UAV Technology-Based 3D Reconstruction for Mine Dump Slope Assessment

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Abstract. In the current scenario, the aim of mining operations is to obtain as much usable ore as possible while maintaining a safe and profitable working environment. In open-pit mining and quarrying operations, the stability of slopes is of the utmost importance from both an economic and a safety standpoint. This is due to the fact that unstable slopes can lead to the loss of human life as well as damage to properties. Unmanned aerial vehicle (UAV) is an emerging technology in the field of geotechnical engineering, and its one-time procurement is sufficient for monitoring and management of large surface mines area. This paper discusses the challenges in implementing UAV technology for mine dump slopes, such as image acquisition, overlapping images, flying pattern, flying altitude, and ground control points (GCPs) acquisition, as well as the major problems involved in 3D dump slope reconstruction. The results show that UAV technology has the capability to deal with such a large structure as well as the importance of GCPs in improving the accuracy of the 3D model.

Keywords: Unmanned aerial vehicle (UAV) · Ground control points (GCPs) · Dump slope

1 Introduction

The stability of slopes in the surface mining industry is a major concern from a safety and economic aspect. Unstable slopes can be dangerous, and they have the potential to cause the loss of human life as well as damage to properties. In surface mining operations, the danger of slope failure is significant since it has the potential to result in a high number of fatalities. Between the years 1901 and 2016, there were 23 catastrophic incidents. These accidents included tragedies that were solely caused by slope failure. The most recent catastrophe at the Rajmahal coal mine occurred in 2016 and resulted in the deaths of a total of 23 persons [1].

UAV is a vehicle without a human pilot onboard to capture high-resolution aerial images at different altitudes. Various studies using UAVs shows that this technology has the capability to perform in difficult situations like hovering over remote areas and capturing images in high-air turbulence zone. UAV technology is one of the fastest growing technologies in every field and especially in geotechnical engineering, the main reasons are low operating cost, easy handling, high mobility, ease of operation, etc., and

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its one-time procurement is enough for the management and monitoring of large surface mining areas. Terrestrial laser scanners (TLS) and Lidar are the conventional technology which is more preferred in the past few decades but in comparison with UAV technology, these are costlier, time-consuming, as well as handling is not easy. UAVs are preferred over traditional ones, the main reasons are compact in design, easy in handling, faster data collection, as well as highly mobile.

This paper deals with the different challenges of using this UAV technology as well as the difficulties in the 3D reconstruction of mine dump slopes. The first section discusses Image acquisition and finding the ideal flight parameters as well as the issues such as flight altitudes, time of flight, and local flight regulations considered before actually flying. The flying type and pattern are another important aspect, which ensures that only good-quality images are collected. The second section deals with 3D reconstruction and associated problems.

2 Methodology

The methodology consists of two different sections. The first section deals with the use of UAV technology for image acquisition and the second section deals with the processing of UAV data.

2.1 Data Collection Using UAV Technology

Image acquisition. It is the initial and one of the crucial steps for the 3D reconstruction, if the images are not acquired properly then the outcome of the images will be very poor. Flying a UAV in a mining area is not an easy task. One of the operational challenges associated with reconstruction using images taken from a UAV is to find the ideal flight parameters required to obtain a better rebuild quality without excessively increasing the amount of time spent in flight or processing. Many issues such as flight altitudes, weather forecasts, and local flight regulations are just some of the many variables that need to be considered before actually flying [2]. In this study, first proper flight planning has been done, so that image acquisition operations will not be hampered. Images are acquired using UAV technology at a suitable altitude of 120 m, and at this altitude, features are properly visible.

Flying type and pattern. The flying type and pattern is the second-most important parameter in flight planning, in which UAVs follows a fixed path to cover the area of interest precisely. Depending on the mission specifications, platform type, and environmental conditions, the flight is typically conducted in the manual, assisted, or autonomous mode (see Fig. 1). The inclusion of Global navigation satellite system (GNSS) navigation systems on board is often utilized for autonomous flying (take-off, navigation, and landing). The type of flight has a significant impact on the quality of the image network. For example, using an autopilot enables you to navigate according to your plans while simultaneously maintaining communication with the platform [3].

Grid flying pattern was used in this study to capture the images, as well as overlapping of images has also been taken care of (see Fig. 2). Overlapping is one of the important factors on which the accuracy of the whole model is dependent [3]. The overlaps between

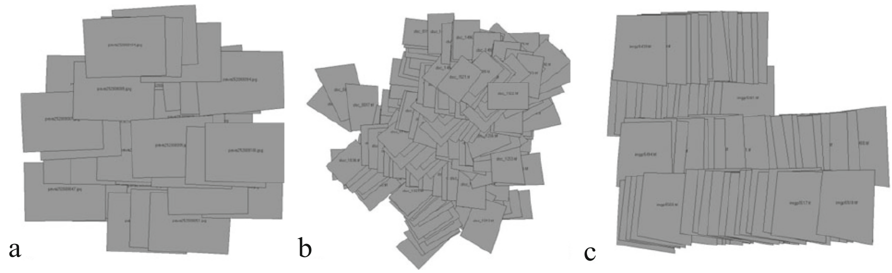

Fig. 1. Different types of flight (a) manual (b) semi-autonomous (c) autonomous, Nex et al. 2014 [3].

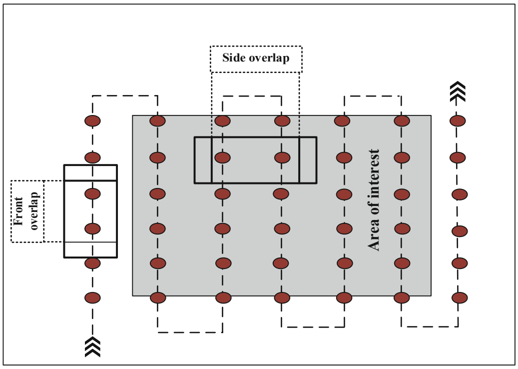

Fig. 2. Flying pattern of UAV.

images must be sufficient to build accurate 3D models and typically require a front overlap of greater than 75% and a side overlap of greater than 60%.

Ground control points (GCP). The collection of GCPs is an additional step that is performed in conjunction with the process of image collection. This is accomplished by the use of a total station (see Fig. 3). After that, these control points are recorded in the images that were taken by the UAV to correctly align and scale the object of interest before doing a digital reconstruction of it during the post-processing stage. Generally, 3 to 4 GCP are at least required which is necessary for the scaling and to improve its accuracy. In this total 8 GCP were collected with help of the total station which is spread all over the area of the dump slope. For the collection of GCPs in the ground photogrammetric targets were used (see Fig. 3).

2.2 Processing of UAV Data and 3D Reconstruction

For the reconstruction process to be successful, it is necessary to obtain a large number of photographs that are correctly exposed to the object, scene, or surface of interest during the stage of image acquisition. This means that the shutter opening, shutter speed, and ISO settings must be in proper balance to accurately capture light.

Fig. 3. Total station for GCPs acquisition and photogrammetric targets for GCPs.

Initial processing. Initial processing starts with the importing of the collected images into the photogrammetric software, for this study pix4d mapper has been used. The first step in data processing is feature detection, which involves finding the locations of feature points in several photographs that are similar to one another. Finding feature points that are invariant to changes in size and orientation is important in order to create matches across a wider region. Geometric distortions make it difficult to find points that are identical regardless of how they are scaled or oriented. The characteristics or key points are then put through a filtering process to ensure that only correct matches are retained. A total of 349 high-resolution images of mine dump slope have been used (see Fig. 4).

Point cloud generation and 3D reconstruction. The purpose of using this point cloud is to get 3D realistic view of the mine dump slope, as well as this point cloud of the dump slope will be helpful in the identification of different failure zones using numerical modeling techniques. Sparse point clouds were reconstructed from corresponding points in a pair of stereo pictures, (see Fig. 5) and the WGS84 coordinate system was used. In a sparse point cloud, the density of points is very less in comparison with a dense point cloud. By using bundle correction, one can reduce the amount of noise or outlines that are created by using sparse reconstruction [4]. The filtering strategy known as bundle adjustment is used to make sure that the model is as robust as possible.

After the bundle adjustment process is complete, a dense reconstruction is used to generate additional cloud points through the use of interpolation, extrapolation, and other algorithms. As a result of this, the density of the dense reconstruction is increased, resulting in a form of sparse reconstruction that is both more desirable and more usable (see Fig. 6) [5, 6]. This is achieved by the implementation of a patch-based multi-view technique, which is generally recognized as being reliable. Triangulation is used to estimate the 3D point locations, and the scene geometry is gradually reconstructed. The total processing time to generate the dense point cloud was about 50 minutes. After the point cloud, the 3D model must be geo-referenced using a small number of GCPs for accurate scaling [7].

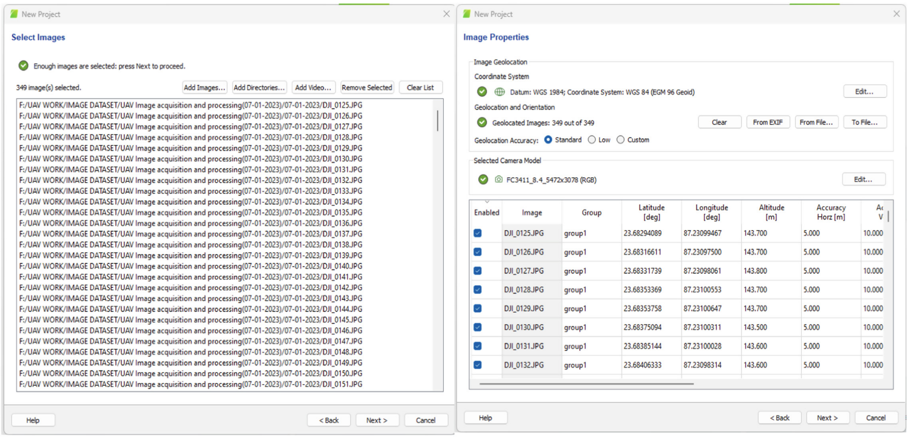

Fig. 4. Images imported in pix4D mapper.

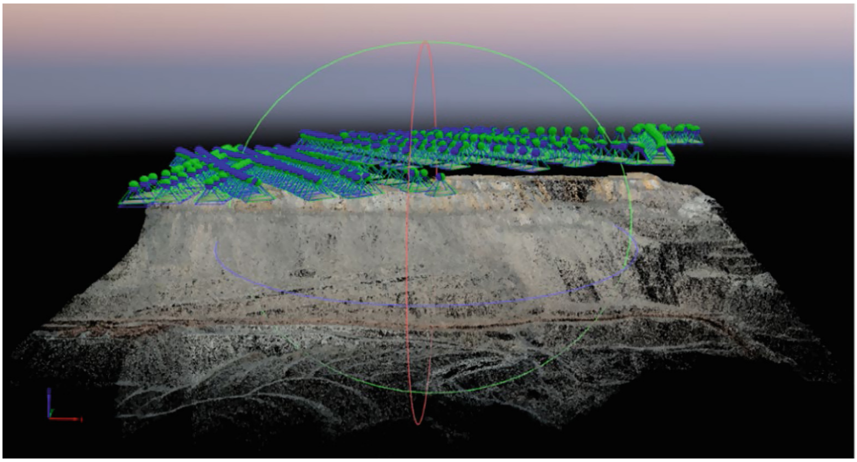

Fig. 5. Sparse point cloud.

The goal of scaling is to increase precision. In general, the DGPS survey is utilized for GCP collection but in this study, GCPs are collected using a total station, and a total of 8 GCPs were collected which spread all over the area of interest so that proper scaling can be done.

3 Result and Discussion

The results show that UAV technology in combination with photogrammetry software can handle large structures like mine dump slopes. Pix4D mapper is one of the leading photogrammetry software preferred for 3D reconstruction. A total of 349 images were used for the 3D reconstruction of the dump slope and which was acquired by UAV

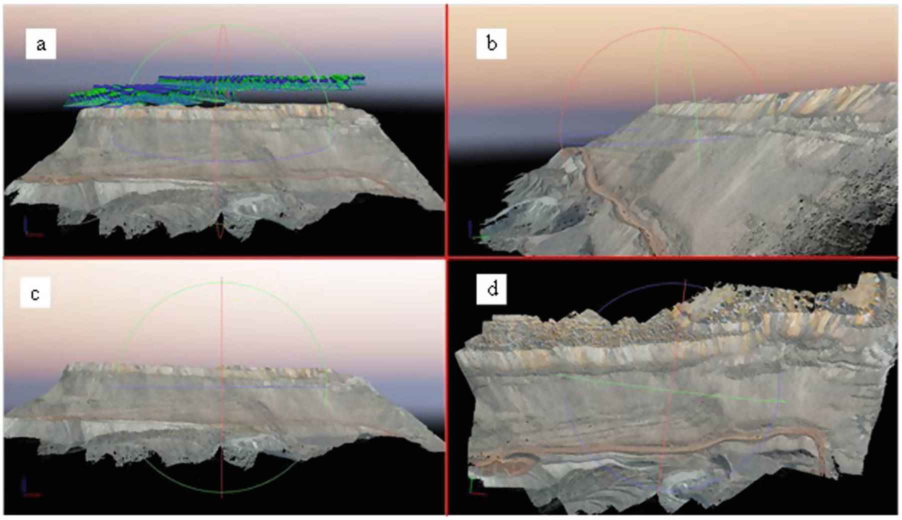

Fig. 6. Dense point cloud (a) front view with different camera position (b) side view (c) front view (d) top view.

technology with the help of a digital camera of 20 megapixels. The average ground sampling distance (GSD) was 3.94 cm per pixel, at this GSD the features are properly visible and the role of GSD is very important from the accuracy point of view. The 3D textured mesh was used at a medium resolution to minimize the distance between the mesh and the points of the point cloud, and the total time taken to generate the 3D texture mesh was 9 min and 31 s. A total number of 3,08,91,668 3D densified points was generated during the densification from sparse to dense point cloud and the time taken for the densification of the point cloud was 50 min and 30 s.

4 Conclusion

The accessibility of UAVs and the enhancement of image sensors are advantageous for 3D reconstruction. UAV technique in the current scenario is the low-cost alternative for 3D reconstruction of mine slopes, while this technique has high accuracy because images are acquired at low altitudes. UAV technology is still in the growing stage and has some limitations like window time. Window time is the optimal time period for capturing images using a UAV. This is because during this time, the sun provides the best lighting conditions for the UAV passive digital camera, and the brightness levels are optimal for capturing well-exposed images with good detail and clarity. Based on this study UAV technology has the capability to deal with large structures within a minimal time period.

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References

1. A. K. Dash, "Analysis of accidents due to slope failure in Indian opencast coal mines." Current Science, Vol. 117, No. 2 (25 July 2019), pp. 304–308 (5 pages).
2. E. Romero-Chambi, S. Villarroel-Quezada, E. Atencio, and F. M. la Rivera, "Analysis of optimal flight parameters of unmanned aerial vehicles (UAVs) for detecting potholes in pavements," Applied Sciences (Switzerland), vol. 10, no. 12, pp. 1–33, June 2020, doi: https://doi.org/10.3390/APP10124157.
3. F. Nex and F. Remondino, "UAV for 3D mapping applications: A review," Applied Geomatics, vol. 6, no. 1. Springer Verlag, pp. 1–15, 2014. doi: https://doi.org/10.1007/s12518-013-0120-x.
4. M. J. Westoby, J. Brasington, N. F. Glasser, M. J. Hambrey, and J. M. Reynolds, "'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications," Geomorphology, vol. 179, pp. 300–314, Dec. 2012, doi: https://doi.org/10.1016/j.geomorph.2012.08.021.
5. C. Hoppe, M. Klopschitz, M. Donoser, and H. Bischof, "Incremental Surface Extraction from Sparse Structure-from-Motion Point Clouds".
6. J. L. R. Jensen and A. J. Mathews, "Assessment of image-based point cloud products to generate a bare earth surface and estimate canopy heights in a woodland ecosystem," Remote Sens (Basel), vol. 8, no. 1, 2016, doi: https://doi.org/10.3390/rs8010050.
7. H. Ren, Y. Zhao, W. Xiao, X. Wang, and T. Sui, "An improved ground control point configuration for digital surface model construction in a coal waste dump using an unmanned aerial vehicle system," Remote Sens (Basel), vol. 12, no. 10, May 2020, doi: https://doi.org/10.3390/rs12101623.