Volume Computation of Municipal Landfill – Comparing GNSS and UAV

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ABSTRACT: In the last few years, unmanned aerial vehicles (UAVs) have seen a significant expansion. At present, UAVs are used in all scientific disciplines working with spatial data. Along with the UAV, various sensors and especially algorithms for processing this type of image data are being recorded. UAVs are easily able to provide data with a very high spatial and temporal resolution for 3D modeling. The aim of this paper is to test the accuracy of UAV application in volume computation compared to standard geodetic GNSS measurements on an example of a municipal landfill. Very high-resolution images were processed in Agisoft PhotoScan. The resolution of orthomosaic is 4 cm per pixel and the DSM vertical accuracy is better than 0.1 m. The result is acceptable difference between 3D models (better than 5%) when calculating landfill volumes. The volume computed from DSM is comparable to the GNSS measurements. UAV has proven to be much more flexible and productive than the GNSS method while maintaining the same output accuracy.

1. INTRODUCTION

Low cost, ease of use, fast deployment and advanced optics and other types of sensors make the UAVs ideal for long-term monitoring of natural processes, crisis control, and industrial applications. We expect, that with falling prices of advanced sensors, there will be more and more studies overviewing the existing properties of the UAVs, creating new uses for this technology. This massive expansion is possible thanks to decreasing costs and the miniaturization of individual unmanned systems, and due to more options in terms of taking and processing image data. The UAV is able to take images of the Earth's surface in high temporal and spatial resolution. Currently, they are available with multispectral or even hyperspectral sensors, and even LiDAR for recording a specific type of data. The variety of collected data types in combination with the high operability make the UAV an excellent tool for regular monitoring, or in monitoring crisis situations. The advanced, readily accessible UAV, sensors and tools for processing collected data allow for easy integration of unmanned aircrafts into the existing systems for monitoring and management of dumps (Tucci et al., 2019; Stalin & Gnanaprakasam, 2017), mineral extraction (Shahbazi et al., 2015; Raeva et al., 2016), evaluating ecological burdens in the form of illegal dumps (Lega et al., 2012), oil spills (Donnay, 2009) or fly ash (Messinger & Silman, 2016).

Effective management of communal rubbish dumps requires the fast recording of very accurate data. Acquiring current information about the communal rubbish dump consists of continued monitoring of the always-changing shape of the dump and mainly the size of the deposited rubbish. Currently, there is a lot of methods, with which it is possible to perform regular monitoring of communal rubbish dumps. Among the most commonly used is, geodetic measuring, especially with the use of GNSS technology. The effectivity and speed of data collection of the UAV, this technology fills the gap between classic aerial photogrammetry and measuring on the ground which make this technology suitable for dump monitoring. For the requirements of volume calculations, it is necessary to acquire highly accurate 3D models, so as to achieve results precise to 1 dm^3. Achieving such precise results using ground measuring tools is often very time consuming, on the other hand, with the use of photogrammetric technology it is possible to acquire highly accurate results in a fraction of the time (Patikova, 2004).

2. STUDY AREA

The communal dump in Horní Suchá (49.7978028N, 18.4818883E) is in the central part of the Morava-Silesian region. The dump was created in the year 1995 and is designated for the depositing of other types of rubbish. Other types of rubbish are considered rubbish that isn't dangerous. Currently, two-thirds of the area of the dump is closed and recultivated. Dumping takes place on the last third of the dump. Measuring took place on both part of dump, the already closed and recultivated part of the dump, as well as the parts where dumping currently takes place. The area of the dump is approximately 840 m^2**.**

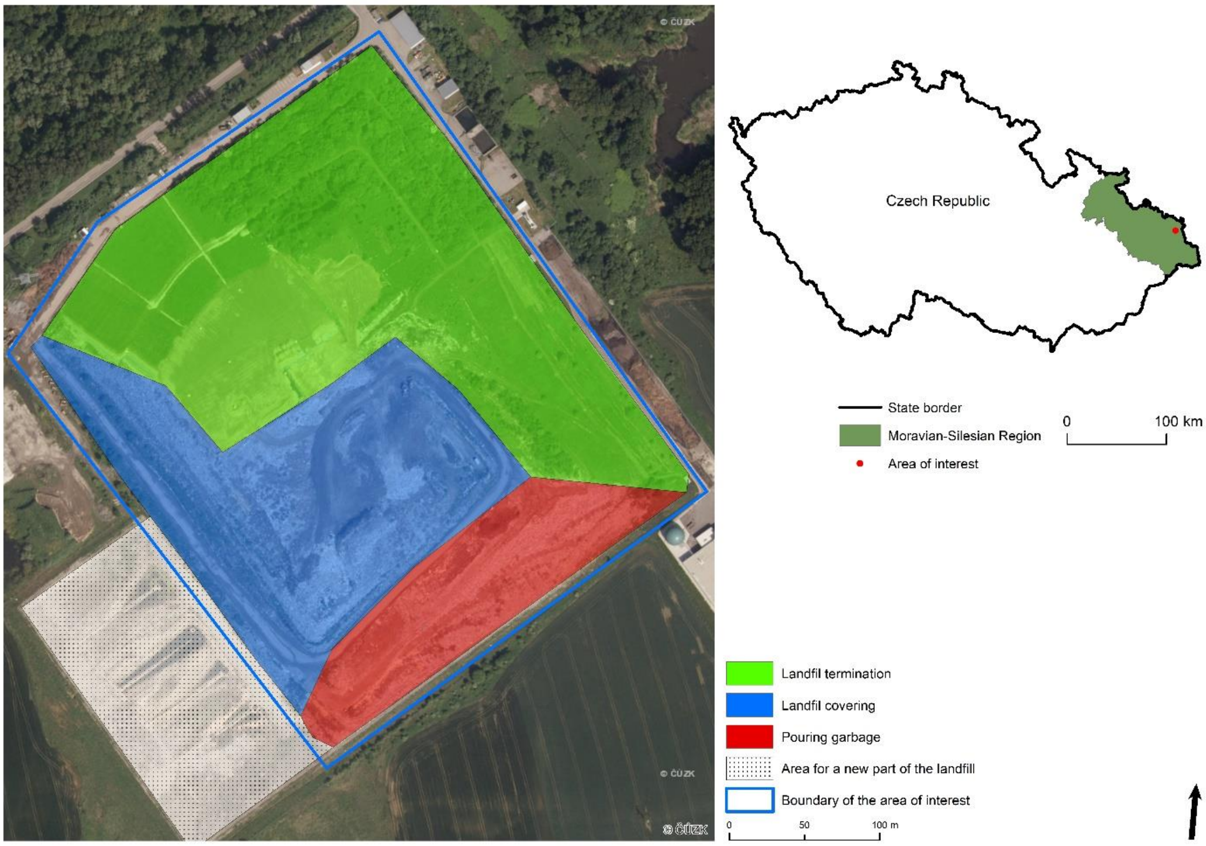

Figure 1 Area of interest

3. METHODS

3.1. Imagery collection and processing

The quadrocopter DJI Phantom 3 Advanced was used for image collection. For the determining of position during flight, the UAV uses a GNSS receiver capable of working with the signals GPS and GLONASS. On the basis of this fact, it was possible to predefine the route of the flight for data collection. The DJI Phantom 3 Advanced is equipped with an inbuilt RGB camera with 12,4 Mpx resolution. It is possible to take the individual images in JPG format, or possibly as well in the RAW format DNG.

The image collection process was divided into two parts, in the first part the UAV flew on a predefined path and in the second part of image collecting, images were taken during a manually operated flight. For planning and conducting the first part, the application DJI GS Pro was used, where it was possible to outline the area of interest and set the altitude of the flight and frontal and side overlapping of the individual images to 75 %. The altitude of the flight was set to 95 m above the earth's surface, which was 35 m above the highest point of the dump, enabling the average resolution of 3,7 cm/px. The high level of overlapping of the images was chosen due to the need to correctly reconstruct the scene with the use of the SfM algorithm (Dandois et al., 2015). The individual images were stored in JPG format. The second half of the image collection took place in manual mode flight in two differing heights - 35 m and 50 m above the surface. The image collection was performed by gradually circling round the entire communal rubbish dump and taking individual oblique imagery in DNG format. The overlap of individual oblique images was varying. The second part of the image collection was done with the aim to construct a high-quality model of the slope of the dump in the Agisoft Photoscan software, especially with the help of oblique imagery. In total, there were 378 images taken in the first and the second part of the image collection.

3.2. SfM processing

All image data were processed in the Agisoft Photoscan Professional software (Agisoft, LLC, St. Petersburg, Russia). Photoscan is a photogrammetric software allowing for the creation of 3D point clouds and digital surface models on the basis of a set of imagery with a sufficient amount of frontal and side overlaps. The Agisoft Photoscan Software utilizes the SfM algorithm, which creates 3D data from 2D data on the basis of identifying shared points contained in the group of overlapping images and calculations of the camera positions by minimalizing distances between shared points. The resulting 3D data has high position accuracy and is highly suitable for the calculation of volume (Alidoost & Arefi, 2017).

All imagery data was imported into the Agisoft Photoscan software. The setting parameters for the creation of individual outputs are in Table *1* The parameters used for reconstructing the scene in Agisoft Photoscan. Due to the fact, that the accuracy of the GNSS receiver of the UAV itself is in the nearest couple of meters, it was necessary to perform georeferencing to attain high accuracy of 3D outputs. The sparse point cloud created in the first step of image processing was therefore georeferenced with the use of 10 ground control points (GCPs) (**Chyba! Nenašiel sa žiaden zdroj odkazov.**). The accuracy of georeferencing is 3,5 cm and reprojection error is 1,76 px. The individual GCPs were recorded by the GNSS receiver with the help of the Real-Time Kinematic method (RTK). The GCPs were marked in the terrain with black and white targets of the dimension 30 x 30 cm. Then, a dense point cloud was created, and a digital model of the surface and an ortho-photo mosaic were then derived. The dense point cloud is formed by 62 500 000 points. The resolution of the digital model of the surface is 7,4 cm/px, where the density of the points is 182 points/m^2. The resulting orthophoto mosaic has the resolution 3,7 cm/px.

Table 1 The parameters used for reconstructing the scene in Agisoft Photoscan

Parameter name	**Selected value**
Align photos	
Accuracy	High
Pair preselection	Yes
Key point limit	40 000
Tie point limit	4 000
Build dense cloud	
Quality	High
Depth filtering	Moderate
Build DEM	
Source data	Dense cloud
Interpolation	Enabled
Point classes	All
Resolution	7,4 cm/px
Orthomosaic	
Blending mode	Mosaic
Surface	DEM
Enable hole filling	YES

Figure 2 Ground control point

3.3. GNSS measurement

The receiver Trimble R10 A and the RTK method with fixed ambiguity with connection to online correction on the national network CZEPOS were used for the measuring of ground control points and points on the entire area of the dump.

The GNSS measuring was done on the same day and the same hour as when image collection with the UAV took place. The characteristic fault lines of the entire dump were determined. From these points, there was a 3D model of the dump created in the ArcGIS 10.6 environment in TIN format. The individual points were localized in the national coordinate system S-JTSK (Datum of Uniform Trigonometric Cadastral Network) and in the height system (Bpv (Baltic Vertical Datum - After Adjustment). For the entire duration of measuring, its accuracy was to the nearest few centimeters.

3.4. Determination of volume and vertical profiles from UAV

When the 3D model was created with the SfM algorithm, it was possible to move on to the calculation of the volume of the dump and vertical profiles. The volume of the dump was calculated as the amount of deposited material above the defined 0 level. The 0 level was determined by GNSS point measuring of the foundation of the communal rubbish dump as 266,05 m above sea level. On the basis of 3D model created with the help of the SfM algorithm, we calculated the volume between the reconstructed terrain of the dump and the 0 level reference determined by GNSS measuring.

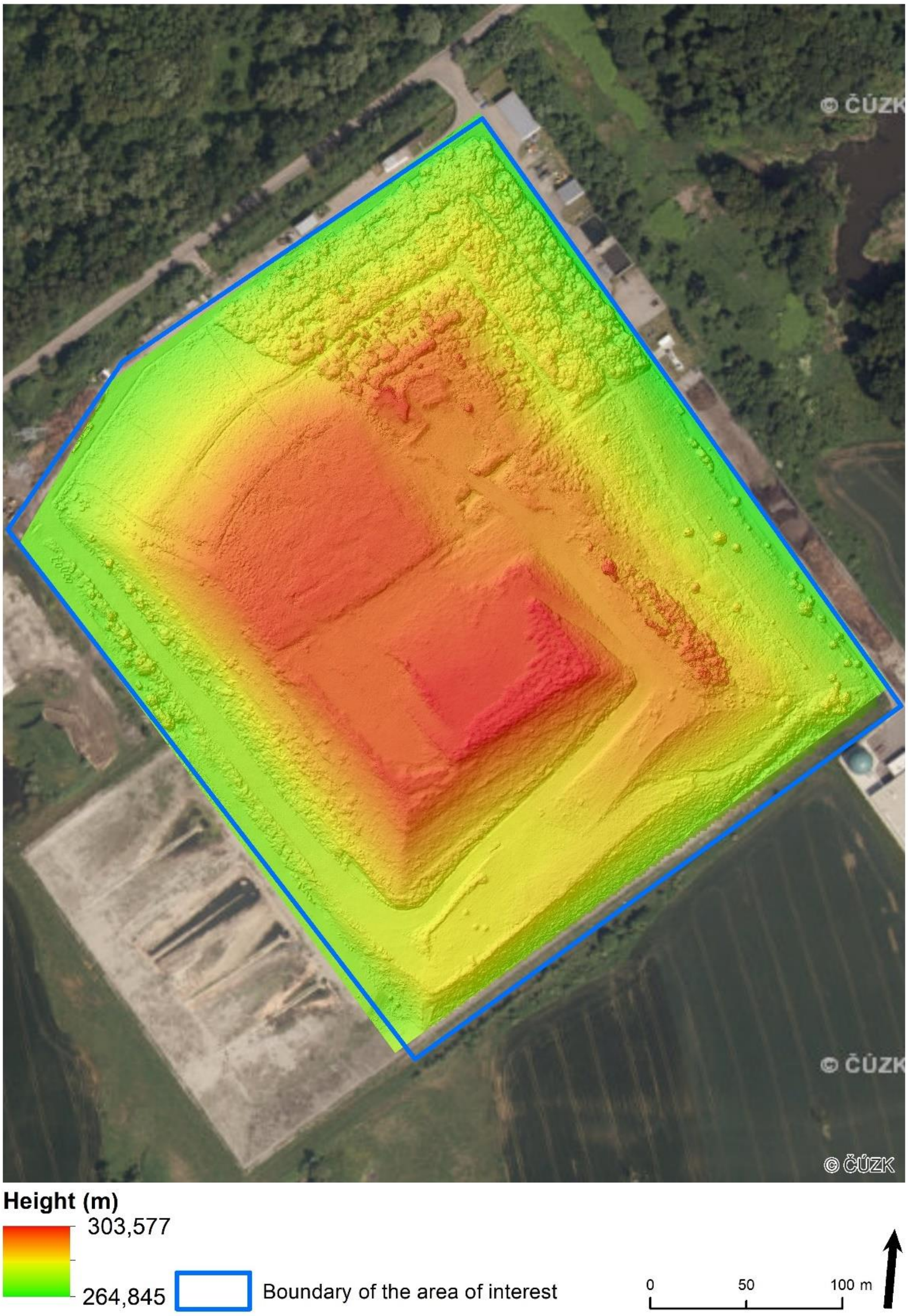

Figure 3 DSM from UAV

On the basis of the 3D model, it is possible to construct vertical profiles along the predefined lines. These profiles are useful for the monitoring of the area of deposited communal rubbish on the area of the dump.

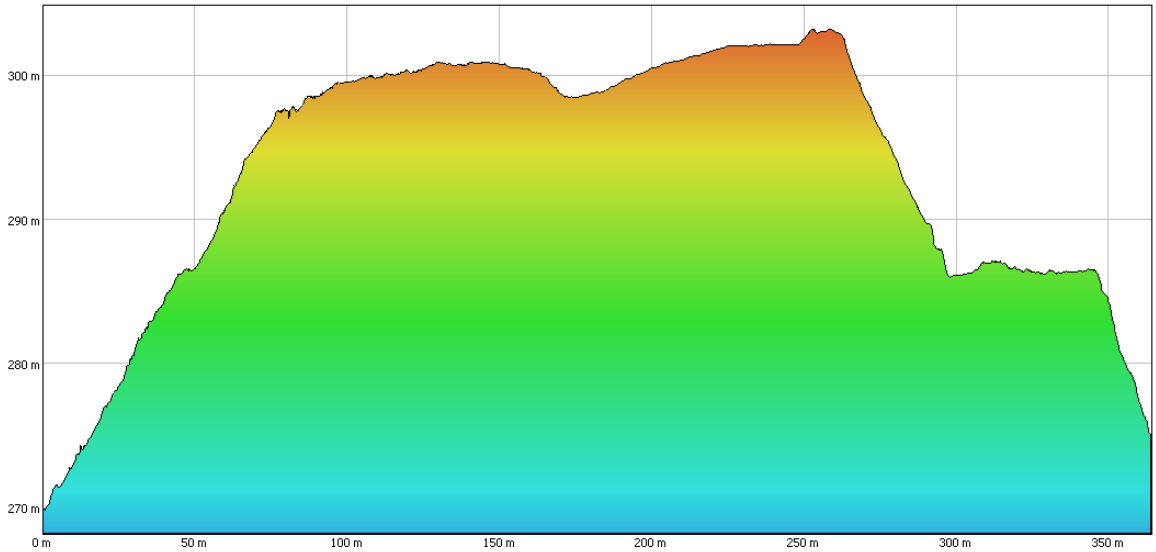

Figure 4 Profil of DSM from UAV

3.5. Determination of volume from GNSS measurement

The processing of GNSS measuring took place in the ArcMap 10.6 software by company ESRI. In the first step, the foundation of the dump was determined by connecting break lines on the foot of the dump into a polygon. In a similar manner, the top part of the dump was determined. The such determined truncated cone was then deformed by gradually adding breakpoints defining the entering pathways leading to the individual levels of the dump. The resulting model was exported in TIN format.

Figure 5 3D model from GNSS

4. RESULTS AND DISCUSSION

The overall volume of the communal rubbish dump was calculated on the basis of the 3D model, which was itself created with the help of the SfM algorithm from the images of the UAV is 2 349750 m^3. For comparison, the overall volume of the communal rubbish dump measured with the help of GNSS is 2 286742 m^3. The difference between these two volumes is 63 008 m^3, which is a difference of 2,7%.

In parts of the recultivated dump, there is very dense vegetation formed by bushes and trees, which would be very difficult to filter out of the 3D model. The greater volume measured in the case of the UAV was probably caused by measuring the vegetation covering the recultivated parts of the dump and weren't filtered out of the 3D model. Filtering wasn't done, because it would cause holes in the resulting 3D model, which would lead to incorrect results of the dump volume. The digital model of the surface put together from the GNSS measuring has its limitations due to there being a small amount of measuring points, which significantly affects the resulting value of the measured volume. Conversely, the digital model of the surface created with the help of the SfM algorithm is significantly more detailed and has a more segmented surface, as the SfM algorithm is able to reconstruct even very small terrain changes.

5. CONCLUSIONS

In conducting this study, we provided a very accurate estimate of the total volume of deposited rubbish onto the communal rubbish dump in Horní Suchá. For the calculation of volume, there were two independent technologies used - UAV and GNSS measuring. This study demonstrated the suitability of small affordable UAVs with RGB cameras in determining the volume of deposited rubbish. We collected a set of RGB images, which were processed with methods of image analysis and we created an accurate 3D model to calculate volume. The difference in volume calculated on the basis of GNSS measuring and data from the UAV is 2,7%. If we compare the time needed for image collection of individual data sets, the UAV is definitely more time effective. Data collection with the help of UAVs including the localization of 10 ground control points took approximately 30 minutes. The measuring of needed points for the creation of the 3D model with the help of GNSS measuring took approximately 90 minutes.

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