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CREATION OF VIRTUAL 3D MODELS OF THE EXISTING ARCHITECTONIC STRUCTURES USING THE WEB RESOURCES

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Digital three-dimensional models of the existing architectonic structures are created for the purpose of digitalization of the archive documents, presentation of buildings or an urban entity or for conducting various analyses and tests. Traditional methods for the creation of 3D models of the existing buildings assume manual measuring of their dimensions, using the photogrammetry method or laser scanning. Such approaches require considerable time spent in data acquisition or application of specific instruments and equipment. The goal of this paper is presentation of the procedure for the creation of 3D models of the existing structures using the globally available web resources and free software packages on standard PCs. This shortens the time of the production of a digital three-dimensional model of the structure considerably and excludes the physical presence at the location. In addition, precision of this method was tested and compared with the results acquired in a previous research.

Key words: **three dimensional models, existing buildings, web resources, free software packages.**

INTRODUCTION

Computer modeling of existing objects (buildings or structures) provided by numerous software solutions has its wide range of applications in science and practice: architecture (Styliadis, 2007; Stojaković and Tepavčević, 2011; Pejić *et al*., 2012; Chane *et al*., 2013); civil engineering (Armesto *et al*., 2009; Elaksher, 2013; Walsh *et al*., 2013); urbanism (Tack *et al.*, 2012; Heo *et al.*, 2013; Musialski *et al*., 2013); geology (Turowski *et al.,* 2013; Fonstad *et al*., 2013; Lato *et al*., 2013); mechanical engineering (Menna *et al*., 2011); video games and movie industry, medicine (Berretti *et al*., 2013), archeology (Haydar *et al.*, 2011; Kersten and Stallmann, 2012; Kochi *et al.*, 2013; Rawashdeh, 2013); safety of people and goods (Gonzalez and Gomez, 2009) etc.

The basic prerequisite for creating presentations of virtual architectonic structures is the existence of a suitable digital 3D model. Creating a three-dimensional model can be done by different methods depending on the type of a building, available equipment, prior knowledge, time available and presentation purposes. The choice of the appropriate method is directly determined by the type and availability of the data necessary to create spatial 3D models. Therefore, we distinguish between three-dimensional virtual models generated on the basis of:

- A newly constructed building;
- An existing building.

Due to the variety of recorded buildings, there are different methodologies and technological approaches in the process of making three-dimensional models of architectural structures. The choice of the appropriate method depends on the following parameters (Krasić and Pejić, 2014):

- **Goal of research** – the purpose of digitalization determines the required quality and type of documents. The documenting process can be conducted for the purpose of obtaining information about the structure of the building, analysis of deformity, two-dimensional and three-dimensional presentation of the structure, creating a virtual reality, the assessment of the value of the structure, etc.
- **Required geometrical precision and visual quality** – various techniques produce a different degree of geometrical accuracy. Certain tasks require a high visual quality which is realized by applying adequate textures from the digital documentation.

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- **Physical characteristics of the structure and its environment** – parameters such as the size and accessibility of the structure and its environment determine the method and type of recording. The methods used for recording small, medium and large structures differ, just as of those which are inaccessible to recording, to a lesser or greater extent.
- **Available budget** – application of certain digital methods can be unavailable because of the cost of the equipment needed or poor cost-efficiency of the time needed to perform the activity (Ortiz *et al*., 2006).

Three-dimensional models of existing buildings and urban structures are used for the purpose of visual presentation, documentation and archiving their physical structure or for the implementation of various analyzes. In the architecture, models are equally useful for the design processes and modeling of the existing buildings, presentations of surroundings employed in new projects, as well as the urban structure of some locations. Models are of importance in cultural heritage documentations, reconstructions or restorations of buildings damaged during time or inaccessible ones. Contemporary analyses concerning: insulation, shadow spreading, acoustics, thermal imaging, etc. (Pejić *et al*., 2013a) can be more efficiently carried out with 3D models of existing urban structures or buildings.

Each one of the applications of 3D models of existing buildings involves various levels of details and realistic presentations of virtual model's textures. Regarding the variety of objects, locations, or desired level of details, different methods and methodologies in documenting the design process are available. Three dimensional models of buildings, originated from simple methods of manual data collecting (measurements) and drawings, have been developed to advanced technologies offering the automatic generation of 3D elements, or entire objects, as well as urban entities (Pejić *et al*., 2013b). Virtualization based on manually collected geometrical dimensions takes a lot of time and is outdated because of high costs when big projects are concerned. These 3D models have no color nor realistic textures, i.e. details (ibid.). In comparison with traditional models, contemporary digital methods of laser scanning (Lato *et al*., 2013; Murphy *et al*., 2013; Santos *et al.*, 2013; Yang *et al*., 2013) and photogrammetry (Barazzetti *et al*., 2010; Remondino and Rizzi, 2010; Stojaković and Tepavčević, 2011; Vallet *et al*., 2011; Pejić and Krasić, 2012; Musialski *et al*., 2013; Ozgun, 2013) provide very accurate presentations of object's characteristics containing the following analyses: surface, structure (construction), behavior in certain conditions, as well as realistic visual presentation.

The photogrammetric method gives us information about 3D structure obtained from 2D photographs (Pejić and Krasić, 2012). Photogrammetry is a technique of representing and measuring 3D objects using the data stored on 2D photographs, which are the base for rectification. At least one dimension and two projections are necessary to obtain information about three space coordinates, that is, from two photographs of the same object its true size can be determined and a 3D model constructed (Stojaković, 2008).

The main scientific contributions of this paper are creation, presentation and deviation testing of web-recourse based photogrammetry method for 3D model creation. The goal of the paper is to investigate possibilities for the creation of virtual 3D models of the existing architectonic structures using exclusively what is available on the internet and the method of photogrammetry. The main idea is to compare this web-resource based approach with traditional semi automatic photogrammetry method in order to demonstrate the possibility for time saving with minimal dimensions deviations of a 3D model compared to a real building. The entire procedure is presented through the case study of the creation of the model of a multi-family housing building in 15, Krivi Vir Street in Niš, Serbia. Also, a comparative analysis of the dimensions of the obtained 3D model with the actual dimensions of the building was made and a deviation obtained was 2,9%. This is acceptable if the building is used for visual presentation or analysis which do not require a high degree of precision.

MATERIALS AND METHODS

The development of contemporary hardware and software allowed the creation of web services with different purposes. The browsing of photographs on the internet is possible on almost every site, while the photograph sharing services (Panoramio, 2015; Flickr, 2015) are very popular. These photographs can be used for the creation of 3D models of the existing buildings using the photogrammetry method. The problem with such sites is that certain locations, interesting for the users (buildings having historical or architectonic importance (Marić, 2012; Alfirević, 2011)), can have a large number of photographs, while on the other hand some private individual buildings do not have any photographs on the internet. In 2007, Google company started the "Street View" project, which implements panoramic street view of many locations in the world into "Google Maps" and "Google Earth". This service has been available in Serbia since 2014 and covers the cities of Belgrade, Niš and Novi Sad. This method provides the acquisition of photographs from the locations which are not very popular, using web services. Based on the globally available photographs, it is possible to create a proportional, photorealistic 3D model in the unknown scale. It is necessary to know at least one length in order to create a digital model in a known scale. There are numerous services for navigation and positioning in the real world which use very precise maps with the satellite (Bing Maps, Google Maps, Google Earth) or aerial images (Gis Niš, 2015) of the terrain. These free resources can be used for acquiring the actual dimensions of the buildings which are necessary for the determination of the model scale.

This is a presentation of the working method (system) for the creation of 3D models of the existing architectonic buildings using exclusively free data available on the internet and free 3D modelling software packages. Based on the earlier authors research, it was concluded that it is best to use the software package SketchUp (SketchUp, 2015) for this purpose. The reason for this is the comprehensiveness of the functions available in the free version of the software. The module for the creation of the model using semi-automatic photogrammetry is an integral part of SketchUp software (Krasić and Pejić, 2014). The greatest advantage in

respect to other softwares of this type is the direct link with "Google Maps", "Google Earth" and "Street View" services. It makes it easier to use in comparison with other software packages and ideal for the production of three-dimensional models of the existing architectonic structures using the photogrammetry method.

This paper presents a system for the creation of 3D architectonic models of the existing buildings using photogrammetry, using a free version of the software package SketchUp and of openly accessible web resources.

CASE STUDY

The entire procedure was conducted on the example of a house in Krivi Vir Street in Niš using exclusively free and openly accessible data from the internet and implementing free software packages. The system is divided into four phases:

- Acquisition of photographs;
- Creation of the model using photogrammetry method;
- Determination of the model scale; and
- Detail modelling.

Acquisition of photographs

Creation of a 3D virtual model using photogrammetry method requires photographs. Since the goal is using data available on the internet exclusively, it is necessary to search the photograph sharing services. When it comes to unimportant or unknown buildings, the search including its name can pose a problem; this was the case of the house in Krivi Vir Street in Niš. For that reason it is better to use the web services for photograph sharing which allow their search using the geographic location. The "Google Maps" service was used for this paper, allowing search using maps (Figure 1). Upon finding location, it possible to search the photographs using the "Panoramio" sharing service or the "Street View" service. For the purpose of having a precise and detailed model, it is necessary to choose as a good quality photograph as possible, preferably taken from the corner of the building. The photo must be downloaded for further usage.

Creation of the model using the photogrammetry method

For the creation of a 2D digital model of the building, a free version of SketchUp 2014 software package was used. The photograph of the building downloaded from the internet was imported to the SketchUp software, where using the semi automatic ground photogrammetry a 3D model was created. After importing the photo, using the photogrammetry module, perspective vanishing points were determined and the origin of the coordinate system was positioned (Figure 2). After that, by using the basic SketchUp modelling tools, all the surfaces making up the building were drawn. After drawing the spatial volume of the building, the textures found in the photographs were projected on the model surface. Since the photograph shows only two facades of the building, a 3D photorealistic model of the part of the building in an unknown scale was obtained.

Determination of the model scale

It is necessary to determine a scale for the obtained 3D model. The photogrammetry method yields the proportional 3D model, so it is necessary to know only one length to determine the scale. By using web services employing aerial or satellite imaging for map display, it is possible to measure the distance between two points on the map with high accuracy. The more detailed the map, the less error in the model scaling will occur. In the case of the house in Krivi Vir Street in Niš, "Google Maps" service was used, because of its direct link with the "SketchUp" software in which the model was created. After finding and importing of the part of the map on which the building is located, the photograph of the location in 1:1 scale was obtained in SketchUp (Figure 3). On the basis of this map, the building was proportionately enlarged and rotated so as to coincide with its location on the map. After this procedure, the 3D model of the building in actual (1:1) scale was obtained. Simultaneously, the 3D model obtained its geographical coordinates, which can be used for downloading the contents (Street View) which require geo-location of the model or for conducting further analyses (shadow casting) or presentations (Google Earth).

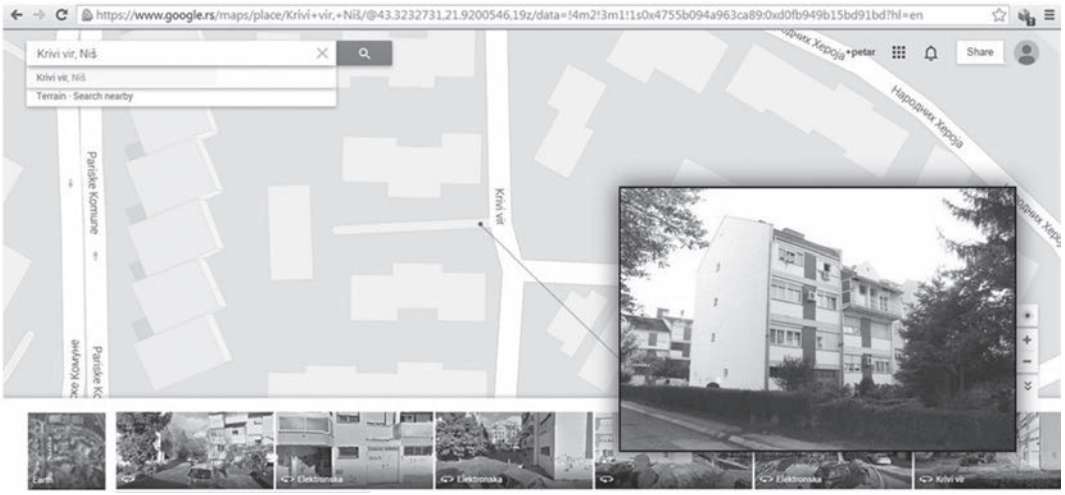

Figure 1. Photograph search using the Google Maps web service (Source: authors)

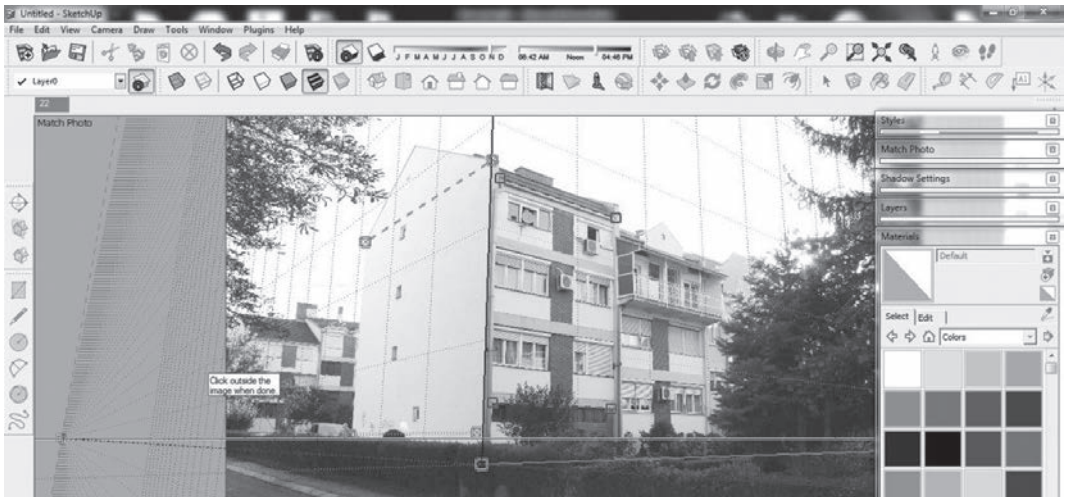

Figure 2. Adjustment of the finishing point of the perspective image
(Source: authors)

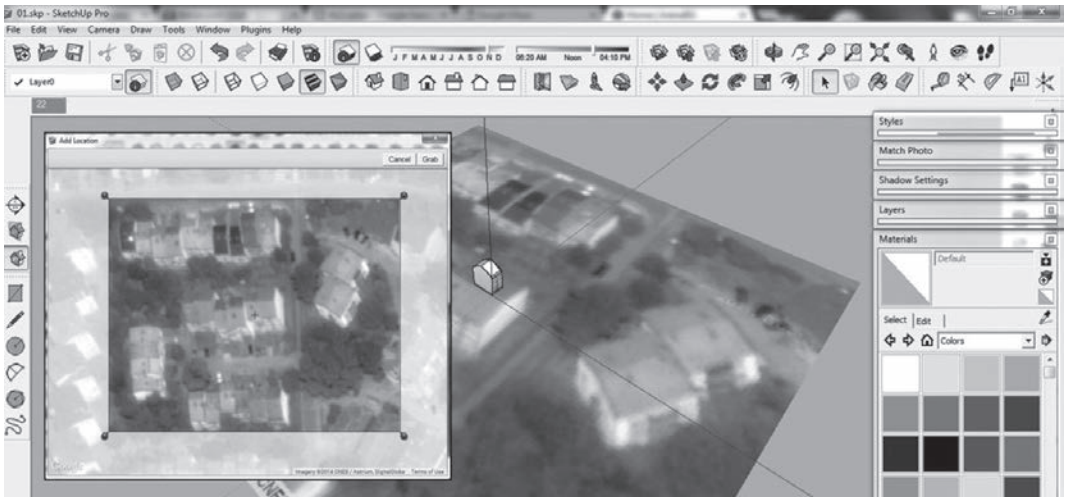

Figure 3. Adjusting the scale
(Source: authors)

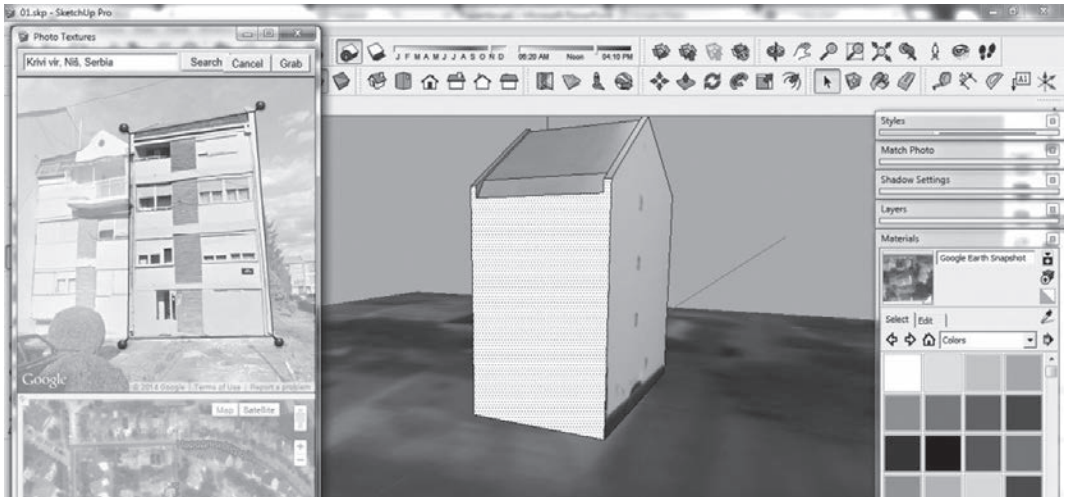

Figure 4. Usage of "Street View" service
(Source: authors)

Detail modelling

The model obtained in this way is often not sufficiently detailed, or (as in our case) not all the facades are created. The presented structure in Krivi Vir Street in Niš borders the adjacent building with one façade, while three remaining facades are free. Based on the procedure described up to now, a 3D photorealistic model of two building facades was created. For completion of the model, it is necessary to create a third façade (Figure 4). For its creation, a direct link of the "SketchUp" application with "Street View" service was used.

After starting the application, the location of the building was found on the map in the lower portion of the web browser, while in the upper part it was possible to perform a virtual "walk" along the streets and find the presentation of the missing part of the building. After that, it was necessary to select the region with the missing part of the structure, and project the photograph directly on the 3D model of the building (Figure 4). The link with the "Street View" service was very useful for the option of viewing the building from several angles and for downloading directly the parts of the textures which were missing or were concealed by other buildings or vegetation on the initial photograph.

RESULTS AND DISCUSSION

The final result of the presented web resource photogrammetry procedure is a photo-realistic 3D "solid" model (Figure 5) of a multi-storey house in Krivi Vir Street in Niš.

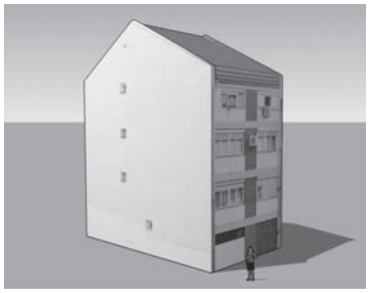

Figure 5. 3D model of the building (Source: authors)

A model obtained in this way can be used further for various purposes (Pejić *et al*., 2013a):

- It can completely replace the physical archives using digital files with the same characteristics;
- Digital data can be used for various kinds of scientific analyses and tests;
- It can help in understanding, presenting and learning about architectonic, engineering and town planning qualities of a certain locality.

The obtained "SketchUp" model can be easily shared using the web and presented to all internet users employing Google Earth and 3D Warehouse with whom the software package "SketchUp" has a direct connection (Pejić and Krasić, 2012). The digital models of the existing building obtained in this way are very suitable for presentation using the Augmented Reality system (Pejić *et al*., 2014) due to the file size and photo realism. They can be implemented when presenting the newly designed architectonic buildings in order to display the real environment in which the building will be constructed. By employing the in-built algorithms in the "SketchUp" software package and using the 3D models obtained in this way, it is possible to conduct the solar analyses (Stevanović *et al*., 2009) of shadow casting or of their impact on the thermal performance of adjacent structures (Krasić *et al*., 2013).

Accuracy of the obtained model

In order to determine the precision of the displayed method, the actual and model dimensions were compared. Control measurements of 12 distances (d_1-d_{12}) were performed on the house in Krivi Vir Street in Niš. The measuring of distances between the same points was performed on the model obtained by the semi-automatic photogrammetry method.

After that the percentage of deviation of each distance of the model in respect to the actual length was calculated and displayed (Table 1). The average value of deviation is provided at the bottom of the table, and it amounts to 2,9% for semi-automatic photogrammetry method.

Table 1. Control measurements and deviations of distances from the model

Distance mark	Length [cm]		Deviation in comparison with the actual length [%]
	Real (measured)	Model	
d_1	641	640	0,15
d_2	1163	1200	3,20
d_3	641	640	0,15
d_4	234	245	4,70
d_5	116	115	0,86
d_6	291	280	3,78
d_7	635	650	2,36
d_8	467	490	4,92
d_9	274	280	2,19
d_{10}	110	115	4,54
d_{11}	257	245	4,67
d_{12}	242	250	3,30
Average value of deviation percentage			2,90

The deviations obtained in this research in comparison with those obtained in other researches (Erickson *et al*., 2013) are higher because of the impact of the human factor and the usage of web photographs and lower quality maps. For that reason, in some areas such as architecture, archeology and protection of cultural heritage, there are higher deviations than in other areas (Remondino *et al*., 2012; Krasić and Pejić, 2014).

CONCLUSION

The main characteristic of the presented web resource based photogrammetry method procedure is the usage of free, globally available data. Demonstrated procedures for creating a 3D model of existing buildings prove that web resource based photogrammetry is possible to implement in practice. The presented procedure for the creation of 3D models of the existing buildings in comparison with the other semi-automatic photogrammetry systems (Pejić *et al.*, 2013a) has one main difference. It is time and work saving due to no need for a physical visit to the location for data collecting because all data are acquired from the internet.

By implementation of this concept, the architects can maximally simplify the model production process of an existing structure. Due to the development of web technology, it is no longer necessary to visit the location of the building, because all the necessary data can be obtained

through the internet. Also, the usage of only one software package which allows complete model production, scaling and geo-locating represents an additional improvement. An average dimensions deviation of 2,9% for the created virtual model in comparison with the real structure is within the acceptable limits.

All this leads to the conclusion that a 3D model of existing buildings obtained using the presented procedure can be used for various purposes in architecture, such as digitalization of archive documents of the existing structures or for the presentation of architectonic, civil engineering and town planning qualities of a certain location. Digital 3D models can also be implemented for different kinds of scientific analyses and tests, such as the shadow casting analyses or thermal analyses.

The biggest limitation of the presented procedure is if there are no photographs of the desired building. The potential problem is if the location is not covered by the "Street View" or similar services which is most important for the production of geometrically complex models. For that reason, it is difficult to find the data on the internet for the location outside big and important cities. The further technological development of hardware, software and internet will contribute to the simplification and overcoming of these problems.

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