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METHODOLOGICAL DEVELOPMENT TO IMPROVE THE ACCURACY OF EXTERNAL STEREO-PHOTOGRAMMETRIC SURVEYS OF BUILDINGS

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Abstract

Although unmanned aircraft (UA) based surveys are becoming a more common solution, their accuracy is questionable. Regulation is a major issue in the use of UA, which is currently having a negative impact on the spread of the technology. Many rules need to be applied during the survey and there are hundreds of settings to use during post-processing. Testing and evaluation of several combinations is necessary for an optimized process definition. In the present research, studies have been carried out focusing on different solutions of survey methodologies. The case studies analyzed different survey, flight rules and their combinations. The study presents the advantages and disadvantages of using UA and makes recommendations for survey methodologies through the evaluations carried out. In addition, several future research directions are presented which could lead to the advancement of building surveys.

Keywords*: unmanned aircraft, building survey, accuracy .*

1. Introduction

Surveys using unmanned aircraft (UA) have been known for a long time, but their use in the construction industry has only started to spread in the last decade [1–7]. The development of survey tools, post-processing software, and algorithms has contributed to the widespread adoption of this technology. Nowadays, we can perform stereo-photogrammetric evaluation and geometric mapping with a hand-held phone. Of course, their effectiveness and usability is questionable, but some simple purposes can be supported. Using professional tools, it is possible to measure buildings and their structures with an accuracy of down to centimetres. [8] In order to obtain high-quality results, it is necessary to perform the survey and post-processing according to a set of predefined rules, but these are formulated as generic guidelines by the professionals and software developers. These definitions need to be refined and tested, to carry out survey work effectively and with sufficient confidence.

1.1. Current rules and instructions

Depending on the tools used for the survey, the methodological rules of the survey and the possibilities for post-processing may vary.

1.1.1. General rules

When using stereo-photogrammetry, sufficient natural light is required, and completely homogeneous and reflective surfaces should be avoided. As it is a passive remote sensing technique, no physical contact is made with the building or structure to be surveyed. It uses a snapshot image where the light reflected from the surface provides the range of data required for the survey. [9] The post-processing software then searches for matching pairs of points on the images captured, which is either not possible or may lead to incorrect results for reflective and homogeneous surfaces. In addition, it is recommended to save the GPS information of the imaging device and store it in images, as this can make the positioning of images a more accurate and faster process. It is also important to have an adequate image coverage (about 80%) and to use as high image resolution as possible and fixed settings. [10]

1.1.2. Rules for the survey of façades

In the case of a building facade survey, it is suggested by the post-process software to use perpendicular photo shooting positions. However, in a terrestrial photo capturing, this can be problematic, but it is feasible with unmanned aircraft. [10]

1.1.3. Missing rules

In most cases, following the rules described in the previous chapters will lead to a good result. However, further efficiency improvements can be achieved by optimizing the routes taken during the survey. The aim of this research is to investigate the optimal survey route for a small-scale building facade. The basic thesis is that with an ordered data set (in this case a set of photographs), the survey can be optimized, and a good quality result can be produced.

2. Used devices and methodologies

2.1. Devices

During the research and surveys, we primarily used a DJI Mavic 2 enterprise drone, which has good flight and imaging characteristics. For the stereo-photogrammetric post-processing we used 3DF ZEPHYR software, which is able to generate a satisfactory final result based on our preliminary tests. The effectiveness of the survey was measured using a reference dataset, which was a registered point cloud taken with a terrestrial laser scanner. The device used was a Leica BLK 360 gen. 2, which was used with the highest resolution (Fig. 1). After registration of the scanned data set, the generated data sets were compared in Cloud-Compare software.

2.2. Methodologies

The methodological steps in the development and optimization of the survey methodologies were the same. These steps are illustrated in Fig. 2 where it is clearly shown that step 1 is photography, step 2 is point cloud generation, step 3 is point cloud manipulation, step 4 is comparison.

Fig. 1. *The scanned building facade.*

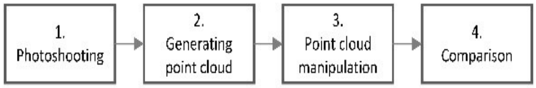

Fig. 2. *Methodology.*

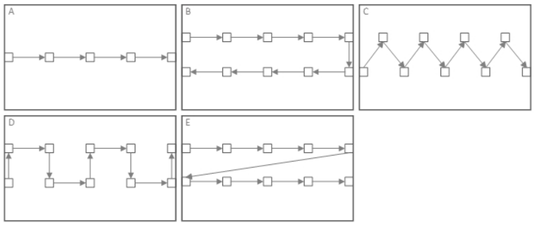

Fig. 3. *Flight paths and combinations.*

The general rules (as described in chapter 1.1.1) have been considered for the flight variations and used to define the flight paths and combinations (Fig. 3).

Our previous survey experience has shown that the sequencing of flight directions and photography can affect the quality of post-processing. In the present study, automatic photo capturing was set on the instrument at a frequency of 3 seconds.

In addition to the photo capturing paths, it is important to note the position of the camera on the unmanned aircraft. For the methodologies tested, the majority of the flights were performed with horizontal camera angle but most were tested between +25 degrees and -25 degrees to the horizontal, too. Furthermore, the distance was also investigated in terms of variations, where the distance sensor on the drone was used to set the flight distance to approximately 2.5 and approximately 5 meters. From a combination of these, 19 different flights were performed as shown in Table 1.

Table 1. *Methodological summary of flights carried out during the research (letter codes can be interpreted in accordance with Fig. 3.)*

Number	Flight path	Distance unit (m)	Camera Angle (°)
001	A	2.5	0
002	A	5	0
003	B	2.5	0
004	B	5	0
005	C	2.5	0
006	C	5	0
007	D	2.5	0
008	D	5	0
009	E	2.5	0
010	E	5	0
011	A	5	+25°
012	B	5	+25°
013	E	5	+25°
014	D	5	+25°
015	A	5	-25°
016	B	5	-25°
017	E	5	-25°
018	D	5	-25°
019	C	5	-25°

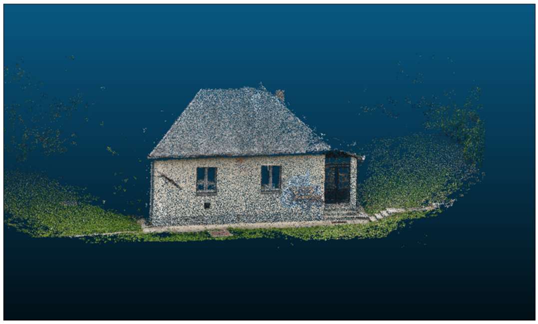

Fig. 4. *The point cloud produced as a result of the stereo-photogrammetric evaluation (for survey 019).*

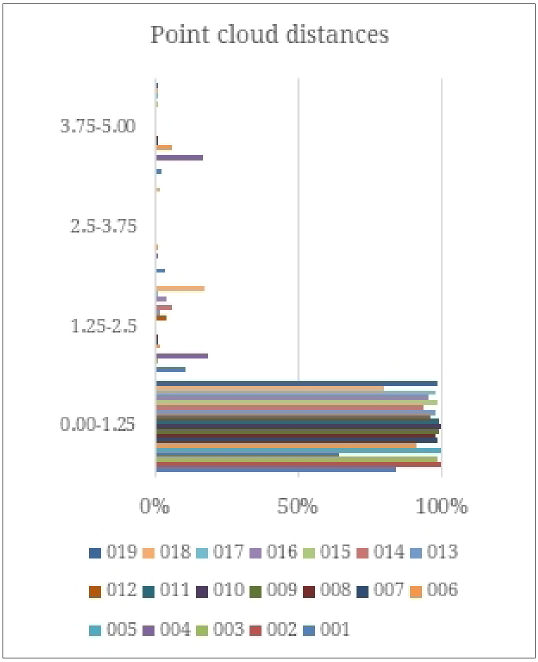

Fig. 5. *Accuracy values from the point cloud-to-point cloud comparison presented on a scale of 0-5cm.*

3. Results

In most cases, the results of the stereo-photogrammetric evaluation resulted in a point cloud dataset with the right density and shape (**Fig. 4**). This meant that each of these files was suitable for comparison.

Several evaluation methodologies were used as part of the research. The first of these was point cloud comparison, where the software compares the distance between points according to hypothetical planes defined by the data set. For the present comparison, CloudCompare's "compute cloud/cloud distance" function was used. The software aggregated the distance of the points into 8 subdivisions for us, based on a scale of 0-5 cm. We then converted these into 4 major units, thus obtaining an accuracy of 1.25 cm for the point clouds compared to the laser-scanned stock. By comparing the cleaned and positioned point clouds, the number of points in the different categories was obtained, which was then expressed as a percentage of the total number of points.

Fig. 5 shows the cumulative results, which clearly show that almost all survey methods have a high accuracy of less than 1.25cm. Measurements 001, 004 and 018 deviate from this. For measurement 001 83.74% of the points, for measurement 004 63.86% of the points and for measurement 018 79.72% of the points were in the marked range.

For the other measurements, more than 90% of the points fell within the 0-1.25cm range, showing very little deviation from the laser scanned dataset. This result was refined by using a so-called "local model" option, which did not show a large deviation from the previous calculation, but for the accuracy calculation we averaged the two values.

Fig. 6 shows that the software also provides visual feedback by coloring the points in the point cloud. On a scale of 0-5 cm, the points are colored from blue to red as a function of distance. In the future, it will be possible to estimate the spread of points and the accuracy of the point cloud compared to a reference dataset, even without precise data analysis.

The evaluation showed that besides the spread of points, the distortion and dimensional deviation of the whole point cloud can also be a problem. Therefore, we compared the total facade length measured on the laser-scanned dataset with the length of the point cloud datasets obtained as the final result of the stereo-photogrammetric evaluation.

Fig. 7. shows the deviation measured between the scanned (9.034m) and the stereo-photogrammetric point cloud. This also gives us an indication of the point clouds' accuracy, since, for a façade of about 9 m in length, a deviation of more than half a metre is a serious problem. Of course, there are procedures to manipulate the point cloud afterwards and to improve the accuracy of the measurement (e.g. by using targets), but the aim of this research is to examine the accuracy of the point clouds on the raw datasets.

As a result of the study, it can be concluded that survey methodologies 002, 005, 006, 007, 010, 012, 015, 017, 019 can be considered as suitable, while the others show cardinal differences compared to the laser scanned dataset.

As future research, we will investigate the level of detail of the generated surfaces, as in many cases it is visually apparent that the point clouds are incomplete (Fig. 8).

We aim to narrow down the methodological proposals to 2-3 main flight proposals. In addition, the testing procedures used here will be tested for larger scale buildings and structures, which may also lead to different results.

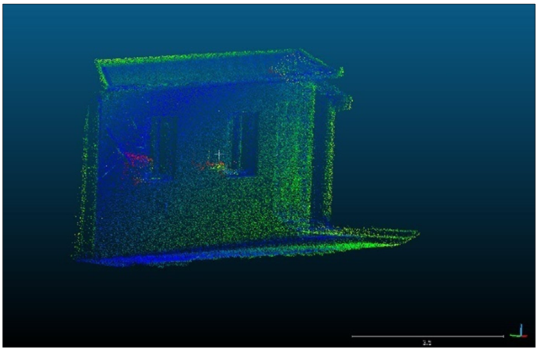

Fig. 6. *Colored point cloud based on the distance computation.*

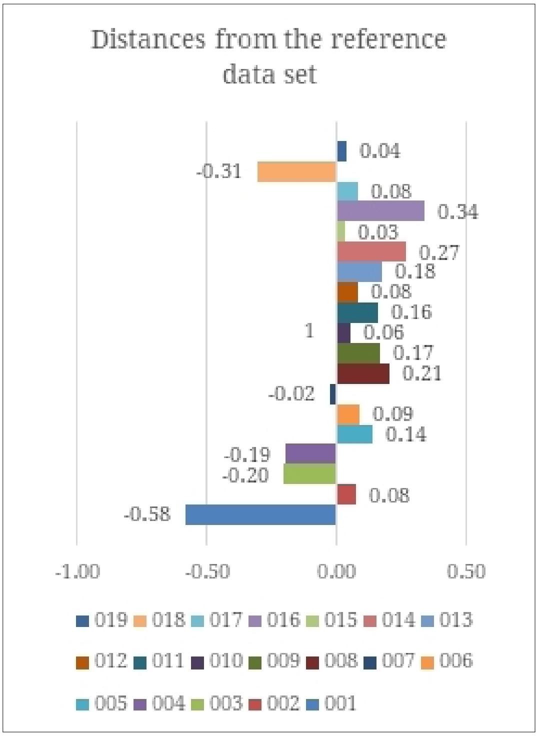

Fig.7. *Differences in the length of the façade compared to the reference dataset for each survey.*

4. Conclusions

The present study examined the use of stereo-photogrammetric surveys with unmanned aircraft, analyzing different flight and photogrammetric methodologies. The main objective of the research was to further refine the photogrammetry rules with a focus on facade surveys. The research investigated the accuracy of the results of the different methodologies through point cloud comparisons. The flight paths, distances and camera positions presented were intended

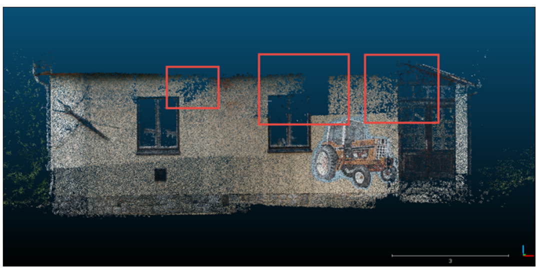

Fig. 8. *Missing parts of the survey.*

to test a single case, but the research could be extended in the future by combining these variations and developing new solutions.

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