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# ENVIRONMENTAL ASSESSMENT OF URBAN AREAS: APPROACHES BASED ON GEOSPATIAL DATA INTEGRATION

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## ABSTRACT

*The present article is concerned with the use of 3D models for environmental assessment of urban areas. 3D video scenes of urban environment are proposed for this purpose. The technique for 3D video scenes construction, requirements and general procedure are described. The list of environmental data requested to gain integrated environmental characteristics by means of 3D video scenes is composed. The accuracy issues of 3D video scenes construction for built-up areas are considered. The testing results of the technique for the assessment of man-made entity (SDW landfill) impact on the industrial cluster environment are presented. Ecological and environmental goals solved by means of 3D video scenes are discussed in the conclusion.*



**Keywords:** Urban environment, Anthropogenic impact, Environmental assessment, 3D modelling, 3Dvideoscenes, Digital elevation model (DEM), Digital object model (DOM), Earth remote sensing, Cartographic modelling.

## Contribution/ Originality

The present study contributes to the theory and methodology of 3D urban environment modelling for the anthropogenic impact assessment. The paper describes a new approach to the impact assessment of man-made objects (entities) on the quality of urban environment using 3Dvideoscenes for measuring purposes.

## 1. INTRODUCTION

Environmental issues are becoming of high priority in providing sustainable territorial development. In the larger sense, it refers to cities because their social and economic progress, as well as associate environment, is directly connected with the increase of man-caused impact on the

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environment. In this regard IT software for decision-making is growing in importance for environment assessment, monitoring and urban environment optimization.

Pollution as the main man-caused impact takes place in the urban environment and connected with territorial development and land use, and is of spatial nature.

Taking into account comprehensive territorial data consideration having regard to their spatial position, the use of 3D urban area models will be the optimal approach.

It allows integrating a variety of information from the territory including Earth remote sensing data and field studies to provide detailed models of high informative value. Interactive 3D visualization is an important tool, because it is crucial in perception, understanding and recognition of topographic features, relationship between natural processes and anthropogenic activity. Besides, the use of GIS technologies allow combining modelling results and non-topographic thematic data, so a wide range of tasks related to accurate spatial localization of ecologically destructive objects and events can be solved, as well as modelling of forecasting prevalence of pollution.

### 1.1. Technique for 3D Video Scenes Construction

3D modelling is able to identify interactions between various natural environment components influenced by man-made sources, and pollution prevalence factors based on terrain features. Integration of Earth remote sensing data and field studies provides detailed models of high informative value. In this regard, the concept of 3D terrain modelling on the basis of data integration is offered.

3D models and 3D video scenes are new digital geospatial products representing 3D models of real objects in the area. They have appearedfor the last twenty years [1].

3D GIS software is preferable to use for the construction of a 3D geoenvironmental model, as they allow constructing 3Dvideoscenes. Hereafter, we will use the term “3Dvideoscenes”.

Source data for the construction of 3D video scenes by 3D GIS tools are raster images of ground surface, digital terrain models including a digital elevation model (DEM) and 3D digital object model (DOM). Environmental component includes environment pollution statistics (Figure 1.)

Earth remote sensing data are the basis for digital terrain model creation. These data are also used for editing and updating terrain features while creating digital object models.

DTMs will be used to construct 3D video scenes for measuring purposes, which are necessary for solving analytical and computing tasks but a vector topological model with 3D data dimension is preferable.

Thus, we should define the following necessary conditions for DTMs creation meeting the requirements for the further construction of three-dimensional video scenes reflecting the ecological state of environment [2-4]:

1. A digital terrain model should include a DEM and DOM (natural and man-made objects) as well as the sources of environmental hazards.

2. Earth remote sensing data should be provided for DTM creation within the large scale range.

3. There must be evidences for the necessary and sufficient level of object details represented in 3D video scene.

4. It is necessary to formulate the requirements for the volume and completeness of environmental attributes, selection criteria, and object generalization.

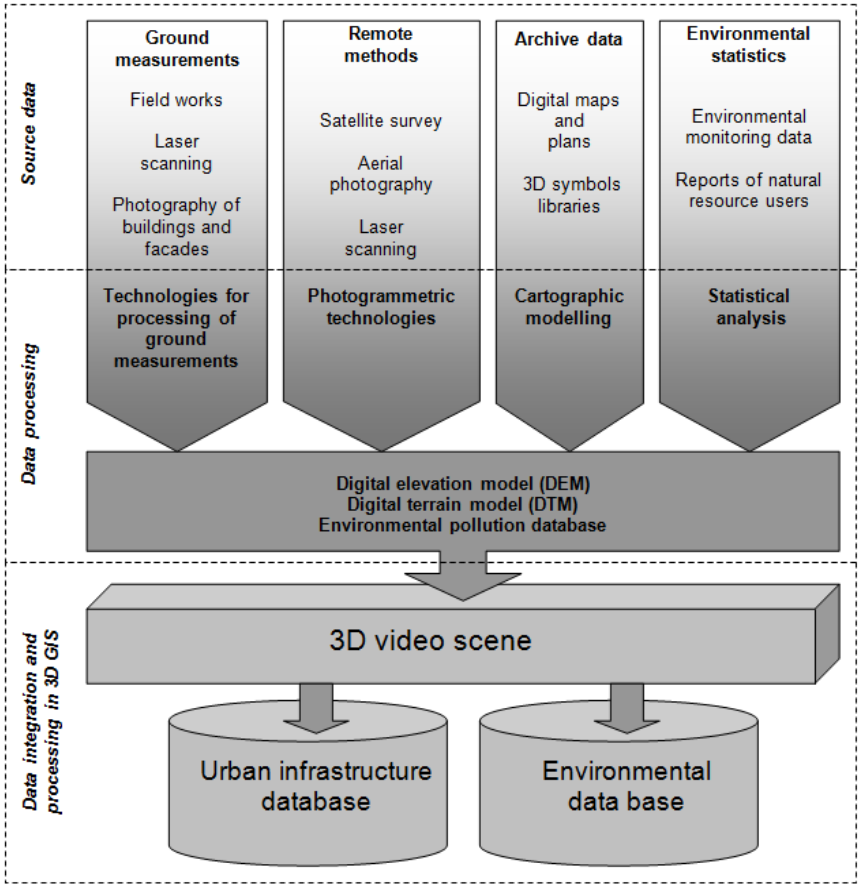


**Figure-1.**A generalized flow chart in construction of 3D video scenes for measuring purposes [1]

Thus, a 3D video scene content created taking into account above-mentioned conditions includes not only basic information on existing urban infrastructure but pollution sources (industrial, heat and energy facilities, SDW landfills, etc.). To analyze environmental situation the environment pollution statistics should be structured. The thematic data structure is governed by the character of the polluted natural component and type of the pollution, so it includes the following basic data groups:

- contamination of air;
- condition of water body;
- soil contamination;
- natural radioecological factors;
- man-mad radioecological factors;
- electromagnetic and noise pollution.

Analysis and processing of environment pollution statistics provide integrated environment pollution indices in terms of comprehensive consideration of existing human-made factors on the considered territory [5, 6].

3D video scene application to assess urban environment opens a number of opportunities for the extended spatial environmental situation analysis. First of all this is interactive three-dimensional visualization at various modelling stages. This helps to increase created model quality and their analysis efficiency. Visualization can present the data in an easy-to-interpret form, and allows investigating various interrelations of spatial objects substantially complementing digital models or textual descriptions. So visualization can be considered as a research tool. In particular, when analyzing ecological situation of the territory, 3D video scenes allow adding dynamic (virtual) objects that graphically illustrate the travel of pollution in progress or a point-of-time level of a territory contamination.

### 1.2. Experimental Works

Experimental studies have been performed using the results of aerial photography (flight scale – 1:8,000, camera focal length − 153 mm, frame size 23 × 23 cm) of three objects located in an even land of Tyumen Region. This area is characterized by rural built-up environment, small timberlands and meadowlands.

Spatial data collection for construction of 3D scenes was performed by the DPS "Delta" Software (TSNIIGAiK, Moscow) and PHOTOMOD software (Racurscompany, Moscow). The mentioned DPSs help not only to create digital topographic maps, plans, models, orthophotomaps, but other digital products too.

3D video scenes were constructed in three 3D GIS environment: GIS "Map 2011", Virtual GIS, and 3D Analist.

A digital elevation model in each 3D GIS is obtained in the form of a regular altitude matrix and triangulated irregular network for GIS "Map 2011", 3D Analist.

The creation of 3D object models was performed by 3D GIS tools. The analysis of three-dimensional video scenes' metrical accuracy was done per each object with regard to the following:

- Accuracy estimation was performed by heights of control points because horizontal coordinates of DPS-based DTM's points are not changed after their import to 3D GIS;
- Well recognized points on the ground surface, construction bottom and roof corners were chosen as control points.

The results of accuracy estimation for one of the objects in Tyumen Region are presented in the diagram (Figure 2).

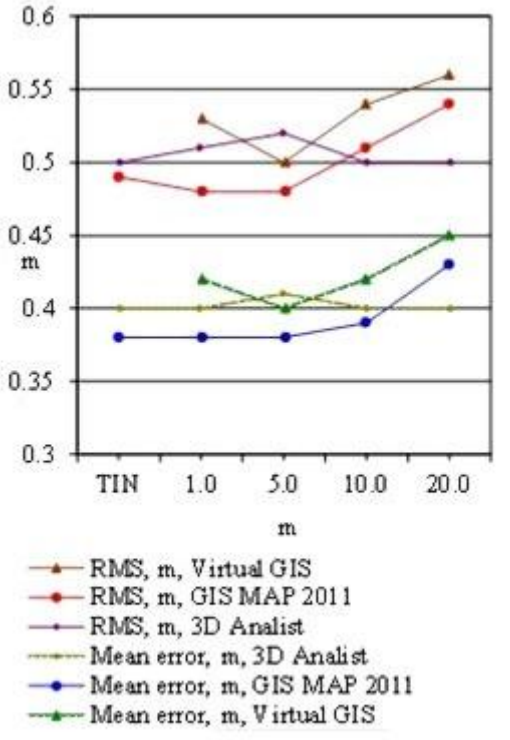


**Figure-2.**A diagram of the results of vertical positional accuracy estimation of control points located on the ground surface and at the bottom corners of construction for GIS "Map 2011", Virtual GIS and 3D Analyst [2]

The analysis of three-dimensional video scenes was carried out depending on 3D GIS software tools, source data forms for DEM creation (contour lines, regular altitude matrix, triangulated irregular network), and land forms.

For example, for the even land the mean errors in altitude for control points from GIS "Map 2011", VirtualGIS and 3D Analist, are virtually of the same order for DEM, the regular altitude matrix with the matrix element size of 1-20 m, and for DEM in the form of triangulated irregular network. At the same time disk storage space for the matrix data is increasing significantly with the decreasing of the matrix element size. For a hilly terrain the mean errors in altitude for control points from GIS "Map 2011" and 3D Analist are virtually the same for DEM in the form of triangulated irregular network and for DEM in the form of the regular altitude matrix with the matrix element size of 1 m. The analysis of DEM accuracy for one of the three objects located in residential zone and industrial site showed that height discrepancies for control points (located on construction corners or close-located points) are within 0.5-1.0 m.

By the results of experimental investigations the recommendations were specified for preparation of source data, digital data capture, and software selection.

Theoretical insights testing of using 3D models in environmental assessment was performed on the example of Novosibirsk city, which is one of the main industrial centers of the West Siberia. A number of geoinformational models were created for the area under investigation, with their 3D

visualization. Morphometric analysis of the urban area and surrounding terrain was performed [7]. It made possible to find out some spatial patterns of pollutant distribution, to specify potential areas of pollutant drift, transit, and accumulation.

The received data allow analyzing the influence of man-made objects on the environment conditions in progress. Industrial facilities and SDW landfills are the main negative factors spoiling the ecological situation and the quality of life. Figure 3 shows the influence of one of the SDW landfills that is located in the area of pollutants transit [8].

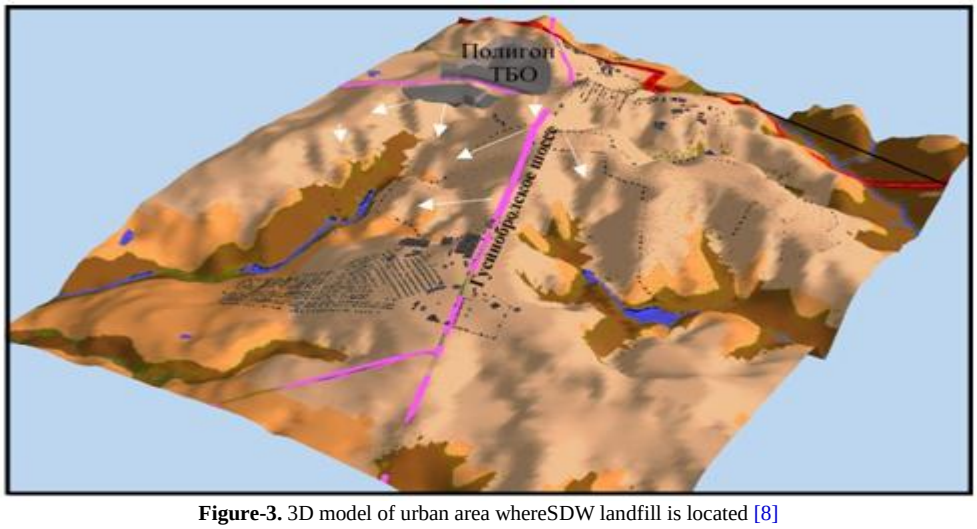


**Figure-3.** 3D model of urban area whereSDW landfill is located [8]

The combination of the basic geospatial frame with the information on existing urban infrastructure and the results of morphometric relief analysis provide by diversified data on spatial processes of pollutants distribution. It allows improving instrumental monitoring and predictability of natural complex component changes that follow the appearance or changing of man-caused impact.

## 2. CONCLUSION

The use of 3D modelling in the environmental assessment of urban areas helps to solve a large variety of tasks concerning accurate spatial localization of environmentally hazardous objects and events, as well as modelling of expected prevalence of pollution. Accuracy characteristics of 3D models are sufficient to get objective and true information on the spatial distribution of environmentally unfavorable events and processes across the area under investigation. Combining of 3D territory modelling results with geospatial thematic information (e.g. territories with unfavorable hydrogeological processes) and non-spatial information (pollutant concentration in monitoring sites) will increase opportunities for analysis of environmental problems, and increase environment assessment reliability of urban areas. The application of GIS technologies for 3D visualization simplifies the interpretation of results and enables to reveal the interrelations between natural processes and anthropogenic activity.

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