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Comparative Study on Photogrammetric Methods for 3D Modeling of Building Heritage

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Abstract: Three-dimensional digital recording and presentation of cultural and historical heritage and spatial entities has become very used in recent years, with the development of the modern computer software and web services. Creation of three-dimensional models of urban spatial units and archaeological sites is significantly promoted by the development of modern software which allow automatic photogrammetry. This paper gives a comparative overview of traditional and modern automatic photogrammetric methods for creating 3D models of urban structure.

Keywords: Photogrammetry, building heritage, 3d models.

1. INTRODUCTION

The first step in making decisions on the method of observation, restoration, reconstruction and protection of the cultural heritage is understanding of historical structures and locations. Without adequate information, such decisions can be ill based, risky and devastating [6]. Definition of architectonic, historical and archeological interests through the analysis of structure, form, envelope of the structure provides a successful conversation which is in agreement with the available techniques and famous character of the structure.

As opposed to other elements of cultural heritage, the process of protection of architectonic monuments is very complex, since these buildings are often still in use, exposed to long lasting action of natural and human factors. In case of major damage or complete destruction of the structures, the quality and quantity of documented information about the monument are very important [3].

Documenting of spatial entities and buildings can be performed starting from the simple methods of manual measuring and recording, and drawing, conclusive with the advance technologies allowing virtual presentation of the elements or of entire structures and cultural-historical entities.

Formation of a 3D model of historical buildings is important in the process of documenting of cultural heritage, and it is performed for the purpose of reconstruction, restoration, analysis or visualization of the structure. The model must answer the requirement such as geometrical accuracy, precision, realistic appearance etc. [5].

The modeling based on manually collected geometrical dimensions requires considerable time and it is outdated due to its impractical character and high cost in case of large projects.

Three-dimensional models obtained in this way do not have a realistic displaying of colors and textures, and do not display sufficient detail and surface damage. As opposed to the traditional methods, contemporary digital methods allow very precise display of characteristics of the structure, that is, analysis of the cladding, structure, behavior of the structure in certain conditions, as well as realistic visual presentation.

One of the widely applied methods for digital documenting of the building heritage is the photogrammetry method [9]. Photogrammetry is method providing data of the three-dimensional spatial structure, using data from a two-dimensional photograph [7].

At least two photographs of the same structure and knowledge of the true length between two points visible in at least one photograph are required for the photogrammetry to be applied [8].

Photogrammetry evolved using development of computers and software. Thus, lately, apart from the already standard methods of digital terrestrial and aerial photogrammetry, developed new automatic photogrammetry which employs numerous software packages. Owing to the ability of the contemporary hardware and sophisticated similarity recognition software, the automatic photogrammetry software and web services have been developed.

For this reason, the momentary methods of digital photogrammetry which are used for documenting of the building heritage can be divided in four groups:

- semiautomatic terrestrial photogrammetry,
- semiautomatic aerial photogrammetry,
- automatic terrestrial photogrammetry,
- automatic aerial photogrammetry.

This paper provides the review of these types of photogrammetry through the examples of culturally and historically important structures and localities. Analysis of positive and negative characteristics of each one of them was conducted, through the criteria for the choice of a proper method of digital documenting.

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2. CRITERIA FOR CHOICE OF A PROPER METHOD OF DIGITAL DOCUMENTING

Contemporary methods and techniques of digital documenting such as photogrammetry represent indispensible instruments in protection and presentation of the building heritage of the present times. Digital recording of the building must be conducted prior to conducting any activities of on it. Due to the diversity of structures and locations recorded, there are different methodological and technological approaches to the process of digital documenting. On the basis of the earlier research [6], the choice of a proper method depends on the following parameters:

- goal of research – purpose of digitalization determines the required quality and type of documentation.
- required geometrical precision and visual quality – different techniques yield a different degree of geometrical accuracy.
- physical characteristics of the structure and its environment – parameters such as the size and accessibility of the structure and the environment determine the type and method of recording.
- available budget – application of certain digital methods can be disabled due to the high cost of necessary equipment and poor cost effectiveness of the duration of the engagement.

3. COMPARATIVE ANALYSIS OF THE PHOTOGRAMMETRY METHOD

3.1. SEMIAUTOMATIC TERRESTRIAL PHOTOGRAMMETRY

Terrestrial photographs are obtained by placing the cameras on or close to the ground [10]. Terrestrial and close-range photographs are usually used in archeology, geomorphology, civil engineering and industry. Convenience of this kind of photogrammetry reflects in documenting of small structures with the precise digital recording of the texture of the building. The model production has low cost due to free software packages such as SketchUp. For implementation of the method and obtaining of the model it is necessary to have foreknowledge of photogrammetry and software 3D modeling. The down side of such method of digital documenting is insufficient precision of small details on the structures which are the object of photogrammetry, because of manual processing and drawing of the model. Because of the great impact of human factor, modeler on the detail level of the model, with the increase of the model detail level, the time necessary for its construction also increases. This method is convenient for small structures where high precision of volume is not required, but rather a realistic appearance, it is suitable for the web presentation on the services such as Google Earth due to a small size of digital files (Fig. 1).

Fig. 1: Presentation of the model on Google Earth

3.2. AUTOMATIC TERRESTRIAL PHOTOGRAMMETRY

In case of automatic terrestrial photogrammetry, the photographs are obtained by placing camera close or onto the ground. In order to obtain a successful model of the building or spatial structure, it is necessary to collect a large number of photographs, for the purpose of higher precision. In this method, it is necessary to spend more time for collection of data (photographs) in comparison to the semiautomatic terrestrial photogrammetry. For implementation of the method and obtaining of the model, due to maximum automatization, no foreknowledge of photogrammetry and 3D modeling is required [2]. But, owing to the advanced software, the time needed for obtaining the model and human engagement is reduced to the minimum.

This method is suitable for the models where high precision in modeling of the detail is required, while the realistic presentation of the model is provided owing to the usage of photographs [11]. The models obtained with this method are detailed, but the digital files are fairly large and unsuitable for a web presentation (Fig. 2). The method is suitable for digital documenting of the building heritage, with high precision and realism. In this way it is possible to obtain 3D models of building or archeological sites of small dimensions, it is not possible to obtain large spatial units, due to the software limitations.

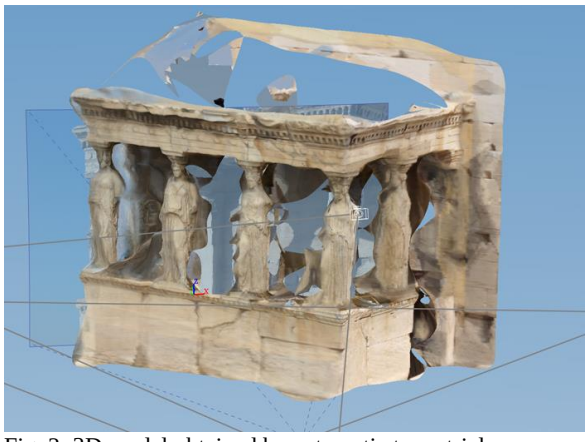

Fig. 2: 3D model obtained by automatic terrestrial photogrammetry

3.3. SEMIAUTOMATIC AERIAL PHOTOGRAMMETRY

In case of aerial photogrammetry, the photographs are taken from the vantage point above the ground, the axis of the camera is usually directed vertically or almost vertically downwards, at the angle of 45º. Aerial photographs and images are most frequently used for topographic planimetric (space measuring) mapping of designs, and they are usually taken from an airplane or satellite. By developing software and free web services, this way of photogrammetry became available to the wide circle of people and massively applied in production of 3D model of urban areas and archeological sites on large surface areas.

This type of photogrammetry is suitable for documenting of large historical, spatial entities. Owing to the free web services and software such as Google building modeler (Fig. 3) and SketchUp, this method of model creation is rendered accessible to everybody. The problem of this service is the limited number of cities, mostly megalopolises of the world. There is a potential for individual recording of a certain area whose modeling is required, but recording of a location from the air significantly increases the cost of model production. The models obtained in this way posse real textures owing to photographs, but the detail level depends on the human factor and the time committed to production.

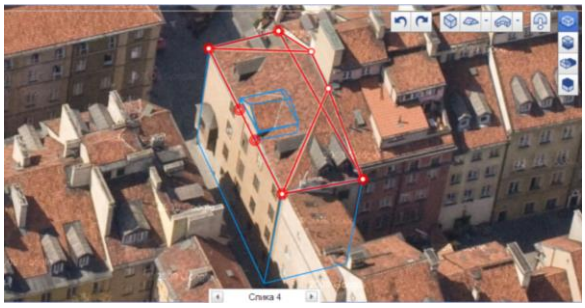

Fig. 3: Modeling process in Google building modeler

3.4. AUTOMATIC AERIAL PHOTOGRAMMETRY.

In case of automatic aerial photogrammetry, the photographs are obtained from a satellite, airplane or unmanned aerial vehicles. This method is intended for production of large scale models, archeological sites (Fig. 4), urban environments or parts of the city [1]. The entire process is fully automatized, starting from the collection of aerial photographs, where the aircraft automatically photographs and area to the processing of photographs and creation of a final model for which are used advanced hardware-software solutions. This method of photogrammetry does not require foreknowledge of modeling and reduces the man-hours required for obtaining a model to the minimum. The problem is high price of the entire process, due to the usage of aircraft, advanced software and hardware. [4]. For that reason, until only a year ago it was used by the great companies such as Google for experimental purposes. Nowadays, there are companies which offer complete systems, UAVs and online server for data procession, but the cost of these systems is very high.

Fig. 4: 3D model obtained by automatic aerial photogrammetry

4. RESULTS

Based on the described factors in table 01 a comparative presentation of the photogrammetry methods is given, with positive (+) and negative (-) factors.

Table 1: Comparative presentation of factors

Factors relevant for photogrammetry	Terrestrial		Aerial	
	Semiauto.	Automatic	Semiauto.	Automatic
Time required for data collection	+	-	+	-
Photorealism of the model	+	+	+	+
Software cost	+	+	+	-
Hardware requirement	+	+	+	-
Foreknowledge of photogrammetry	-	+	+	+
Foreknowledge of 3D modeling	-	+	-	+
Model detail level	-	+	-	+
File size	+	-	+	-
Human factor	-	+	-	+
Web presentation	+	-	+	-

5. CONCLUSION

Production of digital 3D model for documenting of structures represents a contemporary method of presentation and it is used when building heritage is protected. The modern technology of production of digital 3D models is more and more available to a great number of users of web services. For this reason, the method of photogrammetry is used as efficient and quality method for data collection, without a direct contact with the structure. Usage of this method provides high precision in the work on creation of digital models of structures and spatial entities. In this way an unlimited access to cultural-historical structures is allowed, which is an important requirement in conducting of a scientific research hand in protection of building heritage.

Using the terrestrial or aerial photographs, and using some of the presented methods of

photogrammetry, the final product - 3D model of a structure or spatial structure is obtained. The presented methods, guided by the same principles of photogrammetry, create digital models using photographs with higher or lower precision.

Semiautomatic photogrammetry, both terrestrial and aerial, represents a method which has been used for a long time, in comparison to the automatic methods of photogrammetry. It goes without saying that the automatic principles represent a future in the development process of photogrammetric methods and the will be increasingly used in practice in the future, primarily due to a less requirement for skilled human engagement. However, the automatic methods of photogrammetry are significantly more expensive while the obtained models are too complex for a web presentation. Application of digital photogrammetry and a large number of free software packages for its implementation is nowadays more acceptable, regardless of the fact that high precision of three-dimensional models is not obtained.

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