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Interactive Geoinformation Three-Dimensional Model of a Landscape Park Using Geoinformatics Tools

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***Abstract*— The relevance of work is due to the lack of free three-dimensional models of landscape parks and the urgent need to create such models for informing and barrier-free adaptation of users. The current state of cartographic support of landscape parks is low and does not meet users, management, and employees of parks. The object of research is the territory of the multicomplex. The purpose of the research is to develop a three-dimensional model of the regional landscape park for informing and barrier-free adaptation of residents and guests of the city using geoinformatics tools. The methods used in this research are general scientific (system analysis, modeling, higher mathematics) and special methods of mathematical and geoinformation analysis. The work uses the ArcGIS and SketchUp software platforms to create, manage, integrate, analyze, and distribute spatial data. Methods used: geodesy, topography, geoinformatics. The results obtained in the course of the work are of practical importance, are real and tested by the management of the regional landscape park. An interactive three-dimensional geoinformation model implemented in the ArcScene software environment will provide an opportunity further to manage the territory of the regional landscape park. An interactive geoinformation three-dimensional model ensured a 12% increase in the level of informational and barrier-free adaptation of residents and guests on the territory of the multicomplex. The prospects for further research on the creation of a mobile application for park visitors with the ability to search for the nearest bus departure point at their location are determined.**

***Keywords*— interactive geoinformation model; geoinformatics; data analysis; spatial features; geodatabase; vectorization; ArcGIS; SketchUp; geodetic support; cartographic basis.**

I. INTRODUCTION

Today, three-dimensional modeling of not only buildings but also their surrounding territories is becoming increasingly popular [1]. These models are perceived not only as visualization of spatial objects, but they also contain an essential information base, which serves as the basis for analysis, research, and identification of further prospects for the development of the territory or its part.

Three-dimensional models of territories are created using geoinformation technologies. Used the cartographic basis of the area, taking into account the coordinate reference. This approach ensures the exact correspondence of the created model to real spatial objects. The proposed technology realizes the possibility of simultaneous work with both cartographic and analytical geodatabases.

The model implements the help system functions, which facilitates navigation in a massive flow of information. It selects individual blocks of information according to the proposed requests, provides cartographic and three-dimensional modeling tools for further spatial analysis [2].

In the electronic geodatabase of the spatial model, many information sources can be combined, making it easy to compare various information. For example, to understand what underground utilities lie on a particular plot of land, it is necessary to comprehend engineering schemes, which requires considerable time. The information is easily perceived and clearly displayed using a geoinformation three-dimensional model.

Three-dimensional representation of objects in the selected area provides new opportunities and allows user to solve such applied problems [3]:

- Creation of three-dimensional visualizations of the landscape of the territory, urban planning environment and infrastructure,
- Planning of the development of territories, preliminary design of various options for the development of the territory in real-time,

- Conducting landscape analysis, assessing the altitude characteristics of objects and the interaction of objects with each other and with the environment,
- Analysis of spatial data in volume and presentation of the analysis results in a convenient form for perception.

Today, one of the main trends in the world market in the field of design is the transition from two-dimensional design to three-dimensional modeling and the introduction of three-dimensional geoinformation systems [4], [5]. Scientific publications [6]–[15] are devoted to creating three-dimensional models of territories. However, in these works, the results obtained have no experimental confirmation and require additional research, for example, by using geoinformation analysis or other methods of geoinformatics.

The relevance of this work is due to the lack of free three-dimensional models of landscape parks and the urgent need to create such models for informing and barrier-free adaptation of users. The current state of cartographic support of landscape parks is low and does not meet the requirements of users, management, and employees of parks.

The object of research is the territory of multicomplex (http://feldman-ecopark.com). The subject of the research is the methodology and tools of geoinformatics. The purpose of the research is to develop a three-dimensional model of the regional landscape park for informing and barrier-free adaptation of residents and guests of the city using geoinformatics tools.

A. Problem Statement

Several tasks need to be addressed, given the purpose of the work:

- To analyze the existing three-dimensional models of landscape territories abroad and in Ukraine,
- Identify the features of the type of the earth's surface and the territorial location of the regional landscape park,
- To find out the conformity of the initial geodetic support to the established requirements for the formation of quality mapping support,
- To carry out the analysis of the initial data necessary for the development of a three-dimensional geoinformation model of the regional landscape park,
- Develop a geographic database of the regional landscape park, vectorized thematic layers, and add attribute information to each of the thematic layers,
- Develop a digital terrain model, a TIN model, and three-dimensional spatial object models,
- Integrate a digital terrain model and three-dimensional object models to obtain a three-dimensional geoinformation model of the regional landscape park.

To create a geoinformation 3D model of the regional landscape park, people need to use map material, object photos, and information about aviaries, buildings, and other spatial objects as source materials.

The work used a set of source data, includes:

- The master plan of the regional landscape park, executed at a scale of 1:500 in 2018 and provided by the engineer-builder.
- The territory elevation data of regional landscape park, provided by the engineer-builder (DWG file).
- Regional landscape park territory photographs obtained with the aid of a crewless aerial vehicle, provided by the engineer-builder. Animal photo cards are provided by the engineer-builder and obtained from the official site.
- Animal information is obtained from the official site.
- Terrain map downloaded from ArcGIS Online.
- Tools: ArcGIS, SketchUp.

B. Review of the Literature

Having analyzed the existing three-dimensional models of landscape territories, as well as the availability of interactive cartographic materials for the most popular landscape parks abroad and in Ukraine, the following results were obtained. No analogs were found regarding the planned development of a three-dimensional model. On official websites [16]–[24] where maps and models are presented, there is no description of software tools and techniques with which these objects were developed.

Analyzed maps and models have several disadvantages (schematic, conditional; two-dimensional; without coordinate reference to the terrain; attributive information is missing or not enough; the interactivity of the card is partial or absent; it is impossible to imagine the terrain, the size of the park, features of vegetation, lay a route, measure the distance, distribute your time).

Only two maps from the entire sample provide an overview of 360 degrees, which is very useful for people with special needs [17], [21]. The sample for analysis is much larger than that given in research. Landscape parks are not provided with cartographic materials or have only a map with a marked location.

When designing the proposed three-dimensional model of the multi-complex, options are provided for eliminating the existing shortcomings.

1) From the point of view of the user:

- A virtual trip to the park, which is very important for people with special needs and people who are not able to come to the city,
- On-line familiarization with the features of the relief, hydrography, vegetation, animals, spatial features located on the territory, as well as with attribute information about the objects,
- Laying routes, measuring distances, planning the time to visit the park,
- Familiarization with the activities that are planned,
- Quick adaptation and navigation are provided by the spatial reference of the model to the coordinates on the ground.

2) From the point of view of workers and park management:

- Solving environmental issues,
- Tracking the dynamic processes of natural spatial objects,
- Maintaining a database and updating animal information,
- The solution of issues of resource management of the Ecopark territory,
- The organization of tourist routes throughout the territory,

- Rational use of the regional landscape park territory,
- Planning new buildings in the park.

3) From the point of view of the developer: the formulation of a methodology is used for the development of three-dimensional models of landscape parks.

Thus, while working with the interactive geoinformation three-dimensional model of the regional landscape park, the user should: be able to move in any direction; zoom in or out spatial features; get acquainted with the list of animals living on the territory; research the infrastructure (parking lots, office buildings, commercial institutions, playgrounds, the location of vending machines for food and drinks); get acquainted with the terrain; get acquainted with the types of pavement.

II. Material and Method

The results on the study of the landscape park and the analysis of documents provide an opportunity to get acquainted in detail with the object of work. It is necessary to prepare the initial data to begin the development of a three-dimensional geoinformation model of a multicomplex. To create a three-dimensional environment using the original database. Geoinformation data. Two-dimensional spatial geoinformation data obtained by vectorizing the topographic plan of the territory is used to determine the projection sizes of the created three-dimensional objects and their location in the final model of the territory.

Photos of objects are located in the territory of the regional landscape park. It is necessary to use ground photographs to display the real texture of three-dimensional objects. Image data is used as the primary source of digital texture information. The tools are ArcGIS and SketchUp. Map of research area downloaded from the ArcGIS Online resource [25].

Photographing objects must be performed not only from the surface of the earth but also from crewless aerial vehicles. Three-dimensional objects and photo textures during the preparation of the three-dimensional model at the pilot project stage, the territory was conditionally divided into two sections: the territory of the detailed research of three-dimensional objects; adjacent territories (region of a rough three-dimensional model of objects). The first section includes open-air cages and office buildings for more detailed geometric models that are prepared, used for texturing. For the second site, a characteristic feature was the lack of buildings and the presence of a large number of trees.

Creation of a geographic database provides: creating sets of feature classes; creating a raster dataset; definition of data types for fields, the substitution of domains and creation of subtypes; determination of the relationship between spatial data by creating a geodatabase schema in the Access tool (Fig. 1); creating topology rules.

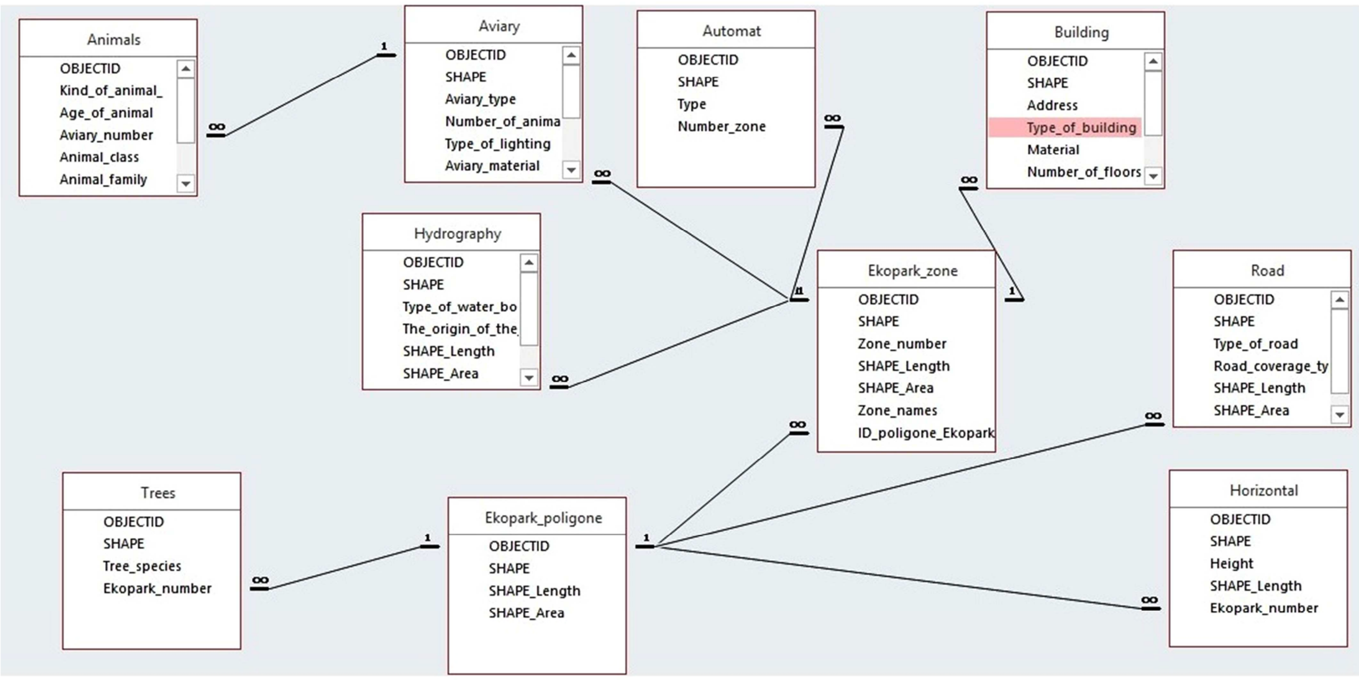


Fig. 1 Geodatabase

The discrepancy between the initial geodetic support and the established requirements for solving the problem is revealed. The recommendations are made to correct errors. The result obtained made it possible to generate cartographic material at the output that complies with the current legislation of Ukraine and established requirements.

The developed geographic database in the ArcCatalog software environment allowed us to provide: feature classes; raster datasets, feature class sets; determine the rules of topological relations. The applied methodology ensured high-quality and accurate work with spatial objects of the regional landscape park.

Vectorization of features and filling in attribute information is using the ArcMap application of the ArcGIS software platform. Vectorization consists of creating vector layers and applying terrain objects in points, lines, and polygons. Vectorization is the main stage in the process of developing a digital map (Fig. 2).

Vectorization of thematic layers and addition of attribute information in the ArcMap software environment made it possible to obtain data on the configuration, location, and attribute information for each spatial object of the regional landscape park.

The spatial features were vectorized:

- Classe “Hydrograph” has 5 objects,
- Classe “Aviaries” has 120 objects,
- Classe “Ekopark_poligone” has 1 object,
- Classe “Ekopark_zone” has 4 objects,
- Classe “Parking” has 6 objects,
- Classe “Road” has 56085.45 m2,
- Classe “Trees” has 2518 objects,
- Classe “Automat” has 10 objects,
- Classe “Horizontal” has 871 objects.

Topology rules provided an opportunity to check the quality of vectorization; no errors were found.

The fourth step is to create elements of a geoinformation three-dimensional model using the ArcScene application of the ArcGIS software platform and the SketchUp tool. There are several ways to create 3D vector data using the ArcGIS software platform.

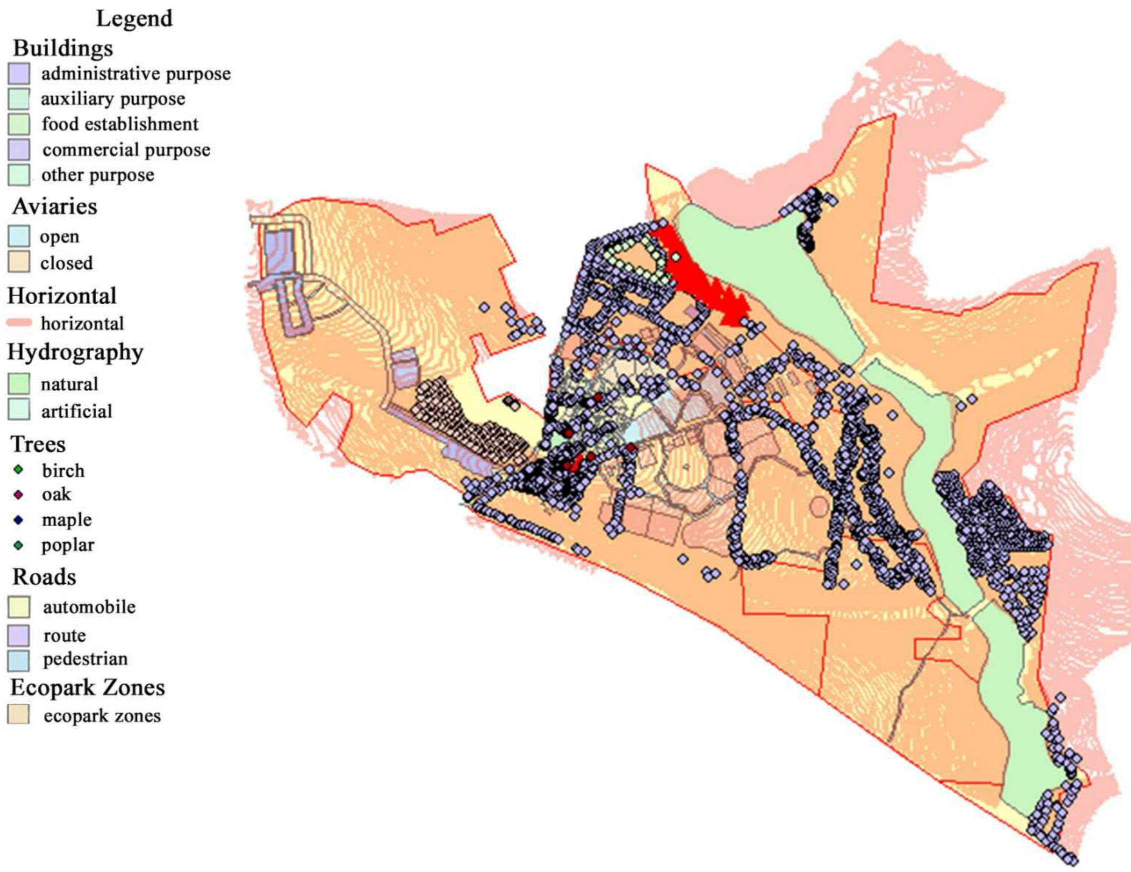
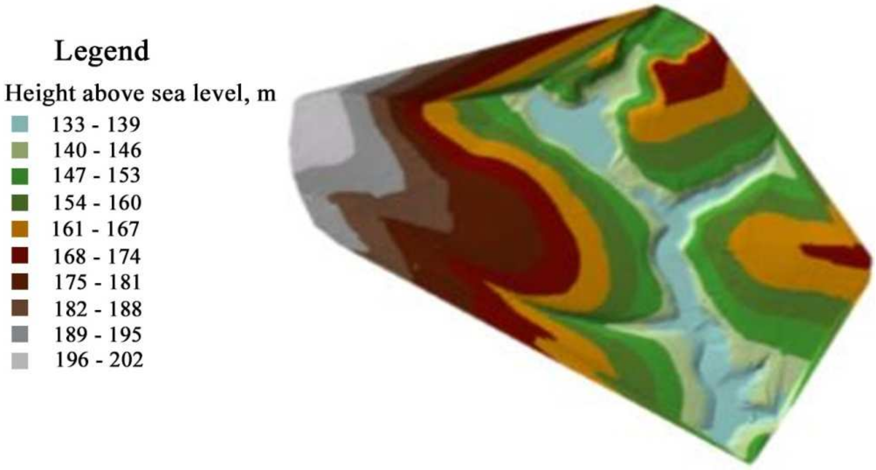


Fig. 2 The result of the vectorization of spatial features of the park

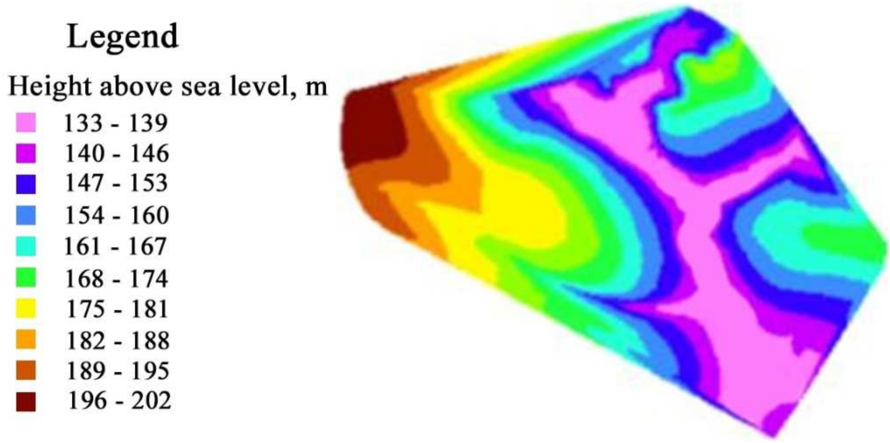
For example, a person can create a feature class that contains Z values and use interactive three-dimensional editing tools to create new features. It is possible to import a set of ready-made three-dimensional models from other formats into multipatch feature classes or convert two-dimensional vector data into three-dimensional using a functional surface, attributes of spatial objects, or a constant value. Three-dimensional spatial models are imported from the SketchUp software environment in. skp format.

A digital elevation model can be obtained using various modern information technologies of geoinformatics [26]. GRID and TIN models are widely used in geoinformation systems and are supported by many types of ArcGIS software. Therefore, it is necessary to take into account the advantages and disadvantages of each model. Let us analyze the formats for representing spatial data GRID and TIN using the example of the territory of the regional landscape park (Fig. 3a and Fig. 3b).

The advantages of the GRID model: GRID nodes on the flat areas will have the same elevation values; the raster type of graphic data allows users to get a smooth surface without sharp edges and protrusions. However, on sections of steep slopes, the pitch of the elevation grid is large. Therefore, the spatial resolution of the model is insufficient to display the “plasticity” of the relief.



a)



b)

Fig. 3 Model of the territory of the object: a – TIN model; b – GRID model

The disadvantages of the GRID model are that GRIDs take up more computer memory than TIN models. Advantages of the TIN model: in areas of steep slopes, the surface is displayed in numerous small triangles, which makes it possible to capture the "plastic" of the relief; more efficient use of computer memory resources to store the model. The disadvantages of the TIN model arise where all the vertices of the triangle lie on the same horizontal. The appearance of such morphological artifacts violates the morphography and morphometry of the relief model and reduces the accuracy and quality of the model itself and its derivatives. The TIN model is better perceived visually [26], is more accurate and takes up less computer memory.

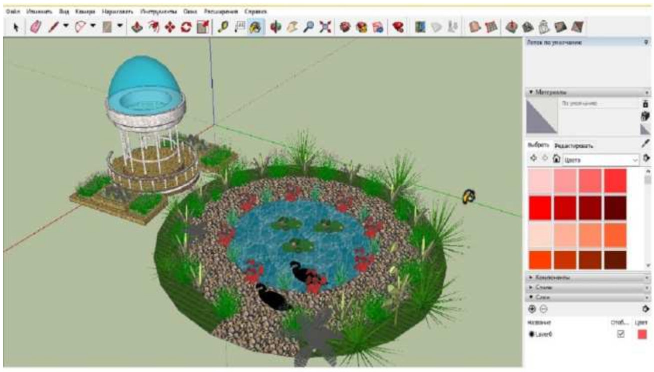


Fig. 4 Window view of creating features

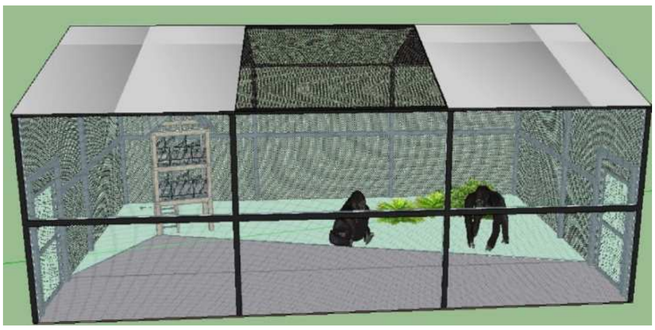


Fig. 5 Spatial object (aviary "Monkeys")

III. Results and Discussion

A. Experiments

The result of the analysis of digital terrain models, TIN models, and GRID models provided the choice of an accurate digital terrain model that is suitable for solving the task. Put the attached satellite image downloaded from the SASPlanet resource [27] onto the TIN surface and turn on the layer display. It can be developed three-dimensional models of spatial objects using the SketchUp software tool (Fig. 4 – Fig. 6).

Fig. 6 Spatial object (aviary "Orix")

Three-dimensional models are importing into the project of the ArcScene software application of the ArcGIS software platform. Three-dimensional spatial objects are transforming into multipatch objects (to obtain a three-dimensional model of the territory). Multipatch objects are replacing with the developed three-dimensional models of spatial objects (created using the SketchUp software). The results of the developed geoinformation three-dimensional model in the ArcScene software environment are shown in Fig. 7.

B. Results

When working in the ArcScene software environment, the following problems arose: three-dimensional models of spatial objects overloaded the hardware of a personal computer, which significantly slowed down the work and made it impossible to work with a three-dimensional model of the territory. At the fifth stage, it was decided to repeat the creation of a three-dimensional geoinformation model in the SketchUp software.

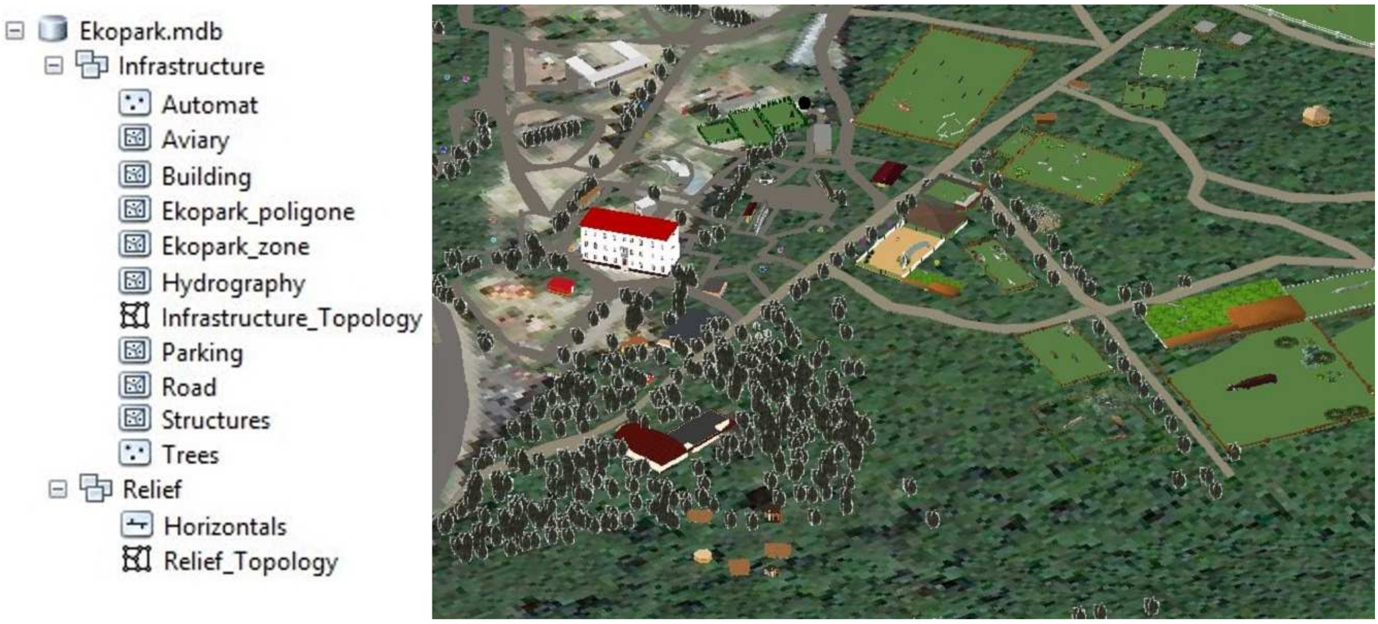


Fig. 7 Geoinformation three-dimensional model of the regional landscape park, developed in the ArcScene software environment

Creating a digital elevation model in the SketchUp software environment involves adding satellite images of the territory of the regional landscape park to the project. Vectorized files are adding from a project created using ArcMap software. After that, three-dimensional models are importing of spatial objects into the SketchUp tool under their location.

The view of the interactive geoinformation three-dimensional model of the selected territory, implemented in the SketchUp software, is shown in Fig. 8. The advantages and disadvantages were assessed of each type of model to ensure the informing and barrier-free adaptation of residents and guests of the city in the territory of the regional landscape park.

Three-dimensional geoinformation model developed in the SketchUp software environment was selected. The geoinformation three-dimensional model of the regional landscape park, created using the ArcScene application of the ArcGIS software platform, can be used in the future to provide the possibility of managing the territory of the object.

The digital terrain model, TIN model, and three-dimensional models of spatial objects provided an opportunity to get a three-dimensional representation of the territory and spatial objects of the regional landscape park. The number of developed three-dimensional models of spatial objects corresponds to the number of vectorized objects.

Fig. 8 Geoinformation three-dimensional model of the regional landscape park, developed in the SketchUp software environment

A comparative analysis of the obtained interactive geo-informational three-dimensional models of the regional landscape park is presented in Table 1. Geoinformation technologies have significantly expanded the boundaries of their applied use [28]. Three-dimensional modeling has become available not only for individual structures and utility networks but also for large enough territories. They found their application in urban planning, urban planning, municipal management, education, landscape design of the park.

TABLE I
COMPARATIVE ANALYSIS OF THE OBTAINED INTERACTIVE GEOGRAPHIC THREE-DIMENSIONAL MODELS OF THE REGIONAL LANDSCAPE PARK

	Interactive geoinformation three-dimensional model of the regional landscape park	
	The software ArcScene	**The software SketchUp**
Type of software	Commercial	Free (except for versions of SketchUp Pro, SketchUp Make)
Ability to record video	There is. Failed to implement due to slow software operation	There is. Implemented in .mp4 format
3D Model Export Formats	.wrl	.3ds, .dwg,.def.,. dae,. fbx, .ifc, .kmz, .obj, .stl, .wrl, .xsi.
Ability to import three-dimensional objects from the library	No	There is

C. Discussion

The paper deals with the main practical aspects of the development of geoinformation spatial models of selected territories, identify the main stages of design, and the problems at each step of creating three-dimensional models. The efficiency of using modern geoinformation technologies to solve several issues applied by introducing geoinformation models on user software platforms is substantiated.

Technology for the development of three-dimensional geoinformation models is proposed using the example of a modern regional landscape park. The main goal of creating such models is to ensure accurate geoinformation and barrier-free adaptation of residents and visitors of the city regarding the research area. Modern research methods are used: general scientific (cartographic, analysis and synthesis, modeling) and special (geoinformatics methods). The results obtained in the course of the work are of practical importance, are real and tested by the management of the regional landscape park.

IV. Conclusion

An interactive geoinformation three-dimensional model involves not only the development of a digital elevation model and three-dimensional models of spatial objects. Also, the research of the territory determining the quality of the cartographic material provided, forming a development methodology, mastering software, as well as determining the source data for the work. The comparison of the developed geoinformation three-dimensional models provided an opportunity to highlight the main characteristics of the developed three-dimensional models and draw conclusions regarding their functionality and use cases.

An interactive three-dimensional geoinformation model implemented in the ArcScene software environment will provide an opportunity further to manage the territory of the regional landscape park. The interactive geoinformation three-dimensional model of the regional landscape park is developed in the SketchUp software environment, has provided a 12% increase in the level of information and barrier-free adaptation of residents and guests of Kharkiv in the territory of the multicomplex. An act of introducing the results of these studies is received.

When analyzing the results, the prospects for further research were identified, for their implementation, it is necessary: Add detailed attributive information to the vectorized layer of spatial objects Trees (age, state), Detail the geoinformation three-dimensional model of the regional landscape park with spatial objects that were not taken into account at this stage of the work; Expand the data of attribute tables, Add tourist routes to the data of the developed geoinformation three-dimensional model of the regional landscape park, Create a geoinformation guide for visitors to a regional landscape park using the Python programming language, Create a mobile application for users of the regional landscape park with the ability to search for the nearest bus departure point, according to their location, Explore the possibilities of managing the territory of the regional landscape park based on the created geoinformation three-dimensional model in the ArcScene software environment.

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