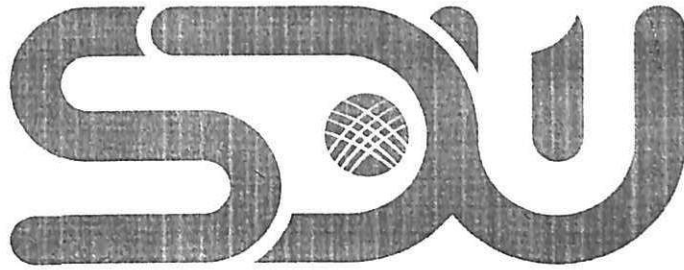


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Creating three dimensional internal organs for
scanning using simulator

THESIS

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Abstract

This thesis is a simulation of scanning the human heart in real time, which will be useful in medical and educational practice in the diagnosis of various diseases of the cardiovascular system. Currently there is an extreme importance of the problem of cardiovascular diseases. According to statistics, they confidently occupy the first place among the causes of death and disability of the population. Diagnosis of cardiovascular diseases is a serious problem. In medicine, modeling of individual organs and the body as a whole is an important task, the successful solution of which will allow you to quickly, accurately and timely identify pathologies, as well as determine the optimal therapeutic effect and predict its consequences. In this thesis, the structure of the human heart was studied and a model of the human heart was created on the basis of Blender software as a basis for simulating the scanning process. From the existing various methods of segmentation of a three-dimensional object, the mesh slicing method was taken as the basis. For the implementation of this project, the Unity3D game development platform was chosen. The end of this work is an original simulator application for scanning a person's heart.

Аңдатпа

Бұл диссертация жүрек-қан тамыр жүйесінің түрлі ауруларын диагностикалауда медициналық және білім беру тәжірибесінде пайдалы болатын, нақты уақыт режимінде адамның жүрегін сканерлеу симуляциясын көрсетеді. Қазіргі уақытта жүрек-тамыр аурулары проблемасының аса маңызды. Статистика бойынша олар халықтың қайтыс болуы мен мүгедектігінің себептері арасында сенімді түрде бірінші орынды алады. Жүрек-қан тамырлары ауруларының диагностикасы маңызды мәселе болып табылады. Медицинада жеке ағзалар мен ағзаларды модельдеу жалпы маңызды міндет болып табылады, оның табысты шешімі сізге тез, дәл және дер кезінде патологияны анықтауға, сондай-ақ оңтайлы емдік әсерді анықтауға және оның салдарын болжауға мүмкіндік береді. Бұл диссертациялық жұмыста адам жүрегінің құрылымы зерттелді және Blender бағдарламалық қамтамасыз ету негізінде сканерлеу процесін симуляциялаудың негізі ретінде адам жүрегінің моделі жасалды. Үшөлшемді объектіні сегменттеудің әртүрлі әдістерінен негіз ретінде меш слайсинг әдісі алынды. Осы жобаны жүзеге асыру үшін Unity3D ойындарды әзірлеу платформасы таңдалды. Бұл жұмыстың соңы-адамның жүрегін сканерлеу үшін бірегей симулятор қосымшасы.

Аннотация

Данная диссертация представляет собой симуляцию сканирования сердца человека в режиме реального времени, которая будет полезна в медицинской и образовательной практике при диагностике различных заболеваний сердечно-сосудистой системы. В настоящее время существует крайняя важность проблемы сердечно-сосудистых заболеваний. По статистике они уверенно занимают первое место среди причин смерти и инвалидности населения. Диагностика сердечно-сосудистых заболеваний является серьезной проблемой. В медицине моделирование отдельных органов и организма в целом является важной задачей, успешное решение которой позволит вам быстро, точно и своевременно выявлять патологии, а также определять оптимальный лечебный эффект и прогнозировать его последствия. В данной диссертационной работе было изучено строение сердца человека, и на основе программного обеспечения Blender была создана модель человеческого сердца в качестве основы для симулирования процесса сканирования. Из существующих различных методов сегментации трехмерного объекта в качестве основы был взят метод меш слайсинга. Для реализации этого проекта была выбрана платформа разработки игр Unity3D. Конец этой работы - оригинальное приложение симулятора для сканирования сердца человека.

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1. Introduction

1.1 Relevance

At present, the method of three-dimensional modeling of physical processes occurring in the objects under study is widely used in science and technology. This approach allows you to more fully explore the object of study, exercise control over it and predict its behavior under given effects. In medicine, modeling of individual organs and the organism as a whole is an important task, the successful solution of which will allow you to quickly, accurately and timely identify pathologies, as well as determine the optimal medical effect and predict its effects. The first and integral stage of modeling is the creation of a geometric image. It should be noted that reliability, accuracy and speed image creation is largely determined by successful three-dimensional modeling in medical practice.

The relevance of the topic of the thesis project from the theoretical point of view is dictated by the need to develop methods, models and algorithms for creating 3D object, simulating scanning process, which can be used to create an interface for human-computer interaction. The relevance of the topic from an applied point of view is determined by the need to create application capable for providing a simulating interface with a printing result as data about structure of heart in real time. Thus, the actual task is to create 3D model of human heart, methods and algorithms for simulating scanning and segmentation process for defining supposed heart disorders.

Since the problem diagnosis of cardiovascular diseases is important, medicine solutions with applying information technologies will remain relevant for a long time.

1.2 Aims and Objectives

Purpose: create an application to simulate the 3D scan of the heart, which will help in examination and diagnosis, as well as in the training of medical students, using the Unity 3D game engine system to improve efficiency and a user-friendly interface.

The main objectives of the study:

- analysis of methods for creating 3D models of the human heart, as close as possible to the human's, a comparison of their characteristics.
- development of a modified method for cutting a 3D object based on a segmentation algorithm and auto-filling of empty spaces.
- implementation of the method using the Unity 3D game engine.
- to conduct experimental studies of the characteristics of the modified method.
- to conduct a test scan simulation.

Object of study: methods, algorithms and programs for modeling, tracking, scanning, segmentation of a 3D object.

On the basis of the developed modified method, a end product has been created that makes it possible to simulate scanning process of 3D object and make segmentation in the virtual model of heart, which allow us to get data about internal organ. This method of segmentation based on mesh slicing algorithm can be used later to another different 3D objects in real time.

1.3 Thesis Outline

The 2 chapter is about methods of using 3D technology in medicine, also the study of emerging problems in the diagnosis disease of internal organs in RK. Formulate the problem to solve. In Chapter 3 - review modeling ways of 3D models of internal organs and related solutions creating of 3D model of heart. Chapter 4 is describing the solution of problem, implementation of simulation of the scanning process of human heart. And in Conclusion chapter conclude finished work.

2. Methods of using 3D technology in medicine

2.1 Emerging problems in the diagnosis

According to the World Health Organization, 18.07 million people are diagnosed with an oncologic diagnosis every year. In 2018, due to cancer in the world, 9.6 million people died. The most common types of cancer are lung cancer, breast cancer, colon and rectal cancer, prostate cancer, and stomach cancer. According to doctors, one of the most common problems affecting the level of morbidity and recovery is seeking medical help in the later stages and insufficient availability of diagnostics of diseases.

At a press conference in Almaty, leading oncologists-members of the American College of Surgeons, as well as the European Association of Surgeons, said that the following diagnostic methods are now in demand around the world. These include radiography, ultrasound, endoscopic examination methods, computed tomography, MRI (magnetic resonance imaging), PET-CT (positron emission tomography, computed tomography), tests for tumor markers, tissue biopsy. PET-CT is a type of tomography that allows you to examine the internal organs [7].

Worldwide, cardiovascular diseases remain the leading cause of death for the population. In most developed countries of Europe, this figure reaches 40% of all deaths, and in Kazakhstan - more than 50%. In recent years, the incidence of myocardial infarction has increased - mortality reaches 30-50% of the total number of cases. About two million people with cardiovascular diseases (CVD) are registered in Kazakhstan. This is 12% of the total economically active population.

Diseases characterized by diseases of the heart system. Urban population (per 100 thousand population) (Table 2.1)

Table 2.1: Diseases characterized by diseases of the heart system. (per 100 thousand population)

	Heart diseases			
	Coronary heart disease		Myocardial infarction	
	2017	2018	2017	2018
RK	483.6	463.4	78.5	81.6
Almaty city	1232.8	541.4	63.0	90.4

The highest death rate in Kazakhstan from diseases of the cardiovascular system. In the second place - diseases of the respiratory system. the third - oncology.

Currently, global changes in higher education are underway in Kazakhstan, which have touched upon the training of medical personnel. One of the key factors for improving the quality of training of medical personnel ready for independent practice is the use of innovative teaching methods in teaching. Teachers of medical universities face a difficult task - to teach students to practice their own medical practice, to take decisive actions in emergency situations, that is, to stimulate clinical thinking, to activate their creative potential, to form a sustainable interest in education, their future profession.

Information and communication and computer technologies: Internet conference, lecture – presentation, computer modeling, video lectures, video films, multimedia lectures, etc., allow to realize the principle of visibility and distance learning, facilitate and positively influence the efficiency of learning material mastering. Computer technologies increase the availability of scientific materials that can be posted on the website of the university, on the personal page of the teacher. Today widespread communication with the teacher in social networks, namely in the student social network "in contact". Meanwhile, the distance learning in medical education is not accepted. This form of communication enables informal, operational discussion of emerging issues, the organization of discussions, the transfer of a number of theoretical materials in electronic form. Information and communication and computer technologies greatly facilitating the learning process in the sense of increasing the efficiency of transmitting educational information, controlling its assimilation, at the same time, are far ahead of the capabilities of universities in their effective use and, most importantly, in rational content with meaningful information [3]. The advantages of such information

and communication and computer technologies are visibility, the possibility of re-listening and viewing the most interesting or difficult places, the possibility of independent work. The disadvantage of this technology is the high cost.

Training based on simulation technologies is one of the youngest branches of medical education in the Republic of Kazakhstan, but it also has a long history [9, 10, 4].

The use of simulation technology in world medicine began in the mid-60s of the twentieth century. Today, the training of a competent specialist to work in practical health care, and especially in emergency and emergency medicine, emergency medicine and emergency situations is not possible without the use of simulation technologies. Simulation technologies allow you to simulate any urgent condition. Training is conducted using the latest high-tech dummies such as patient simulators and specialized simulators, computer programs, as well as simulation scenarios.

The advantages of using simulation technologies to prepare future doctors to work with patients, help them of any complexity without harming their health - using dummies as a patient. Working with simulators allows you to work out therapeutic and diagnostic methods of any complexity. The advantages of training on simulation robots: there is no risk to the patient's health; objectivity in the assessment of knowledge and skills; ability to control the technology of medical manipulations.

2.2 The structure of the heart for visualization

The structure of the heart is widely represented in the scientific literature, at the same time, its size, as well as the parameters of its individual structures, characterized by individual variability, remain poorly understood today. So, in the available domestic and foreign literature there is no information about the morphometric parameters of the human heart in the age and sex aspects. To understand the pathogenesis of diseases, clinical features, the use of adequate therapeutic measures require in-depth knowledge of the structure of individual structures of the heart. At the same time, the development of cardiology and cardiac surgery, accompanied by new proposals in the field of diagnosis and treatment of heart diseases, puts forward new demands on morphologists on the anatomical

rationale for the emerging modern methods and techniques for treating one of the most important organs of our body. (See Figure 2.1) The material for the

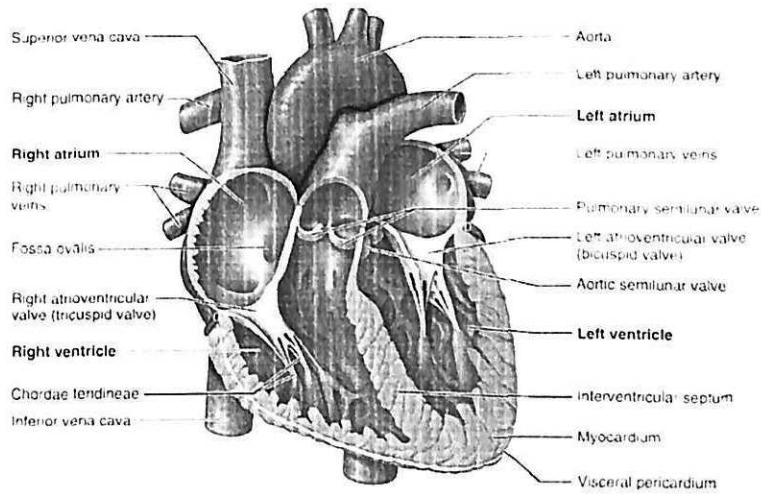


Figure 2.1: The structure of the human heart

study were 259 hearts of persons deaths from various non-heart diseases, aged 21 to 96 years. 68 women and 191 men were examined. When selecting the material, the following criteria were used: 1) the violent nature of death (mechanical asphyxiation, traumatic brain injury, incompatible with life); 2) heart mass is not more than 450 g for men and 350 g for women; 3) the absence in the history of the presence of chronic heart disease; 4) the absence of the opening of scars in the myocardium and traces of impaired blood supply to the heart. In each case, the following parameters were measured under standard conditions: height, trunk length and shoulder width, mass, heart length and width, maximal myocardial wall thickness of the right and left atria and ventricles, longitudinal and latitudinal dimensions of the interatrial and interventricular partitions of the heart, oval length and height pits, the circumference of the left and right atrioventricular orifices, as well as the aortic and pulmonary orifices. Measurements were made of the length and height of the semilunar valves of the aorta and pulmonary valves, the cusps of the bicuspid and tricuspid valves of the heart; points: 1 - between the upper pulmonary veins, 2 - between the lower pulmonary veins, 3 - in the middle of the distance between the previous points. Statistical processing of the obtained results was performed using a standard software package for applied statistical analysis (Statistica for Windows v. 6.0). The methods of parametric and nonparametric statistics are used. Methods descriptive (descriptive) statistics included an estimate of the arithmetic mean (M), the average error of the mean

(m) - for signs that have a continuous distribution. To assess the intergroup differences in the values of the characteristics, Student's t-test was used. Differences were considered statistically significant at $p = 0.05$ [11].

2.3 Existing programs for training in medical practice

VR-surgery People who want to get under the "knife" inexperienced neurosurgeon, you will not find in the afternoon with fire. To solve this problem simulators NeuroVR was created, in which budding professionals hone their skills without harm to patient health. A broadcast operations through virtual reality, not only allows doctors to gain experience from around the world, but in case of difficulty consult a more experienced surgeon, regardless of where it is located. In April 2016 Dr. Shafi Ahmed intestinal tumor removed at the Royal London Hospital, broadcasting operation in the Internet. (Figure 2.2) In the same year, French doctors from the University Hospital of Angers for the first time in the world have removed a brain tumor during surgery using VR-devices.

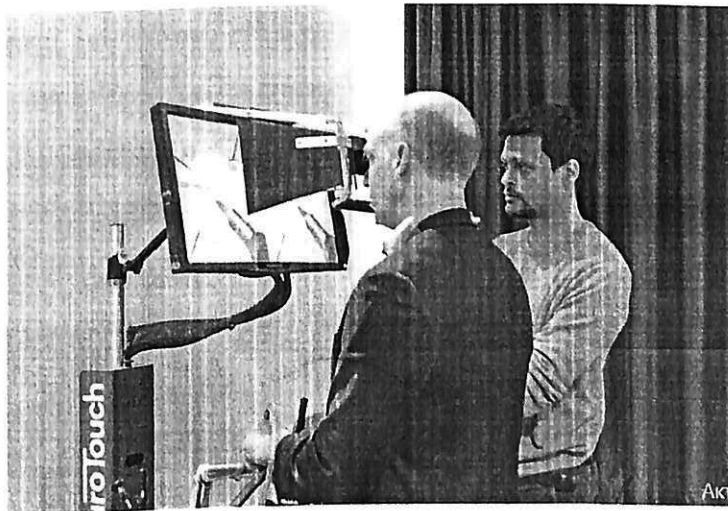


Figure 2.2: VR-surgery

3D-diagnostics Virtual reality facilitates diagnosing disease process: using ultrasound, CT and X-ray data are collected, which are then converted into three-dimensional model of the damaged organ. (See Figure 2.3) Then, doctors can examine the 3D-model problematic body from all angles, not to miss anything important. For example, using the Stanford Virtual Heart program developed

by the school of medicine at Stanford University, students study the heart and determine possible defects. It is much more effective and less expensive than the use of plastic models.



Figure 2.3: 3D-diagnostics

Anatomy Atlas of the Visible Body One of the most famous full-3D anatomical atlases. The annex presents the 3D-model of a human body with a huge variety of designs (more than 2500). Here are a few words to the representatives of iMedicalApps Application: Rarely any application can stun, but Visible Body - one of those applications. It is ideal for students and teachers of anatomy, as well as for patient education. Consider the hundreds of thumbnails sorted by department and anatomical systems, run the 3D-model of interest to departments or anatomical structures, rotate, zoom, tilt model to explore every angle, examine information about the anatomical sites, find the right education and add them to an existing model. In general, very detailed and complete 3D-model of the human body, developed by highly skilled professionals. As for the price - on the Play Market app is worth a thousand rubles, so it is rather suitable for professionals, for which such detail is relevant.

3. Modeling 3D models for use in simulating scanning

3.1 Modelling software

Speedy development of technology in such a short time led to the same rapid growth in the software and computer equipment. Commonplace steel and visual effects that are today available to anyone due to the wide dissemination of programs to create computer graphics and, in particular, three-dimensional modeling [6].

1. **Autodesk 3Ds Max** - this software is very popular, and a great role in this was played by the fact that the program is focused on architectural visualization. In 3Ds Max has models that are needed to create various architectural projects from the standard tools doors and windows to the stairs, fences and vegetation (Figure 3.1)

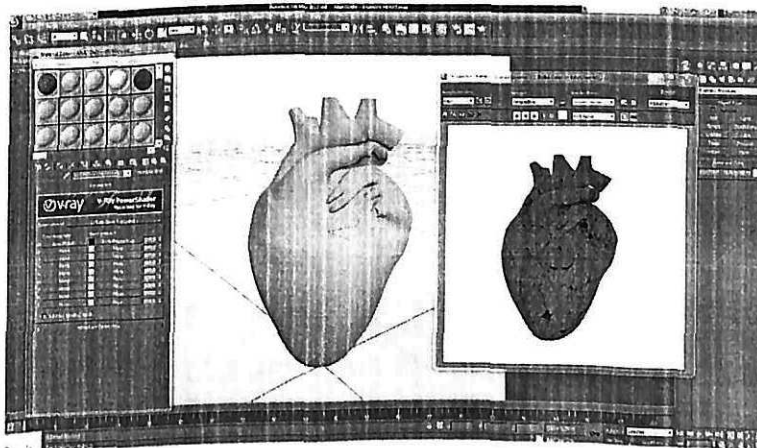


Figure 3.1: 3D's Max Studio

In addition, in this 3Ds Max has a means of adjusting the lighting three-dimensional scene. Also in the software it has been integrated photorealistic

renderer that allows you to achieve very high realism.

Lack of specific tool offset by a large number of plug-ins, which greatly increase the possibility of built-in programs. For example, Afterburn module allows simulates realistic explosions, and when using Dreamscape software gets new tools for creating natural landscapes and water.

2. Autodesk Maya - for a long period, this is the package opposed to the main competitor in the market of 3D software - 3Ds Max. Experienced 3D-artists, this product is used more frequently than others. This three-dimensional program is often used by such known studios as Dreamworks, Walt Disney etc.(Figure 3.2)

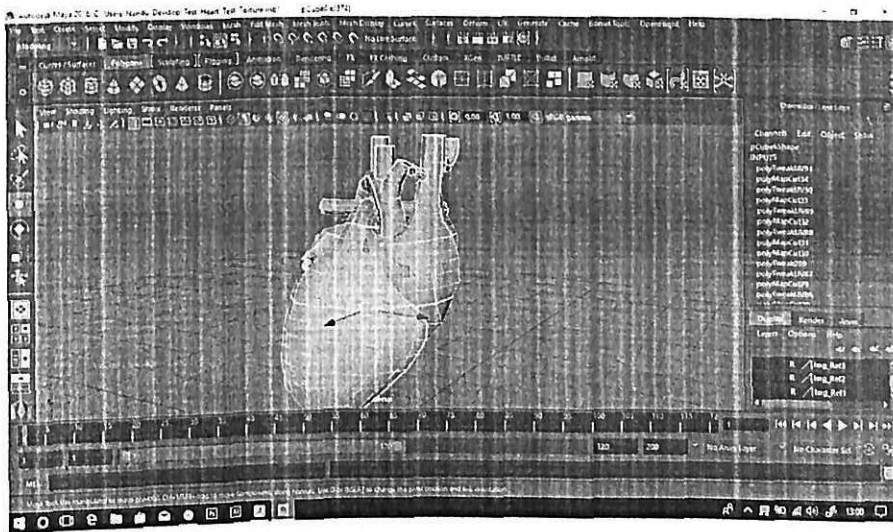


Figure 3.2: 3D Autodesk Maya

This editor has almost everything you need for of 3D-graphics. Maya gives you the opportunity to go through all the steps involved in creating 3D - from modeling and animation to texturing, compositing and rendering layering. The main feature of the package is PaintEffects module, it allows you to paint with a brush 3D-objects such as grass, three-dimensional patterns, and others.

3. Blender 3D - it is free software, which is developing rapidly, not giving way to commercial programs. The secret lies in the fact that the creation of any user modifications can be carried out for this editor. Many of the modules and plug-ins that have appeared in the Blender, were added to completely different people who worked on a variety of functions for solving specific tasks. (Figure 3.3)

In comparison with commercial alternatives size of this program is very small few tens megabyte. Cross-platforming is one of the major advantages of the program. Editor consistently works as on Linux, and the Windows [1].

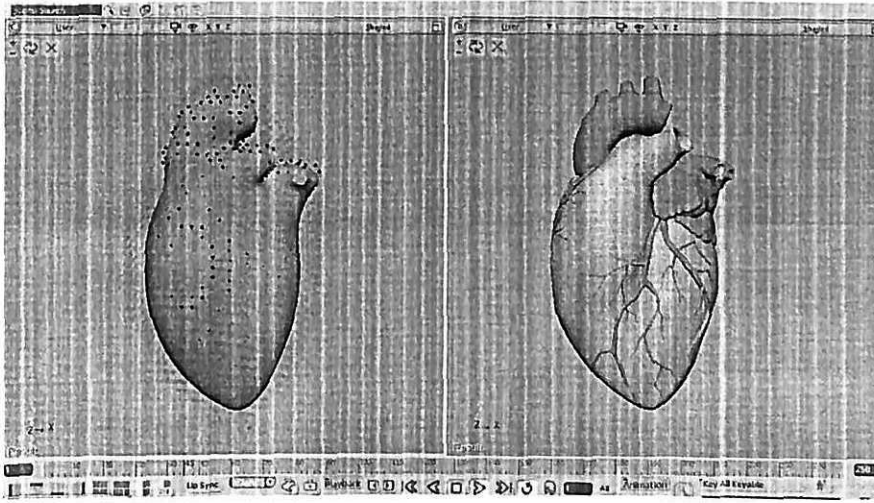


Figure 3.3: 3D Blender

Blender contains a large group of modules for the modeling of 3D-objects. For example, the program can be used a particle system, set the weight of certain particles, use guides and external forces, such as wind. Also in the editor there is a fluid simulator that offers great opportunities for creating effects of fluid bodies, such as liquids or smoke. The user can calculate the physical problems, such as modeling the behavior of soft bodies.

As demonstrated by the comparative (Table 3.1), the best of the three editors, despite the fact that it is not free, it is Autodesk Maya 2018. Due to its unique features and affordability in the development of this program now has the largest number of fans both among fans and among professionals. Perhaps, there are very few spheres of human activity associated with three-dimensional graphics, which is not used. It is actively used to create games and movies, architecture and construction, medicine and physics, as well as in many other areas.

3.2 Algorithm for creating three-dimensional images of human bodies on tomographic data

The first and integral stage of modeling is the creation of a geometric image. It should be noted that reliability, accuracy and speed of image creation largely determine successful mathematical modeling in medical practice. An effective, non-invasive method of obtaining images of the structure of the organs of the human body is tomography. The tomogram obtained as a result of scanning is

a set of flat sections that form a three-dimensional array of data. Schematically, the process of obtaining a tomographic image is presented in Figure 3.4

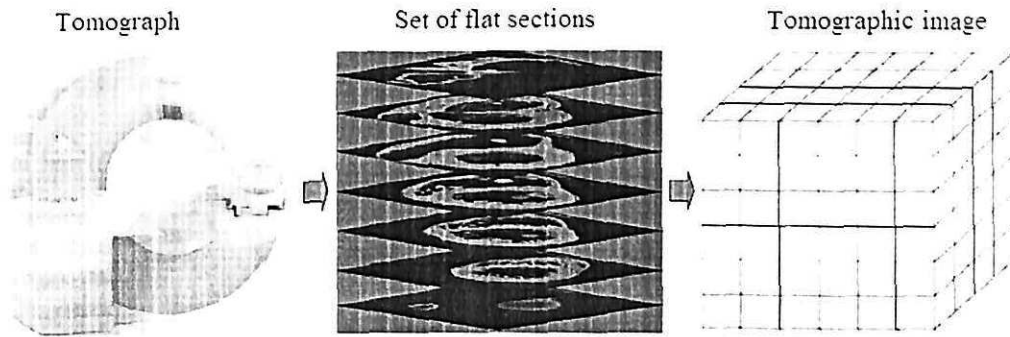


Figure 3.4: The scheme of creating images using magnetic resonance imaging (MRI)

These data are usually used to view an object in three mutually orthogonal directions, measure linear and angular dimensions, and also visually determine pathologies. Such capabilities are usually embedded in the software supplied with the tomograph, but there are also some software products, such as Seg3D, which also allow visualization. To build a three-dimensional geometric image, various approaches are used. Among them, we can distinguish the method of manual construction of the contours of individual sections, followed by automatic merging into a three-dimensional image [5], the method of deformable surfaces [8], the method of frontal growth [2]. The first approach is implemented in the program Mimics. Its advantages include the possibility of determining the highly noisy areas of the scanned object based on the a priori knowledge of an experienced doctor. This feature is especially relevant when the tomogram is of poor quality. The disadvantages of the approach are: the dependence of the quality of the geometric image on the experience of the doctor, large time costs and, as a consequence, the impossibility of application in everyday medical practice. In the method of deformable surfaces an iterative procedure is organized, at each step of which the surface is deformed so as to deliver a minimum to a functional that depends on the first, second derivatives of the surface and the external field. The advantages of this method are as follows: the possibility of building an automatic algorithm, obtaining a smoothed surface bounding the body, the possibility of identifying a discontinuous boundary. However, when using this method, the starting surface should be close enough to the true one, and additional algorithms

should be considered to identify multiply-connected areas. The frontal growth method is iterative. To use it, the study area is represented as a collection of subdomains. At each iteration, adjacent subdomains that satisfy the given similarity criterion are added to the current growth area. The process runs until the number of elements added during the iteration is zero. The method allows: to build an automatic algorithm, get a closed area, has a high speed, is applicable for simply connected and multiply connected recoverable areas.

Stepwise algorithm deformable model

For any given image region segmentation algorithm proposed k^* as follows:

1. Register this averaged image in image using mutual information, where the average image obtained by averaging the data for the base image. This step makes the algorithm invariant to scale, rotation and translation.
2. Use the modified EM-algorithm for estimating the density for distance maps with the sign $p_s(dk)$ inside and outside the object of interest from the secondary form which has been calculated a priori.
3. Calculate a normalized histogram for the image / volume.
4. Use the modified EM-algorithm for estimating the density p_g for each class (q_k), where k is the number of the class $k = 1 \dots K$.
5. Initialize control points $\phi()$ for a deformable model, and for each control point $\phi()$ in the deformable model calculate the current distance between the marks indicating the outer $(-)$ or inner $(+)$ position of each of the eight nearest neighbors wrt circuit.
6. Check the label $k = X(\phi())$ for each control point: (A) If the point is assigned to the field $k = k^*$ then
 - I. Rate the region label for its neighbors, using Bayesian classifier so that they are $(-)$ the distance.
 - II. If some of these sites also belong to the class k^* Then, move the control point in an adjacent position, ensuring a minimum total energy (i.e., expand circuit).
 - III. Otherwise, do not move this point (steady state).
- (B) If the point is assigned to the field $k = k^*$ then
 - I. Rate the region label for its neighbors, using Bayesian classifier so as to have the distance $(+)$.
 - II. Move the control point in an adjacent position, providing the minimum total energy (i.e. compress circuit)

7. If iteration adds a new control point, using a cubic spline interpolation across the surface, and then flatten all of its control points using a low-pass filter.
8. Repeat steps 5, 6 and 7 until the control points no changes position.

We have presented an approach to segmentation of objects, which depends on the intensity of the gray level, and from the information on the form, and we have applied the algorithm to the 3D images. Among other segmentation techniques based on the form that compute the mean and variance of the Gaussian distribution, and assume, in this method, the mean and variance are included in the estimated density which is calculated using our modified EM algorithm. This algorithm is very fast and works both in 2D, and in 3D.

3.3 Modeling methods and medical requirements for 3D models

3D-scanners may differ in many ways: the field of use, size, shape, technology. Modern units are used in industrial and consumer sectors, as well as in medicine. Particular attention should be paid to an ultrasonic 3D-scanner is a real boon for modern medicine. Devices are provided with energy, color, fabric, continuous and pulsed-wave Doppler. The scanner is characterized by a high resolving power, however indispensable in mammology, obstetrics, urology, research vessels and muscle tissues, echocardiography, neonatology and paediatrics. 3D-scanning (three-dimensional) scan - the process by which the transfer of the real physical shape of the object, the object or product in digital form, in other words, the obtained three-dimensional computer model of the desired object or subject. 3D-technologies allow to completely eliminate manual labor and the need to make drawings and calculations on paper - the program allows you to see the model from all angles already on the screen, as well as to eliminate the revealed shortcomings are not in the process of creation, as is the case with hand-made, but directly in the development and to create a model for a few hours.

3D-scanner illuminates the laser product and receives information about the distance to the surface of the object being scanned. Based on this data plot surface model is constructed, that is a cloud consisting of millions of pixels. This so-called polygonal modeling. Upon receipt of a sufficient number of such sites built-in scanner software stitches them into one object in automatic or manual

mode. When scanning the surface of the 3D-scanner detects various noise - these may be features of the object - the mud, the motion of the object during scanning, tags, and the external conditions and the characteristics of the scanner - light, temperature, oscillations scanner support. Unnecessary irregularities are formed, which are removed during processing of the scanned image obtained with the same software.

As a result, the finished three-dimensional image is constructed, which can already be printed. If necessary, the three-dimensional image can be changed, for example, to reduce by means of three-dimensional graphics programs. During printing, the printer reads the 3D-printed file containing the data of three-dimensional model, and causes successive layers of liquid material, building a three-dimensional model of a series of cross-sections. These layers corresponding to the virtual cross sections in the CAD-models are joined or fused together to create the desired shape of the object. When printing, the printer uses the supports that are needed to build the model fragments are not in contact with the underlying layers or the working platform. The pillars themselves are not part of a given pattern, and upon completion of printing or break off (in the case of using the same material as that for printing of the model) or dissolved (in water or acetone - depending on the material to create poles).

Programs to create or edit the existing three-dimensional models on the market of application software are many. Some of them, for example, 3D Studio MAX, are licensed therefore distributed on a fee basis. Many of them are the same 3D Studio MAX, require more hardware resources, which could adversely affect both the speed of the computer itself, and at the time of construction of 3D-models. Among the open-source 3D-editors are quite popular Blender is a program related to the software with open source software (Eng. Open-Source Software). The app does not overload the hardware of a personal computer, you can create a model with an acceptable quality, supports the import and export images in a special format for the subsequent three-dimensional printing.

To support the management of 3D-printing uses computer-aided design (CAD). In most cases, the model prepared for printing should have STL format. Almost all printers have their own software for print management, partly commercial, partly - open source.

When scanning a human hand fragment was obtained finished three-dimensional

image. But prior to printing, to remove all the noises that were recorded 3D-scanner during operation. This helps embedded software, in particular, David-3D (three-dimensional scanning carries objects and transformation of the results for subsequent import models in the 3D-editors are). Artec Studio 10 (professional tool for creating solid models) and many others. 3D-scanners allow duplicate already existing facilities, which means that the modeling process can be accelerated significantly. They allow you to recreate an almost perfect copy of the model. Most often scanner manufacturers provide users with the necessary software package, but not always, they are equipped with all the necessary tools.

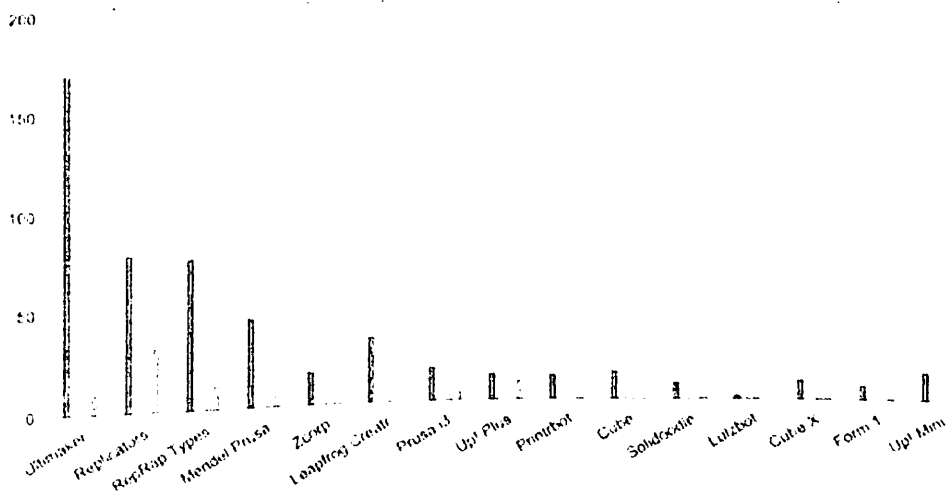


Figure 3.5: - (pink) Europe – (yellow) North America – (green) South America – (blue) Other world

4. Implementation of the scanning process

4.1 Three-dimensional scanning solutions

The three-dimensional laser scanning is relatively "young" in the field of high precision measurement technology originated in the 90s of the last century through the active introduction and development of a surveying device such as reflectionless laser tachometers, which did not need special mirrors for measuring the distance to the point. The scanner itself, the subject process, and the result is characterized by a number of parameters such as:

scan Rate It determines the number of points, which measures the scanner for a second;

grid resolution referred to the distance between two adjacent points of the scan on the distance from the scanner to the different specific cases

scanner accuracy referred to the total resulting measurement error having both random and systematic component.

Noise level a three-dimensional scanner - this is a random component of the total error of measurement points. Rate noise can be conducted repeated measurements of the same object under the same conditions [13].

Laser scanners based rangefinders

The basis of this technology is a system of active laser rangefinder that uses the principle of time of flight or phase. TOF laser rangefinder - laser pulse is directed to a point a given sector, the markup notional grid. For each point individually collect data on its relative remoteness radiation receiver acting as the origin of the coordinate system, and angles of rotation data mechanical mirror, which subsequently interpreted as the zenith and azimuth angles for constructing

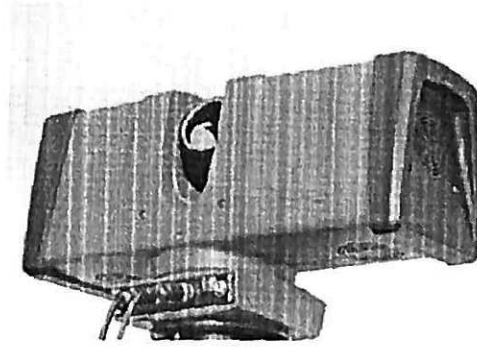


Figure 4.1: Time-of-flight laser scanners, to the left - Surphaser 25HSX, right -Konica Minolta Vi-910

a spherical coordinate system. The advantage of this method is its high precision, speed of measurements, as well as the amount that covers the scanner. Among the shortcomings can be identified high cost of equipment and the demands on the choice of the laser source. A good example of this type of device is a scanner Surphaser 25HSX. (Table 4.1)

Phase laser rangefinder - the laser radiation is modulated in phase by one or more harmonic signals. The desired distance to the object is determined by comparing the phase of the baseband signal at the output of the radiation receiver (this phase of the radiation transmitted the path to the object and back) with the reference signal phase (a phase of the laser source). This provides a very high accuracy of distance measurement (it may be compared with the laser wavelength) but the range of such distance meters substantially smaller than the ranging pulse. In addition, due to the complexity of the hardware implementation of 3D-scanner working on phase ranging principles, they are very expensive, and is currently not widely available [12].

Laser triangulation scanners calibration pattern.

The principle of operation of such devices is based on triangulation. Receiver radiation, which might be a silicon matrix is calibrated for a set of reference marks, the distance between them is known. This procedure allows you to determine the distance of the system and the position of the field relative to the receiver array. After that point, or a horizontal line projected laser radiation source illuminates the object being scanned. The optical receiver system focuses the reflected light on the array, and position on it of the incident light spot indicates the direction of the incoming light. Based on this determined angle between the incident and reflected radiation on the object, and accordingly, the distance to the object [14].

(Table 4.1.1)

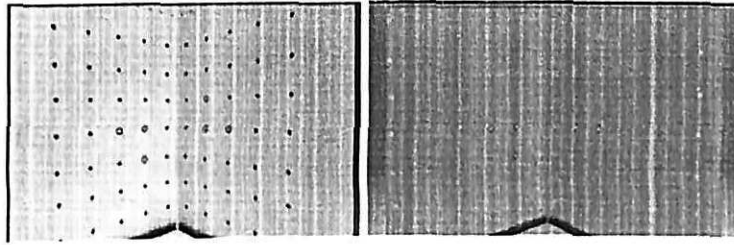


Figure 4.2: Scanner triangulation type field before and after calibration by benchmarks

4.2 The platform for implementing the process

Compare 6 solutions for cross-platform development, which were very popular in 2018 and try to find the best solution.

Cross-platform frameworks PhoneGap, Xamarin, Unity3D, Qt and Appcelerator Titanium, Telerik Platform currently holds 80% of the market cross-platform development.

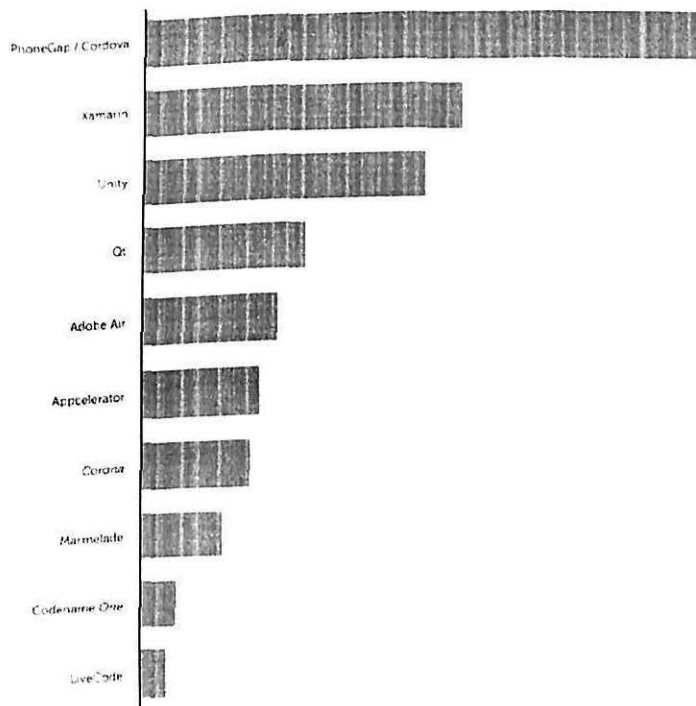


Figure 4.3: Overview of cross-platform solutions for the development of 3d applications

Futuristic technology of Star Wars and Star Trek is gradually becoming a reality. Platform amazon Sumerian will create its own three-dimensional virtual

reality and augmented reality characters or reproduce existing images. With the help of "Sumer", the user can create a cross-platform worlds under Oculus devices, HTC Vive, iOS-devices with WebVR browsers, and soon after the appearance of support on Android with ARCore. (Figure 4.3)

The list of features of the platform include:

- Editor: Web editor to create three-dimensional scenes, special effects, import resources, writing scripted interactions and the possibility of cross-platform publishing.
- Object Library: a library of objects and templates.
- Importing resources: the user can download the 3D-resources for their scenes. Sumerian supports FBX, OBJ, and in the future. and Unity-projects.
- Script library: JavaScript-script library, working with 3D engine language to take full advantage of its advanced features.
- Characters: animated, realistic three-dimensional characters with a choice of gender, voice and language.
- Integration with Amazon Web Services: Amazon Polly and Amazon Lex built-in support for adding characters to speech and spoken languages in the world. In addition, the script library can be supplemented by technology AWS Lambda, lets you select a set of AWS-services.

Since Sumerian does not require a 3D experience or programming to create a deep-developed interactive VR and AR-scenes, can log into the control panel and see how it all works. (Figure 4.4)

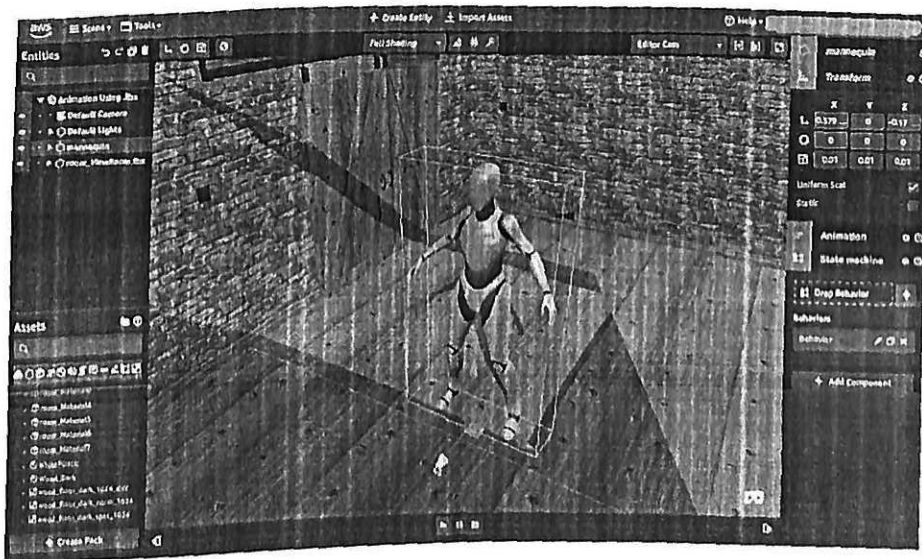


Figure 4.4: Scanner triangulation type field before and after calibration by bench marks

- 3D-engine provides high-quality results without any complex configurations
- There are many good free plugins
- Unity allows the developer to make their own shaders and change the way that renders the Unity game.

Disadvantages:

- UI and the complexity of use for beginners
- The source code is not available
- Unity compilers are not optimized for ARM processors on some mobile devices.

4.3 3D objects segmentation methods

As parametric deformable models and deformable geometric model (arrangements of levels) are powerful and broadly utilized techniques for the division of assignments; Nevertheless, the two of them will in general flop on account of commotion, poor picture goals utilized fringes or shrouded structures, and they don't exploit from the earlier models. However, especially in the field of medical imaging, authorities have well limited forms of the family figures. Thus, additional restrictions based on the form of objects, are very necessary in addition to information about the level of gray of these objects.

To permit a fragmented structure, Leventon et.al. Utilized a type of from the earlier, wherein the scattering has been gotten based on full PCA, and utilized in this structure until development sets levels to the greatest a posteriori structure. Chen and associates. Decided the vitality practical, which essentially limits the Euclidean separation between the predefined point and its shape. In a thought of division bend was produced dependent on the shape and posture parameters of the preparation set which were advanced utilizing provincial vitality practical. The and its from the earlier structure the scattering got from the preparation information used to decide a Gaussian dissemination, which is then utilized in the external part outline vitality level sets. In a type of from the earlier limits was shaped from the highlights of the outskirts and this fringe is utilized as a major aspect of a lot of levels. As of late Tsai et.al. utilized a deterministic model to speak to the ideal shape as a straight mix of weighted two-dimensional guide of separations with a sign and valued the weight by limiting the cost capacity dependent on common data. Furthermore, Yang et al. In depicts a multidimensional

Gaussian shape with probabilistic model these loads.

In contrast to previous studies in our approach instead of direct use of the medium-density image, we estimate the signed card distances inside and outside of the object of interest to the registered training samples. using our modified electromagnetic algorithm and use this estimated value. the density of the external energy component of the proposed framework of the deformable model. This idea forms invariant to rotation and translation, and it overcomes the inability of deformable models to stay in noisy environments, or when there is no edge.

Scan tool

3D scanning will be done by planes. This choice is justified by the fact that the intersection of a plane with any other spatial geometric primitive is well known in higher mathematics and has a rigorous analytical presentation, which will be useful to us in developing the analytical structure of a feature.

The presence of a grid of parallel planes helps to solve the problem of an invariant description of an object (it gives a necessary condition for constructing features invariant to the transfer of a 3D image). If a spatial object is scanned by a grid of parallel planes, then moving the original 3D image does not change the shape of the sections obtained by the scanning planes (the discrete scanning step is ignored). Therefore, the resulting sections and the signs extracted from them will not change their value when transferring a 3D image to any vector in space. In other words, the calculated features will not depend on the spatial position of the object. (Figure ??)

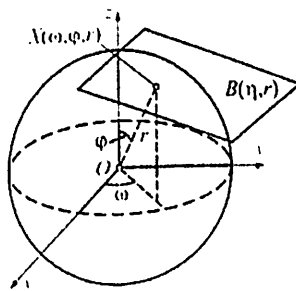


Figure 4.6: Determination of the spherical coordinates of the plane

5. Simulation of scanning, testing, analysis of results

Choosing a platform for implementing the system

Four reasons to choose Unity 3D:

1. Support for common programming languages The most notable benefit in using Unity 3D is the freedom to use C, BOO or JavaScript to implement your actions and algorithms. These three languages are not only powerful but also common and easy to learn. This makes the learning curve less steep since you won't need extra hours to learn new languages.
2. A simple but powerful graphical editor With most smartphones packing a greater graphics processing punch, game developers need a simple, fast and reliable way to delivering graphics intense games. With its OpenGL graphics API, Unity 3D will render all your designs and scene layouts with remarkable precision. The simplicity of Unity 3D's graphics engine is good news to both the developer and the end user. Designing, coding and deploying a game will be fast and simple.
3. The Unity 3D asset store Sometimes, modelling your characters or scenes could be the most time-consuming part of game development. Simple animation movements could easily turn to a daylong nightmare. Unity 3D will take care of this by offering access to a rich catalog or ready-made art, visual programming implementations, extensions and scripts that will cut short your time to delivery. Working with assets from the asset store is a perfect example of code reuse. There is no need to re-enact all the common programming fetes needed to make your game work. The Unity 3D community and asset store ensures that you attain this without watering down app quality.
4. Cross platform support and code modification If you think taking your mobile

game over to Windows or Android would do you good, you won't have to do any changes to the code. Unity will let you export the game to 17 different platforms. Even Xbox, Wii and Linux are supported. Even though most developers create their games with the top three platforms in mind, the possibility of extending your reach will increase popularity and sales. Unity 3D's ability to cross render and room for code modifications means you can optimize each game for the different platforms easily.

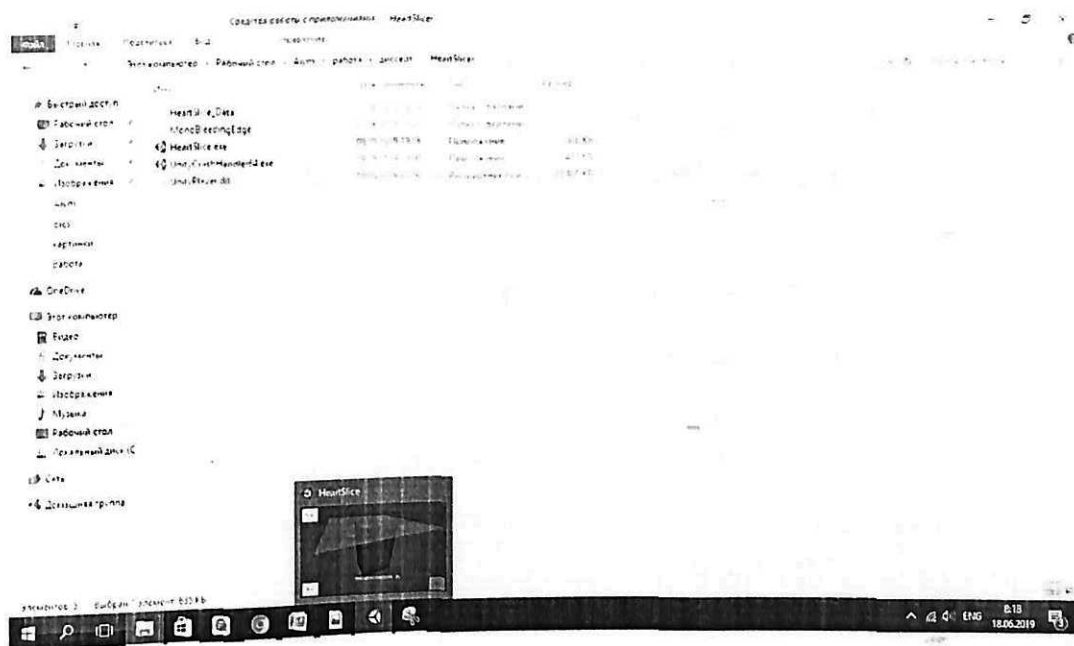


Figure 5.1: Heart simulation process running on Unity 3D

Choice of programming language for system implementation

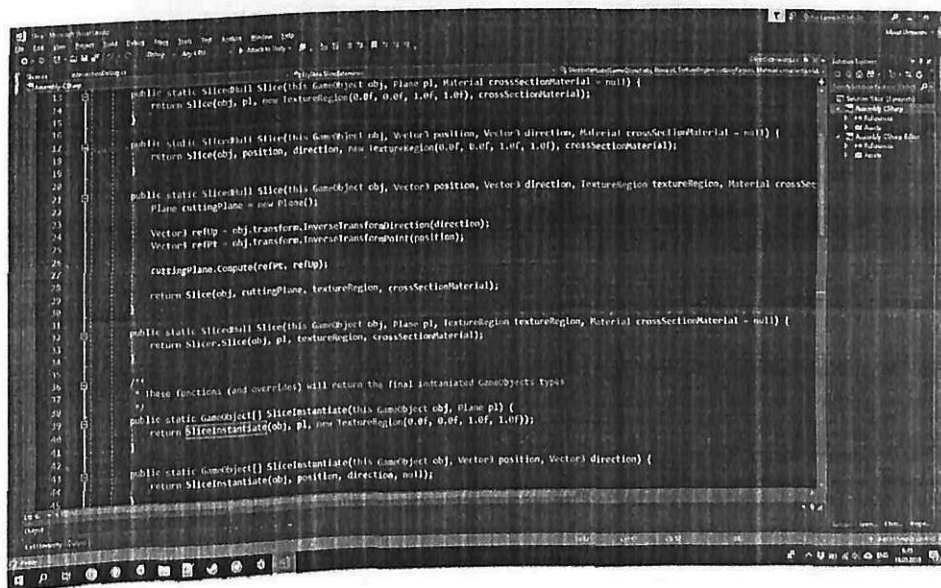


Figure 5.2: Mesh slicing algorithm for segmentation 3D object written in C# supported by Unity3D (Appendix B)

As the programming language in accordance with the chosen platform. C version 8.0 was used. Since C is the one of the languages of the Unity 3D platform, it was chosen to implement the simulation scanning process. C is a powerful object-oriented programming language that offers solutions for small and large programming needs. C is a type-safe language. By default, only implicit conversions are considered safe. This is provided at compile time and, in some cases, at runtime. According to many sources, this is one of the most valuable programming languages for teaching programming. In addition, compared to other programming languages, C is relatively simple and easy to learn, which makes it the best choice for beginners and even experienced developers.

Selecting a computer software for modelling and animating 3D object

As the software of modelling 3D heart with chosen platform, Blender 3D was used. Professional free and open source software for creating three-dimensional computer graphics, which includes tools for modeling, animation, rendering, post-processing and editing video with sound, layout using Node Compositing, as well as creating interactive games. Currently, it is the most popular among free 3D editors due to its fast and stable development, which is facilitated by a professional development team.

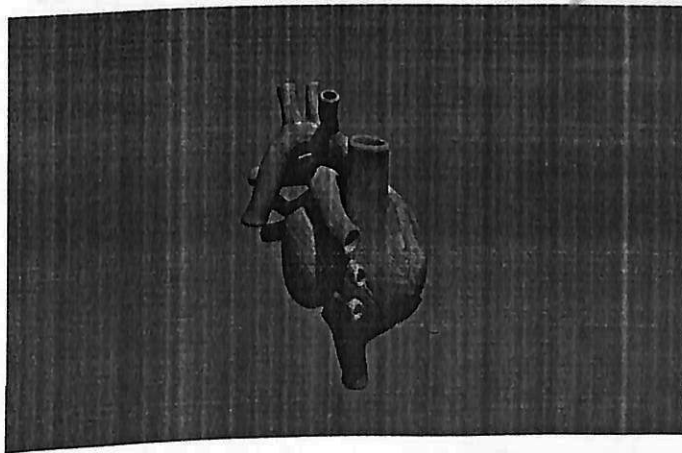


Figure 5.3: 3D model of human heart

Testing application

This is the interface when you open application for the first time. (Figure 5.4)
For starting scanning process you need to press "SCAN" button and scanning process will start. (Figure 5.5)

After the finishing simulation process, you can see 3D model of heart same as human heart for 89%. (Figure 5.6)

This button "SLICE" on Figure 5.7 was added for additional feature of thesis work, can be helpful for learning internal structure of heart in medicine universities for educational purposes.

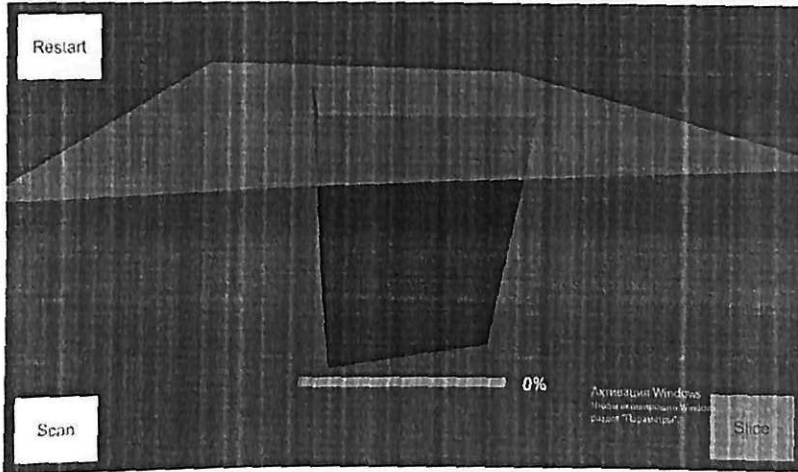


Figure 5.4: Starting interface of simulation of scanning

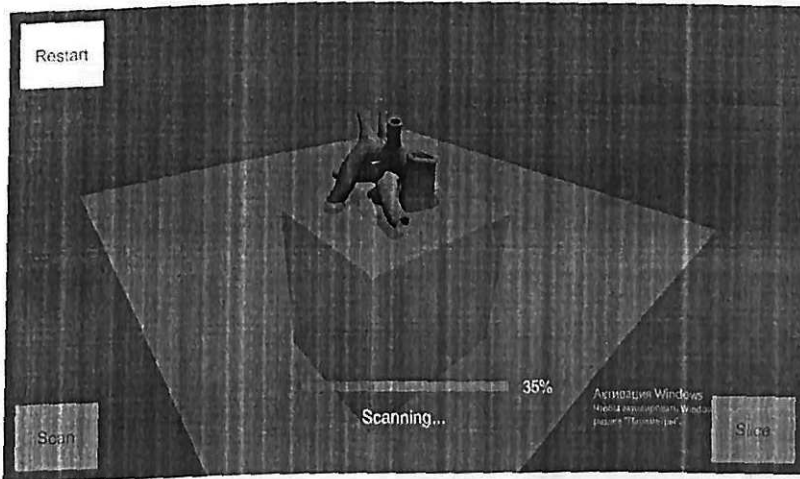


Figure 5.5: 35% of simulation of scanning of 3D model of human heart

The most time was spent for creating a 3D heart model that you can trust. 3D heart in thesis is accurate, and as you can see, visually beautiful. The model was developed using manual method on Blender software. The animation was rigged on Blender software. Application interface and simulation process of scanning was developed on Unity 3D game-engine platform.

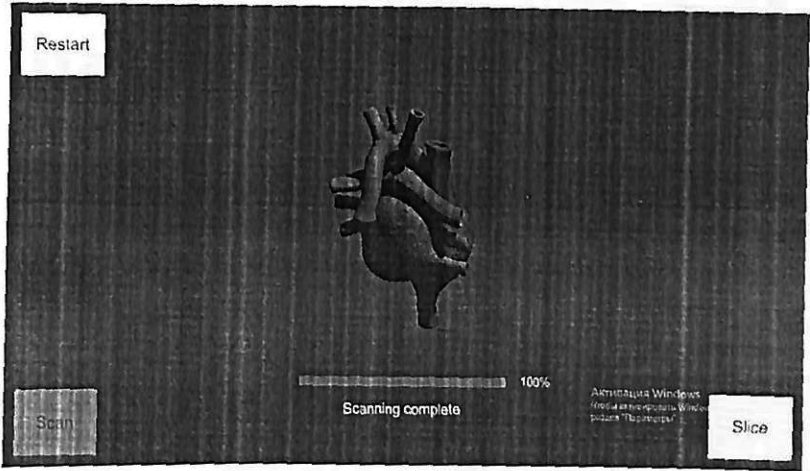


Figure 5.6: Slicing 3D heart for full learning



Figure 5.7: Sliced part of 3D model of human heart

6. Conclusion

The thesis work presents a method for creating, scanning and segmentation of a 3D model of the heart in the simulated time mode using the Unity 3D game engine system to increase efficiency and a friendly interface. A three-dimensional model of the human heart was modeled using the Blender software, which, in the course of the analysis, revealed the easiest and most accessible efficiency in achieving the set task. A modified simulation method for scanning and segmentation of a three-dimensional object has been developed, which is also recommended for further use. Based on the technology and taking into account its features, a simulation window interface was developed and tested, demonstrating the operational possibilities of implementing the application as outputting the necessary information about the structure of the scanned internal organ. The analysis of the most suitable platform for the implementation of the product by features, functionality and efficiency. The game engine Unity 3D was chosen. During the thesis, the existing methods of creating, scanning and segmentation of the 3D heart model in the simulated time mode were studied. For the final verification of the application, three different assessments were performed. First, the possibilities of accurate modeling of Blender 3D were evaluated. After that, the possibility of implementing the simulation process was verified, with all the features involved. Finally, an experiment was conducted to test the system as a whole. As a result of testing data that depends on the correct three-dimensional model, and comparing with the reference patterns in the database, the developed method turned out to be effective. Even if the data provided by the simulator is not completely reliable, since some sections may not be detected, the proposed set of functions and the algorithm provide a good overall accuracy.

Further work on the problem of diagnosing cardiovascular disorders can be carried out in several directions:

- increase the speed of the application,
- the database can be expanded to include a full stock of disorders and deviations from the norm,
- to improve the quality and detail of 3D models for scanning,
- in addition to this, the simulation system can also be expanded for a more advanced level of diagnosing the internal organs of a person;

This will provide additional flexibility and freedom to the user in medical and educational practice and facilitate the use of three-dimensional models, including sections, which will be recognized by the simulating system.

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