Results of application of 3D technologies for modelling the terrain of cutting areas in the North-Western Federal district of the Russian Federation

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Abstracts. The article discusses the use of 3D technologies for modeling the terrain of cutting areas in the North-Western Federal district of the Russian Federation. The technique of obtaining three-dimensional terrain maps, the translation of laid out maps into a vector format using Autodesk 3ds Max® software and the Terrain® tool is described. The preparation of the created 3D models for processing by a CNC milling machine using the ArtCam® software (ASCII STL text file format) is presented. The results of milling processing of the surface of the frame are presented.

1. Introduction
The terrain of the cutting areas during wood harvesting operation determines the principles of organization of cutting operations, which, along with the choice of a Park of forestry machines [1, 2], is especially relevant recently in connection with the difficulties of developing the leased forests in the North-Western Federal district of the Russian Federation [3]. The terrain of the leased forests determines the planning of work for a long period [4], drawing up work plans, tracing forest roads, choosing the types of forestry machines, construction of temporary and permanent forest roads, and other structures. The construction of technological schemes also depends on the terrain.

The terrain is evaluated according to a number of criteria, the main of which for loggers are:
1. average slope of the territory of the leased forests,
2. river flow rate,
3. number and location of irregularities in the surface of the earth.

Many cutting areas in the North-Western Federal district of the Russian Federation combine the features of a plain and hilly terrain, hilly and mountainous terrain (micro-elevations, small wetlands, swampy areas, and biotopes). Largely, the relief also affects the construction and operation of skidding roads, which are built without excavation. The relief of the cutting areas globally determines the choice of the spatio-temporal structure of logging production, control, and management of technological processes.

1.1. Problem
The software interface of the geolocation systems of modern forestry machines is not informative (figure 1), has a 2D model at the base of the presentation, the software is expensive, requires the installation of additional equipment, and does not visually display the terrain [5]. In addition, as a
result, it is not actively implemented among the region's loggers, despite the high demand from industry representatives.

![Image](https://via.placeholder.com/150)

**Figure 1.** The software interface of the geolocation systems of modern forest machines.

### 2. Methods and Materials

2.1. **Solve the problem. Creating a 3D digital 3D model of the terrain**

A method for processing terrain data for a given topographic survey.

According to a given map of the area (figure 2), a 3D model of a fragment of the earth’s surface (North-Western Federal district of the Russian Federation) was made, which in appropriate proportions displays all the features of the relief, elevations, and folds of the area. Existing alternatives [6] now have not found wide application due to the high cost and complexity of obtaining the source data.
Figure 2. Area of the North-Western Federal district of the Russian Federation, scale 1:50 000.

The simulated fragment of the map of the area shown in figure 2 is shown in figure 3.

Figure 3. Simulated map of the area. Scale 1: 50 000.
2.2. **PC 3D modeling with Autodesk 3ds Max® software**

Additional digital information and cadastral surveys were not used. The reconstruction of the earth’s surface of this plot was carried out along the relief lines from the map markings.

The first thing to do is translate the scanned map fragment into a vector format. To do this, all the terrain lines on a given map fragment must be converted to vectors, or polylines. To convert a raster image (scanned map) into vector lines, you can use any of the available vector graphic editors: Autocad®, Coreldraw®, Illustrator®, or the built-in vector tools in any other graphic or engineering programs.

Closed vectors were drawn along all terrain lines, describing a section of the surface curvature at different heights. Further, to obtain a 3D surface of the relief map, it was necessary to arrange these vectors proportionally to the height at which the slices corresponding to these vectors are in reality.

It is important to note that for the convenience of work, so that there is no confusion in the dimension, a digital layout was created in the size of 1 × 1 with a terrain plot.

After placing each slice to the corresponding height, the vectors could be combined into a closed curved surface, forming a 3D model of the terrain. This process can also be done in many 3D editors. For simplicity, Autodesk 3ds Max® software and its Terrain® tool were currently used for simplicity (PC simulation results are shown in figure 4).

![Figure 4. Computer model of the relief.](image)

Implementation of modeling on 3D equipment on a CNC milling machine.

Based on the obtained 3D model of the terrain, a program for its milling by material (or a 3D printing program) was created on a CNC milling machine.

The simulation plot is shown in figure 5.
Figure 5. The part of the computer model of the relief.

The created 3D model must be prepared for the processing process with a CNC milling machine. To do this, export the model from the CAD program (Computer Aided Design System) to the Cam program intended for the preparation of control programs for CNC milling machines, focused on the use of computers. In this situation, it was decided to use ArtCam®, as this program is mainly aimed at 3-axis machining of complex artistic terrain. The choice of ArtCam® was recognized as optimal due to the complex high-poly relief surface.

To import into the Cam program, the 3D model is exported in stl (stereolithography) format. The rationale for choosing the stl format is a file format widely used for storing three-dimensional models of objects for use in rapid prototyping technologies, usually by the method of stereolithography. Information about the object is stored as a list of triangular faces that describe its surface, and their normals. An STL file can be text (ASCII) or binary [7]. For modeling, the text format ASCII STL is used.

2.3. 3D modeling process
After importing into ArtCam®, the relief surface is converted from a triangulated surface to a gradient height map. Such a height map is a color information about the relief, where higher elevation points are displayed in white, and as the height of the point decreases, the color tends to black. The computer displays such a map in a 2D view as a black and white image, and in a 3D view, we can observe a three-dimensional layout.

Milling is created on the surface of the height map. The task of modeling is to calculate the trajectories of the milling cutter in such a way that, with its passages, it describes the curved surface line by line and accurately, while layer by layer cutting off the unnecessary thickness of the workpiece.
The following material with the specified parameters was used as a workpiece: sheet plywood, 12 mm thick, 70 × 70 cm in size (length × width), glued in a stack of 3 layers (total total workpiece thickness was 36 mm).

Two types of milling cutters were used for processing: roughing was carried out with the help of an end two-entry milling cutter with a ball diameter of 10 mm, with a step of 4 mm. On a layer in 6 layers. The second stage of processing was finishing milling. It was made by a spherical mill with a diameter of a sphere of six mm. Processing was carried out line by line in one layer with a step of 0.6 mm. After milling, a small finish was required to sand the mold and polish it. It is worth noting a feature that became visible after processing the layout - relief maps coincide with dark stripes of glued veneer layers along the line. This gave the layout additional volume and clarity.

The results of modeling the terrain are presented in figures 6–8. 3D-model of the relief of the selected area (Scale 1: 4000, Side view) is shown in figure 6.

![Figure 6. 3D-model of the relief of the selected area. Scale 1: 50 000. Side view.](image)

3D-model of the relief of the selected area (Top view) is presented in figure 7.
3. Results and Discussion
The simulation results suggest that the visual representation of the terrain of the harvesting area is more informative in volume, ecological, which makes it possible to more efficiently plan the technology of logging in the phase of planning forwarding roads, developing routing of skidding, choosing equipment and technology depending on the slope of the terrain (up to 45° rationally the use of modular equipment for harvesting wood, with slopes of more than 45° it is necessary to use

Figure 7. 3D-model of the relief of the selected area. View from above.

3D-model of the relief of the site (Frontal view) is presented in figure 8.

Figure 8 3D-model of the relief of the selected area. Front view.
alternative types of technical solutions) [8], as well as whole and formulate his optimal strategy more reliably [9].

Using the results in conjunction with the forestry machines software [10, 11] in the North-Western Federal district of the Russian Federation [12, 13] will allow more fully use the functionality of the programs for positioning forestry machines [14, 15], namely:

- **Travel log and apiary border.** The harvester leaves a track on the map, which, for example, allows the forwarder to track the route of the forestry machine. The apiary border can be displayed on both sides of the machine line, where the working range of the boom of the hydraulic manipulator is visible. The use of 3D models will allow for more optimal tracing of the forwarding roads.

- **Alarm.** If the forestry machine enters a special zone (micro-elevations, waterlogged areas, key biotopes), acoustic and light alarms are activated. The operator on site defines special zones.

- **Drawing (notes).** The operator has the ability to display the topography of the cutting area in the most complete way, as well as plot additional details on the map using points, lines, shapes and text.

- **Harvesting.** The system can import blank files created on board the forestry machine and display them on the screen. Billets on the site can be displayed by selecting any area on the map.

- **Visibility.** The 3D image of the relief (3D-model), unlike the 2D-model, allows you to more elegantly present the terrain to the operator, which will avoid overturning the forest machine on terrain not suitable for development.

- **Planning.** More optimal planning of tracing of forwarding roads, whiskers, loading points, culverts.

In general, taking into account the topography of the logging area determines the choice of the spatio-temporal structure of logging production, control, process control, etc.

4. Conclusion
Volumetric modeling of geo-informational relief data of the territory of forest exploitation on the basis of 3D-technologies allows us:

- more clearly increase its initial representation to the decision maker (DM)
- more efficient planning of logging production technology for a long period
- more efficient tracing of forestry roads,
- more efficient choice of forestry equipment and technological schemes for the development leased forests.

The results can support logging companies of the North-Western Federal district of the Russian Federation for more efficient development leased forests.

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