mental work, the degree of its responsibility. When designing workplaces, it is necessary to take into account such factors as: temperature, noise, light, dust emission and other sanitary and hygienic requirements for the organization of workplaces.

It is necessary that the working room be provided with the correct location and layout of the workplace. According to GOST 12.2.032-78 “OSSS. Workplace while sitting. General ergonomic requirements” indicated that the design of the workplace, as well as the relative position of all its elements must comply with the physiological, psychological and anthropometric requirements. And besides this correspond to the nature of the work.

First of all, it is necessary to organize a periodic airing of the working room, and for this to enter the schedule of technological interruptions. For women and men, the height of the working surface when doing computer work should be 655 mm. Work is done only at a personal computer, therefore, the working surface will be rectangular in shape. The permissible location of the monitor is a vertical plane at an angle of ±30° from the normal line of sight and in a horizontal plane at an angle of ±30° from the sagittal plane.

5.2 Production safety

Production safety is understood as a system of organizational measures and technical means that prevent or reduce the likelihood of exposure to working personnel of the dangerous traumatic production factors that arise in the work area during work. In our work it is necessary to find out the dangerous and harmful factors that may arise when working with an information system. Subsequent selection is made using GOST 12.0.003-74 “Dangerous and harmful production factors. Classification”. The selection results are shown in the table below.

Table 19 – Harmful and dangerous factors when working with a computer

The source of the factor, the name of the type of work	The list of factors (according to GOST 12.0.003-74)		Relevant regulatory documents
	Harmful	Dangerous	
1) Work at the computer	1) Insufficient level of illumination in the working area; 2) Excess noise; 3) Increased level of electromagnetic radiation; 4) Increased air temperature in the workplace	1) The impact of electric current. 2) Mechanical injury	1) GOST 12.1.006-84; 2) GOST 12.1.003-83 3) SanPiN 2.2.1 / 2.1.1.1278-03 4) SanPiN 2.2.4.548-96;

5.2.1 Analysis of harmful and dangerous factors that may arise in the laboratory during research

Chemical, psycho-physiological and biological harmful and dangerous factors can be excluded, since the work is performed on a computer. Physical hazards include increased noise levels in the room, insufficient light in the workplace, increased air temperature, electromagnetic radiation, and other factors. The latter should be given increased attention, since in this work it is most important compared to other factors. During the long-term exposure to

electromagnetic radiation on a person, his own fields change, distort, causing the development of various diseases. There are several reasons why the problem of the effects of an electromagnetic field on a person is so important when working with a computer: two sources of electromagnetic radiation (system unit and computer monitor); a person works at a close distance with a computer, i.e. there is no possibility to work at a safe distance; prolonged work at the computer, and, therefore, prolonged exposure to the electromagnetic field.

According to SanPiN 2.2.1 / 2.1.1.1278-03, it is necessary that the illumination is provided rationally, and its brightness is distributed evenly on the working surface and that surrounding it. The problem of poor light distribution is that when transferring a person's gaze from a brightly lit surface to a dimly lit surface, the human eye is forced to adapt, which leads to more rapid fatigue and decreased performance. In order to improve the uniformity of the lighting, it is necessary that the walls and ceiling of the working room be painted in light colors. You also need to use a combined lighting - lighting, in which local lighting is added to the general lighting. Also, the correct distribution of illumination contributes to the absence of sharp shadows, reflected and direct brilliance (ie, increased brightness of the luminous surfaces); and the constancy of light in time.

SanPiN 2.2.1 / 2.1.1.1278-03 states that the extreme value of production artificial illumination in work rooms, offices, offices, representative offices is 300 lux, the coefficient of pulsation of illumination (Kp) must be greater than 15%, and the coefficient of natural illumination with a combined or top illumination is 1.8%.

The production weather conditions are very important in the organization of work, therefore it is necessary to take into account the provision of normal production weather conditions. The microclimate in the production area is characterized by such indicators as: relative air humidity, air velocity, air temperature, intensity of thermal exposure. Increased temperature and air velocity, lower relative humidity adversely affect the human body, reducing overall health and increasing human fatigue.

To create an optimal production microclimate is carried out using technological, sanitary and medical and preventive measures. Measures to ensure optimal and acceptable microclimate:

- Installation and repair of ventilation and air conditioning systems.
- Protection of the facade of the building (except the north) with sun protection devices. These include curtains, blinds, visors, awnings. They are more effective when located on the outside of the facade (outside). Also effective sun protection is the use of sunscreens.
- Use of humidifiers.

This type of work should be attributed to category Ia, since the person works in a sitting position at the computer, and, consequently, physical loads are very insignificant, which will not affect the mechanisms of human thermoregulation. The criteria for the optimal functional and thermal state of a person determine the optimal microclimatic conditions. Thanks to them, during the 8-hour work shift, a person feels thermal comfort, the minimum tension of the person's thermoregulation mechanisms is ensured, and high performance conditions are ensured. SanPiN 2.2.4.548–96 specifies the optimal as well as permissible values of the microclimate indicators at the workplaces of the production premises; for convenience, they are listed in the table below. These parameters can be achieved with the help of air conditioning systems during the warm period of the year and with the help of water heating during the cold period of the year.

Table 20 – Optimal values of microclimate indicators for the workplace in the production area

Period of the year	Category of work on the level of energy consumption, W	Air temperature, °C	Relative humidity, %	Air flow rate, m/s
Cold period	Ia (to 139)	22-24	60-40	0.1
Warm period	Ia (to 139)	23-25	60-40	0.1

Table 21 – Permissible values of microclimate indicators for the workplace in the production area

Period of the year	Category of work on the level of energy consumption, W	Air temperature, °C	Relative humidity, %	Air flow rate, m/s
Cold period	Ia (to 139)	20-25	15-75	0.1
Warm period	Ia (to 139)	21-28	15-75	0.1-0.2

The noise source is the computer cooling system, which is a working fan. The increased noise level adversely affects the human body. Its long-term effect causes various diseases of the peripheral nervous system, a change in heart rate, an increase in blood pressure, which ultimately leads to an overall decrease in labor productivity. Therefore, it is imperative to get rid of whenever possible sources of additional noise in the computer. To do this, the following measures are applied: noise insulation of noise sources; regular replacement of worn parts; regular maintenance of equipment; the placement of noise sources in the room in a rational manner, also with this should use mutual noise reduction; replacement of parts producing noise, less noisy or completely silent. According to GOST 12.1.003-83,

the extreme level of noise in laboratories is 50 dB when a person performs work on a personal computer.

Since the work is done at the computer, there is such a dangerous factor as electric current. Therefore, it is necessary to identify the safety requirements that apply to electrical installations, which in turn are sources of hazards. In most cases, the cause of electrical injuries is a contact with current-carrying parts of an electrical installation that are under dangerous voltage, or a contact with the body of an electrical device when it is under voltage due to insulation damage.

In order to eliminate the danger of electric shock, it is necessary to ensure compliance with such electrical safety rules as:

1. Visual inspection of the electrical wiring of the equipment in the absence of any insulation problems before switching on the electrical device to the supply network.
2. In the case of detection of those, you must immediately disconnect the electrical device from the mains before correcting the problem.
3. The prohibition of contact with devices that are naturally grounded when electrical equipment is on.

In GOST 12.1.019-79 it is indicated that it is necessary to apply protective sheaths to current-carrying parts; ensure the safe location of live parts; use for them isolation, which is working, additional, double and reinforced; apply workplace insulation; to control the current-carrying parts.

According to SanPiN 2.2.2 / 2.4.1340-03, when using a computer, it is necessary to comply with such requirements as:

1. Electrical equipment must be factory-made. And there must be compliance of electrical equipment with the requirements of state standards and technical conditions;
2. During operation and maintenance, it is necessary to comply with the requirements of the passport of electrical equipment and operating manuals, which were developed by the manufacturer.

Additionally, you can apply organizational and technical measures to ensure electrical safety, which means orientation methods, such as: warning signals, signs, labels; marking of parts of electrical equipment; warning signs; coloring of current carrying parts; light signaling.

SanPiN 2.2.2 / 2.4.1340-03 states that the following security measures should be followed when working with a computer:

1. The presence of artificial and natural lighting in the workplace during the operation of a personal computer;
2. The maximum duration of continuous work with the monitor without a regulated break is 1 hour.
3. Providing window openings with such adjustable devices as: blinds, curtains, external visors, which allow to exclude the direct brilliance due to the sun's rays;
4. The presence of a non-reflecting reflector having a protective angle of at least 40 degrees for local lighting fixtures.
5. The distance from the monitor screen to the eyes should be in the range of 600-700 mm, but no closer than 500 mm;

5.2.2 Analysis of harmful and dangerous factors that may arise in the laboratory during research

When conducting research using augmented reality glasses, therefore, there is a danger of mechanical injury. The source of mechanical injury when working with the developed system can be a violation of the human vestibular apparatus (dizziness) in the process of testing with virtual reality using virtual reality glasses. In other words, there is a risk of falling of a person who has poorly developed vestibular apparatus or has a neurological disease (for example, Parkinson's disease, multiple scleroses).

5.2.3 Justification of measures to protect the researcher from the effects of dangerous and harmful factors

In GOST 12.1.006-84 the following limit values for the level of electromagnetic radiation are indicated: on the magnetic component - 0.3 A/m; on the electrical component - 5 V/m. Nowadays, liquid crystal monitors are commonly used in which the level of electromagnetic radiation is lower than that of older monitors with a cathode ray tube. Nevertheless, the level of electromagnetic radiation in liquid crystal monitors still exceeds the standards. This can be avoided by applying shielding of current-carrying parts of the computer, as well as its entire body. Additionally, you must enter short breaks at the computer for the staff to relax.

Mechanical injury may occur when a person falls due to a disruption of the vestibular apparatus when using virtual reality glasses. As a means of protection against mechanical injury may be the use of special fastening seat belts attached to the ceiling and supporting the test in case of a fall. Another type of protection that was used by us in the course of research may be another insurer who, if there are problems with the vestibular apparatus in a patient, will hold it.

5.3 Ecological safety

5.3.1 Analysis of the impact of the object of research on the environment

Now it is necessary to consider in this subsection the nature of the environmental impact of the projected solution, as well as to consider the rationale for measures to protect the environment.

The devices used in this work do not emit dangerous and harmful substances into the water and into the air, since the actual use is only of a computer and various peripheral devices connected to it. Consequently, it can be concluded that when using equipment, there is no harm to the hydrosphere and atmosphere.

5.3.2. Analysis of the "life cycle" of the object of study

In the process of research, computer equipment is used that must be disposed of in case of malfunction. It can be concluded that the disposal will affect the lithosphere of the hydrosphere and the atmosphere, since the faulty equipment is waste to be recycled.

5.3.3. Justification of measures to protect the environment

In case of equipment malfunction, it is subject to the disposal procedure. The disposal procedure means that the equipment will be written off first; then, in order to confirm the presence of equipment malfunction, it will be checked by experts who will disassemble the device. Then there is the processing of materials (plastic, various metals). Waste recycling is an activity that consists of handling wastes for their safe disposal or reuse.

5.4 Safety in emergency situations

5.4.1 Analysis of probable emergencies that may occur in the laboratory during research

Based on GOST R 22.0.02-94, an emergency situation can be interpreted as a situation in a certain territory that has developed as a result of an accident, a catastrophe, a dangerous natural phenomenon, a natural or other disaster that may or has already caused human casualties. people or the natural environment, violation of human living conditions and significant material losses.

The object of research itself cannot be the cause of an emergency, however, when conducting research, emergencies such as fire, earthquake may occur. The cause of fire in the working area may be a violation of safety when using computer equipment.

5.4.2 Justification of measures to prevent emergencies and the development of procedures in case of an emergency

To eliminate the causes of fires in the laboratory, the following measures should be done:

- Workers and employees entering the workplace must undergo a fire prevention briefing;
- Employees must know the location of fire extinguishing equipment and be able to use it
- It is necessary to ensure the correct thermal and electrical operation of electronic equipment;
- Firefighting equipment and primary fire extinguishing equipment must be kept in good condition and be in a visible and easily accessible place;
- Timely preventive inspection, repair and testing of equipment;
- Prohibition of smoking in an unspecified place.

To prevent fires from short circuits, overloads, proper selection, installation and compliance with the established mode of operation of electrical networks and automation equipment are necessary.

In the event of an emergency, it is necessary to immediately stop the work of people, take measures to protect and evacuate people from the emergency zone, and if necessary, disconnect the equipment from the electrical supply network.

Conclusion

This section has reviewed social responsibility in the study. There were considered such items as industrial and environmental safety. The organizational arrangements for the layout of the working area were determined. Were identified various harmful and dangerous factors and methods of dealing with them. A list of measures was identified to reduce the threat posed by possible emergencies. Finally, legal and organizational security issues were examined. The results of this section will help to better implement this research project in the framework of laboratory research.

Conclusion

- A review of the literature on the topic of the master's thesis was made, information on the use of virtual and augmented realities in rehabilitation was found;
- Based on the materials studied, the requirements for the developed complex for the rehabilitation of motor functions were formulated;
- Virtual environment for augmented reality system was created;
- Three scenarios of BFB training for the rehabilitation of motor functions were developed;
- The developed scenarios were implemented on the Unity platform;
- Program for data visualization and mathematical analysis was developed using Matlab.

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Appendix A

Chapter 1. Literature review

Student:

Group	Full name	Signature	Date
1DM7I	Shorokhov Daniil Igorevich		

Scientific Supervisor and Technical Advisor:

Position	Full name	Academic degree, rank	Signature	Date
Assistant professor	Gubarev Fedor Aleksandrovich	Candidate of Technical Sciences		
Assistant professor	Tolmachev Ivan Vladislavovich	Candidate of Medical Sciences		

Advisor-linguist of the Department of Foreign Languages:

Position	Full name	Academic degree, rank	Signature	Date
Assistant professor	Glushkov Sergey Viktorovich	Candidate of Philology		