Validation of Data Collection Methods for Survey Stockpiles Measurement

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Abstract

The paper focuses on validating data collection methods for surveying stockpiles, critical in industries like construction and mining, ranging from traditional manual approaches to advanced technologies such as LiDAR and drones. The study assesses accuracy and reliability, considering factors like equipment precision and data processing. It examines various measurement techniques and devices, comparing their accuracy, usability, and results. This work underscores the importance of reliable data in fostering efficiency and sustainability across industries.

Keywords: *stockpiles, laser scanning, drone, iPhone, measuring, volume calculation*

Introduction

Accurate measurement of stockpiles is crucial for various industries, including construction, mining, and agriculture. The reliability of these measurements depends largely on the data collection methods employed during surveys. Ensuring the validation of these methods is imperative to guarantee the precision and credibility of the gathered information.

Stockpile measurement plays a pivotal role in inventory management, resource planning, and regulatory compliance for organizations dealing with bulk materials. The methods employed for data collection range from traditional manual measurements to advanced technologies such as LiDAR (Light Detection and Ranging), drones or mobile phones. Each method comes with its own set of advantages and limitations, making it essential to scrutinize their accuracy and reliability.

This exploration into the validation of data collection methods for surveying stockpiles aims to address the challenges associated with ensuring the precision and consistency of measurements. It involves assessing the accuracy of measurements stockpile materials by different methods.

By comprehensively validating these data collection methods, industries can enhance their decision-making processes, optimize resource utilization, and meet regulatory requirements with confidence. This topic not only contributes to the advancement of stockpile measurement techniques but also underscores the significance of reliable data in fostering efficiency and sustainability in various sectors.

Tested area

As a tested area we chose a Packing plant – STRABAG, who allowed us to use the premises for the measuring. There are eleven piles of gravel of various sizes as seen in the Figure 2.

To collect data were chosen four methods. Laser scanning method, unmanned aerial vehicles (UAV – drone), mobile mapping and photogrammetric method using iPhone.

Methods of data collection

The laser scanning method is a technology based on the non-contact determination of spatial coordinates of objects, suitable for subsequent 3D modeling and visualization of buildings, especially for more complex and extensive structures. It is widely used in various areas, encompassing the scanning of interiors, exteriors, historical buildings, underground spaces, and many other objects. The primary advantages of this method are its high speed and accuracy. The output of this technique is a point cloud, which can be used to create a 3D model of the building.

Drones are unmanned aerial vehicles (UAVs) equipped with cameras, sensors, and other tools used for collecting data from the environment. They have become invaluable tools for scientists and researchers because they can gather data in areas that are difficult to access or too dangerous for humans.

Mobile mapping utilizes various vehicles such as cars, ships, railcars, drones, and others as carriers for scanners. The collected data may come from multiple cameras, diverse sensors, different times, depths, or viewpoints. Through registration, we can compare and integrate data obtained from these varied measurements. The equipment includes an In-

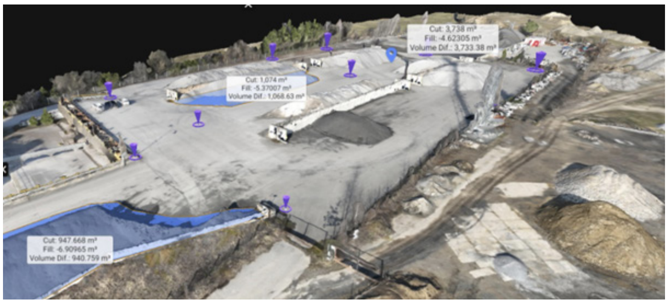


Fig. 1. Tested stockpiles
Rys. 1. Badane zwałowiska

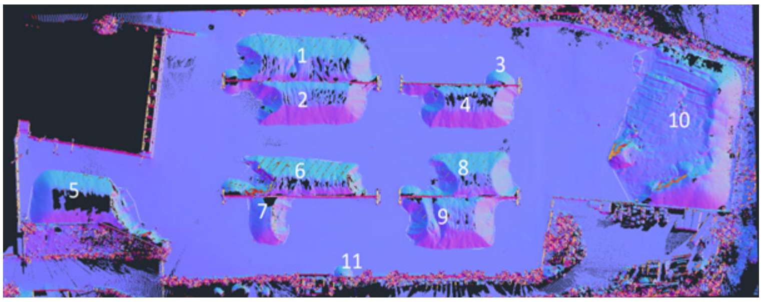


Fig. 2. Tested stockpiles – point clouds
Rys. 2. Badane zwałowiska chmura punktów

Fig. 3. Leica RTC360
Rys. 3. Skaner laserowy Leica RTC360

Fig. 4. DJI Mavic 3
Rys. 4. Dron DJI Mavic 3

Fig. 5. Geo SLAM ZEB Horizon
Rys. 5. Skaner ręczny Geo SLAM ZEB Horizon

ertial Navigation System (INS), which comprises an Inertial Measurement Unit (IMU) and a GNSS receiver determining the device's position for field measurements. When operating inside buildings, the use of Simultaneous Localization and Mapping (SLAM) technology becomes necessary. The IMU, typically consisting of three accelerometers and three gyroscopes (for all three axes in space), determines tilts and accelerations. These parameters are then used in calculating the coordinates of measured points. The IMU provides the necessary data for determining the motion trajectory, refined further using GNSS or SLAM.

The photogrammetric method using an iPhone involves installing an application for collecting photos with an automatic calculation of cubic volumes.

Used devices

- Leica RTC360

This highly automated and innovative solution for capturing data in 3D reality effectively combines the powerful RTC360 3D laser scanner with the Leica Cyclone FIELD 360 application. This application enables the automatic re-registration of scans in real-time directly in the field. The Leica Cyclone REGISTER 360 software is then employed for fast processing into the final cloud (Figure 3).

- DJI – Mavic 3

The DJI drone is equipped with a photogrammetric camera and an RTK receiver, enabling the rapid and precise creation of 2D maps, 3D models, or point clouds. This drone provides advanced settings for flight parameters, and the RTK module ensures an accuracy of 1 cm or 1.5 cm and beyond. Additionally, the Mavic 3 comes with built-in GPS, offering a maximum flight time of forty-six minutes (Figure 4).

- Geo SLAM ZEB Horizon

It is characterized by its long range, speed, and high accuracy. With a range of up to 100 meters, the ability to capture 300,000 points per second, and achieve 6mm relative accuracy, the ZEB-HORIZON proves to be excellent for outdoor applications. Its lightweight and compact design also make it well-suited for indoor surveys. The processing is automatic and very user-friendly (Figure 5).

Fig. 6. iPhone SE – installed application
Rys. 6. Aplikacja w telefonie IPhone SE

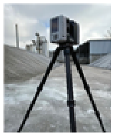
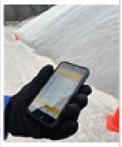
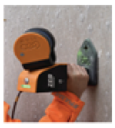
Method	data measurement				
	description	time	cost of equipment	service difficulty	weather resistance
Terrestrial laser scanning	stop&go method tops of stockpiles extra cover creating point clouds Leica	2h/site	30 000 €	start-stop button tripod leveling position selection survey on top stockpile 	high resistance to dust and water
Evaluation		3	5	3	2
Photogrammetry dron	flying the same flight path taking photos in raster dji	0,2h/site	3 000 €	automatic takeoff and landing automatic flying basic drone control skill is essential safety 	limits for rain, fog, wind
Evaluation		1	2	3	3
Photogrammetry mobile phone	slow walk with mobile phone - iPhone iPhone	2h/site	600 €	patience on the walk no shake 	limits for rain, fog, wind
Evaluation		3	1	3	3
Mobile laser scanning SLAM	hand mobile method tops of stockpiles extra cover creating point clouds GeoSLAM	0,2h/site	45 000 €	start-stop buttom survey on top stockpile 	high resistance to dust and water
Evaluation		1	5	2	2

Fig. 7. Comparison of individual methods
Rys. 7. Porównanie stosowanych metod

- iPhone SE – application Stockpile report for volume calculation

With this application, it is possible to calculate timely and accurate stockpile volumes and tonnage using data collected by an iPhone. The installed app utilizes real-time automated cameras, and the post-processing of data is automatic (Figure 6).

Data collection and processing

The data collection took place in the selected territory, as shown in Figure 2. Identical points were strategically placed, measured by a total station, and subsequently used for data collection and processing in laser scanning, drone flying, and mobile mapping methods. Uti-

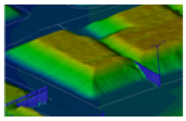
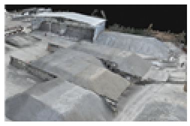
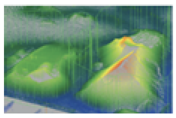
Method	data postprocessing							
	description	time	cost of aplication	difficulty processing	difficulty calculation volume	accuracy	data sharing	photo
Terrestrial laser scanning	Tromble bussines center - connection, cleaning, classification, mesh, volume calculation of point clouds	2h/site	16 €	Trimble bussines center no online solution desktop software subject knowledge	draw polygon stockpile plane adjustments report editing	probably the most accurate method 1-2 percent	offline external cloud	
Evaluation		3	1	3	3	1	4	**2,8**
Photogrametry dron	Pix4D, Propeller - upload data (photos and coordinates) to the cloud for calculation solution: Pix4D, Propeller	0,5h/site	100 €	Pix4D, Propeller - simple upload of data to the cloud	draw polygon stockpile plane adjustments report pre-prepared	very good, 1-2 percent	online aplication	
Evaluation		2	3	1	2	1	1	**1,9**
Photogrametry mobile phone	Stockpile report - upload data (photos and coordinates) to the cloud for calculation solution: Pix4D, Propeller	0,5h/site	80 €	Stockpilereport.com simple upload of data to the cloud	draw polygon stockpile plane adjustments report pre-prepared	more complex shapes - measure from a high deviation or not at all 3-4 percent (hodnocení mezi 3-4)	online aplication	
Evaluation		2	3	1	1	3	1	**2,1**
Mobile laser scanning SLAM	connection, cleaning, classification, mesh, volume calculation of point clouds	2h/site	15 €	GeoSLAM no online solution desktop software Volume - 2000Euro plus subject knowledge	draw polygon stockpile plane adjustments report editing	very good, 1-2 percent	offline external cloud	
Evaluation		3	1	3	3	1	4	**2,5**

Fig. 8. Comparison of individual methods – processing

Rys. 8. Porównanie stosowanych metod – obliczenia

Stock pile name	Leica RTC360 Cloud Compare [m3]	Leica RTC360 TBC software [m3]	Mavic 3 Pix4D.cloud [m3]	Mavic 3 Propeller [m3]	GeoSLAM [m3]	iPhone SE Stockpilereport.com [m3]	Site volume [m3]
1	1 324	1 268	1 308	1 336	1 353		1 362
2	989	1 083	1 074	1 081	1 115	1 105	1 226
3	26	28	25	27	30	34	
4	892	879	902	923	907	890	961
5	901	902	947	941	948	1 256	1 050
6	970	982	1 000	1 008	967	972	989
7	220	238	226	235	234	242	
8	713	722	723	736	720	716	719
9	996	1 000	1 020	1 042	1 010	1 022	916
10	3 553	3 504	3 738	3 761	3 752	3 567	3 814
11	8	10	9	9			
Completed	9 014	9 072	9 404	9 492	9 419	9 528	9 675

Fig. 9. Volume results

Rys. 9. Porównanie uzyskanych objętości

lizing identical points ensures compactness and processing accuracy.

Before the measurement, individual devices were compared based on measurement time, purchase price, difficulty of data collection, and resistance to weather effects, and were rated from 1 to 5. The results can be seen in Figure 7.

Upon completion of data collection using all selected methods, processing was carried out using various software. For the Leica RTC360, Cloud Compare, and Trimble Business Centre (TBC) were employed. Data from the Mavic 3 drone were processed in Pix4D Cloud and Propeller, while GeoSLAM utilized automatic processing in its own software. The application on the iPhone is also automatic after data collection.

Following the processing of all data, the cubic volumes of individual stockpiles were calculated, and the results were compared. A comprehensive comparison and evaluation of data processing collection took place, considering factors such as data collection time, processing application price (user licenses), processing difficulty, volume calculation difficulty, accuracy, and data-sharing possibilities. The results are presented in Figure 8.

Evaluation of the methods

After evaluating and comparing individual methods in terms of data collection speed, processing efficiency, and result accuracy, the laser scanning method emerges as the most accurate. However, this method, despite its precision, involves a longer data collection and semi-automatic processing compared to using an iPhone application. Although the data collection is rapid with the iPhone app, and the processing is automatic, the difference in the achieved results is not significant.

The conventional method of measuring stockpile volume involves the use of battens and a measuring wheel. Results indicate that the laser scanning method deviates by 1.5 percent from the average, the UAV method by 1 percent, mobile mapping by 4 percent, and manual surveying with a measuring wheel by 7 percent from the standard deviation.

The findings highlight the advantages of both photogrammetric methods over the classical measurement method, which is widely used today.

The laser scanning method (TLS) proves to be the most expensive. While data acquisition speed is moderately fast, the semi-automatic processing, maintaining overlap between individual scanner positions, requires the expertise of a surveyor.

The mobile mapping method is the most expensive regarding equipment acquisition. The data acquisition process is very fast and can only be performed by a trained worker, with the processing being semi-automatic.

Using a drone is moderately expensive, with a very fast data acquisition process that requires a trained worker. The processing, however, is automatic.

The Stockpile Report on iPhone is an extremely cost-effective option. Data acquisition is moderately fast, and the processing is automatic. The accuracy is surprisingly satisfactory, meeting the required precision for measuring stockpile volume.

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Walidacja metod pozyskiwania geodezyjnych danych pomiarowych składowisk

W artykule skupiono się na walidacji metod gromadzenia danych do badania składów, kluczowych w branżach takich jak budownictwo i górnictwo, począwszy od tradycyjnych metod ręcznych po zaawansowane technologie, takie jak LiDAR i drony. W badaniu oceniano dokładność i niezawodność, biorąc pod uwagę takie czynniki, jak precyzja sprzętu i przetwarzanie danych. W artykule opisano badanie różnych technik i urządzeń pomiarowych, porównując ich dokładność, użyteczność i wyniki. Praca ta podkreśla znaczenie wiarygodnych danych dla wspierania wydajności i zrównoważonego rozwoju w różnych branżach.

Słowa kluczowe: *zwałowiska, skanowanie laserowe, dron, iPhone, pomiary, obliczanie objętości*