A Low Cost Method for 3-D Documentation of Cultural Heritage Objects

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***Abstract* – In this paper a low cost method for 3-D documentation of cultural heritage objects is presented. Cultural heritage is a testimony of past human activity. As such, cultural heritage objects exhibit great variety in their nature, size and complexity. From small artefacts and museum items to cultural landscapes, from historic buildings and ancient monuments to city centres and archaeological sites.**

Cultural heritage around the globe suffers from wars, natural disasters and human negligence. The importance of cultural heritage documentation is well recognized and there is an increasing pressure to document our heritage.

***Keywords* – Cultural Heritage, 3D Modeling, Photogrammetry, Documentation.**

I. INTRODUCTION

The need for digital documentation, preservation and conservation is given by the constant threat and danger that are affecting the Cultural Heritage. Currently three main approaches can be distinguished, for the optical recording, documentation and visualization of heritage sites, monuments and finds:

1. Image - based methods (e.g. photogrammetry): these methods are widely used for 3D reconstruction of architectural objects [1],[2], for precise modeling of terrain and cities [3] or monuments and statues [4] and lately also for precise and detailed modeling of complex objects using consumer-grade digital cameras [5]. Image-based methods use projective geometry or a perspective camera model. They are highly portable and the sensors are often low priced.
2. Range - based methods (e.g. laser scanning): these techniques are based on active sensors that directly capture the geometric 3D information of an object using artificial laser light (e.g. ShapeGrabberTM) or projecting a pattern (e.g. BreukmannTM) without requiring a mathematical model to derive 3D information from 2D observations. Applying different measurement principles, they capture millions of points in relatively short time but require great editing efforts to correctly model the recorded 3D data. They are quite expensive and often unpractical in some field campaigns.
3. Combination of image - and range -based methods: in many applications, a single 3D modeling method that satisfies all project requirements is not yet available. Photogrammetry and active sensors have been often combined in particular for the recording of large architectural objects or complex archaeological sites, where no technique by itself can efficiently and quickly provide a complete and detailed model [6 - 9].

Comparisons between image-based and range-based modeling are reported in numerous papers [10], [11] and the experts agree that at the moment, for all types of objects and sites, there is no single modeling technique able to satisfy all requirements of high geometric accuracy, portability, full automation, photo-realism and low costs as well as flexibility and efficiency.

Anyway, for some projects, like those described in this paper, currently available image based technologies can offer a lot of improvements in the current practices, and the generated documentation.

Currently on the market there are a lot of low cost software packages, and digital cameras with constantly increasing performances. Every conservation work, field work, excavation, according to the regulations, must include documentation and photography. Since the photographs are already taken, there is no reason not to do that in photogrammetric manner, which would also enable their use in the image based 3D modeling of the object.

There are three case studies presented in this paper. The main goal of these examples is to accentuate how easy 3D documentation can be implemented in the current work practices. The first two case studies are two churches, which complete 3D models were made in less than 4 hours. From these models, all the measurements can be derived and they can also be used in a presentation proposes. The third case study is a measurement check project, in which the precision of the approach presented in this paper is checked.

As it can be seen from the conclusion, the approach presented in this paper, can efficiently be implemented in the current work practices. The recent developments in the new technologies enabled this, so there is no reason not to use the full potential of image based 3D modeling.

II. CASE STUDY 1: CHURCH ST. ATANASIJ IN BITOLA (NEAR VERO SUPERMARKET)

The church “St. Atanasij” is a new church build in 2008/2009. As it can be seen the exterior is almost finished, and this year it is planned to start with the interior.

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Fig.1. Church St. Atanasij

The 3D image based model of this church, was made using low cost digital camera (previously calibrated) – Canon PowerShot A430 (4MP) and PhotoModeler application. Reference measurement points were taken during the field work, which later were used for adjusting the scale and dimensions of the object and also for precision checking.

The whole project of 3D modeling was finished for less than a 4 hours. During the field work, 10 photographs were taken, covering the object from all sides. The location of the near market, enabled the generation of "high" angle photos, for one side of the church.

High ground photos from the south side could not be taken, so as an alternative, photos from a greater distance were taken. This on other side reduces the precision of the generated 3D model, due to small number of pixels available in the digital camera – 4MP. In order to increase the precision of the generated 3D model, it is advisable to use a digital camera with higher resolution, and also printed target marks which should be placed on the object before it should be photographed.

Fig.2. Image based model of the church St. Atanasij

III. Case study 2: Church St. Spas, location Cebren, Mariovo

The church St. Spas, near the monastery complex "Cebren" is a small church (6.3 x 4.3 m) build from simple river stone.
The interior is divided in two with a wooden altar. All four walls from the church interior are decorated with painted frescos. According to the available scientific literature, the frescos are dated back from the XVI century. Their preserved area is ~ 60 m^2. Aldo the exterior of the church is restaurated several times through the centuries, the interior is kept untouched, which gives the real value to this church.

Not so far from the church in the future is planned a big hydro plant – "Cebren" to be build. This means that the location of the church would be under water, and the church, along with the nearby St. Dimitrij church, and the archeological site "Chebren" has to be dislocated.

Dislocation of this objects, means that the generated documentation must be elaborate and precise, so they can be brought back in their original form, in the new location.

The photographs used for generation of 3D model of the church St. Spas, were taken by an amateur photographer, during his field work. The camera model used was Sony DSC R1 (10 MP) and the photographer was told, to keep the parameters of the camera constant and to take photographs from all sides of the object. The other day in the office, the camera was calibrated with the same parameters.

The goal of this "assignment" was to prove how easily and efficiently the Photogrammetry and 3D modeling can be used, and which are the benefits of their use in the field work:

The church St. Spas is located in the Chebren locality - 4 hours driving with terrain vehicle, on a bumpy road, on which you can drive only when the soil is dry meaning only in summer. This means that when you arrive on the location, you must generate as much information's as you can, because you don't know when you will have another chance. The generation of the photos used for the 3D model was in a time interval which was less than 10 minutes, but yet, from these photos, all the dimensions of the object can be derived, back in the office.

In the same manner, the interior of the church (which is most valuable) can be 3D modeled, but for this kind of project, a special preparation work is required and appropriate lighting.

Fig.3. Church St. Spas

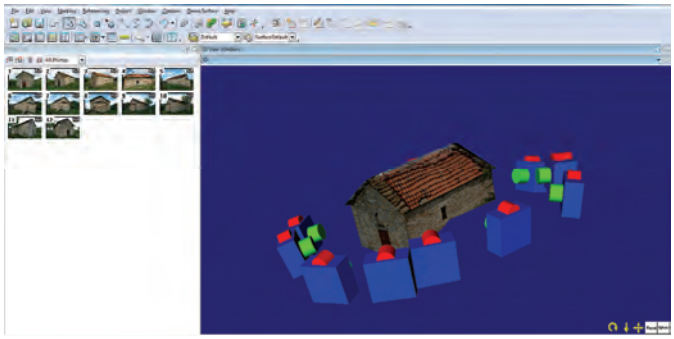

Fig.4. Generated 3D model of the Church St. Spas, along with the camera stations

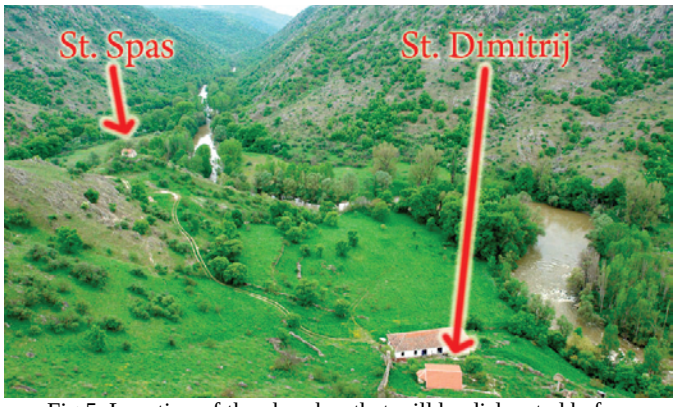

Fig.5. Location of the churches that will be dislocated before building the "Chebren"hydro plant

The nearby church St. Dimitrij (Fig. 5) is also planned for dislocation, this church is bigger, it is reconstructed 4 years ago, and its altar part is dated back from the XVI century.

The previous two case studies have shown how easy is to generate a 3D model of an object, and by doing that, to generate an elaborate and precise documentation.

The question that should be answered is how precise is the generated documentation.

In the previous two projects, real measurements of the objects have been taken, but simply for orientation and scale proposes, and some minor accuracy tests. Also for these two objects, an analog generated documentation already exists, and from which by comparison it is determined an error less than 2 cm in all measurements. Yet, the problem with this documentation is that we don't know how accurate the analog measurements were, and from which points the measurements were made.

The achieved accuracy in a 3D modeling project is dependent of a number of factors, concerning the used camera and its handling, the object and its size and not to forget the clear definition (natural vs. targeted) of the measured points.

For accuracy check in this paper a third case study is presented, and in this case the goal was not to model in 3D the object, but simply to use the approach as a measurement tool and to check its precision.

IV. Case Study 3: Entrance of the Bitola Museum

The building of the museum in Bitola is build in the middle of XIX century, to serve as a military school. In this school the father of modern Turkey – Mustafa Kemal Ataturk had studied, which makes this building one of the most valuable in Bitola. It is big object, and to generate a 3D model would be a serious project, in which a lot of preparations should be made. Yet, its entrance gives a perfect opportunity to check the precision of the approach elaborated in this paper. The balcony above the entrance makes it possible to place and measure the distance of a printed target marks and by doing so a big coverage of the object is ensured and the precision can be checked. 20 target marks were placed on the object, and the distances between them were precisely measured. The placement of the targeted marks also enabled more precise referencing, and greater precision of the measurements.

The goal in this project was not to model the entrance, but simply to check the precision of the elaborated approach, and its possible use in the cultural heritage documentation.

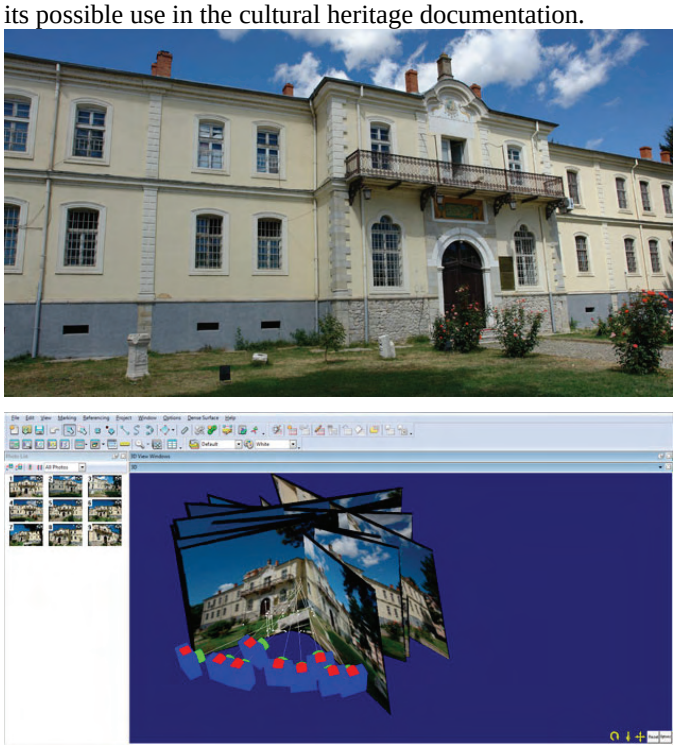

Fig.6. Entrance of the museum in Bitola

Table 1 shows 10 previously measured (real distances RD) between the targeted marks. MD (3D Measured Distances) - the distances measured in the Photo modeler application. The camera used in this project was previously calibrated Sony DSC R1 (10 MP).

As it could be seen from table 1, the Absolute Error (AE) in the largest distance (3,3 m) is near 1 cm, which means Relative Error (REL) ~ 0.3 %.

The generated errors in the other measurement are even smaller and in the analog measurements they are often neglected. Also it should be noted that the used camera had a resolution of 10 MP, which today is a standard for entry level models. Semi professional and professional digital cameras used in the field works, have a resolutions even double than

this, which means even greater precision of the generated 3D models.

Table 1. Accuracy check of the 3D generated model

RD (cm)	MD (cm)	AE	REL	REL (%)
54.2	54.3	0.1	0.00185	0.1845
66.5	66.2	0.3	0.004511	0.451128
73.4	73.7	0.3	0.00409	0.40872
78.3	78.1	0.2	0.002554	0.255428
86.4	86.9	0.5	0.00579	0.5787
95.8	95.6	0.2	0.002088	0.208768
98.5	98.3	0.2	0.00203	0.203046
122.2	122.5	0.3	0.00245	0.2455
324.1	322.9	1.2	0.003703	0.370256
335.3	334.2	1.1	0.003281	0.328064

This example clearly shows that the generated image based 3D models of the cultural heritage objects, offer a level of precision greater than the analog measurements.

V. CONCLUSION

The previous case studies have shown that the image based 3D modeling offers a great potential in the processes of documentation and presentation of cultural heritage.

We can see that it is easy to educate the current staff, to take field photos of the heritage objects, in a photogrammetric way. As it is said in the beginning of the text, since the photographs must be taken during the field works, there is no reason not to do this in a photogrammetric manner.

The experiments made in the area of image based 3D modeling, had shown that if the digital camera is properly calibrated, and if 3D modeling procedures are followed, than the generated models, have far greater accuracy, than the drawings generated trough the current practices.

Another positive side that should be mentioned is the speed for generation of 3D model. If the cultural heritage object is properly photographed, than the appropriate 3D model can quickly and efficiently be reconstructed back in the office.

The 3D modeling approach has also the advantage of reconstruction an object from old photographs. There are a numerous examples of long gone (ruined) objects, from which old photographs exist. In some of these examples, the only requirements are two photographs from different angles, and some kind of reference point (for example the base of the ruined object).

We can freely say that the current analogue practices are old, imprecise and can't match the new technologies. With the current development of the technology, we have mobile phones equipped with digital cameras with more than 5 MP, whose photos can also be used for generation of 3D models. Also with the images from mobile phones, we have the possibility of geo referencing, which means that every generated image, has also meta information about the location on which it is taken.

Trough the heritage sites around the world there are numerous examples of successful implementations of image based 3D modeling.

Image based 3D models can also be used in educational and presentation proposes. There are endless possibilities offered by this technology, and according to the experts it will become standard practice in the documentation activities.

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