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Volumetric Estimation of Stockpiles using UAV

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Abstract: ***Small scale Unmanned/uninhabited aerial vehicles (UAV) are becoming progressively common mainly due to the extensive possibilities in terms of accuracy, expenses, and abilities. The purpose of this study is to validate the utilization of UAVs for earth stockpile volume calculations on sites. Volume estimations are also crucial in many of surveying practices and that too achieving efficient and highly accurate volume estimation is both theoretically and practically important practice. Due to the increased accessibility of low-cost UAVs, this innovation could soon revolutionize numerous industries including those that require volumetric estimation. Traditionally volumetric estimation included mainly theodolite (TST), a global positioning system (GPS), terrestrial laser scanning (TLS), and airborne light and direction ranging (LIDAR) which were highly accurate but time-consuming. Methods of data collection and post processing techniques were explored. Volumetric accuracies were assessed by comparing collected data of various heaps and it was 98.64% accurate. According to the latter, if selected heap 1 the extracted volume was 13320.52 m3, which was 1.36% less than volume derived from UAV (13141.796 m3).***

Keywords: Unmanned Aerial Vehicles (UAV), Stockpiles, Digital terrain model, Volumetrics

1. Introduction

1.1 UAV

One of the fascinating things about UAV is that there is no need for a person to be seated inside it. So that's what is the reason why we are using these unmanned vehicles the most in today's world. As we know that Robotics is improving day by day so things are getting more and more autonomous because of this. If we start doing a comparison between a Manned and Unmanned mode of shipping of materials then we definitely choose a UAV over Manned Aircraft because by using this we can easily get rid of life-support systems which are mandatory for an aircraft which is carrying a human. UAVs are the successors of Remotely Piloted Vehicles (RPV's) which were used by the military of many countries before World War II but instantly after the end of this war, UAV came in the picture and until the beginning of 1980, these advanced unmanned vehicles served the purpose of the Weapons System. In the industrial world, there are several manifestos that are completely based on the utilization of UAV for solving a large number of issues effortlessly. On the basis of wing configuration, UAVs are divided into two major categories: Fixed Wing and Rotary Wing. For the accomplishment of rough and tough work, a Fixed Wing Aerial vehicle is always elite because it is completely effortless to operate.

1.2 Photogrammetry

An approach that is used for determining mathematical values such as area, volume, size, etcetera with the help of photographs (picture of a particular object) by converting those several 2D images into a 3D scene is known as Photogrammetry. Overlapping of photos play an important role in photogrammetry and the amount by which one picture includes the area covered by another picture is predefined. Forward overlapping between two photos on the same flight line is 60% whereas lateral overlap varies from 20-40% which is between the photos on an adjacent flight line. So by making effective use of imbrication of pictures that are taken by a camera, we can easily utilize this technique in various branches such as mining, mapping and many more. Aero Photogrammetry is a branch of photogrammetry in which aerial images (taken by a camera which is paced in the air) are used for the collection of geographical information such as cartography, topography, feature recognition, etcetera in the case of a land survey. The information gathered in an aerial survey with the help of photography should be georeferenced. This georeferencing of data can be achieved by using GNSS(Global Navigation Satellite System).

In historical times Volume estimation of stockpiles was a major issue for the geoscience industry but after the introduction of this photogrammetry technique, this tedious task is now completely accessible, simple and cost-effective for the Engineers. Accuracy is a term that plays a prominent role in every project, whether it is vertical or horizontal. The results in the case of volume estimation of the stockpiles will be more accurate if the land surface is presented well and the images which are captured by UAV camera are of high resolution. The number of coordinate points (X, Y, Z) and as well as the mechanism which is used for photogrammetric interpolation also plays a crucial impact on the preciseness of the Volume estimation of the stockpiles.

The software which can provide us with correct outcomes for contours and then for Volume are pix 4D, Agisoft, Cloud Compare, ArcGIS, Global Mapper, Google Earth and many more.

1.3 Importance of Volumetric Calculation

Volumetric Calculations plays a significant role in every field where photogrammetry is required, so its execution in an accurate and quick manner is mandatory in order to make it cost-efficient. In various engineering branches such as in mining whether it is surface mining or open cast mining, this cut and fill volume assessment is the major obstacle. Volume Approximation is also similarly important in a lot of surveying activities where the surveying is done with the help of Unmanned Aerial Systems (UAS). In this hi-tech era, it is essential for us to update each and every instrument and the methods of doing calculations should be advanced enough to make sure that the values of Volume which we

are getting are correct i.e theoretical and practical results should be almost similar. Unmanned Aerial Systems (UAS) automation is potentially highly supportive to the domain of volume computation given its flexibility, affordably, and ease of use (Raeva et al. 2016). So that's what is the reason why we are using this technology in our research for getting the results for volume of stockpiles.

2. Previously Used Methods

2.1 Total station

The total station method is a very commonly used approach in surveying. The total station is designed for measuring of slant distances, horizontal and vertical angles and elevations in topographic as well as for solution surveying tasks. The estimated results can be recorded into the internal memory and transferred to the computer interface for further processing and generate a map of the surveyed area. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM), plus internal data storage and/or external data collector [(2)]. When concerned with the volume calculation even a small amount of deviation in angle measurement or distance could rapidly impact the final calculations. There is also an increased cost associated with the total station approach versus the potential capability to determine similar data with a UAV.

2.2 Airborne LIDAR

Airborne LIDAR systems can be described as light detection and ranging also known as 3D scanning that scans real objects to produce three-dimensional discretely surfaces which represent the actual real objects. A LIDAR instrument mainly comprises a laser, a scanner, and a particular GPS receiver. Two kinds of LIDAR are topographic and bathymetric. Topographic LIDAR commonly utilizes a close infrared laser to map the land, while bathymetric LIDAR utilizes water-penetrating green light to measure ocean bottom and riverbed elevation. While this technique has changed elevation data for mainly larger areas, it isn't especially appropriate for small scale applications. Airborne LIDAR is not a perfect system for volume computations given its negligible adaptability, altitude constraints, cost to ensure adequate point distribution.

2.3 Terrestrial Laser Scanning (TLS)

An active LIDAR (light detection and ranging) system can be described as TLS that calculates the distance to surfaces by measuring the flight time of emitted pulses of light These emitted pulses are used to generate 3D point clouds of the scanned area for further study. It rotates along a vertical axis around the base and the distance between data observations increases with distance from the sensor so multiple survey locations are used with TLS to ensure no portions of a given area are excluded. TLS also requires manual filtering of a raw point-cloud to sort the clutter/noise through the object of interest points. In many disciplines, TLS has become an industry-standard because of its relatively straight forward approach, and generally because of the level of small-scale detail that is missed by other techniques. TLS is capable to obtain measurements within 6mm at a range of 50 meters, these characteristics create a demand for TLS since it is highly accurate but also costly for the survey.

3. Statement of Problem

Professionals from domains like construction, mining or agriculture need to keep track of the volume of stockpiles because it plays a pivotal role in the successful completion of work. It enables officials to know the amount of material they have for the particular project. It also improves their planning and efficiency to perform the task. There are various ways of estimating the volume of these stockpiles, but the existing methods are time-consuming and require half a dozen people for the same. Even the work needs to stop until the process is not completed. In other words, more amount of stock can neither be added to the pile nor taken from the pile, which affects the production and consequently reduces the efficiency during the span of the volume estimation process. The modern the day to the problem is using UAVs for mapping and volume estimation purpose. The work that takes a week using total station can be completed in hours with a single UAV operator and that too without compromising accuracy. Drone mapping can cover tremendous zones essentially more quickly than standard ground methods. Thusly, various endeavours are seeing passionate cost venture assets by changing to UAV based mapping and volume estimations.

4. Terminology

4.1 Ground Control Points (GCP) and Original Ground Level (OGL)

These are the points which are made (or placed) on the site near the stockpile and are used as reference points during the processing of data captured during the flight. These points help in increased accuracy. These points are placed near the piles in a way that they create a triangular model. The Easting, Nothing and Elevations of all the GCPs are calculated using Total Station (TS) or Digital Global Positioning System (DGPS). OGL is the level of the original ground over which stockpiles are present. The texture of the ground surface is carefully and OGL is calculated by surveyors. OGL is used during data processing.

4.2 Real-Time Kinematic (RTK) and Post Processing Kinematic (PPK)

Real-Time Kinematics is a real-time process by which we can upgrade the efficiency of information which we are obtaining from the Global Navigation Satellite System. The technique utilizes fixed base points and is completely based on sending the amendments to a rotating receiver to enhance the accuracy of the signals received from the satellite-based positioning system. A particular Ground Control Point is called as a base point when it continuously sends the modifications and the calibrations of the data of the Drone's position. After that, the computations obtained by using drones are compared with subsequent computations obtained by GNSS at the base stations. So this technique helps in the decrement of common glitches between two consecutive measurements. This makes the communication task more apparent and as well as simple.

Post Time Kinematics is also a technique that is used for making data more accurate and transparent but the corrections provided by PPK are after the completion of the data collection. Therefore, in this case, there is no requirement of the base points. The hardware of RTK and PPK are almost similar but there are a lot of variations in their workflows.

5. Methodology

In this paper, we elaborate technique pertaining to estimation of volumes of stockpiles using an Unmanned Aerial Vehicle. In the modern era, we can witness that technology keeps on increasing day in and day out making the complex tasks of professionals easy, precise, time-efficient, economical and many more. Here we are discussing such a novel technique, which makes the task of volume estimation simple and can be performed in hours. For this firstly, the site to which the material is put can be observed using google earth and using the same a km file is exported of the desired area. For the process to be accurate we need the original ground level of the desired area. The original ground helps in estimating the volume with precise accuracy. These are the prerequisites before reaching the field.

Secondly, at the site of the material where you are supposed to perform the produce, Place the ground control points near the heaps. At least 4 are required on any site. The ground control points play a significant role in the data we collect from the site. It helps in the formation of the triangular model and results in increased accuracy. The latitude and longitude of all the ground control points along with the elevation from mean sea level have been calculated using a Total Station or a Digital Global Positioning System. All the values have been noted carefully.

Thirdly, a mission has been planned for the automatic manoeuvring of the unmanned aerial vehicle over the desired site using .kml file for the data acquisition. Normally, the flight time of unmanned aerial vehicle is up to 25 minutes so the parameters during the mission planning have been modified accordingly. The side and front overlapping should be kept to 70%. Both these overlapping are directly proportional to the time required to complete the flight. As you increase the overlapping the no. of images captured will be more and consequently the time required to complete the mission increased. Similarly, the height at which the vehicle is manoeuvring is indirectly proportional to the time required for the completion of the mission and spatial resolution. The height of flying should be kept up to 60m. As we increase the height at which the drone is flying, the area covered will be more, the images captured will be less and ultimately the time of flight will be less. However, in doing so the spatial resolution will also be decreased which results in less accuracy of the results. Hence, these considerations should be kept in mind during mission planning.

Next, the flying part came into the picture. The drone flies over the desired area in a fully autonomous mode and captured the data. We should continuously monitor the flight data whether the area is completely covered or not. Is there a connection established with enough satellites or not. Is the drone camera is properly clicking the images or not. As the drone captures the images, it also saved the latitude and longitude of that particular point at which image is captured and helps in geotagging. After the flight, the data is taken from the aerial vehicle. It should be noted that the ground control points should overlay on the initial location at which their coordinates are calculated during the entire flight time. If they are disturbed, the whole captured data is meaningless and of no use. In that circumstance, the flight should be taken again along with the coordinates of ground control points because the coordinates of ground control points are used as reference points for flight data. The flight data is then processed and georeferenced utilizing the ground control points. The output will be in the form of Point Cloud, Orthomosaic, Digital Elevation Model, Contours and many more. The volume is estimated using the digital elevation model and shown in the result. The original ground level volume is also calculated and based on the texture of the ground location, the original ground level volume is added or subtracted from the heaping volume to find the net volume of a stockpile.

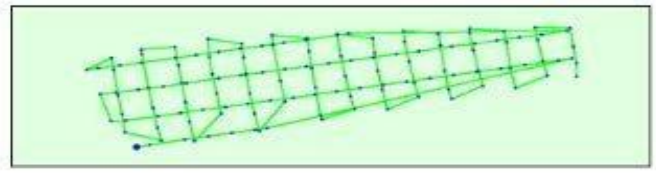

Figure 1: Path of UAV and images captured

The image shows the path of an unmanned aerial vehicle in green and the blue dots represents that the image is captured at this particular location.

6. Bulk Density Calculation

The ratio of the Mass (m) of a stockpile to its volume (V) is known as its Bulk Density. The main purpose of Bulk Density is to figure out how much the amount of Bulk solid can be stored in a container, truck, train or a silo for hauling it from one place to another. The SI unit of Bulk Density is pounds per Cubic foot. As the size of particles is directly correlated with the stuffing of material and unoccupied space, so by making changes in size, the Volume of the Bulk material will also get changed, therefore affects the Bulk Density. For illustration, the packaging of the particles of well-defined shape is of higher quality in comparison to that of the granules of uneven shape and size. Bulk density is not at all an elementary property of the material which can affect its performance, but it is playing a major role in the quality management of unprocessed substances for illustration differentiating between long strands and fine strands.

7. Results

7.1 Point Cloud

The densified point cloud is a dataset that represents objects or space to reconstruct the model. The X, Y, Z position and colour information are stored for each point which represents geometric coordinates of every single point.

Generally, the point cloud is generated using 3D laser scanners and LIDAR (light detection and ranging) technology and techniques. The point cloud library contains numerous algorithms including filtering, feature estimation, surface reconstruction, and segmentation.

Figure 2: Point Cloud generated

7.2 Orthomosaic

Orthomosaic maps are some of the most common techniques for commercial drone mapping services. The orthomosaic is essentially a 2D map composed of several orthophotos or orthoimages. It has a uniform scale and can be used for 2D measurements such as distance and surface.

Figure 3: Orthomosaic Generated

7.3 Digital Elevation Model

A digital elevation model (DEM) representation or 3D model of the terrain's surface, created from terrain elevation data with respect to any reference datum. It's the simplest form of digital representation of topographic surface. DEMs can be used to determine the terrain attributes such as slope, elevation, and aspects at any point.
Several methods are used to create DEM
a) Conversion of printed contour lines
b) Photogrammetry

Figure 4: Digital Elevation Model

7.4 Contours

Joining points of equal elevation through an imaginary line on the ground surface is known as a contour. In other words, every point on a contour line has the same elevation as that of the assumed intersecting surface. A contour map, therefore, gives an idea of the altitudes of the surface as well as their relative positions in a plane. In this way, contour serves the need of both a plan and a section.

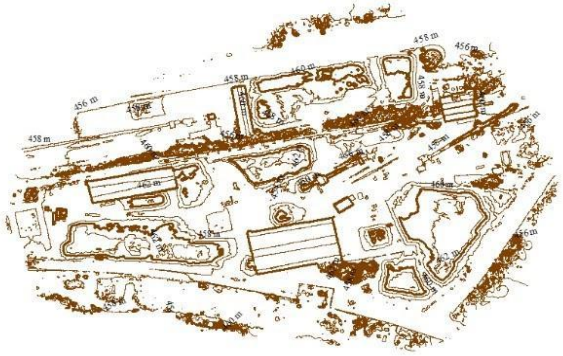

Figure 5: Contours Generated

7.5 Volume Calculation of heaps

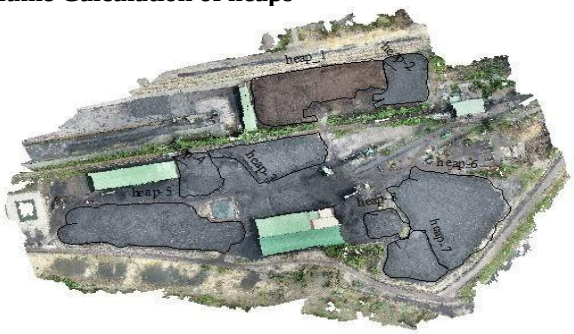

Figure 6: The figure above represents the marking of all heaps in the area considered.

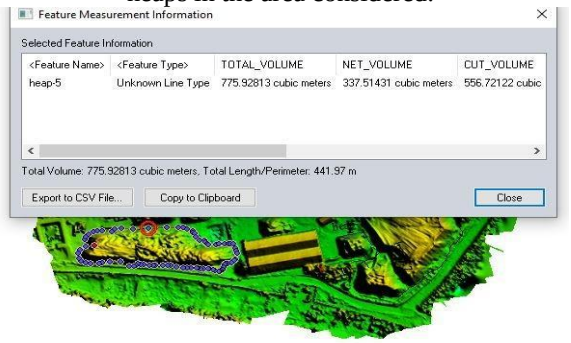

Figure 7: The figure above demonstrates the calculated volume of heap-5 shown by blue marking.

Table 1: This table shows the calculated volume of the heaps shown above

S. No.	Name	Volume (cubic meter)
1	Heap- 1	13141.796
2	Heap- 2	797.23502
3	Heap- 3	547.51691
4	Heap- 4	591.41461
5	Heap- 5	775.92813
6	Heap- 6	744.61044
7	Heap- 7	480.27002
8	Heap- 8	313.57781

8. Conclusion

In this study, the volume estimation of the stockpile is calculated using an unmanned aerial vehicle rather than the traditional method with Total station. The data obtained from the site were post-processed in Global mapper from the point cloud, digital elevation model obtained from processing in pix4d and ArcGIS. The volume obtained by computations of various models is then compared with the actual volume and is found accurate up to 98.64%. Furthermore, the time taken to complete the process by unmanned aerial vehicle is 6 times faster than the conventional Total Station (TST) method.

9. Limitations

Photogrammetry is a technique which is providing a helping hand in a lot of areas such as in Image-based mapping, Topographic Mapping, Site planning, etc. But there are some restraints, which makes this approach problematic. Environment plays a major role in Aerial Photogrammetry. Due to this, in bad weather conditions, it sometimes becomes so coamage of electronics of the UAV is so high during the Heavy Rainfall and Heavy Gust. Simplicated to execute the process of photogrammetry successfully. The probability of the diluent to select a specific period of a year for photogrammetry when the climatic conditions aparly, in the season of Heavy Snowfall, the snow cover defeats the targets and this thing can mislead us by giving a false ground impression. Because of all these issues, it is more favorable.

Furthermore, it is completely impossible to use Photogrammetry for the mapping of the area which is hidden by man-made objects and one clear example for this is the rooftop of a building or a house that is covered somehow with man-made objects. One other problem of photogrammetry is the accuracy of the mapping contours and as well as the cross regions, which is less when the area of the mapping site is not completely acknowledged because of the presence of thick vegetation, tree canopy and many more.

10. Application and Future Efforts

Future efforts should be focused on a number of factors that could potentially include a further understanding of this technique as well as improving photogrammetric results. There are areas that need to be viewed as the most influential on the accuracy of results and steps should be taken to identify a method that results in maximum possible accuracy.

Some UAS system parameters that could be improved include optimal altitude for data collection, angle of the camera during the collection of data as well as the distance from the object being surveyed. Mainly research into the optimization of equipment parameters that includes camera calibration specifics ,acquisition techniques and variations in UAS systems. Weather plays an influential factor in the success of a UAS project as well as site layout should also be considered in future studies .There are many other influential parameters that could alter the results of this study and each should be closely examined in detail for further studies to identify the minor settings in order to increase the accuracy of future projects. With the elimination of inconsistent results in UAS and photogrammetry, it has the potential to replace traditional methods of volume estimation thus presenting a more cost and time-efficient method.

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