Comparison of creating 3D models from UAV: Case study windmill Černilov

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Abstract— **Modern world wants to have realistic and precious real-world models. One of the representations of the real world is 3d models. This paper compares approaches and processing time for creating a 3D model based on UAV-borne image data. Image data for 3D model was collected by two approaches by an UAV. Both approaches were controlled by planned flights with specific parameters. Creating 3D models was processed in two software tools. One of them was freeware, and the second one was licensed. Results from the processing of 3D models show different processing times and quality of 3D models given by tools and data collection approaches.**

Keywords — 3D model, 3D modelling, photogrammetry, drone, UAV

I. Introduction

The modern world wants to have a realistic model of everything – processing, physics-based, behaviour, etc. [1][2][3]. A new trend in 3D modelling has started this millennium. Realistic and precious modelling of physical objects, especially 3D modelling, is desirable. These models cover scale from small objects (e.g. miniature) to large areas (e.g. cities, whole countries).

In recent years [4], 3D models have been increasingly used in many industries, such as film, computer games, architecture, industrial design, medicine, and many others. These models provide accurate and detailed visualisations of objects and enable the creation of complex simulations to achieve in the real world. With modern technologies and possibilities, it is very easy to create own 3D model of a physical object.

There are many tools and programs for creating 3D models, such as Autodesk 3ds Max, Blender, SketchUp and many others. These programs allow the creation of models from various sources, such as digital scans, drawings, and hand modelling.

There is also the possibility of processing a 3D model from image data obtained from an optical sensor. The optical sensor can be a digital camera, a mobile phone camera, or a drone camera. Data other than RGB image data and laser data can also be obtained. Laser data is acquired using a laser sensor known as LIDAR [5]. When the laser beam is sent out, it hits an obstacle, and some of the light is reflected to the LIDAR. The LIDAR then picks up this reflected signal and uses it to determine the distance and position of the obstacle and plot a point at that position. The points obtained in this way have a very high accuracy; a group of these points is called a point cloud. An unmanned vehicle is a very suitable carrier for LIDAR.

UAVs have become a popular tool for capturing aerial data for creating 3D models. Using drones to collect data for 3D models has several advantages over traditional methods, including the ability to collect data quickly and efficiently and capture data from hard-to-reach or hazardous locations.

Unmanned Aerial Vehicles (UAVs), also known as drones, are remotely or autonomously controlled aircraft. They are typically equipped with sensors and cameras and can be used for various applications, including surveillance, mapping, inspection, and delivery.

The whole process of creating a 3D model using drone images can be described as following basic steps. The first step is to plan the drone flight. It involves selecting the area to be mapped, defining the flight path, and setting the altitude and camera angle to capture the required data. Once the flight plan is created and uploaded to the drone, the flight itself can start. The drone is typically flown in a grid pattern, capturing overlapping images of the area to be mapped, called waypoints. The third step continues with image processing, which uses photogrammetry software to create a 3D model. Photogrammetry software uses algorithms to analyse overlapping images and create a 3D model of the area. Tools can create more outputs like a point cloud, tie points, triangle meshes and orthophoto map, digital terrain model, and digital surface model.

The following step is post-processing. The 3D model can be refined by adding additional data, such as ground control points, to improve the model's accuracy. This step may also involve removing any errors or anomalies in the data. The final step is exporting the 3D model. Once the 3D model is complete, it can be exported to various file formats for other software applications or 3D printing [6].

Using drones as a data source for creating 3D models has numerous applications, including surveying, construction, urban planning, and environmental monitoring. Drones provide a cost-effective and efficient method for capturing data, and the resulting 3D models can be used to improve decision-making and planning processes.

Planning a drone flight for 3D models requires careful consideration to ensure that the drone collects the necessary data to create accurate and high-quality 3D models.

The planned flight can be generally described as the process consisting of the following steps. The first step is to define the area to be mapped. Here it is necessary to follow the rules for flight with drones and prepare documents for special types of flight if required. Before planning and starting the flight, it is essential to check the weather conditions and obstacles. Wind, rain, and other weather factors can affect the flight. The second step is to set important parameters for flight planning. The altitude, camera angle and overlaps are crucial for capturing high-quality image data.

The altitude should be set to ensure that the drone captures the entire area to be mapped and gives very high spatial detail. The camera angle should be set to capture the necessary detail; here are more recommendations on what camera angle to set. The flight path should be defined to ensure that the drone covers the entire area to be mapped. It can be done using specialised software that allows users to plan the flight path and adjust the altitude and camera angle as needed. For accurate 3D models, capturing overlapping images of the area to be mapped is essential. It helps the photogrammetry software to stitch together the images and create a 3D model.

The third step is to set the ground control points (GCPs) that improve the accuracy of obtained data and also 3D model; it is an optional step. The GCPs are usually marked points on the ground that are visible in the images captured by the drone. The drone flight should be planned to capture these points in the images.

The planned flight can be called the automatic flight. During the automatic flight, the UAV is monitored and controlled by an operator (pilot) on the ground, who uses a remote control or computer system to guide the aircraft. The pilot can hit the drone controls anytime to interrupt flight during automatic flight.

With these steps, drone flights can be planned effectively to ensure that the drone collects high-quality data for creating accurate and high-quality 3D models.

TABLE I. shows searched terms in scientific databases related to creating 3D models from data obtained by UAV. The paper focuses on classic UAVs which have a built-in camera. Built-in cameras usually capture images in the visible part of the light; i.e. RGB imagery is collected. The result of searching in scientific databases reveals that this is a research niche because of the low number of papers focusing on this topic.

TABLE I. SEARCH TERMS IN DATABASES SCOPUS AND WOS. SOURCE: AUTHORS.

Search term	Scopus	WOS
3D model	109564	25093
3D model & aircraft	3022	188
3D model & UAV	3865	427
3D model & UAV & creating	356	21
3D model & UAV & RGB	573	25
3D model & UAV & creating & RGB	36	1

The aim of this paper is to compare approaches to creating 3D models from data obtained by a UAV. This paper compares different tools to create 3D model by the speed of creating a model and by visual interpretation of the output model. It also compares approaches to obtaining image data by planned UAV flight.

II. CURRENT SOLUTIONS – STATE OF THE ART

The paper [7] shows how low-cost solutions (UAV and software) are used to get the best input data by only one flight for a 3D model. Their system was tested on the complex the Sacro Monte di Varallo Sesia. They defined 3 flight plans for planned flights, two Nadir and one oblique.

A 3D model of castle Landenberg [8] demonstrated a combination of aerial and terrestrial photos. The authors use mini-UAV and DSLR camera image combinations to create 3D models. The camera was only DSLR Nikon but was used by two approaches – aerial and terrestrial. For creating 3D model, they used Photomodeler 6 software. They achieved an excellent high-resolution textured 3D model of the castle.

Article [9] focused on using low-cost tools to create a precise 3D model. The authors focused on using the smartphone camera and DSLR camera as a source of data for 3D models. Images from Google Earth data and GCPs improved input data. Data were processed using Agisoft PhotoScan tool.

Using UAVs as a source of input data for a 3D model on demand brings a big advantage when it is necessary to reconstruct any disaster. Authors [10] applied a small UAV to obtain image data of Onagawa town after the earthquake, the first example. For the second example, they collected data by UAV of Kathmandu after the earthquake. 3D models were developed by structure-from-motion technique from video footage of disasters. Other authors [11] also focus on creating 3D models of disaster scenes from data obtained by a UAV. These authors evaluate commercial and open-source software for creating 3D models. They want to show how these tools can support rapid response to help during a disaster.

Road condition [12] can be another use of 3D model created by image data obtained by a UAV. The authors collected image data by a UAV and processed it using the structure-from-motion technique. After the 3D model was created, flexible segmentation strategies were used to understand road quality.

BIM is another part of using 3D models. Paper [13] focuses on the historic BIM model of Averof's Museum. The source data were obtained by planned flight with two vertical and one oblique route.

Authors [14] also use a UAV as a data source for 3D models, and the model was created using open-source software VisualSfM. After creating the model, they compare it with the result from the commercial software Photoscan. The results were also compared with the 3D model from the terrestrial laser scanner survey.

Inspection of anything is a traditional way of using 3D models of real-world data. A model of Placed River Trail Bridge [15] was created for bridge inspection. The authors focus on the processing of inspection, where inspection must consider the design of the UAV, the choice of cameras, data acquisition, geometrical resolution, safety regulations and pilot protocols. They used obtained UAV image data and a hierarchical Dense Structure-from-Motion algorithm for creating 3D model.

The authors of this paper tried another approach for collecting data for 3D model. The paper [16] shows how combining circular flight and spherical camera can bring advantage of faster data obtaining with high-quality images covering a wide area.

III. METHODOLOGY

Drone DJI Mavic 2 ZOOM was used to collect data. The application Pix4Dcapture (version 4.13.1) was used for planning flights by two approaches. The first approach (doublegrid), see Figure 1. , for planned flight creates a flight plan with 8x9 flight lines, with 60% image cover in both directions and 266 images were obtained. The second approach (circular), see Figure 2. , for planned flight creates a one-level circular flight with 20° steps for obtaining images by camera angle set to -35° to the flight axis, and 18 images were obtained. Output mosaic has a spatial resolution 1,9 cm/px.

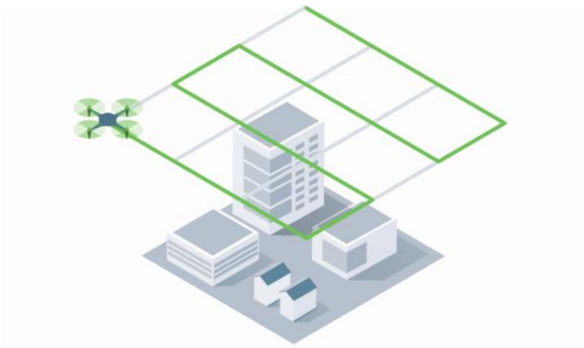

Figure 1. Planned flight - doublegrid

Source: [17]

Figure 2. Planned fligh – circular

Source: [17]

The data collected for the 3D model by both approaches was processed in two software tools, Pix4Dmapper and Meshroom. Pix4Dmapper (version 4.8.2) is commercial photogrammetric software that supports creating 3D models, and Meshroom (version 2021.1.0) is open-source 3D Reconstruction Software based on the AliceVision framework. All data processing was performed on a computer with the following configuration: AMD Ryzen 9 5950x 16-core, 4.0 GHz; 64 GB RAM, Nvidia 3050 10 GB GPU, Windows 10 PRO, PC has installed drivers and support Nvidia Cuda.

IV. RESULTS AND DISCUSSION

TABLE II. shows the processing time of two approaches for data collection (circular and doublegrid) processed in two software tools. Based on the processing time, we can conclude that Pix4D uses better machine resources and probably has a better algorithm for creating 3D models. Also, the output screens of models show different outputs.

TABLE II. PROCESSING TIME

Processing time [min:sec]		
Approach	***Pix4Dmapper***	***Meshroom***
Double grid	57	121
Circular flight	7	15

The following images, see Figure 3. Figure 6. shows the visual output of created 3D models. In the first view, we can see that Figure 4. and Figure 6. look better.

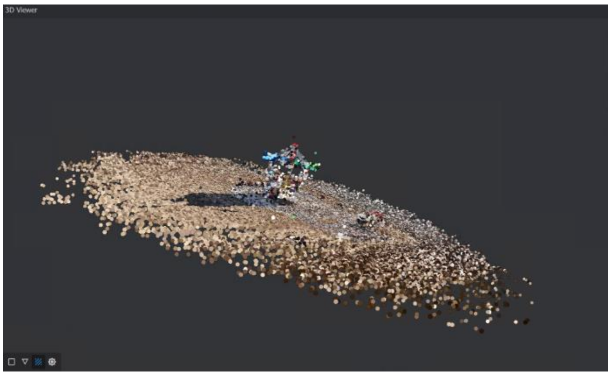

Figure 3. 3D model from circular flight contructer in Meshroom

Figure 4. 3D model from circular flight contructer in Pix4Dmapper

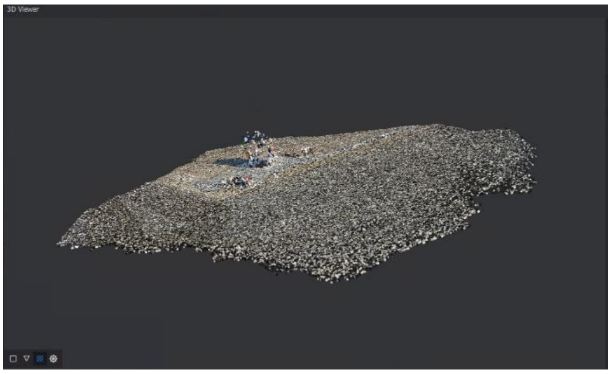

Figure 5. 3D model from doublegrid flight contructer in Meshroom

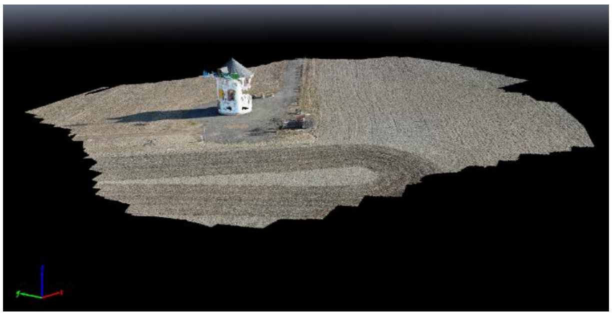

Figure 6. 3D model from doublegrid flight contructer in Pix4Dmapper

In this way, Pix4D can improve the output 3D model by build-up 3D model based on triangle meshes. See Figure 7. and Figure 8. images show the detail of created models by point cloud and triangle meshes. A triangle mesh is a type of polygon mesh. It comprises a set of triangles (typically in three dimensions) connected by their common edges or vertices. Triangle mesh completed blank space between points of models.

Figure 7. Detail of 3D model from Pix4Dmapper – point cloud

Figure 8. Detail of 3D model from Pix4Dmapper – triangle mesh

V. CONCLUSION

This paper compares different software tools for creating 3D models from data obtained by a UAV with different approaches.

The creation of 3D models from UAV data is very suitable for various applications, e.g., inspection, reconstruction, and others.

This paper investigated output 3D models from data acquired by a UAV on two different flights. The first type of flight - a double grid - achieves better visual results when exploring a complete area of interest. The second type of flight - circular - achieves better results for individual objects with higher spatial detail. One-level circular flight can only be practised on small objects, like in this case.

For larger objects to be created as 3D models, it is necessary to fly on multiple levels, always with a specific camera tilt angle in relation to the scanned object.

The powerful hardware is required for creating 3D models from data obtained by an UAV, even for small observation and creating 3D model of simple and single object. For creating 3D models from UAV-borne image data is better to use commercial software which provides faster processing and better result given by software features. Using powerful hardware with support GPU calculation for 3D model is best option for fastest processing of 3D models.

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