Feasibility Study on UAV-assisted Construction Surplus Soil Tracking Control and Management Technique

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Abstract. Construction surplus soil tracking management has been the key management issue in Taiwan since 1991. This is mainly due to the construction surplus soils were often regarded as disposable waste and were disposed openly without any supervision, leading to environmental pollution. Even though the surplus soils were gradually being viewed as reusable resources, some unscrupulous enterprises still dump them freely for their own convenience. In order to dispose these surplus soils, site offices are required to confirm with the soil treatment plant regarding the approximate soil volume for hauling vehicle dispatch. However, the excavated soil volume will transform from bank volume to loose volume upon excavation, which may differ by a certain speculative coefficient (1.3), depending on the excavation site and geological condition. For managing and tracking the construction surplus soils, local government authorities frequently performed on-site spot check, but the lack of rapid assessment tools for soil volume estimation increased the evaluation difficulty for on-site inspectors. This study adopted unmanned aerial vehicle (UAV) in construction surplus soil tracking and rapidly acquired site photography and point cloud data, the excavated soil volume can be determined promptly after post-processing and interpretation, providing references to future surplus soil tracking management.

1. Introduction

Since 1991, Construction and Planning Agency of Ministry of the Interior, Taiwan has been performing the planning, setup, database establishment, personnel training, alert and circulation, system operation and maintenance of the "Construction Surplus Soil Information System". Construction Surplus Soil Information Service Center was further established in year 2000, providing a platform for online declaration and data exchange for construction surplus soil across the nation, which is the current declaration and tracking system for construction surplus soil management. Currently the system maintenance and system update development is performed by Architectural Institute of Taiwan, which so far has provided 5.52 million registry lookup of declaration and inquiry services. The aforementioned system recorded the basic site information of the construction surplus soils, soil handling and disposal site information, and monthly actual transported soil volumes, which greatly contributed to the overall tracking management of construction surplus soil in Taiwan.

2. Literature Review

2.1. Surplus Soil Tracking Management

In early days, the surplus soil originating from construction works is regarded and handled as waste in Taiwan. The tracking of surplus soil disposal clearance is hence being strictly controlled and supervised, so in case a soil handling and disposal vehicle did not carry a valid certificate for the

generation site and handling site, the driver would be penalized in accordance with relevant laws and regulations. Construction Surplus Soil Information Service Center (www.soilmove.tw) was also established for the tracking management of these construction surplus soils. Both the construction contractor and soil treatment facility are required to declare online regarding the generated volume of excavated soils and the actual received capacity, in order to verify the exact transported soil volume form site to site in dual direction. However, this surplus soil tracking system confirmed the excavated soil transportation only from the site declared information without further assessment tool. Many unscrupulous enterprises discovered loopholes in the hauling process and forged the declaration form to dispose the soil otherwise. Therefore, the management authority routinely performed on-site spot check to estimate the excavated soil volume and authenticate the actual disposed soil volume according to the monthly report. Up to now, on-site inspectors could not quickly determine the actual soil volumes at the excavated site and disposal site. They could only wait for site measurement, signature verification and direct submission from the survey engineer at end of the year.

Thus, the demand for a rapid soil volume estimation method is rising, in order to assist the on-site inspectors in determining the in-situ excavated soil volume and verifying the declared amount on the declaration form, which would enhance the overall inspection quality.

2.2. UAV Introduction
An unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without any human pilot aboard. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may be operated with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers.

2.3. UAV Aerial Photography
Most UAVs have a lower flight altitude than aircrafts. UAVs can capture ground images of high resolution and are less susceptible to photo quality degradation due to cloud obstruction. They can even obtain side-view images of buildings that are hard to be captured in general aerial surveying operations. This is of high application significance for the monitoring, investigation and recording of certain regional topographies. UAV aerial photography does not require aerial-photogrammetry-grade dedicated cameras and only requires common digital cameras. This is mainly due to the current digital camera and digital camcorders are highly advanced in terms of image resolution and sampling frequency and other specifications, in addition to the advancements of various measurement theories. Compared to the photogrammetry-dedicated cameras, the general, non-dedicated cameras have the following advantages: smaller sizes, lightweight, easy to be acquired inexpensive, easy access to captured images, reusable memory cards and the captured images can be output directly in digital images for further modification on personal computers.

3. Methodology
This study mainly utilized the UAV-captured images from different flight paths and various camera angles, by stacking these multiple images in software to generate point cloud data, in order to compute the volume of these dense point clouds. The implementation of UAV in construction surplus soil tracking consisted of three procedures: (1) Point cloud generation through Agisoft PhotoScan using the aerial photographs, (2) File conversion of point cloud data using Autodesk Recap, (3) Excavated soil estimation using Autodesk Civil 3D, as shown in Figure 2. Upon the completion of the data preprocessing in the first step, in order to enhance the accuracy and reliability of the overall dataset, the ground control points in the targeted site is next included in data interpretation. These ground control points have known XY coordinates and elevations from ground survey, which would effectively improve computed outcome from the UAV aerial photography. On the other hand, considering the delineation of excavated soil mass requires manual observation and identification, multiple delineation computation is performed in the third step before soil volume estimation. By implementing statistical method to discard deviated values, better estimation of construction surplus soil volume can be achieved.

4. Case study and Results

In order to evaluate the feasibility in implementing UAV-assisted construction surplus soil tracking, this study conducted an in-situ experiment in an actual excavation site. The construction site is a new bridge construction site and is located in Guanyin Township, Taoyuan City, Taiwan. The newly constructed bridge spans across Dajyue River with a main span of approximately 43 metres and prestress girder, as shown in Figure 3. As the traffic volume of the bridge increased, its span area is required to be expanded. Partial soil mass is excavated with the approximated volume of 400m3, and can be divided roughly into 8 sub-heaps according to the site operation.

The UAV model adopted in this study is DJI Phantom 3 and its corresponding flight parameter specifications are tabulated in Table 1. The amount of UAV flights was two times. Aerial images from different flight paths were overlapped (as shown in Figure 4) to gather a more accurate computation outcome. The overall site aerial photography is illustrated in Figure 5.
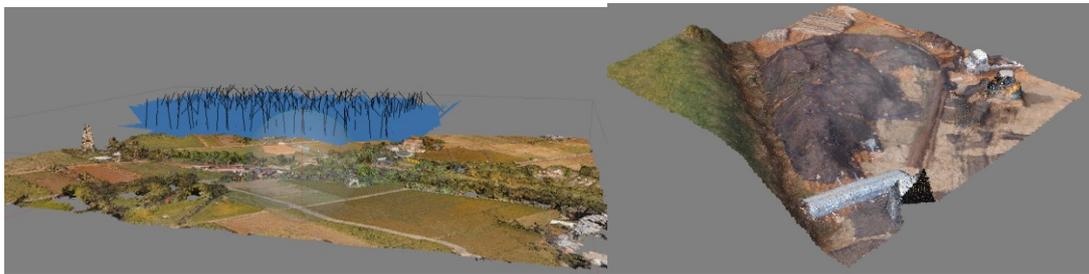

**Figure 1.** Point cloud data generated from excavated soil mass
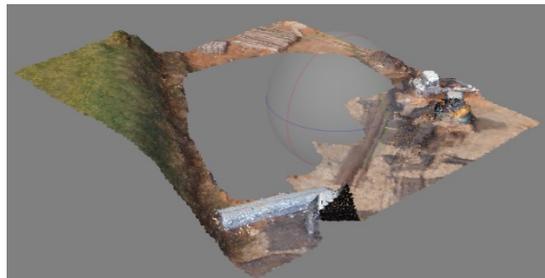
Figure 2. Topographical information of excavated soil mass

Figure 3. Aerial view of overall site

Table 1. Flight parameter specifications

Item	Parameters	Item	Parameters
Number of images	248	Camera stations	248
Flying altitude	95 m	Tie points	229,696
Ground resolution	3.4 cm/pix	Projections	756,005
Coverage area	0.195 km²	Reprojection error	0.792 pix
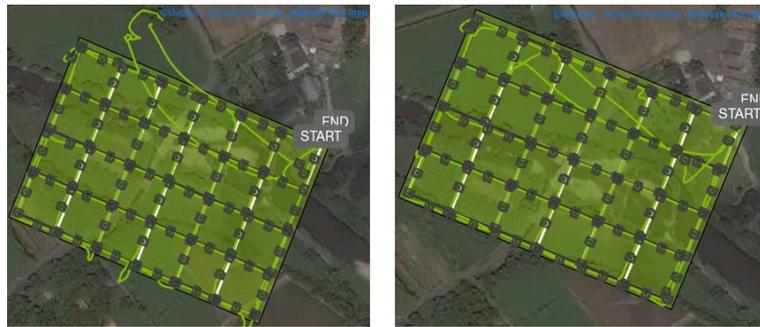
Figure 4. Flight paths of UAV: first flight (left), second flight (right).

Figure 5. Aerial photography of the soil heaps in Dajyuesi Bridge site

This study uses UAV to conduct on-site aerial photography. Aerial photographs were processed using Agisoft PhotoScan to generate point cloud data and the direct soil volume estimation is shown in Table 2. The soil volume from each soil heaps are identified from Table 2, in which the eighth soil heap may have to be backfilled to the original construction site and not being hauled away from the site, so this sub-heap is excluded from actual computation. Current computation accuracy is up to two decimal places. It is observed that the volume of soil heap 1 is the largest, followed by soil heap 3, while soil heap 6 is the smallest. In practice, soil heap volume should only consist of cut volume and no fill volume, due to the soil heap is usually piled up gradually from ground surface without any fill volume. The fill volume shown in Table 2 is mainly due to the manual delineation process may have included the region around soil heap and created the fill volume. Nonetheless, this in fact can assist in inspecting whether the delineate soil region is appropriate. For instance, if there is no fill volume, the delineated region may be smaller than the actual region, so the delineated region should be expanded in order to obtain a result closer to the actual value. However, if the fill volume is too large, this may indicate that the delineated region may be too large and accidentally included possible topographical noise nearby the soil heaps, which should be resolved by manually contracting the delineated regions.

In short, the delineated area is more accurate if the computed fill volume is a negative value which is as close to zero as possible. From Table 2, the fill volume of soil heap 1 and 3 are relatively deviated from zero value, indicating that their delineated regions are influenced by external factors. These factors maybe the combined effects of absence of ground control points, interfering objects above the soil heaps such as tree branches, or even the low image resolution during delineation process, as shown in Figure 6. Ground control points is included next for better estimation of overall excavated soil quantity.
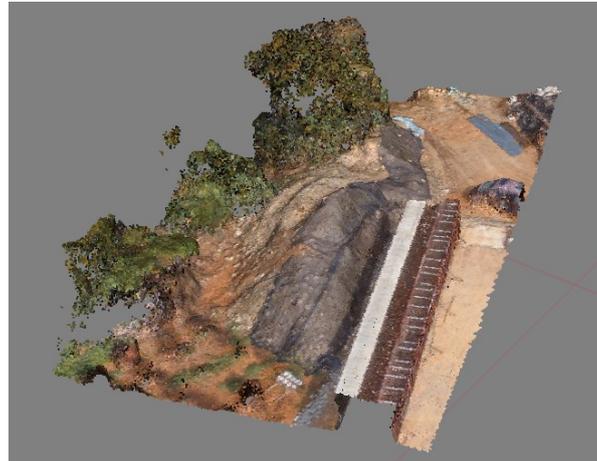
Figure 6. Soil heap: Difficulty in region delineation due to obstruction of tree branches

Table 2. Soil volume directly computed from UAV aerial photography

No. of heap	Area(m^2)	Volume(m^3)	Cut(m^3)	Fill(m^3)
1	177.12	140.83	144.80	-3.97
2	117.86	75.73	76.58	-0.85
3	154.05	86.30	98.19	-11.89
4	68.75	38.05	39.02	-0.98
5	21.64	7.10	7.34	-0.25
6	18.49	5.51	5.89	-0.38
7	22.89	8.70	9.79	-0.09

Figure 7 shows the location of the three ground control points established in site, which are the control points being measured using ground survey technique prior to the commencement of the construction project. These ground control points are commonly used as the known coordinates in aerial triangulation measurement. By using the three ground control points, all the actual latitude, longitude and elevation of the ground surface are known, which is highly beneficial to the overall survey accuracy computation. After estimation correction using ground control points, the overall computation error narrowed down to only 3.27cm, as shown in Table 3. Point 1 as shown in Table 3 had the smallest error while both Point 2 and 3 had approximately 4cm error. This is mainly due to the elevation of the two points were slightly increased for the UAV to easily distinguish the Point 2 and 3 on-site, which incidentally caused slightly higher error at the two locations. Nevertheless, the eventual error was controlled within acceptable range.

Table 3. Coordinate error after ground control point correction

No. of point	X error(cm)	Y error(cm)	Z error(cm)	Total(cm)	Pix
Point 1	-0.10182	0.0118223	-0.009064	0.102904	0.032
Point 2	0.927141	3.27955	-2.1221	4.01476	0.048
Point 3	-0.695334	-3.28729	2.17796	4.00415	0.097
Total	0.671676	2.68091	1.75565	3.27425	0.061

Figure7. Ground control points (GCP) near the Dajyuesi Bridge site

In this study, soil heap 1 with the largest soil volume is selected for value correction. In order to reduce the error arising from manual delineation, multiple delineation computation is performed 10 times and the corrected cut and fill volume are shown in Table 4. Overall fill volumes as observed in Table 4 are negative values which are very close to zero value, indicating the delineated region is actually very close to actual soil volume. The mean fill volume from the 10 delineation results is -0.47m^3. This is significantly accurate comparing to the former analysis without considering ground control point, which is -3.97 m^3. The mean volume of soil heap 1 is found to be 136.88 m^3 and is less 4 m^3 compared to original outcome of 140.83 m^3. However, the standard deviation is about 7 m^3, which is still a relatively large error in terms of statistical performance.

Table 4. Soil volume computed from UAV aerial photography with GCP

No.	Volume(m^3)	Cut(m^3)	Fill(m^3)
Original data	140.83	144.80	-3.97
1	137.7	137.8	-0.1
2	139.6	140	-0.4
3	133.2	133.5	-0.3
4	139.9	140.7	-0.8
5	120	120.9	-0.9
6	132.3	132.7	-0.4
7	136	136.2	-0.2
8	146.3	146.5	-0.2
9	141.9	142.6	-0.7
10	141.9	142.6	-0.7
Average of 10 times	136.88	137.35	-0.47

5. Conclusions and Suggestions

Implementing UAV in aerial photography is relatively cost-effective, high flexibility, low life-threatening risk compared to conventional aerial photogrammetry, providing that the measured area is not too large. Digital cameras in UAV can have higher resolution power and can be easily obtained, while both the storage and access to the capture images is relatively simple and can be viewed directly, all of which are the advantages of UAV over conventional aerial practices. In actual

aerial photography process, certain interference was induced to subsequent analysis due to errors of intermediate procedures, including the error of ground control points. If characteristic points are required during image control points during the aerial photography, the following control point features should be sought for better outcomes: 1. Right-angled interface with distinguishable colors 2. Not obscured by obstacles 3. Not too close to nearby buildings 4. Not shielded by shadows 5. Ground objects that are difficult to move 6. Flat ground surface. This study found that by considering the ground control points, the overall survey accuracy is significantly increased with its accuracy of approximately smaller than 4m3. Considering current soil disposal vehicle capacity of 14m3, the accuracy of this approach is controlled within 1 vehicle trip and this has significant progress towards the construction surplus soil tracking management. The subsequent analysis after the UAV aerial photography only required 1 processing day to estimate on-site soil volume, which has a significant advantage towards the overall administrative work efficiency. Hopefully the research outcomes from this study can become the future reference for the design of flight survey task, ground control point distribution, flight route planning and revision.

Due to the current legislative limitations in UAV aerial photography, such as the compliance to the no-flight zone (NFZ) regulations of local governments, corresponding permits should still be applied through standard administrative procedures. Regarding the inability of image overlapping due to noises above the soil heaps, LiDAR is recommended for future studies to overcome this situation. Flight altitude of UAV can also be reduced for quicker and more accurate computation in point cloud data generation.

6. References

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