DEFINITION OF THE GROUND SURFACE DEFORMATIONS AND CONSTRUCTIONS IN THE ROCK BREAKAGE ZONE

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Annotation

The article discusses the issue of improving the efficiency of surveying and geodesic observations of deformations of areas worked up by underground mining. The authors made an analysis of the current state of the issue and based on this, it was proposed to use different approaches to solving the problem, taking into account the features of the observed object. The use of electronic tachometers for performing linear measurements using observation stations to study the processes of displacement of rocks and the earth's surface deserves attention. In this case, benchmarks can be determined from leveling. In studies of deformations in large areas of dumps or quarries, it is advisable to use the method of coordinate reference frames using GPS. The coordinates are calculated not only the magnitude of the deformation, but the direction of displacement. Modern digital methods allow you to explore inaccessible objects that are dangerous to perform work on them by traditional methods. The article provides an example of processing a digital survey made from an unmanned aerial vehicle. The possibility of using this method to monitor deformations has been proved, and to improve the accuracy of determining the values of deformations, it is advisable to improve the accuracy of image processing by including the use of additional characters in standard programs.

Introduction

In 2010, there was a collapse of the ground surface in the mine of Ordzhonikidze, which was undermined by underground mining, which caused human losses and material losses. To prevent further similar incidents, for this purpose, and near the lying areas, a project has been created to upgrade the observation station, which is being improved every year. It should be noted that the observation station in this area has existed since 1954.

A modern observation station includes 20 profile lines that run along the earth's surface and main buildings. 123 ground points are fixed with metal rods 150-180 cm long. In addition to ground benchmark, which are used to study the ground surface, sixty wall marks were laid, which serve to observe the deformations of the buildings of a substation, a garment factory, and other important objects located in the same territory.

Instrumental observations are conducted in accordance with the requirements of the instructions [1]. It is known that the classical methods involve the implementation of linear measurements of the distance between the benchmarks and the measurement of the excess between the benchmarks. At first, geodesic roulettes were used for linear measurements, then a range finder, and now an electronic total station. The excess between the benchmarks is determined by the results of high-precision leveling.

Leveling on closed passages is performed in one direction, and leveling on open passages is in the forward and reverse directions. The permissible discrepancy in closed and double passages does not exceed $15\sqrt{L}$ mm, where, as is known, L is the travel length in kilometers. As a result of the leveling of the leveling passages, it was established that the actual values of the residuals are less than f_{per}.

The lengths of the intervals between ground benchmarks are measured with an SET 630R total station with a standard error m_S = 2 mm. The centering of the total station is carried out with the help of optical centers, and the centering of the reflector using the tripod. The lengths of the lines are measured in the forward and reverse directions, which provides a relative error in the measurement of the length of the intervals between the benchmarks of the profile lines no coarser than 1:10000.

According to the results of the research performed, it was established that it is impossible to perform the work strictly following the provisions of instructions that are twenty or more years old. Old documents are focused on the use of routine instruments and inefficient measurement processing technologies. Considering the modern achievements of science and technology, it is necessary to constantly improve the classical methods of performing work, increasing their efficiency.

1. The use of electronic tachometers in the observation of deformations

One of the significant achievements in geodetic instrument making is the development and manufacture of an electronic tachometer. Electronic tachometers allow increasing the efficiency of instrumental observations of various deformations, including the displacement of rocks.

With the help of the total station SET 630R, work is carried out to determine the length of the intervals between the benchmarks with sufficient accuracy. In addition to the dignity of this device with respect to its accuracy, it can significantly reduce the time taken to make measurements. It is often possible to choose a station in the alignment of the profile line, from which all the benchmarks are visible, and from one such point to measure the lengths of all intervals. Using a total station allows you to determine the length of the intervals from a point located not in the alignment of the profile line. To do this, it is necessary to perform linear and angular measurements, which are convenient for solving the given task of the station, which are necessary for determining the lengths of intervals from linear-angle constructions.

Based on the equal influence of linear and angular measurements, with a relative accuracy of linear measurements of 1:10000, it is assumed m_β=20" at m_S=2 mm. The SET 630R total station has an angular measurement accuracy of 6".It was previously established that to determine elevations with a mean square error $m_h = \pm 3$ mm at m_β=6″, S= 0 m and at tilt angles from 1º to 10º, the lengths of the lines should be measured with an accuracy of 15 cm to 2 mm, which allows electronic total station SET 630R.

Considering the difficult conditions of the territory where works are performed to monitor the deformations of the ground surface and buildings located near the collapse zone, it was decided to use other methods in parallel. Therefore, special polygonometric strokes were laid along the profile benchmarks. Prior to this, observations on the reference lines of the profile line were performed using the measurement of distances and elevations and the values of horizontal and vertical deformations were determined.

Using this technique, the results of observation of deformations on the reference points did not exceed the critical values [2].

As a result, the determination of the coordinates of the benchmarks on the initial and subsequent dates, they found significant values of deformations that exceed the critical ones. The calculated differences of the coordinates of benchmarks characterize the magnitudes and directions of displacement for a certain period of time.

In practice, there was a case when the distance between the benchmarks from adjacent series of observations changed by 12 cm. and the coordinates of the benchmarks, between which this distance was determined, changed respectively by 76 cm and 57 cm. If the coordinates of the benchmarks had not been determined, then such significant values of the benchmark offset would not have been detected. In complex areas of land that are undermined by underground mining, such cases are not alone.

When performing work on the observation of deformations of the earth's surface and buildings in the territory located near the collapse zone, the electronic SET 630R total station was used to determine the planned-high-altitude position of the profile line reference points.

In practice, the correctness of the selected measurement characteristics was confirmed when studying the deformations of the ground surface and structures located above or near the developed space. The method of measuring the lengths of intervals or their determination from linear-angle constructions using electronic total stations was applied on the profile lines of the observation station in the territory in the mine of Ordzhonikidze in Kryvyi Rih [3-5].

2. Coordinating working benchmarks with GPS

As mentioned above, in practice there are often cases when classical methods for monitoring the movement of rocks do not give reliable results. Coordinating the benchmarks of the profile lines of an observation station on specific dates of various series of observations allows to obtain a complete description of the deformation processes occurring in a given area.

When using GPS to determine the X, Y, Z coordinates, the known formulas for calculating the values of horizontal and vertical deformations are respectively transformed [6]. Linear elements - the lengths of the intervals, which are used in the formulas, are calculated from the coordinates of the frames, and the directions of the deformations are determined from the results of the analysis of coordinate increments and from which the directional angles of the directions are calculated.

Previously, the authors considered the issue of improving the efficiency of work on monitoring the deformations of the ground surface and the structures located on it, by constructing special networks in the form of quadrangles or triangles, at the vertices of which there are deformation frames. This allows to obtain the strain values for large areas, and not only in the directions of the laid profile lines.

3. The use of digital photogrammetry in deformation studies

Recently, there has been significant technological progress in the field of digital technologies, which has led to a significant improvement in the quality of digital cameras and their resolution.

A positive factor affecting the widespread use of digital imaging techniques in mining is the improvement in digital image quality, along with a significant decrease in the cost of digital cameras. As a result, the surveying service received an effective measuring tool that can be used to solve a wide range of surveying tasks for providing open-pit mining at a higher level.

Particularly noteworthy is the variety of programs that are designed to perform filming with unmanned aerial vehicles. The programs allow you to process data from surveys, create 3D models, calculate the volume of mineral extraction and the area of objects.

The advantages of many programs are that they can be used in conjunction with any unmanned aerial vehicle and process images taken with any DSLR or GoPro digital camera; allow you to get the final result with high speed and accuracy; just importing images from the camera into the program for processing; after constructing a three-dimensional digital model, you can calculate the volume of a certain area and solve other tasks.

Aerial photography of the area, which is carried out by unmanned aerial vehicles, is today relevant and cost-effective in solving a wide range of tasks of mine surveying and mining. In 2017, the EBEE SENSEFLY unmanned aerial vehicle was presented on the territory of the career № 2 of CGOK, LLC TNT-TPI. Based on the results of the survey, pictures were taken of a part of career № 2.

The processing of survey results was carried out using several software products, one of which is Agisoft Metashape Professional. Due to the large amount of data obtained as a result of a quarry survey, there are certain requirements for the processor and the graphic card. For processing the obtained images, the processor power, the characteristics of the graphics core and the video card are important. Snapshot processing was performed using the fourth generation 4790K Intel® Core ™ i7 processor.

Despite the high performance of the processor, the processing lasted more than 12 hours. Due to adverse weather conditions, of the 210 images, 130 were taken for processing. Fig.1 shows the characteristics of the camera.

Type	Resolution	Focal Length	Pixel Size
Frame	**5472 x 3648**	**10.2 mm**	**2.4 x 2.4 μm**

	Value	Error	F	Cx	Cy	B1	B2	K1	K2	K3	K4	P1	P2
F	**4416.46**	0.12	1.00	0.03	-0.62	0.01	-0.00	-0.13	0.04	-0.03	0.04	0.02	0.28
Cx	**-32.2697**	0.048		1.00	-0.04	-0.08	-0.04	0.02	-0.02	0.02	-0.02	0.69	0.02
Cy	**-9.93983**	0.049			1.00	-0.02	-0.08	0.02	0.02	-0.03	0.02	-0.04	0.13
B1	**0.804109**	0.02				1.00	0.00	0.00	-0.01	0.01	-0.01	-0.02	0.03
B2	**0.059513**	0.021					1.00	-0.02	0.03	-0.02	0.02	0.01	-0.05
K1	**-0.101064**	8.8e-005						1.00	-0.96	0.91	-0.85	0.01	-0.06
K2	**-0.351346**	0.00067							1.00	-0.98	0.95	-0.00	-0.02
K3	**0.674133**	0.0019								1.00	-0.99	-0.00	0.03
K4	**-0.353447**	0.0018									1.00	0.01	-0.04
P1	**-0.000786635**	1.7e-006										1.00	0.00
P2	**-0.000304893**	1.9e-006											1.00

Fig. 1. Elements of camera calibration and correlation matrix

In fig. 2 shows a digital model with a color characteristic of heights.

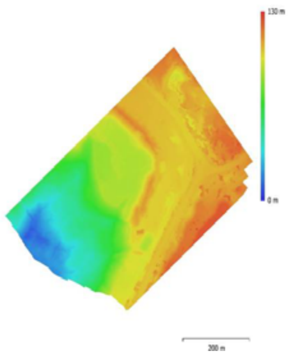

Fig. 2. Digital model with a density of 161 points per m^2

The graphic window can be represented as a sparse or dense cloud of points, as a model or a tile model. In fig. 3-5 are some perspectives of the resulting model.

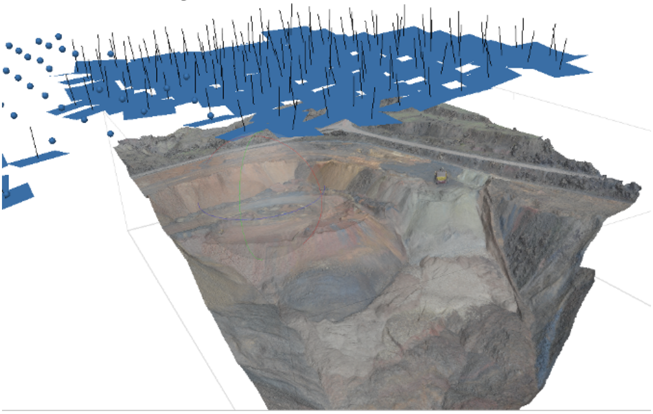

Fig. 3. Perspective 1

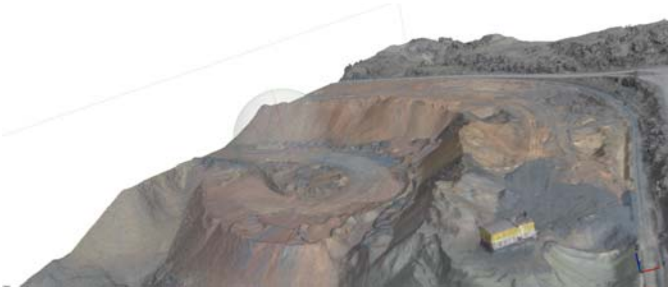

Fig. 4. Perspective 2

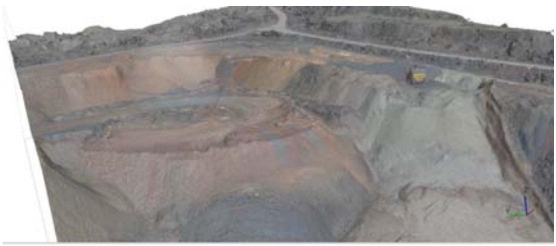

Fig. 5. Perspective 3

In fig. 6 shows a model with contours.

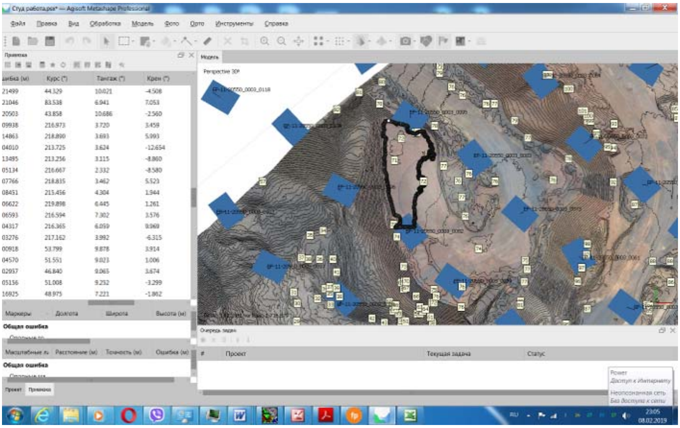

Fig. 6. The model combined with contour

The program also allows you to build a model in the form of contour or orthophotomap with a binding file. The use of digital imaging, made from an unmanned aerial vehicle, can be used to monitor deformations in areas that are dangerous for people to find on them (landslides, collapse zones, etc.).

Conclusions

Currently, unmanned aerial vehicles are widely used in remote sensing, in drawing up and updating plans, and in solving a wide range of mine survey tasks. The widespread introduction of this type of survey in mine surveying is facilitated by the use of a GPS system installed on board a UAV, which allows you to perform a planned reference with centimeter accuracy. It does not always require a planning and high-rise justification on the set, which is important when working under the conditions of the open method of field development.

The disadvantage is the dependence on weather conditions and insufficient accuracy for observing deformations, the magnitude of which is less than the accuracy of the determinations. In addition, the equipment has a low reliability.

When creating plans on a scale of 1: 500 and when observing deformations, digital imaging can be used in conjunction with satellite and tachometric surveys.

The problem of improving the accuracy of digital shooting from unmanned aerial vehicles can be solved by improving the image processing process, which should be based on the use of a sufficient number of identifications.

Literature

1. Dolgikh O. V., Dolgikh L.V. Investigation of methods for monitoring the deformations of the surface earned by mountain works. Mountain Herald. - Krivoy Rog: KNU, 2016. - № 101. - P. 46-49.
2. Dolgikh L.V., Dolgikh O.V. Investigation of the territory of the crater zone in the mine of Ordzhonikidze // Collection of scientific papers " Visnyk KNU". - 2011. - № 27. - P. 70-73.
3. Dolgikh A.V. Transformation of mine data for modeling by neural network methods. // Girnichiy visnik. - Krivoy Rog: KNU, 2013. - № – 96. - P. 85-89.
4. Fedorenko P.I., Dolgikh A.V. The use of new technologies at mine surveying service of mining enterprises // Development of ore deposits. – Krivoy Rog: KNU, 2003. - № 82.- P. 68-72.
5. Dolgikh A.V., Dolgikh L.V. The use of neural networks in the study of the ground surface, earned by underground mining. Collection of scientific papers "The quality of mineral raw materials." - Kriviy Rig, Dionat Publishing House (Chernyavsky D.A.), 2014. - P. 387-392.
6. Dolgikh O.V. Using the capabilities of modern devices in the study of landslides in the territories of mining enterprises. Collection of scientific papers "The quality of mineral raw materials." - Kriviy Rig, Publishing Center of "KNU", 2018. – P. 323-331.
7. Fedorenko P.I., Dolgikh A.V. The use of new technologies at mine surveying service of mining enterprises // Development of ore deposits. – Krivoy Rog: KNU, 2003. - № 82.- P. 68-72.
8. Instructions for monitoring the movement of rocks and the ground surface in underground mining of ore deposits. - M .: Nedra, 1988. - 112 p.