Analisis of the possibility of automating the photogrammetric mission planning for unmanned aerial vehicle, based on data from airborne laser scanning

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Key words: Automation, mission planning, laser scanning, photogrammetry, UAV

SUMMARY

The industry for UAV (Unmanned Aircraft Vehicles) photogrammetric flights continues to evolve. Usage for this technology includes multiple fields such as forestry, civil engineering, ecology and more. Automation of photogrammetric mission planning and execution is one of the key aspects for UAV flights for the reason of saving time of the operator and ensuring safety of the mission. Another problem that is mentioned in the paper is acquiring data that is useful for such a task.

This paper presents own implementation as well as overview of UAV photogrammetric mission planning workflow for mapping buildings based on ALS (Aerial Laser Scanning) datasets, and a way for its automation. For each step, existing industry–tested commercial solutions are presented along with their advantages and problems. There are also overviews of common data formats for all elements of the workflow. Data used for the experiments comes from polish national repository of ALS datasets, that covers the whole area of Poland. In the created application, after selecting a feature (building) by coordinates, relevant by proximity LiDAR (Light Detection and Ranging) data packets are downloaded. Afterwards comes modelling of terrain features using methods such as Poisson Surface Modelling or Ball Rolling Algorithm. Experiments prove superiority of the former method. A 3D model of the building is then either automatically extracted from the MESH model, based on LiDAR classification data or by user input. Finally, the plan for a photogrammetric mission, suitable for autonomous flight is generated and uploaded to a controller (smartphone).

While this paper is focused on missions with the goal of collecting data for buildings, the code is adaptable, so it can easily be modified to facilitate planning flights for tree outcroppings and other features. Conclusions present how different algorithms and factors (i.e., height, age, and neighborhood) of the selected building influence the validity of the created mission plan. In some cases, the mission plan is flight ready after the initial selection of a feature, while sometimes creating a plan is impossible or requires additional user input or even another UAV mission with a LiDAR sensor to collect more accurate or up to date data.

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1. INTRODUCTION

The usage history of UAVs is extensive and fascinating. Starting from the middle of the XIX century, unmanned air balloons carrying explosives were used during the siege of Venice in 1849. With the passing years and technological progress also came advancements in UAVs. During the 1st World War, radio–controlled "flying bombs" were utilised, and during the Cold War, unmanned aircraft were used for reconnaissance purposes (Prisacariu, 2017). In the modern age, the usage of UAVs goes beyond military operations. Development of multi–rotor aircraft, expansion of the Information Technology industry and drastic reduction of production costs opened the UAV market for stakeholders from areas such as Civil Engineering, Agriculture, Forestry and Archeology.

Photogrammetry and Remote Sensing is a field of study that is tightly knit with UAV technology. Photogrammetric missions aim to acquire spatially significant data about AOI (Area of Interest). In the earlier stages of photogrammetry, the data acquired was a collection of photos of the chosen area. Later came innovations in remote sensing – LiDAR, multispectral photos and radar imagery, that expanded the variety of information collected. That information can consist of a 3D representation of an area in the form of a point cloud and images depicting properties of objects not visible to the human eye. The process of collecting data about a specific area is based on a photogrammetric mission plan. Such a plan includes, but is not limited to, information about the flight path and points for taking photos. Usage of a mission plan in its purpose maximises the quality and reduces the number of gaps and inconsistencies in collected data, therefore reducing the risk of repeating the mission.

Technological advancements were also made in the area of automation. More and more tasks are now assisted and automated by computer software. For example, draft offices resigned from drawing on sheets of paper in favour of CAD (Computer Assisted Design) software. Such computer programs are continuously updated to reduce the complexity or automate repeatable tasks. Such a topic of automation is the main subject of this paper.

There are many variables to consider while planning a photogrammetric mission, such as GSD (Ground Sampling Distance), overlap between photos and time of flight. To make this process easier, many companies and institutions designed templates of mission plans that can be adjusted for specific areas of interest, along with software that streamlines this process. Examples of those will be presented in the related works section.

Planning a photogrammetric mission should be based on previously collected data. In the case of large–area photogrammetry, it is usually the outline of the region of interest and a Digital Terrain Model. It allows the creation of flight lines, planning the overlaps, and calculating suitable flight altitude. Volumetric objects require more informative data since flights are typically conducted closer to the object, emphasising collecting data with possibly the fewest blind spots. This paper presents a proposition of photogrammetric mission planning workflow based on ALS (Airborne Laser Scanning), which, compared to ULS (Unmanned Laser Scanning), offers lower resolution LiDAR data but is readily available for more areas. The experiment section will focus on mission planning for buildings (volumetric features).

2. RELATED SOFTWARE

Many computer programs help remote sensing experts plan their photogrammetric missions. Those can be standalone software focused solely on mission planning, or complex solutions, guiding the user through the photogrammetric workflow, from mission planning to final product generation.

2.1 Agisoft Metashape

According to an article describing a new feature of this photogrammetric software, "Agisoft Metashape Professional provides functionality for generating drone flight plans for objects with complex geometry" (Agisoft LLC 2022). Using this program, the user starts with data collection with regular flight line paths and then processes photos collected to create a 3D model of the surveyed area. Then he can select the object from the model, along with selecting fragments representing obstacles. After selecting parameters such as camera model, resolution, overlap, safety distances, and camera tilt angles, this software creates a flight plan for the selected object (Figure 1). Results can be then exported to KML format, suitable for importing into DJI Pilot or Litchi drone apps.

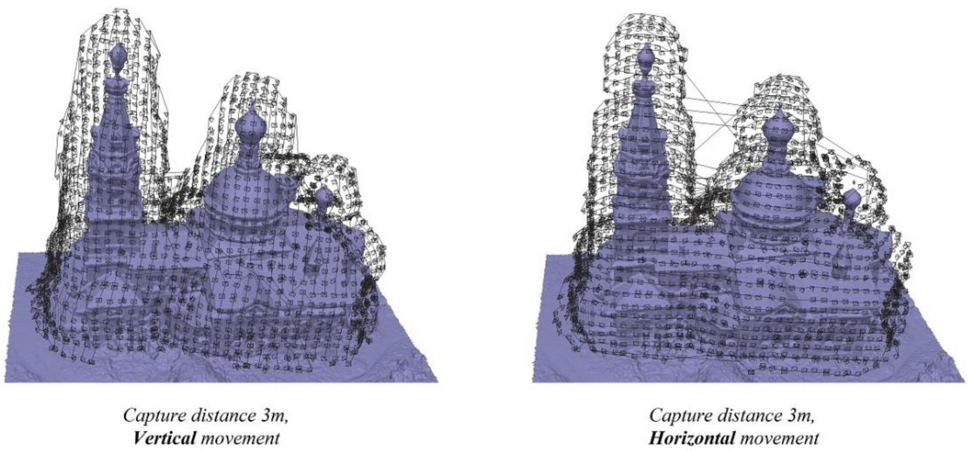

Figure 1 Mission plan examples from agisoft metashape. Left – vertical focused, right – horizontal focused (Agisoft LLC 2022).

2.2 UgCS

UgCS is a comprehensive photogrammetric mission planning software from SPH Engineering, providing the user with tools for creating mission plans for various objects (SPH Engineering 2021). Most of the patterns are included in this solution, from area photogrammetry and scanning to corridor mapping and search operations to facade scanning (Figure 2). Planning is based on configuring the parameters of the flight, which are then used in creating optimal flight patterns, multiple of which can be merged into a complete photogrammetric mission plan. As in the previous program, flight plans and other data are transferred using KML format, but flight control itself can be carried out with the UgCS software using DJI Mobile SDK.

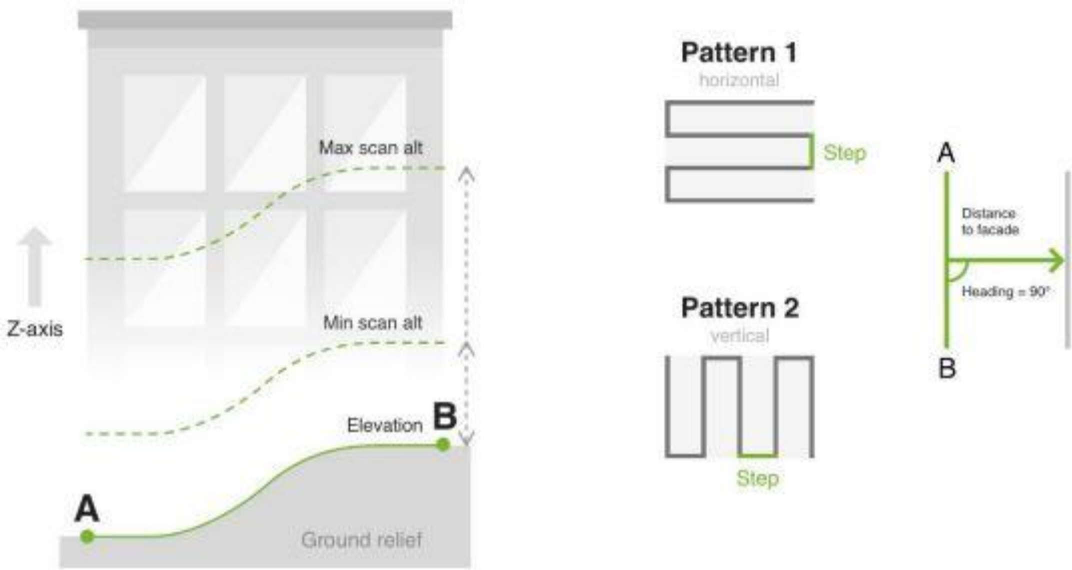

Figure 2. Facade scanning pattern in UgCS software (SPH Engineering 2021)

2.3 Litchi

Litchi (VC Technology Ltd 2022) is both a mission planning software and a drone app. It allows users to plan missions using waypoint markers and mission settings. Control of UAV includes, i.e. heading, camera tilt and photo intervals. This application is much simpler than its previously mentioned counterparts. Therefore, it does not supply the user with mission planning automation tools. Data can be exported from and imported into the app using KML and CSV formats. Due to the integration of mission planning and pilot apps, it bridges the gap between planning and execution and therefore is a valuable tool for small photogrammetry projects.

3. PLANNING PHASES AND AUTOMATION

3.1 Defining objectives and limitations

Defining objectives consists of selecting AOI, required type and quality of data (GSD and coverage for photogrammetric missions, point density for LiDAR) and possibly more. Along with defining restrictions, this process can hardly be automated since most of those parameters are specific to the mission. However, once decided, they define how the rest of the mission planning process should be conducted.

3.2 Gathering data about AOI

Primary data useful for photogrammetric mission planning includes orthophoto maps from previous missions and DEM. Those datasets are not sufficient for mission planning for volumetric objects like buildings, which are the main focus of this paper. Ideally, existing building 3D models could be used as source data for mission planning. ALS is a compromise between the availability of DEM models and the complexity of 3D models. In Poland, ALS datasets from project ISOK, covering the whole area of the country, are available for free download and usage, which includes commercial purposes (Izdebski 2021). This dataset contains classified point clouds with the planar resolution of 4 (standard I) to 12 (standard II) points/m^2. In the latter standard, data was collected from flight lines perpendicular to each other, assuring better coverage of the area. The classic procedure to acquire that data consists of selecting one chunk in the country's geospatial portal and downloading associated data by clicking a hyperlink. This method quickly becomes time–consuming when multiple LiDAR datasets are required.

The gathering of these datasets can be automated using the python scripting language. Once AOI is defined, it is spatially intersected with locally kept data section geometries. Those at least partially inside the AOI are saved to a list. Then, a get feature information request is created and sent to the geospatial portal for all selected sections. That request is explicitly sent to a WMS (Web Mapping Service) and contains the centre of a section. Then from WMS responses, hyperlinks to data sections are extracted and queued for download. To reduce the volume of the downloaded data, once collected, ALS sections are not downloaded again unless specified by the user. The implementation of this workflow can be viewed at this address: http://e.pc.cd/rWMotalK.

3.3 Intermediate processing

After collecting data concerning AOI, comes the step of transforming that data into a format useful for flight planning. Whole ALS point cloud sections are unnecessary for planning photogrammetric missions for singular objects. The format of the data should also be considered. While faithfully representing terrain features, point clouds have blind spots that might create problems during later processing steps. Among the products created from ALS, MESH and voxel models can be mentioned. MESH models are 3D representations of features and terrain, consisting of connected triangular shapes, possibly with textures. Voxel models represent objects using cubes placed in regular intervals, much like raster cells in a photo. In Agisoft Metashape, generated MESH models are converted into voxels and then used to estimate possible flight paths. Conversion of point clouds into these formats also helps filter out the outlying points collected during LiDAR scanning.

During the research, python scripts were created to convert ALS data to two mesh models, one for the selected building and the other for the surrounding environment. Chunks of LiDAR are intersected with a buffer of AOI and merged into a single point cloud. That way, processing time can be shortened due to a reduction in the data volume. The Poisson surface reconstruction algorithm returned the best results for creating terrain MESH models during the tests. Fragment of the model representing the building is then extracted using the point cloud classification. During these steps, the user can preview the generated models and make corrections that are deemed necessary. This script can be viewed here: http://e.pc.cd/MWMotalK.

3.4 Flight plan creation.

In the related software section, several flight patterns were shown. Flight plans in the Agisoft Metashape tool can be used to map complicated structures, and the flexibility of patterns and single point editing of the other two programmes are also handy. In this research, other flight patterns were tested. A continuous flight path can be created using a discretisation of a sphere (Figure 3) (Hüttig, 2008).

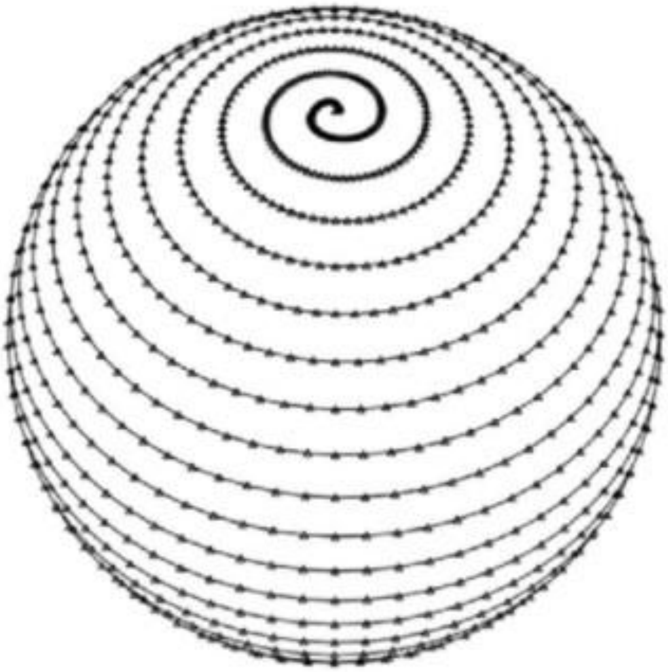

Figure 3 Discretisation of a sphere (Hüttig, 2008)

A flight plan is created using the MESH models from the previous step as a reference. The fragment of this model representing a building is transformed using a spatial buffer. The radius of that buffer is equal to the necessary distance from the building, depending on the used camera, safety reasons or other preferences. Then, lines are constructed from the centre of the building in the directions derived from sphere discretisation. Parameters of the sphere – number of revolutions and density of points on the sphere are customisable. Lines intersecting the buffer create potential points for photoshoots. For each position, rotation and tilt of the camera are calculated to face the nearest fragment of the building. If any fragment of the flight plan is covered too densely with photography positions, those are filtered based on the required overlap. A code snippet of the presented approach can be found here: http://e.pc.cd/p7TotalK.

4. EXPERIMENTS AND RESULTS

The possibility of usage of the presented algorithm was tested on four buildings of varying properties. This selection is proposed to show different problems during creation of photogrammetric mission plans.

4.1 Outdated ALS

The first testing object was a fire station (Figure 4) built in 2020, situated in an open area in Legionowo, Poland. The ALS data for the area was collected in 2012 and 2018 (Figure 5), so neither dataset is helpful in planning a photogrammetric mission for this object.

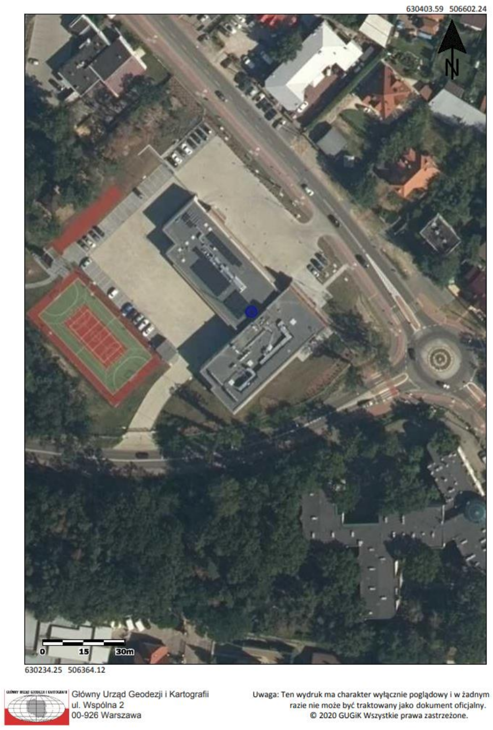

Figure 4. Orthophoto map depiction of the fire station in Legionowo.

Figure 5. Colorized ALS point cloud from 2018, depiction of the area of the fire station in Legionowo.

4.2 Sparse point cloud

The second object of interest is a flat house (Figure 6) in the township of Kępno, Poland. It is a five–story building with sparse trees surrounding it. ALS covering the area is of the lowest possible density, 4 points/m^2.

After downloading and preparing the data, the MESH model of the surrounding area was generated (Figure 7). Vegetation surrounding the building was removed during the Poisson surface reconstruction algorithm. Unfortunately, due to the lack of ALS coverage on the northern wall of the building, the model was warped. It has also caused the automatic building selection to misbehave. It can be observed in orthogonal view during the optional manual building selection step (Figure 8). Despite the loss of quality, the algorithm was executed and created a mission plan (Figure 9) for the selected object. The distances from the building exterior vary since the positions for taking photos are set at an equal distance from the warped building model.

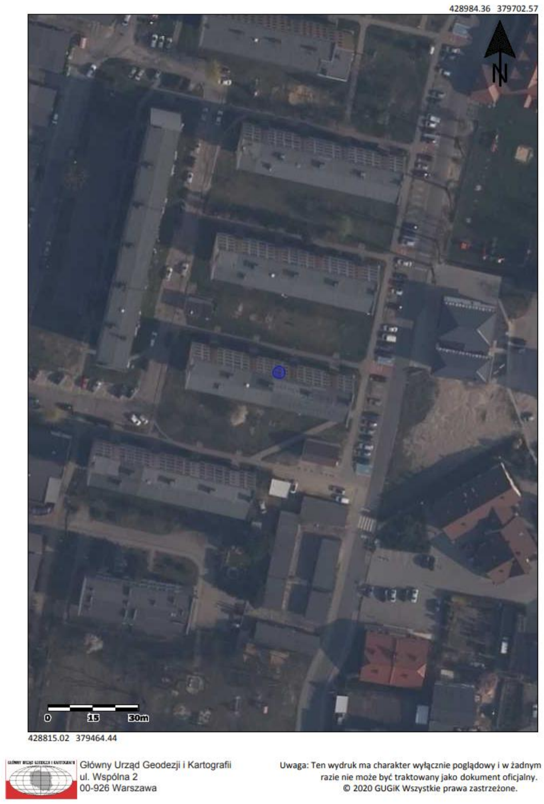

Figure 6 Orthophoto map depiction of the flat house in Kępno.

Figure 7 MESH model of the flat house and surrounding area.

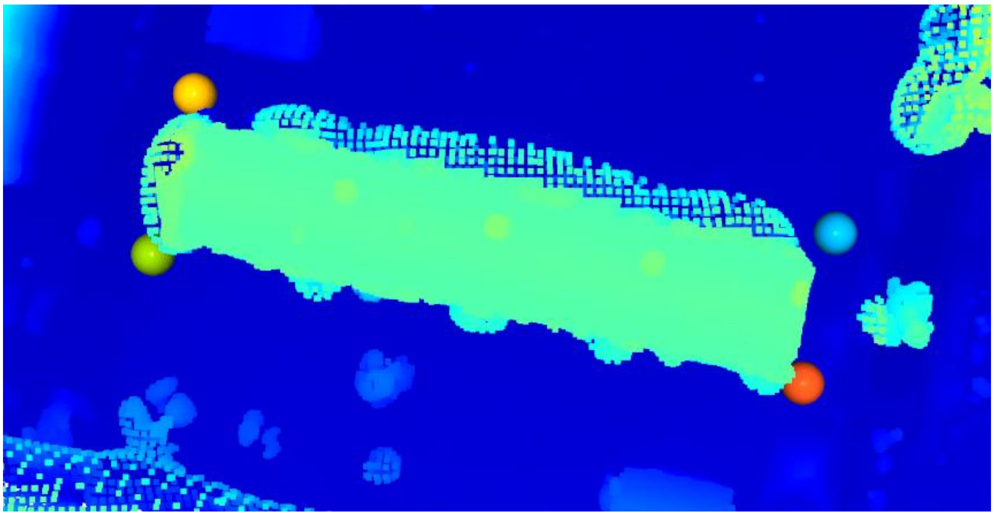

Figure 8 Manual selection of the flat house building and warped walls.

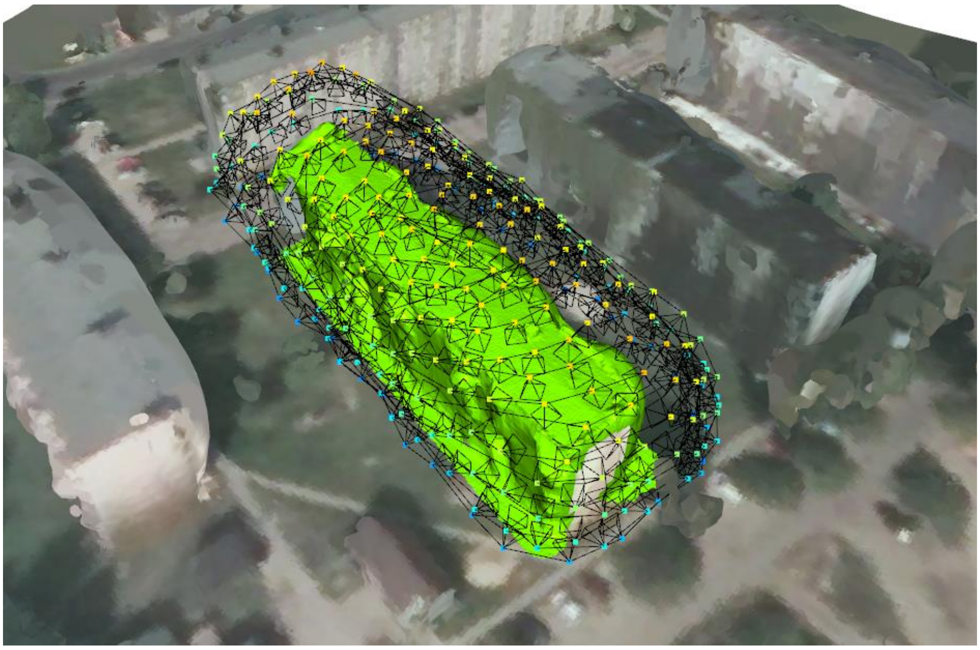

Figure 9 Flight plan for mapping the flat house.

4.3 Squat buildings

The flight pattern of the photogrammetric mission should be selected based on the characteristics of AOI. In the case of the MZA Repair Facility in Warsaw, Poland, the object is a short warehouse sprawling over a large area (Figure 10). The mission plan generated for this building reveals a drawback of using the spiral flight pattern. The sides of the building can be mapped appropriately. On the other hand, photos' coverage of the roof is sparse and done inefficiently (Figure 11).

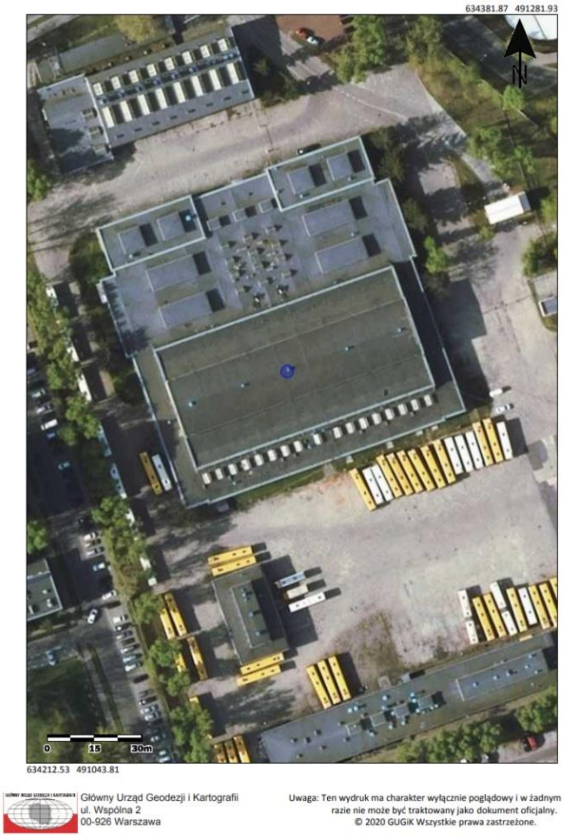

Figure 10. Ortophotomap depiction of MZA Repair Facility in Warsaw, Poland.

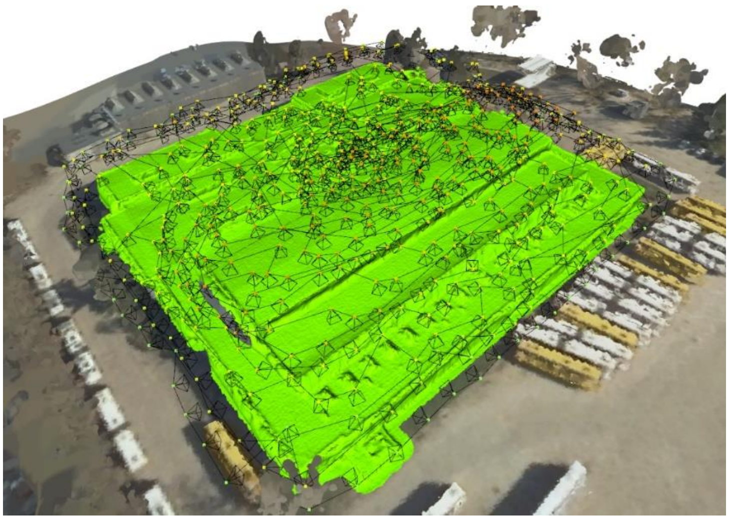

Figure 11 Flight plan for mapping the repair facility.

4.4 Suitable conditions

This section's fourth and final object is the train station in Legionowo, Poland (Figure 11). The building is approximately three stories tall, was built before the last ALS campaign and is covered by a standard II point cloud (12points/m^2). The intermediate data in the form of MESH model is comparably accurate, and the generated flight plan covers the whole building with dense photo positions (Figure 13).

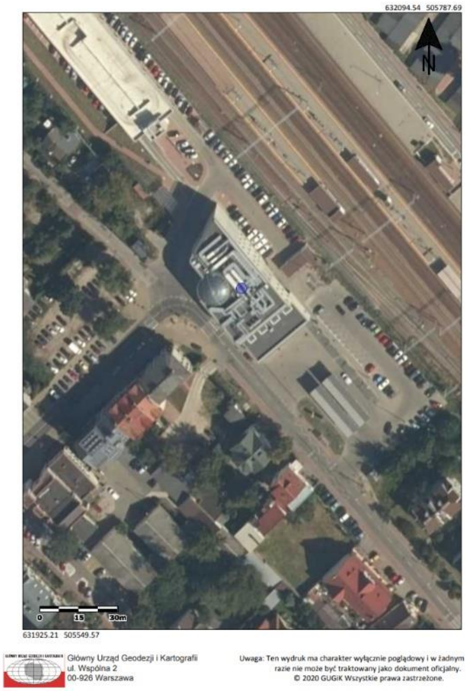

Figure 12 Ortophotomap depiction of the train station in Legionowo, Poland.

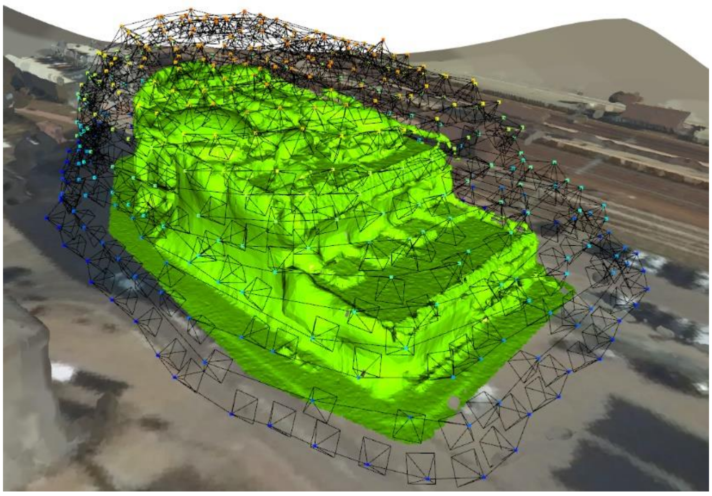

Figure 13 Flight plan for mapping the train station.

The generated flight plan was then exported to a CSV format suitable for the Litchi drone app. Data exported contained information about waypoints, camera external orientations, and intervals to stabilise the UAV. With the use of a cloud storage application (e.g. Google Drive, pCloud), the mission plan can be transferred to the controller (smartphone). In the experiment, pCloud was used to transfer the data to the smartphone with the Litchi app installed (Figure 14). After loading the flight plan to the controller, it is possible to start the flight in autonomic mode.

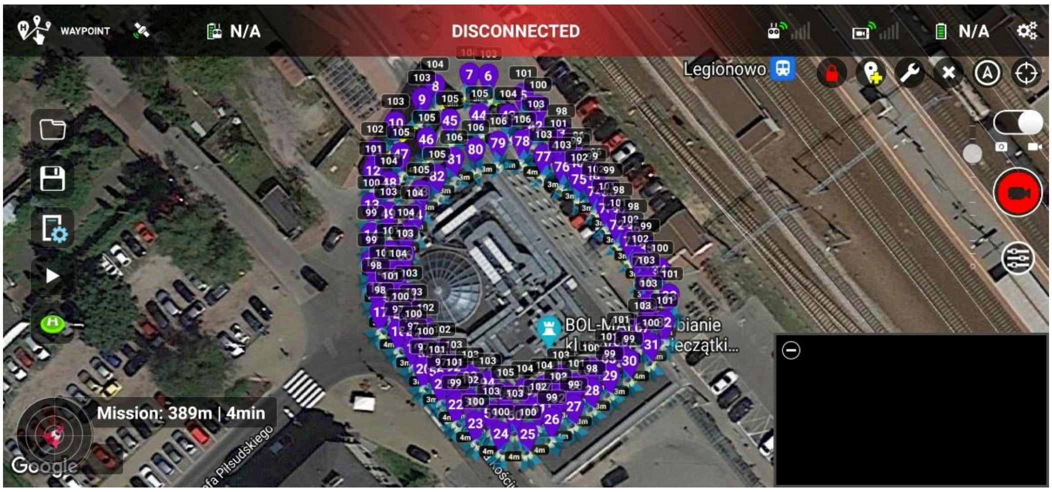

Figure 14 Fragment of a flight plan for the train station.

5. FUTURE WORKS

Experiments presented in this paper focused mainly on validity of algorithms presented and finding the obsticles for mission planning, they only touch on the aspect of mission execution. Further in, field tests are required to assess the correctness of the presented method of mission planning. Additionally, other patterns for mission planning can be implemented and tested. That includes, but is not limited to vartical and horizontal lines patterns.

This work did not include the topic of collision avoidance. UAVs possess an array of sensors helping them to avoid collisions in flight. However, the favourable option would be to include an algorithm to detect obstacles based on pre flight data in the created scripts and modify the flight plan accordingly. Another aspect of this paper that can be improved is the usage of voxel representation of the terrain. Representation of the terrain in a voxel grid could prove helpful in implementing algorithms based on spatial relations of entities. Voxel models prove to be computationally efficient methods for geometric operations, as they can use GPU acceleration for the computation procesess (Hermann, 2014).

Data used in the experiments comes from a single source, ALS from the project ISOK. There are other sources of ALS data with varying quality. As more modern LiDAR units, Geiger mode and SPL LiDARs are assessed for their usefulness for large area mapping (Stoker, 2016), their resulting datasets can be used to assess the influence of higher quality point clouds on generated photogrammetric mission plan validity.

6. CONCLUSIONS

ALS datasets are suitable for use in the automation of photogrammetric mission planning workflow for buildings with certain restrictions. Those restrictions are:
– the temporal validity of the dataset used,
– the quality of the dataset (planar density).
Usage of circular flying patterns can be useful in planning photogrammetric missions for non–squat buildings. The usage of other flying patterns can mitigate the object shape restriction (see related software section).

The automation presented covers the workflow from after defining flight parameters and AOI to the generation and export of flight plans suitable for autonomous flight. When adequately developed and tested, this tool can significantly reduce the time needed for planning the photogrammetric mission.

REFERENCES

Agisoft LLC, 2022, Agisoft Metashape, St. Petersburg.

Hermann A. et. al, 2014, Mobile manipulation planning optimized for GPGPU Voxel-Collision detection in high resolution live 3d-maps, Conference ISR ROBOTIK 2014, Vol 45, p. 1, München

Hüttig C, Stemmer K, 2008, The spiral grid: A new approach to discretize the sphere and its application to mantle convection, Geochemistry Geophysics Geosystems, Vol 9, p. 2–3, Berlin–Adlershof.

Izdebski W, 2021, Podstawowe usługi danych przestrzennych dedykowane do wykorzystania w systemach informatycznych państwa ver. 1.10, p. 13, Warsaw, Główny Urząd Geodezji i Kartografii.

Prisacariu V, 2017, The history and the evolution of UAVs from the beginning till the 70s, Journal of Defense Resources Management, Vol. 8, p. 184–187, Brasov, Air Force Academy.

SPH Engineering, 2022, UgCS, Latvia.

Stoker M. et. al, Evaluation of Single Photon and Geiger Mode Lidar for the 3D Elevation Program, Remote Sensing, Vol. 9

VC Technology, 2022, Litchi, London.

BIOGRAPHICAL NOTES

Jakub Górka is a research assistant at Warsaw University of Technology, Faculty of Geodesy and Cartography. As a former student of the faculty, he defended his master of science thesis in the summer of 2021. Specialist in process automation, he is employed in a number of projects at the WUT regarding innovative usage of UAV data in the fields of forestry and civil engineering.

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