# 3D modelling by UAV survey in a church

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***Abstract***

The aim of the study was to make a 3D model of a Catholic Church in Székesfehérvár (Alba Regia) by using UAV indoor. This paper presents the process of the UAV photographing, modelling and evaluation of the results. The appropriateness of the steps is also presented. The chosen Church called the 'Great Patroness of Hungary' is located out of the downtown and will be rebuilt in the near future thus the survey and modelling can also be considered as a historical memory conservation.

## I. Introduction

Modelling of historical building and locations has a long history but nowadays new methods and techniques are available for this purpose. Using Unmanned Aerial Vehicles (UAVs) facilitates and accelerates surveying of these locations and gives the same accuracy as the traditional ways of mensuration.

Scientific experiences show that using UAVs for surveying historical places and use them in archeology is a precise, very perspective and not too expensive method [1].

DJI Phantom 3 Advanced UAV was used for surveying as previous experiences showed that this DJI model has a good accuracy but in the future DJI Mavic Air will be used for the same purpose as this UAV has and improved indoor navigation system and can be used in smaller areas, too.

During the survey many photographs were taken inside the Church from different heights (generally the height difference was 1 meter) and different point of views (3 positions and on every height three directions were used during photography).

Agisoft PhotoScan was used for 3D modelling although other Shareware/Freeware software could be used for modelling.

The surveying of the Catholic Churches continues and we plan to create the 3D models of each Catholic Churches in Székesfehérvár.

## II. Completed work

### A. *History in brief*

The city of Székesfehérvár was the former capital of Hungary for 500 years. Many Hungarian kings and queens were crowned and buried here. There are eleven Roman Catholic Churches in Alba Regia and most of them are located in the historical downtown.

The name of the chosen Catholic Church is the 'Great Patroness of Hungary' which refers to the special connection between Virgin Mary and Hungary. The Church is located in a suburban area of Székesfehérvár 3 kilometers from the city center.

Figure 1 shows the frontage of the Church.

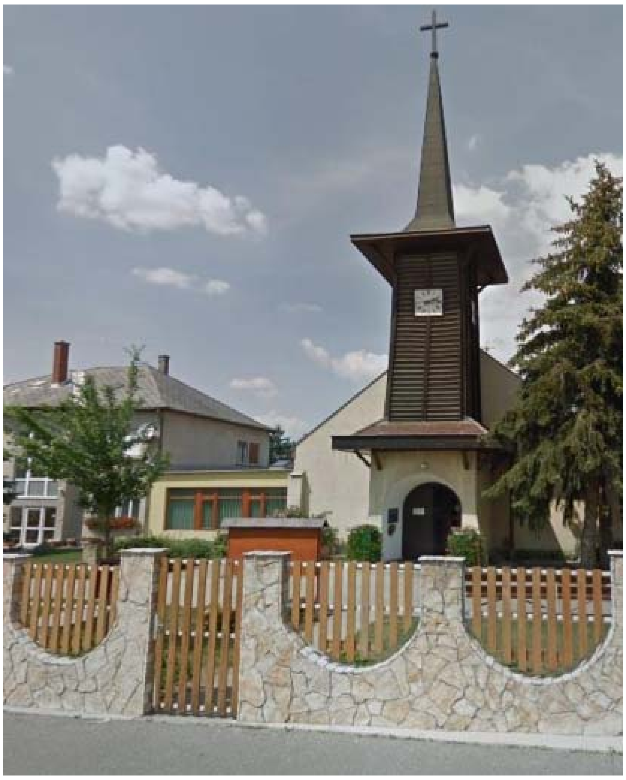

Figure 1. The Church of Great Patroness of Hungary [2]

The Parish of Great Patroness of Hungary was funded in 1939 and the now-known form of the Church was built in 1995. As static problems were revealed in recent times the Church will be renovated or rebuilt in the near future [2].

Figure 2 shows the result of a former surveying.

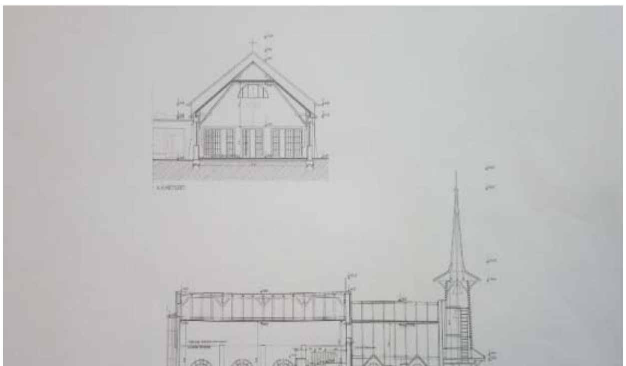

Figure 2. Cross-section of the Church

*B. Short description of the UAV*

The Chinese DJI company can be considered as one of the leading UAV manufacturers in the world. The DJI Phantom 3 Advanced UAV is available since 2015 and beside its good features cannot be considered as the latest techniques [3-4].

The UAV weighs 1280 grams and has a 15.2V 4480mAh battery which allows maximum 23 minutes' flight time. The onboard Sony EXMOR 1/2.3" camera has 12 million pixels and has a FOV of 94° with 20 millimeters focal length. The ISO value changes between 100 and 3200 for video recording and 100 and 1600 for photographs. The shutter speed varies between 8 and 1/8000 seconds. The resolution of the video caption is 2.7K (30fps).

The camera is hanged on-board with the help of a 3-axis gimbal which helps to stabilize the camera during flight.

For navigation DJI Phantom 3 UAV uses GPS/GLONASS system outdoor and has a vision positioning system for indoor positioning. The hover's horizontal accuracy is between 0.3 and 1.5 meters and the vertical accuracy is between 0.1 and 0.5 meters depending on the positioning method.

This UAV can reach approximately 3 kilometers distance outdoor from the home point which is marked before the flight starts. The 'Go home' function helps to find the hover in case of being lost or invisible.

*C. Taking photographs*

During the flight the UAV's controller was switched to manual mode as no GPS or Glonass signals were available inside the building. All photographs were taken manually from three locations from the ground up to 10 meters and three photographs were taken with 45° difference in camera axis on every location.

Camera calibration is a fundamental prerequisite for precise image processing [5]. This process were made in lab before flight. During the flight the DJI GO application was used and beside the UAV pilot an external observer helped the safe flight. The air ricochet and turbulence made the survey harder than in case of outdoor flight.

A little more than one hundred picture were taken and the flight lasted for 15 minutes.

Our plan to use DJI Mavic Air during the future surveys as its technical parameters and flight properties are more sophisticated however Phantom 3 Advanced UAV is still a good choice for surveying purposes, too.

*D. Modelling in Agisoft PhotoScan*

For modeling, a Russian program called Agisoft Photoscan was used [6]. It is a simple and fast-to-learn point cloud production software. We can create a detailed and accurate digital terrain model, digital surface model, and georeferenced orthophoto-mosaics.

We can generate a photorealistic 3D model by a fully automated and intuitive workflow.

The whole procedure is as follows:

The "Add Photos" command within the Workflow module allows you to retrieve images. This was preceded by the separation of the images in order to select the best-quality images with an appropriate overlap.

The next step in designing the model was to apply the 'Align Photos' command. In this procedure the program finds common points for the relative orientation of image pairs or group of images.

Here we can set the set the quality of the image matching (we use the medium option). As a result we get the camera positions (coordinates of projection centers) and the rotation angles of images. In this phase we can see a sparse point cloud of those points which were used for image orientation.

The next step was to use the 'Build Dense Cloud' within the Workflow menu, which generated a dense point cloud. Before running the command, it was possible to select the desired quality (we set it to moderate). This step took more than 50 minutes to model the church inside (See Figure 3).

Figure 3 Fragment from the point cloud

The point cloud itself is similar to a model because it is very dense and it can be seen from a distance as a real model. However, there is a lack of topology between the points. At this step we can start to edit and delete the unnecessary and wrong points. This editing process is supported by the software with different selection tools. There were many points that were not part of the temple, which could be deleted in order to get a better designed 3D model. The selection had to be done carefully because the selection tool works as a 2D tool, but the points are in 3D space. As a result, even points that are not visible in the current view can be deleted.

To build topology between the points we chose the 'Build Mesh' command in the 'Workflow' menu. As a result, we got a model of triangles (TIN model) as it is seen in Figure 4.

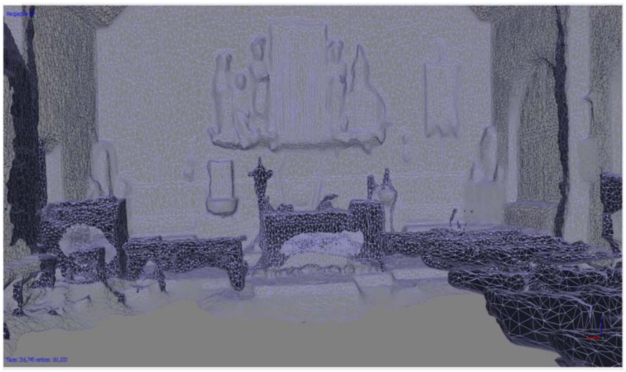

Figure 4. TIN model

The purpose of the TIN model is to joint points with lines in the point cloud. The triangles formed between the dots are not visible to the naked eye, but it can be seen after proper magnification.

In addition, it is possible to fill some larger holes in the model automatically. In our case, the floor and the upper part of the church had some the minor deficiencies. However, we didn’t use this feature, because the Close Holes function can hide these areas but it also modifies geometry.

In the next step the generated TIN model can get a texture by applying the Build texture function.

Texturing images removes minor imperfections in the TIN model. The program applies color adjustments to the images to create the best possible model. So the quality of the final model depends to a large extent on the resolution of the images (see Figure 5).

Figure 5 Textured model

The final step was the 'Build Tiled Model' command, which visually generated the best model. This model has already put a heavy load on the computer and has stuck several.

The textured and tiled model is hardly distinguishable from a distance, but the details show that in the latter the details appear much sharper (compare Figure 5 with Figure 6).

Figure 6 Fragment from the textured model

Figure 7 Fragment from the tiled model

Publication of the completed model was also made with Agisoft Photoscan software. The program can export in many file formats.

These are:

- Wavefront OBJ
- 3DS models
- VRML models
- COLLADA
- Stanford PLY
- STL models
- Autodesk FBX
- Autodesk DXF Polyline
- Autodesk DXF 3DFace
- U3D models

• Adobe PDF
• Google Earth KMZ

We generated a 3D PDF with the program. In addition, it is possible, for example, to read and save the points, save the tiled model independently, or even share it online within the program.

The software can even generate a report on modeling, producing a few pages of PDF. This document includes camera calibration, camera positions, control points, and other processing parameters.

## III. RESULTS AND CONCLUSIONS

We needed to get photos taken by an UAV, and we needed to do a geodetic survey to have data for an accuracy check of the 3D model. The photos were taken by using a DJI Phantom 3 UAV, and we used a Foif total station with its necessary accessories for the geodetic surveying. The UAV flight took place in 3 setups, in different heights and towards 3 separate directions. At the end of the day, 127 photos were taken.

In the geodetic survey we used 3 instrument setups, and we chose 21 control points on the site to measure. We took the measurements with extra care, in a specific way to be able to create a network and adjust errors at the same time. In order to minimize instrument errors in the surveying, we measured each points at twice permits. The deviation of coordinates of each points in the network are far less than 1 cm.

The accuracy test was performed with the help of Agisoft Photoscan as well. We placed the 'Markers' on the images of the textured model, which correspond to the ground control points measured in the field with Foif RTS 332 measuring total station.

After carrying out the error assessment the greatest residual was about 4 cm. The overall RMS value was 2.6 cm.

As a conclusion we can say that the UAVs can be used effectively for 3D modeling even indoors. The Agisoft Photoscan software (the latest name is Agisoft Metashape) is a perfect choice to go through the whole process.

## ACKNOWLEDGMENT

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