Digitization, scanning, and reverse engineering technology for creating 3D virtual space

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Abstract. The article describes digital technology. The stages of digitization, scanning, reverse engineering, 3d modeling, prototyping, and rendering are described. The software used is described. The illustrations of the project for rendering a motorcycle are attached. The work is of practical significance. The publication contains links to programming and procedure descriptions. The illustrations show the actual execution of the project. The formation of new physical quantities of a motorcycle is described. The simulation process is shown. New aerodynamic properties of motorcycles are revealed. The purpose of various file storage formats, cloud storage, and prototyping formats is described. The procedures for exporting files are specified. The scientific novelty is the description of the optimal technological process, using a minimum set of software tools, selected file formats, architecture for storing information and technical documentation, including drawings, including drawings and 3d models.

1. Introduction
Understanding (feeling) of three-dimensional space in a person is associated with the coordination of movements in space, in an ortho-normal (vector) coordinate system. For example, the human brain can't determine how many centimeters an object is long. Taking an object in your hand, for example, a chess piece (the figure of the Bishop-Queen), a person can not give its size or weight. In the physical world, a person's estimate of size and weight will be inaccurate (approximate). In 3D space, a person immediately falls into an ortho-normal (vector) coordinate system (ORT). ORT is the length that is recognized as a unit of measurement. For example: an ORT can be one centimeter, one kilometer, or one cell of a notebook leaf, etc. In 3D space, a person sees the size and set weight of an object. When objects of the material world are transferred to 3D space, the person additionally receives accurate information about the object. The transfer of objects of the material world to digital space is possible using computer technology. Reliability of information is achieved by high quality digitization of objects. 3D virtual worlds are formed from 3D images. Visiting 3D virtual museums, exhibitions, panoramas, and libraries is becoming especially popular. Digitization technology begins with determining the size of an object. Depending on the size of the digitization object, a selection of digitization hardware and software is made. Depending on the complexity of digitization, different types of scanners are used. Digitization technology starts with scanning. To digitize an object, you need to use 3D-scanners.
2. Theoretical framework
Digitization technology starts with scanning. To digitize an object, you need to use 3D scanners. Depending on the size of the digitized object, the technical specialist selects the scanner. Objects of any complexity are digitized using three-dimensional scanning technology. When writing this study, the following methods were used: measurement, description, modeling, and digitization. The digital world is formed from 3D prototypes of digitized scanning objects. Initially, the digitized objects are stored in the form of point clouds. 3D scanners provide high scanning accuracy. 3D scanning technologies allow you to digitize any surface and create an interactive 3D model. The importance of the digitization process is to preserve the image as an interactive 3D model. Modern 3D scanners provide high scanning accuracy.

3. Results and discussion
Consider the following processes: 1 - scanning, 2 - digitization, 3 - reverse engineering and placement of 3D - objects in digital space, 4 - prototyping. The main digitization equipment is cameras and a projector. During the scanning process, the image obtained from cameras in different planes is combined (combined into one). The result is a 3D copy of the object that matches the original. To perform a scan, you need to determine the technical parameters of the object. Additionally, we use hand-held scanning devices from Artec and Creaform companies, as well as domestic RangeVision scanners. The object parameters are: width (x-axis), height (y-axis), and depth (z-axis). When digitizing, all axes have an orthonormal coordinate system.

3.1. 1st process - The scanning process
The scanning process begins with placing the scanning object (object) on a flat surface. A technical specialist performs calibration-setting the accuracy of measurements. 3D scanning of medium-sized objects is optimally performed in manual mode. The scanner has its own software. The scanner used is Range Vision Spectrum, ScanCenter NG.

3.2. 2nd process - The digitization process
The digitization process involves saving the point cloud of the scanned object in various file storage formats. The point cloud is saved in several file storage formats at once, such as the OBJ file format. OBJ is a geometry description file format developed by Wavefront Technologies for their Advanced Visualizer animation package. The file format is open source and has been adopted by other 3D graphics application developers. It can be exported/imported to e-Frontier's Poser, Maya, XSI, Blender, MeshLab, Misfit Model 3D, 3D Studio Max and Rhinoceros 3D, Hexagon, CATIA, Newtek Lightwave, Art of Illusion, milkshape 3d, Modo, Cinema 4D, Zanoza Modeller, PC LIRA, Mineways, etc. For the most part, this is a generally accepted format. The OBJ file format is a simple data format that contains
only 3D geometry, namely, the position of each vertex, the relationship of the texture coordinates to the vertex, the normal for each vertex, and the parameters that create polygons. https://ru.wikipedia.org/wiki/Obj. To create a prototype of a digitized object (item), use the STL format. Using this file format, it is possible to export a file from digitization programs to a simulation and reverse engineering program, followed by Prototyping. The methodology for exporting files is described on the website https://www.cubicprints.ru/blog/post/export-3d-modeli-v-STL-format, includes performing the following operations:

1. St STL SolidWorks SolidWorks SolidWorks Autodesk Inventor (mechanical desktop);
2. In The SolidWorks Student Design Kit (In The SolidWorks Student Edition);
3. Export to STL from autocad;
4. Autodesk 3ds Max (3D Studio Max);
5. SketchUp program;
6. Blender;
7. Rhinoceros (Rhinoceros 3D);.
8. Professional engineer;
9. COMPASS-3D;
10. Solid Edge ST6-ST8;
11. Zbrush Programs. Format export obj https://sites.google.com/site/raznyeurokipoinformatiki/home/opengl-s/zagruzka-formata-obj. Storing the point cloud in various formats makes it possible to model it.

![Figure 2. Digitized object.](image)

### 3.3. 3rd process - Reverse engineering process and placement of 3D-digitized objects in digital space

Reverse engineering is the reverse engineering of the missing part of an object. Modeling completion of the missing part of the object is performed on a computer, software the Result of reverse engineering is a drawing or 3D model. The reverse engineering process is performed in the Blender program. Geomagic Design X is used for reverse engineering.

Modeling of motorcycle structural elements is performed in the 3Ds Max software. For example, to improve the aerodynamic properties of a motorcycle, the streamlined surfaces of the front part of the motorcycle wing(part) are modeled. A part prototype is created. Aerodynamic properties are tested on it. The ANSYS Discovery Live software simulates physical processes. New aerodynamic properties of the motorcycle are revealed [1], [2].
3.4. 4th process – Prototyping
Prototyping a motorcycle part is an industrial design. Customizing motorcycles is a new direction in prototyping. The motorcycle gets new parts that are considered exclusive. Motorcycles with new parts have new properties (speed, weight, maneuverability, aerodynamics, stability, strength). The rendering of a new motorcycle is designed depending on the goal. Rendering — English rendering — "visualization") is a term in computer graphics that refers to the process of obtaining an image from a model using a computer program. Learn more at https://coremission.net/gamedev/chto-takoe-rendering/. Rendering allows you to create new motorcycle parts depending on the goal. For example, to increase the speed of the motorcycle, it is planned to form new streamlined forms of the front wing of the wheel. Calculations are performed in several ways: the first - calculations are performed in parallel – multithreaded rendering, on multiple processor cores; the second - single – threaded-calculations are performed on a single thread synchronously. Further details on the link https://coremission.net/gamedev/chto-takoe-rendering/.
As a result of rendering, new forms of motorcycles are designed, with new physical properties (speed, weight, maneuverability, aerodynamics, stability, strength).

4. Conclusions
In conclusion, it should be noted that it was sufficient for the project to use: Geomagic Design X - for reverse engineering, ScanCenter NG - for scanning and matching scans in 1 object, to conduct modeling and rendering in the 3Ds Max program, then use the software-ANSYS Discovery Live to simulate physical processes. The full technological process can be found at the link https://drive.google.com/drive/folders/1vPROi4w6bviVIAeZvZPtkGm9IDMNYyWIK?usp=sharing

Russian scientists suggest using technologies in the educational process [4]. Issues of digital processes were considered in the works of the team of authors [5], [6]. Additionally, studies on digitizing the audio signal into a digit are proposed for calculating the Doppler frequency [7]. Additional calculations of the Doppler frequency will allow you to detect changes in speed when approaching and removing the object relative to the reference point. Joint research by scientists allows us to bring the rendering process to a new modern level.

We worked on the project:

- The rendering process was completed by the «Umatex Research Center».
- The main task of the IT- project was the development of the body kit.
- Executor of the project - "Project center "Children's Technopark", Russian state social University (RSSU), Moscow.
- The work was carried out under the guidance of V. K. Ganshin. - head of «"Project center "Children's Technopark"».
- The design of the body kit (shed, body ) and its 3D-modeling was carried out by the master of the 1st course, the direction of training "Software Engineering" - Bakin M. A.
- The digital cloud is formed by a training master, a 4th year student, the direction of training "Software Engineering" - Karmitsky K. S.

More information about the "Project center "Children's Technopark", Russian state social University (RSSU), Moscow. can be found at the link: http://technopark.rgsu.net/.

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