

Waste Volume Estimation using Drone based Photogrammetry

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Abstract— Municipal Solid Waste Management is a big challenge, especially in urban areas. The conventional method of calculating the amount of waste removed based on the number of truckloads is very trivial and therefore leaves the civic authorities with no concrete method to calculate the quantum of waste removed/existing at the site. The article describes a case study of a dump yard in Mumbai Metropolitan Region where an existing dumping site is being revived by using Biomining for effective utilization of land. The technique uses drone-based Photogrammetry, GIS software, DGPS and Ground Control Points to accurately calculate the volume of solid waste removed during a certain predefined interval. The technique can be extended for use in Mining and Excavation for stockpile volume calculation. The research article presents detailed steps to calculate the volume of waste removed. It is then compared with the conventional method, thereby giving valuable information to the authorities to estimate the quantum of work for effective utilization of finances and monitor the work in progress to plan activities.

Keywords— Municipal Solid Waste Management, Drone, Photogrammetry, Volume estimation, Biomining, GIS, GPS, Dumping yard, Mining, Excavation, Stockpiles.

I. INTRODUCTION

The use of modern day technologies like drone based mapping for managing of dump yard and solid waste management locations is discussed in the following article. Waste disposal is a prominent problem for major metro cities especially Mumbai, which on an average generates about 7500 Metric Tonne of waste per day[1]. This creates a huge problem of waste disposal for which the Municipal Corporation of Greater Mumbai, (MCGM) has allotted few major dump sites across and in the outskirts of the city. The following report is pertaining to one such dumpsite located in North East Mumbai. The co ordinates of this dump site is 19°10'16"N & 72°58'33"E which comes under T ward and have an area of 25 Hectares. The site has been operational since 1968[1]. Over the years the dump pile grew to a height of approx 40 meters . MCGM decided to remediate by stopping further dumping at site so as to use the location for alternate purposes considering the lack of usable land in metro cities.

The same was to be achieved using the technique of Biomining. Biomining includes segregation of waste to separate sand that can be used for agriculture and dry waste that will be sent to cement factories to be used as fuel [2].

The entire process of mining of waste had to be monitored for the following purposes 1. Estimation of waste volume reduction from the dumpsite 2. Management of dumpsite for design and planning 3. Ensuring of compliances and safety. A safe, economical, reliable and accurate method was needed to meet the objectives specified above.

The primary objective of waste volume estimation had to be fulfilled using state of the art drone based aerial photogrammetry technique. In Aerial Photogrammetry the camera is mounted in an aircraft / UAV pointed vertically towards the ground. Multiple overlapping photos are taken along a predefined flight path and interpreting photographic images and patterns [3]. Drone based photogrammetry involves capturing of high resolution images using drone and processing of the same in a photogrammetry tool using suitable ground references captured using Differential GPS devices. The following article gives the detailed methodology for estimating the volume.

II. METHODOLOGY

A. Site inspection, preparation and flight planning

The following step involves inspecting the site and preparation of the drone flight plan along with finalization of GCP location. Google earth satellite base map was used for this process. Location for the GCP was selected such that it is not in close proximity of tall structures and power lines as it results in poor location accuracy. The final location is also based upon availability of space wherein a bench mark can be established without any form of disturbance as the same needs to be kept intact so that it can be used repetitively as a datum reference. The permanent benchmarks help in establishing the datum level. Some temporary benchmarks were placed on the dumping heaps every month based on changing site topography to allow for accurate modeling of pile height and troughs. Bench marks were made of corrugated plastic sheets with reflective black and white markings and a nail driven in the centre allowing

for accurate identification of centre points while taking DGPS measurements. This step also involves analyzing the drone flying height, altitude, overlap and extent. Fig 1 shows the satellite imagery of the target site.



B. Installation of GCPs, establishment & measurement of permanent bench mark using DGPS

Markers were placed and some permanent benchmarks were established using cement and brickwork. In total 12 GCP were created out of which 6 were on ground level and remaining were placed on piles of waste carefully to avoid being obscured or blocked by excavator activity. The GCP location are shown in Fig. 2. The points were then measured with dual frequency DGPS Trimble R6-3. The accuracy achievable is up to 10 mm in XYZ. Before collecting the same Base station is established using R6-3 base device and base measurements are recorded at intervals of 1 second. The base need minimum of 6 hours of observation and should be active during measurements of rover points. Rovers are placed over GCP and readings are taken for 30 minutes each. The technique used is Post Processed Kinematic. It functions by using base data for correcting the rover coordinates to mm level global accuracy. Capturing of one such point is shown in fig 3.



Fig. 2 GCP location on the base map

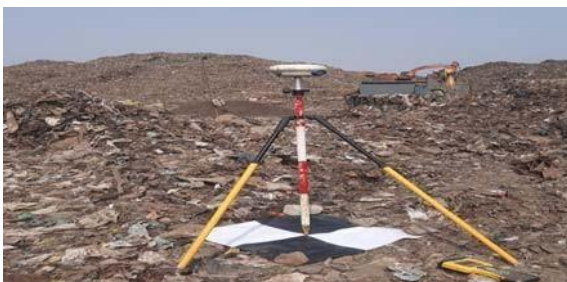


Fig. 3 Measurement of Permanent Benchmarks using DGPS

C. Processing of DGPS data points using Trimble BusinessCentre.

The captured DGPS data is processed using Trimble Business centre, a proprietary software tool for carrying out post processed kinematic survey data processing. The data is processed and output is generated along with a quality report. The quality report is reviewed to identify errors and assess whether the desired accuracy is achieved. The final output consist of CSV files containing location information.

D. Drone based data collection

Drone is flown over the area of interest to capture images of the area at high resolution. 400- 600 images were captured. Drone used was DJI Phantom 4 Pro. The drone was flown at a height of 120 meters and images were captured with an overlap of 75 percent side and 85 percent along. They were checked on site for haziness, exposure correction or fogging and stored in .JPG format. Images were captured for the entire dump yard area with an additional 50 meter buffer area to ensure all the necessary details are captured. The entire process was automated and GPS based navigation was used through drone deploy an android based application for drone flight automation which is shown in fig 4.

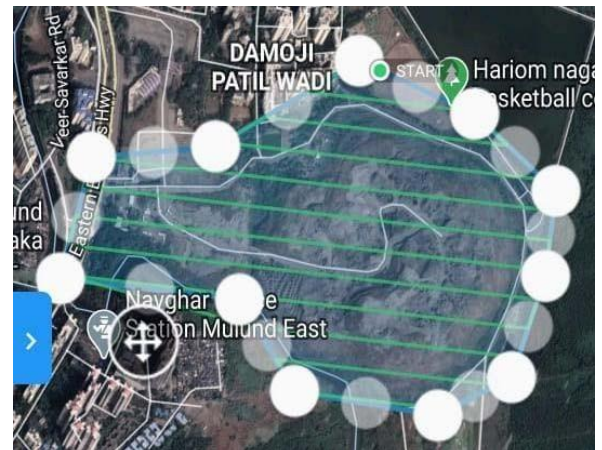


Fig. 4 Drone Flight plan using Drone deploy software

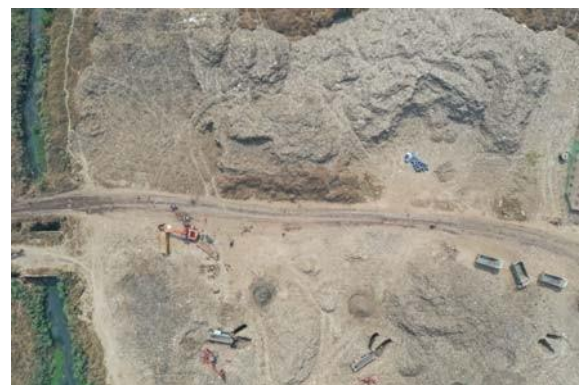
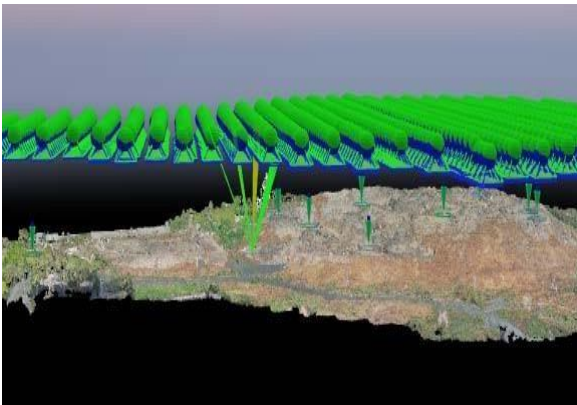


Fig 5. Drone captured aerial view of the target location

E. Aerial Triangulation and generation of 3D point cloud.

Aerial triangulation is carried out in this step using the software Pix4D. Images with control points were imported in the software and the photogrammetric process is carried out. Aerial triangulation represents the process for determining the correct position and orientation of each image in a series of aerial images so they can be compiled into a map [4]. The quality report is generated to ensure the accuracy is well within the acceptable range of 2 x Ground Resolution in XY or upto 3 x Ground Resolution for elevation. The outcome as shown in fig. 6 consist of an accurate georeferenced tie points that form the basis of the next step.



F. Generation of Orthomosaic and dense pointcloud

It involves generation of dense point clouds along with high resolution orthomosaic. The point cloud is generated in .LAZ format and is generated from tie points. Each point has a XYZ value in WGS 84 UTM 43 N Zone projection and RGB color value associated with it. The point cloud has classes wherein the software has pre classified points in ground, vegetation and buildings. The dense cloud is used to generate a digital surface model which is later used for the orthorectification and generation of a true orthomosaic in .Geotiff format as shown in fig. 7.



Fig. 7 Orthomosaic generated from point cloud

G. Point cloud classification and generation of DTM(digital terrain model)

In this stage of data processing the point cloud is imported in GIS point cloud classification tool. The tool is used for manual classification wherein the entire pointcloud is sliced in sections and the ground points are separated from non ground points. The final set includes the following classes (Ground, Roads, Vegetation, Buildings , Noise). The points in ground and road class is used for the purpose of generating the digital terrain model (DTM) of the area. The DTM is generated using the Triangulation algorithm at a resolution of 0.5 meters (fig. 8). The same will be used in further steps for volume calculation.

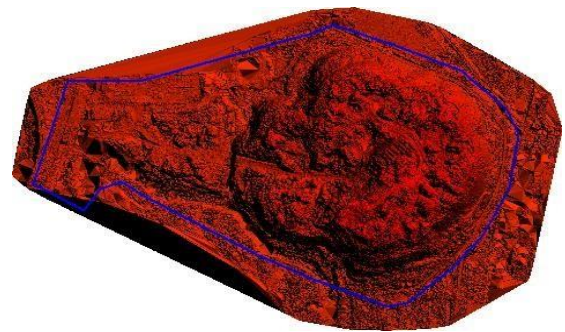


Fig. 8 Digital terrain Model (DTM) of the target site

H. Volumetric assessment using DTM

The DTM along with the datum surface created in the GIS tool is then used to calculate the volume between the two surfaces measured in cubic meters. The datum surface is created with reference to mean sea level as our DTM is also with reference to mean sea level. Volume is also calculated using the method of mean elevation. The datum is 29.29 meters above MSL. Everything above the datum is considered as dump and waste. Volume estimated by dividing the target area into various zones is shown in fig. 9.



Fig. 9 Volume estimation of waste in the target location

III. RESULTS

A sample calculation for the month of January is shown below and the final results are tabulated in table 1. The sample calculation shows the amount of waste volume remaining at the end of each month and the difference in the value of two months gives the value of the waste actually removed. The value obtained is compared with the truck load method and the difference in the two values gives variation. The entire dumping site was divided into 18 zones and the average volume of all the zones was calculated as shown in fig. 10.

| Sr. No. | Zone | Average Height (M) | Ground Bottom Culvert | Average Height (M) | Area (Sq.M) | Volume (Cu.M) |
|---------|-------------|--------------------|-----------------------|--------------------|------------------|-------------------|
| 1 | A | 45.11 | 29.29 | 15.82 | 17148.22 | 271334.86 |
| 2 | B | 54.30 | 29.29 | 25.01 | 23690.62 | 592427.24 |
| 3 | C | 35.50 | 29.29 | 6.21 | 13976.32 | 86798.34 |
| 4 | D | 67.31 | 29.29 | 38.02 | 8066.59 | 306697.38 |
| 5 | E | 62.82 | 29.29 | 33.53 | 5919.78 | 198499.49 |
| 6 | F1A | 29.78 | 29.29 | 0.49 | 12378.82 | 6062.87 |
| 7 | F1B | 41.22 | 29.29 | 11.93 | 18044.21 | 215306.20 |
| 8 | F | 66.57 | 29.29 | 37.28 | 17171.15 | 640148.53 |
| 9 | G | 41.74 | 29.29 | 12.45 | 3019.12 | 37580.29 |
| 10 | G1 | 44.09 | 29.29 | 14.80 | 29935.59 | 443156.84 |
| 11 | H | 55.24 | 29.29 | 25.95 | 5781.66 | 150046.67 |
| 12 | I | 46.47 | 29.29 | 17.18 | 12333.89 | 211871.10 |
| 13 | R2 | 46.66 | 29.29 | 17.37 | 9500.92 | 164996.42 |
| 14 | Top Portion | 63.05 | 29.29 | 33.76 | 65603.71 | 2214830.03 |
| 15 | L | 30.00 | 29.29 | 0.71 | 15450.39 | 11043.36 |
| 16 | R1 | 31.45 | 29.29 | 2.16 | 5492.53 | 11848.10 |
| 17 | J | 32.45 | 29.29 | 3.16 | 19330.60 | 61120.84 |
| 18 | K | 33.00 | 29.29 | 3.71 | 12602.34 | 46814.58 |
| | | | | TOTAL | 295446.46 | 5670583.14 |
| | | | | | 5.671 | M.Cu. M |

Fig. 10 Sample calculation for month of January 2020.

Table 1 Comparison of Volume estimated by Drone Photogrammetry & Truck load method

| Sr. No. | Month | Volume removed in cubic meters by drone Photogrammetry | Volume removed in cubic meters by truck Loads | Variation in % |
|---------|---------|--|---|----------------|
| 1 | Nov-Dec | 35750.71 | 38789 | 8.50% |
| 2 | Dec-Jan | 35852.53 | 39079 | 9% |
| 3 | Jan-Feb | 35650.70 | 38430 | 7.8% |

IV. CONCLUSION

The method adopted gives a reliable, transparent and quick method for estimating the volume of waste removed in a particular interval. It gives the authority a economical, non hazardous and concrete method for evaluating and monitoring the work in progress and also estimating the deadlines of work completion. Deploying manpower in such geographical topography is also eliminated by adoption of this method.

V. DISCUSSION

There was a variation of approximately 10% in the values obtained. The following are the possible explanation for this variation .

1. The deviation is because of some parameters such as average density assumed for converting truck loads to volume is not accurate because of settlement of ground surface due to compaction and settlement of dumping piles.

2. The difference can also be associated due to pilferage in the truck load method adopted.

The greatest challenge to the widespread use of drones is their acceptance and integration by broader society [6]. Earning a “public license” for drone use involves addressing an array of psychological, social, economic, political, environmental and legal issues [7]

Improving the reputation of drones from killer machines or privacy interrupters to a technology is a challenge.

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