Automation of Spatial Model Creation in GIS Environment

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Summary

Geographic information systems (GIS) are currently under intensive development. Their foundation is built on spatial information, enabling an easier way spatially oriented data processing. This article is devoted to creating solid models of historical sites using the latest methods and techniques for collecting spatial data and its processing and use in GIS. Most geographic information systems (GIS) currently used in practice are based on the use of 2D optionally 2,5 D spatial data. With the rapid development of computer technology and the increasing need for analysis and modeling of real 3D environments, a new generation of GIS known as 3D GIS. 3D GIS are able to like 2D storage, handling, storing, analyzing and generating output data stored in the database, but in the case of 3D GIS data that describe and show 3D objects and phenomena. The paper is a draft application that is designed to integrate into one whole object-oriented programming and the programming language VBA with the formation of spatial models in GIS environment. For display of spatial objects in the programming environment is used ArcGIS data format options MultiPatch.

Keywords: 3D GIS, spatial information processing, spatial models, MultiPatch

1. Introduction

Currently increases the importance and use of solid modeling objects. This helped the development of computer technology, software equipment and in particular the creation of new data models enabling full 3D approach. The transition from two-dimensional to three-dimensional space in computer CAD and GIS systems was a matter of time and today it is possible to create three-dimensional map outputs based on information from two-dimensional nature, all within a single computer system. Currently digitization project of cultural heritage ongoing, which includes the creation of spatial models of objects and buildings.

2. Trends in the spatial models creation

The beginnings of spatial models date back to the 50th-60th-ies of the last century. Spatial models passed a gradual evolution and refinement, which was closely linked with the use of quantitative (statistical) techniques and procedures. They focused mainly on the structural analysis of point, line, area presentations geographic objects, phenomena and their surfaces presented in 2D space model [1]. However, at present placed great emphasis on efficient and most accurate creation of spatial models that describes the reality of the modeled phenomenon. Creating solid models expands in various areas of social life. Their application of spatial patterns found in medicine, automotive industry, in tourism, in the simulation of manufacturing processes and the like. Effective tool for capturing the real fact is a 3D display. Excellent research and commercial offices come every day with the latest applications based not only software products that make it possible to create the perfect 3D display various models. This fact ends the era of presentation in 2D environments.

3D GIS should be able to represent, manage, manipulate, analyze and promote informed choices related to 3D phenomena. The definition of 3D GIS is largely the same as the 2D GIS. In 2D GIS systems are widely distributed and used, are able to

effectively handle most tasks. The same type of system may not be able to handle 3D data when required complex 3D applications.

3D GIS 3D data are badly needed to obtain the necessary information. Such a system is not just a simple extension to another dimension (the third dimension) of 2D GIS. By adding the third dimension to existing 2D GIS requires a thorough examination of many aspects of GIS, including the concepts of representation and modeling aspects of structuring data. Existing GIS software packages are often used as well as understand the use, handling, storage and analysis of 2D spatial data. Capabilities and performance of this software for 2D and 2.5D data are generally acceptable GIS community [7].

The most important part is the process of 3D GIS modeling. Recently, industry has developed a number of different types of geometry and topological models. 3D model can be displayed in TEN (Tetrahedral Network), CSG models, TIN models, 3D layered or topological models, the basic voxel models or 3D polyhedron models. However, the market is limited by the number of appropriate solutions.

Evolution of data modeling for 3D GIS can be divided into two directions. The first is a full 3D approach that directly points to the creation of a data model suitable for 3D GIS. Molenaar [8] proposed FDS (formal data structure) for 3D vector map, which can be regarded as a generalization of 2D versions of FDS. The second direction is based on the terms of the integration of GIS and DMT. DMT became a separate discipline in the 50th 20 years Century [9]. The problem in spatial modeling representations concerns spatial relationships. Egenhofer [10], Kainz [11] and Pigot [12] described a representation of spatial relations between objects in 2D and 3D space based on mathematical foundations.

Regarding the issue of model construction, CAD and computer graphic most software packages provide an interactive tool for manual construction of object models with recognizable boundaries. Handheld design is a laborious method not deal with a large number of objects. For objects with recognizable boundaries there has been significant progress in computational geometry based on 2D and 3D Voronoi tessellation [13], [14] in the construction of TIN and TEN (tetrahedral networks). To question the use of the 3D model was a significant step seen in the other two disciplines using CG technology, specifically CAD and Virtual Reality (VR). Only in recent decades has grown to be 3D GIS discussed in the GIS research community [15], [16]. The development of this particular GIS industry seems to be relatively slow due to lack of administrative data models and data structures, also due to the lack of

a comprehensive theory of object relations and databases for the 3D environment [17].

Rongxing Li [16] and Fritsch [18] believe that 3D spatial modeling, structuring and derive data using object-oriented leads to better 3D GIS. This assumption goes mainly to the complexity of 3D spatial data as well as some of the positive attributes of object orientation, where as each physical or spatial real world object can be defined in the developers' software.

Carlson [19] proposed a model called simplical complex. Use the term 0-simplex, 1-simplex, 2-simplex and 3-simplex to describe spatial object node, line, surface and volume.

Data modeling and structuring of 3D spatial objects in GIS has been so successfully achieved than in CAD [23]. Data modeling in GIS is not only geometric and attributes aspects, but also topological relational data. Topology of spatial data must be addressed in order to determine the relationships and connections between objects. Many other data models have been proposed: SDM (Simplified Data Model) [20] and some object-oriented (OO) models such as OO-model proposed by De la Losa and Cervelli [21], 3D TIN based on OO modeling [22].

A new trend design and final production models of phenomena observed in 3D is a collection of spatial information revolution, which is supported by modern approaches in this area. This approach significantly solves the problem of the quality and quantity of collected input data for creating solid models. The basic assumption of success is based on inputs received in sufficient detail (ie, spatial information). One of the main inputs represent geodetic measurement baseline reference object. Progressive methods are based on terrestrial laser scanning or surveying using GPS and GNSS technologies. Finally, the final form is enhanced by the possibility of conceptual connections through GIS systems (GIS 3D) [2] [26].

Spatial object model can be displayed in three different details:

- Block model, which shows the basic view of the area, for example. buildings are indeed correct height, but not sculpted roof,
- urban model as a block model of the basic shapes of roofs,
- a detailed model includes all the essential details with photo textures.

In the field of spatial models is needed to address a variety of tasks. An appropriate application software product is an integral part. The market is on offer multiple software products enabling the production of spatial patterns.

Currently the most widely used software can include PhotoModeler, AutoCad, Microstation, a simple program Google SketchUp. These programs include import / export tools that allow generated models used in GIS environment.

The integration of the necessary components and different types of objects requires solving the following problems related to the representation of reality spatial models:

Design of spatial models:
- •Design an integrated model or scheme allows the derivation of a single data structure is able to maintain all the components of the geometric representation of real world objects, whether obtained from direct measurement or derivation from the same database. Each geometrical component must be able to represent real world object seen various different authors.

The construction of the spatial model:
- development of appropriate tools and methods for acquiring 3D data,
- transformation of coordinates in the current geo-referenced, if the various components to be included in a single database,
- Development of methods for data structure that combines data from different inputs and from multiple sources into a single database to be maintained in a uniform system for database management,
- a proposal for the organization of thematic classes representation of the real world objects with common aspects of the same category,
- Addressing the uncertainty resulting from disparities between the various data files during the integration process and conversions to notice "data quality" to be delivered to the end user.

Use of spatial models:
- use existing components such as 2D data and DMT, the preparation of these components for inclusion in the higher dimensional model. The objective is cost savings in recurrent data collection for 3D GIS,
- provide additional spatial operators and spatial analysis functions, the development of appropriate graphical visualization to facilitate the selection of appropriate perspectives and views corresponding to the appropriate disclosure of details of objects stored in the database,
- design 3D display cartographic information
- design user interface and query language, allowing users access to integrated databases,
- development of spatial index structure that speeds up data retrieval and storage procedures for the integrated database,

- develop tools to navigate between models stored in the database in different locations and computing platforms.

Maintenance of spatial data:
- design modification procedures, including the development of consistency rules that ensure logical consistency and integrity of an integrated database (especially in the process of updating) [7].

3. Collection methods and data sources used for creating solid models

Collection of spatial information necessary for the formation of spatial patterns is one of time and financially demanding tasks. There are many different sources of geospatial data and based many ways their collection.

In practice, apply two main methods of data collection:
- Direct (direct data collection for the house or on the unprocessed image)
- indirect (based on the data that are available in processed form (eg, maps, statistics, etc..).

Choice of data collection methods depends on the application (deployment) GIS and the types and nature of objects whose data is to be obtained. In any case, the collection of data is sufficiently accurate and complete to the specified application. Set of basic spatial data is a representative result of geodetic application of selected methods for determining the spatial position of the reference object. Geographic information obtained in this case is seen as a means of knowing the monitored phenomenon. Geographic information involves spatially associated information presented by X, Y and Z coordinates. A full-featured score harvest spatial information represent data in digital form, which is the basic foundation for the deployment of 3D GIS. Collection of information, which must result data in digital form, is a key pillar for the use and success of 3D GIS deployed in the area of spatial patterns.

Due to the high demands made on the completeness and perfection of data collection is divided into two main classes namely:
- geometric figures, including topological relationships with neighboring objects
- descriptive and thematic data [4].

According to Pavelka [4] may be the method to obtain the spatial coordinates presented in the following form:
- Digital Photogrammetry (aerial, terrestrial, satellite) – Measuring method enabling modeling in 3D space using a 2D image [28].
- Laser scanning (air, land) - is currently the most

effective method of spatial measurement and three-dimensional (3D) models. It is a non-contact determination of spatial coordinates, with extreme speed, accuracy, complexity and security, work on the principle of spatial polar method [25], [27].

- Triangulations of 3D scanners – to obtain the shape of small objects are devices that typically use a combination of several CCD cameras, laser pointer or other assistive devices.
- Radar Interferometry (air, satellite) – a method that treats two or more radar satellite images used to create a digital terrain model or monitoring deformations of the earth's crust.
- surveying methods (land measurement)
- GNSS (Global Navigation Satellite Systems)
- Special (physical) – Physical Geodesy.

Another source for obtaining geographic information may be:
- satellite records
- historical records
- aerial photographs
- Project documentation
- population data
- reports of research
- ownership relationships
- Economic Indicators
- administrative data
- ground measurements
- Maps [3]

4. Automating the creation of spatial models

Geographic information systems (GIS) in present are under intensive development. Their foundation is built on spatial information, enabling an easier way spatially oriented data processing. It is the integration of different tools that significantly contribute to alleviating the difficulty of processing spatial data. Current trends in GIS can geo-location with the implementation of the spatial coordinates of subjects and their subsequent visualization in different views (2D, 3D). GIS tools offer many techniques that can be applied for imaging in 3D environments. State of the art approaches offer different sizes available (customized data templates) to work with 3D data in ArcGIS environment.

Options to view the data in 3D view in ArcGIS effected through ArcScene. [25] For displaying data there are several options:
- The first one uses 2D data, where example. Altitude value is obtained from the generated terrain model, or can be stored in the table attributes (Base Heights). To view 3D buildings feature Extrusion is used, which is just stretching a 2D

object. In this case, not a true 3D objects, although it appears that way.
- The second method is to use a display model 3D characters point layer. Unlike MultiPatch format displays objects contain no information about the position, represent only the view. For 3D characters can use a standard library or through ESRI software to create this object.
- The third option is to use the format MultiPatch. The object can be created by programming language or use graphic programs such as. Google SketchUp

Problematic part in the body render object type (Solid) is that the body is made up of faces (polygons). His rendering can be implemented as a combination of several areas. This is feasible only if the points forming surfaces will have the same x, y coordinates. Types of vector layers from the point, polyline and polygon Z Z Z do not see objects with the same x and y coordinate that differs from the coordinate. This effectively solves the problem of data format MultiPatch. The only disadvantage of this format is the impossibility of direct editing in ArcGIS applications, but only through programming languages. MultiPatch represents 3D geometry used to represent the surface or container elements, which occupies the discontinuous area or volume in 3D space. MultiPatch formats include 3D circles and triangles, which are used in combination to 3D modeling packages. MultiPatch formats can be used to represent simple (spheres or cubes) or complex objects (isosurfaces, buildings, trees) (Figure 1). MultiPatch can be displayed as a container for a collection of geometries representing the 3D surface [5].

MultiPatch can not be created directly, it is necessary to use these options [24]:
- geoprocessing tools (Extrude),
- data import existing models of software such as Google SketchUp, Collada, 3D Studio Max or OpenFlight,
- The third option is to use the features of ArcGIS in conjunction with the application ModelBuilder, Interpolate Polygon to MultiPatch, or Layer 3D to Feature Class,
- The last option is to create MultiPatch formats programmatically ArcObjects programming language (VBA, VB.net, C #, Java ...) (Fig. 2).

Using VBA programming in Visual Basic Editor Toolbars have been developed that allow the user to create different types of 3D models, or part thereof. Toolbar 3D model can be used in ArcScene application, toolbar spatial objects is built into the program ArcMap and spatial results are displayed in 3D ArcScene.
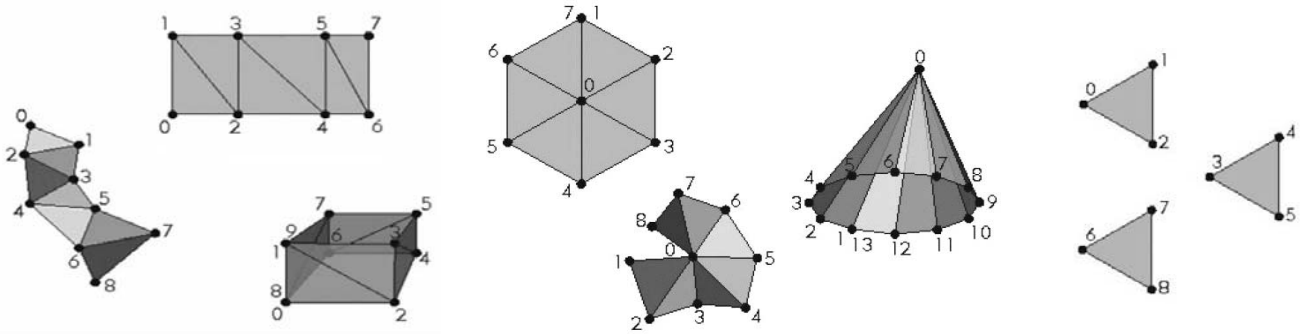
Fig. 1. Geometry formats of Multipatch

Rys. 1. Formatowanie geometrii Multipatch

```
Dim pNewFeatClass As IFeatureClass
Set pNewFeatClass = ft
Dim pInsertFeatureBuffer As IFeatureBuffer
Dim pInsertFeatureCursor As IFeatureCursor
Dim pZA As IZAware
Dim pmultipatch As IMultiPatch
Dim pGCol As IGeometryCollection
Dim pstrip As IPointCollection
Dim bod As IPoint
Set pInsertFeatureBuffer=pNewFeatClass.CreateFeatureBuffer
Set pInsertFeatureCursor = pNewFeatClass.Insert(True)
Set pmultipatch = New MultiPatch
Set pGCol = pmultipatch
Set pstrip = New TriangleStrip
Set bod = New Point
bod.PutCoords px(1), py(1)
bod.z = pz(1)
pstrip.AddPoint bod

Set bod = New Point
bod.PutCoords px(2), py(2)
bod.z = pz(2)
pstrip.AddPoint bod

Set bod = New Point
bod.PutCoords px(3), py(3)
bod.z = pz(3)
pstrip.AddPoint bod
pGCol.AddGeometry pstrip
Set pZA = pGCol
pZA.ZAware = True
Set pInsertFeatureBuffer.Shape = pGCol
pInsertFeatureCursor.InsertFeature pInsertFeatureBuffer
```

Fig. 2. Sample code in VBA to create a triangle

Rys. 2. Przykładowy kod dla utworzenia trójkąta

The 3D-2D polygon objects created in the format MultiPatch based on attributes contained in 2D polygon layer (attributes from a height). (Fig. 3) tool quickly generate three-dimensional models of buildings as well as the wider area.

The advantage of using the format Multipatch is also possible to add additional descriptive properties of the object (Fig. 4).

The tool is able to create and generate spatial objects and in greater numbers. Figure 5 is an example of creating layers of spatial objects in the total number of 4821 objects. Height of buildings has been hashed table of attributes.

For better handling and management of spatial objects was accompanied by a toolbar tool Add object. It is about adding more objects to format MultiPatch already formed layer. (Fig. 6) The input is a 3D polygon layer, which must be read and marked in ArcMap environment. After pressing tool Add Object window appears with layers, which will place a new object layer

hole where you want to add an object, click the confirmation window appears with the location and name of the layer. The result can be displayed in ArcScene program. The picture below shows the green and red layer, which can be inserted into the already formed layer, the result is shown in green. It also includes the possibility of removing one object and replace it accurate model.

The use of the possibilities offered by format MultiPatch are endless. Below are some of them that provide exceptional use this format in conjunction with the proposed applications:

- One of the basic functions provided by MultiPatch format is the possibility of creating virtual cities in the ArcGIS environment.
- Analysis of visibility (This function calculates the visibility between a pair of points, the position is displayed in 3D space and is relative to the element. It also determines what is visible along a line between these points, if they are shown on the surface).
- Sun and shadow analysis simulation.
- When lifting height analysis, the analysis is to determine the height ratios of buildings, also determine the relationships between them and mutual influences. One of the most important functions at a height ratios and determining the location in space that can be built up (Buidable volume).
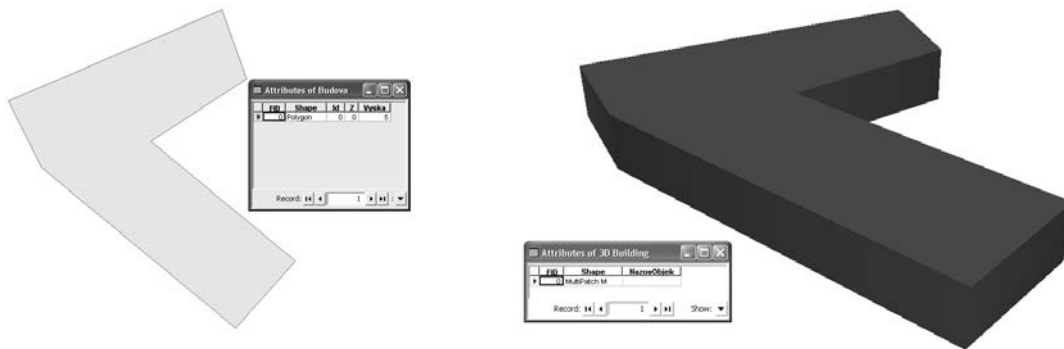

Fig. 3. Creating a spatial object model

Rys. 3. Tworzenie modelu obiektów przestrzennych

Fig. 4. Table attributes of created object

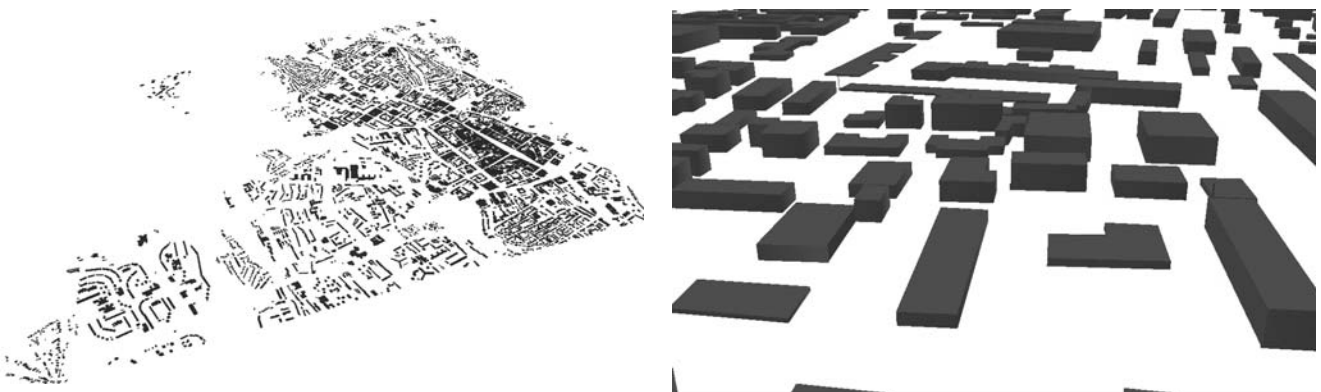Rys. 4. Atrybuty tabeli utworzonego obiektu

Fig. 5. Created spatial objects of Kosice
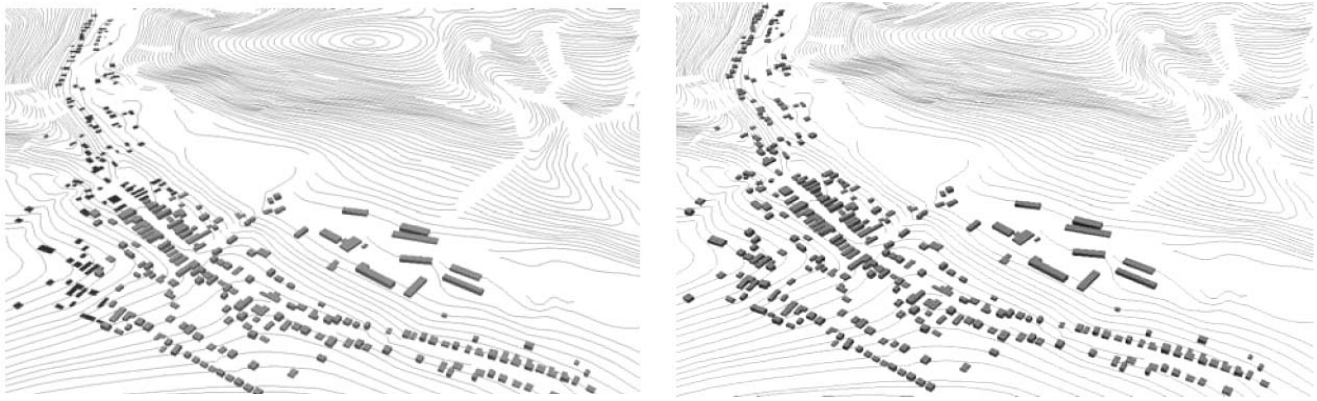
Rys. 5. Utworzone obiekty przestrzenne dla Koszyc

Fig. 6. Example of adding objects to have formed a layer

Rys. 6. Przykłady dodatku obiektów dla utworzenia warstwy

Conclusion

Three-dimensional models and modeling in the field of geodesy and GIS are changing common practices and standards. In the near future we can expect a more thorough implementation by surveying processes not only in GIS but also within the surveying. Addressing such complex issues as the creation and use of 3D models in a GIS environment is endless. To a large extent influenced by the use of specific software, different instrumentation, data format are used and the actual processing of geographic data.

The main task of GIS should be processing the most current geographic data in the shortest time. A rationalization of the work, do certain tasks before and better than others. The basic idea of this work is just the automation of spatial models in GIS environment. Information technology of today makes us right to their use. Journey best and fastest treatment is directed through the software and its treatment options. Any software can edit a kind of programming language.

Will need more 3D geo-information, research and development of 3D GIS has become very important. The main conditions were particularly difficult for the task in the life of many sectors, such as urban planning, engineering construction, management, and protection from the weather and other.

Acknowledgement

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Automatyzacja tworzenia modelu przestrzennego w środowisku GIS

Systemy informacji geograficznej (GIS) są obecnie w fazie intensywnego rozwoju. Ich fundamentem jest informacja przestrzenna umożliwiająca przetwarzanie danych przestrzennych w łatwiejszy sposób. Niniejszy artykuł jest poświęcony tworzeniu stałych modeli obiektów historycznych za pomocą najnowszych metod i technik zbierania danych i ich przetwarzania i użycia do tego celu GIS. Większość systemów informacji geograficznej (GIS) obecnie używanych w praktyce bazuje na wykorzystaniu danych przestrzennych 2D bądź 2.5D. Wraz z szybkim rozwojem technologii komputerowych i rosnącą potrzebą analizy i modelowania realnych środowisk 3D, powstała nowa technologia zwana 3D GIS. 3D GIS podobnie jak 2D jest w stanie przechowywać, obsługiwać, analizować i generować dane wyjściowe z tym wyjątkiem, że dane 3D GIS opisują i przedstawiają obiekty i zjawiska w środowisku 3D. Niniejszy artykuł jest projektem stworzonym w celu integracji obiektowej bazy danych oraz języka programowania VBA wraz z utworzeniem modelu przestrzennego w środowisku GIS. Do przedstawienia obiektów przestrzennych w środowisku programowym użyto opcji formatowania danych ArcGIS MuliPatch.

Słowa kluczowe: 3D GIS, przetwarzanie danych przestrzennych, modele przestrzenne, MultiPatch