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Displacement Earth's surface modeling with GIS technologies use in the mining of mineral deposits

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Abstract. The results of geodetic (mine surveying) observations and the results of three-dimensional modeling of the earth's surface displacements at the observation station, laid over the 124th longwall of the Blagodatnaya Mine in the Western Donbass (Ukraine), are presented. To determine the displacements and deformations, the ground benchmarks of the profile lines were coordinated using a GNSS receiver and an electronic total station with an accuracy of their spatial position of 4-5 mm. Processing of the results of observations was carried out using the software product SAMARa (Automation System for Mine Surveying). Spatial 3D models of the displacement of points on the earth's surface in the zone of influence of mining operations have been built. With their help, it is possible to solve problems of establishing the actual values of displacements and deformations of the earth's surface in undermined territories. A 3D model of displacements of points on the earth's surface, predicted according to the methodology of the current State Standards of Ukraine, will make it possible to assess the impact of underground mining on the ecological situation of the undermining area and the safety of civil and industrial structures in the hazardous zone.

1. Introduction

Geodetic (mine surveying) observations of the movement of the earth's surface are traditionally performed at in advanced (before mining) established observation stations. As a result of observations, the values of displacements and deformations of the earth's surface along the line of benchmarks (profile line) are obtained. Modern geodetic equipment allows to obtain the displacement vectors of separately placed benchmarks and their lines. This became possible with the advent of precise tacheometers, GNSS receivers, unmanned aerial vehicles (drones) [1-6]. At the same time, not all geodetic equipment satisfies the required conditions for the accuracy of observations. The scope of unmanned aerial vehicles is limited by weather conditions, insufficient survey accuracy, the difficulty of marks fixation, and the presence of plant life. The use of GNSS receivers in the static survey mode increases the time of geodetic work, subject to constant changes in the relief above the moving longwall, and in the RTK mode, the accuracy of observations is reduced. Air laser scanning is also dependent on weather conditions and the difficulty of determining relatively small benchmarks, which in most cases should be sunk.

The usage of electronic tacheometers allows to increase significantly the accuracy and speed of observations and decrease the influence of weather conditions. The use of rigid plumbs solves the problem of centering over sunk benchmarks. With traditional measurement methods (horizontal angles,



length, elevation), systematic and random errors accumulate and, with a significant length of the profile lines, lead to a decrease in the accuracy and reliability of the obtained results. In addition, the results of observations make it possible to analyze only along the trajectory of the profile line without the possibility of estimating the spatial displacement vectors. The use of new observational technologies allows obtaining the displacement vectors of references within the displacement trough with almost the same accuracy, which is necessary for comparison with the predicted values [7].

The scientists [8-11] performed physical simulations of subsidence resulting from successive extraction of partially overlapping lava panels and study of ground motion characteristics. The mechanism of subsidence of the earth's surface during multilayer mining of coal by longwall has been studied. The results cannot be adapted to the conditions of Ukraine due to the low thickness of coal seams and the specificity of rocks. Many works in the field of displacement of the earth's surface from the influence of mining [12-16] are based on numerical modeling and probabilistic analysis of the displacement of surface points based on the correlation recognition of rock mass parameters. A feature of our research is the use of the results of full-scale geodetic observations in the territory of a part-time job in computer modeling of the vector of movement of points.

The study of the spatial displacement vectors of points with a significant amount of observations of the displacement process was not carried during undermining operations either in the Western Donbass and or in other mining regions of Ukraine.

A typical observation station, consisting of four profile lines (figure 1) and several separately located benchmarks was laid in the zone of influence of the 124th longwall of PSD Blagodatnaya mine, PJSC DTEK Pavlohradvuhillya (Ukraine) to establish the displacement vectors of points in modern conditions of development and advancement speeds of the longwall face of 170-200m/month.

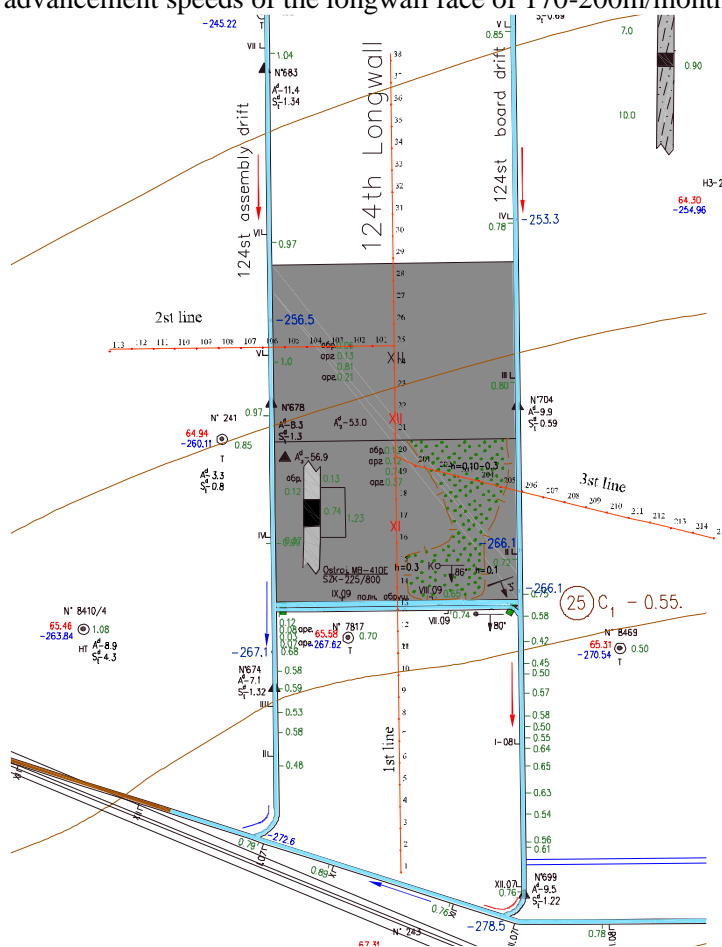


Figure 1. Plan of the observation station.

The face entry is passed along the course of seam c1 at a depth of 335 m. The mining and geological characteristics of the site in the mining area of the 124th longwall is characterized by the following indicators:

- extracting seam thickness is 1,15-1,20 m;
- seam inclination is 2-3°;
- longwall length is 220 m;
- strata control is complete collapse;
- sediment thickness is 65 m;
- average speed of longwall face advance is 150-170 m/month;
- undermine is secondary.

The roof of c1 seam is represented by mudstones, siltstones and weak sandstones. According to the testing of rock samples, the compressive strength is in the range of 12-30 MPa. Longwall mining is carried out for seam rise by the OSTROJ MB-410E complex.

The thickness of the overlying rocks was undermined by the mining works of the c₅ seam. The thickness of the rock layer between the seams is 78 m.

2. Methods

Setting out the position of the observation station benchmarks was carried out using a TOPCON-235N total station and a Hi-Target V100 GNSS receiver in RTK mode with an accuracy of positioning the spatial position of the benchmarks of 2-4 cm. Observations of the spatial displacement of points were carried out with an electronic tacheometer using a rigid plumb OZH-3, converted to a prism system of the tacheometer. The reflecting prisms were preliminarily calibrated and the OZH-3 level was adjusted. The prism installation height was 1,2 m, and the centering accuracy did not exceed 1,2 mm. During each measurement, the plumb rod was rotated three times in the horizontal plane by an angle of 120°, which increased the centering accuracy to 0,7 mm. Polygonometry points of the 4th class, laid on the industrial site of the mine, were used as starting points for the setting of the observation station profile lines. The benchmark of the profile lines in the form of sunk metal rods with a diameter of 20 mm and a length of 1,2 m were set at intervals of 20 m, which corresponds to the instructions for performing instrumental surveying observations at typical observation stations.

The upper part of the benchmarks was covered with a square metal plate of 0.8 mm thickness with a side of 20 cm. The plates are needed to search for benchmarks hidden under the ground using a metal detector when performing subsequent observations.

The first observation, with an interval of 7 days between the two series, was made before the start of the movement of the 124th longwall face of the seam c₁. As a result of the benchmark recultivation work, reference points 1-3 were lost until the 2nd observation. Examination of the spatial displacement of the profile lines benchmarks were carried out from one point (the benchmark of the first profile line No. 15). The maximum measurement distance did not exceed 500 m, which corresponds to the absolute maximum error of linear measurements of 2,5 mm. Part of this error for the used device is instrumental (2 mm) and is present in every equal measurement. Based on this, the relative accuracy of measuring the distance between the benchmarks of the profile line, taking into account the accuracy of centering a rigid plumb line, was 1/10000.

3. Results and discussion

It was established that there was a significant compression of the earth's surface in the direction of the seam course when the face of the longwall moved at a distance of 330 m from the face entry in the area of benchmark No. 20. Figures 2-4 show plots of subsidence, horizontal deformations and earth surface displacements along the trajectory of profile line No. 1. The starting point of the graphs along the longwall movement direction is taken to be the position of the 9th reference point of profile line No.1.

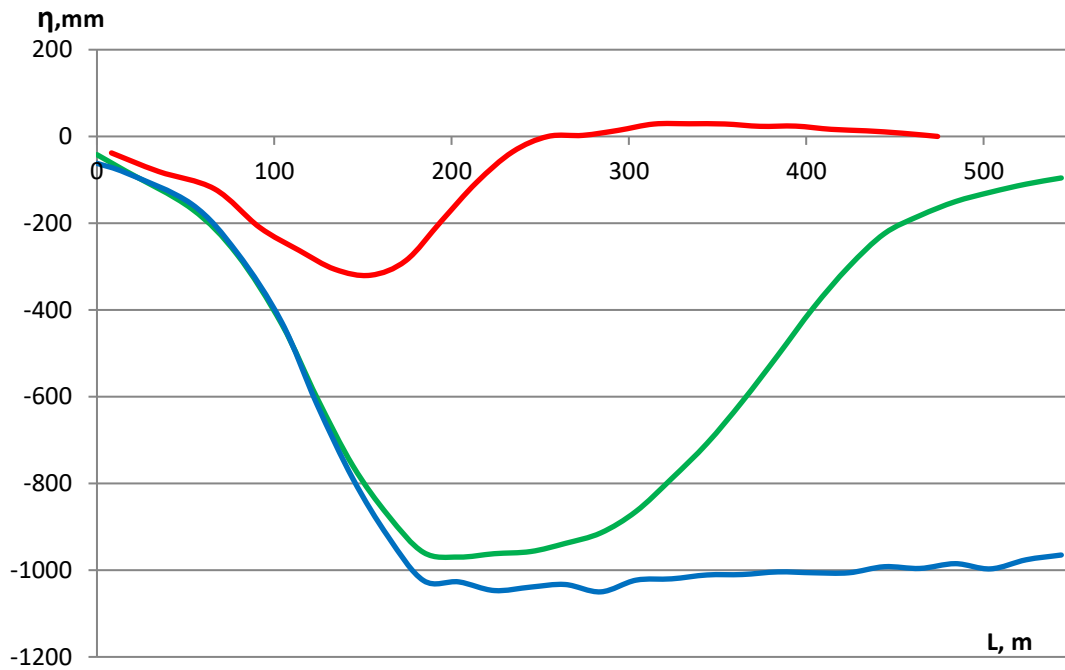


Figure 2. Graphs of subsidence along profile line No.1.

(— 2nd, — 3rd, — 4th observations)

The results of processing of instrumental surveying and geodetic measurements indicate the formation of a zone of ground surface uplift ahead of the moving cleaning face. This is evidenced by the graphs of earth surface subsidence at the time of the second observation.

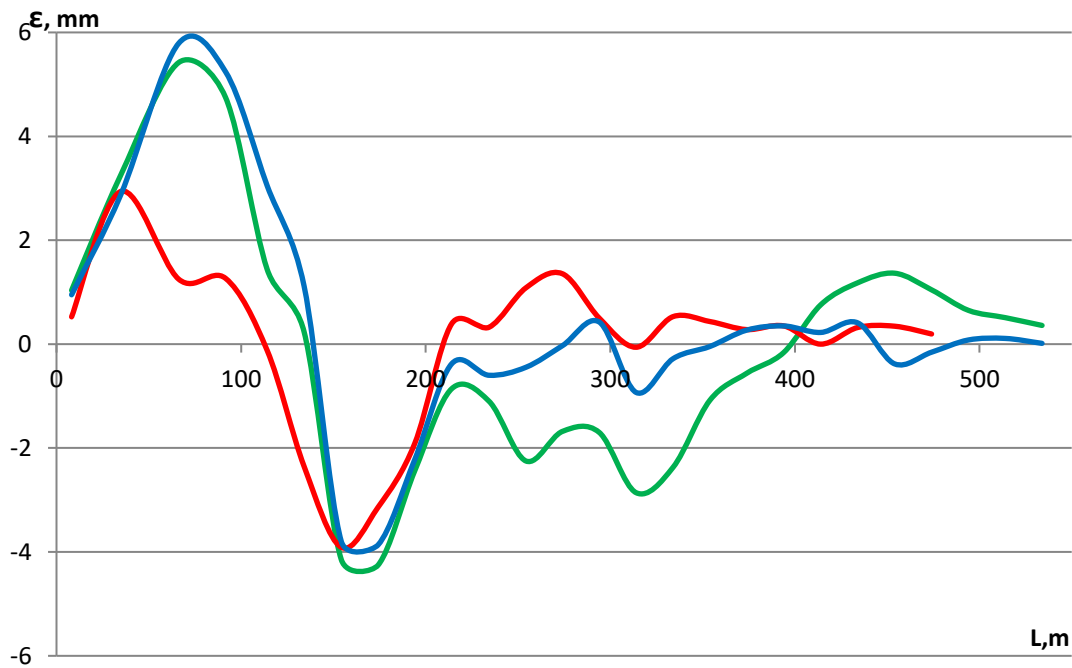


Figure 3. Graphs of horizontal deformations along profile line No.1.

(— 2nd, — 3rd, — 4th observations)

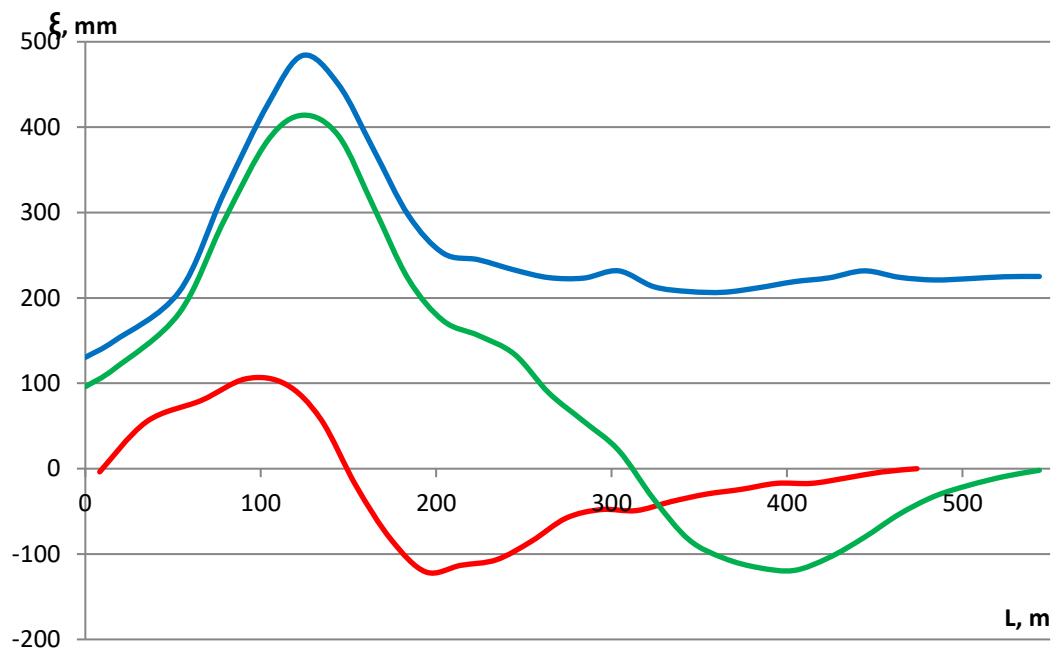


Figure 4. Graphs of horizontal displacement along profile line No.1.

(— 2nd, — 3rd, — 4th observations)

Observations of subsidence of profile line No.1 after the end of the 124th longwall face show stabilization of maximum subsidence within 1000 mm (4th observation).

It should be noted that after the end of the influence of the 124th longwall face on the first profile line, the horizontal displacement of the earth's surface above the mined-out space has values of about 230 mm. This result indicates the displacement of the rock mass and the earth surface in the direction of the moving face, which does not agree with the existing theories about the processes of displacement of the earth surface and rock mass [7, 17-20].

Because of measurements for each series of observations, the spatial coordinates of the benchmarks were obtained, by which the magnitudes of displacements and deformations of the earth's surface were determined. To determine the displacements and deformations, the ground benchmarks of the profile lines were coordinated using an electronic tacheometer with an accuracy of their spatial position of 4-5 mm.

It is known that with a low-angle seam bedding, the nature of the distribution of displacements and deformations of the earth's surface is symmetrical with respect to the main cross section across the seam course. On this basis, the results of geodetic observations under these conditions of undermining can be extrapolated in a mirror image relative to the trajectory of the 1st profile line (along the rise line of the seam).

Office processing of the results of instrumental geodetic observations was performed using the software product SAMARA (Automation System for Mine Surveying) on the base AutoCAD platform. The import of survey points is made in the coordinate system of the mining enterprise.

Figure 5 shows the isolines of the earth's surface subsidence and the displacement vector of the reference points at the time of the 3rd and 4th observations (the last one, when the displacement process has ended). The vector of displacement in the horizontal plane is shown for each benchmark.

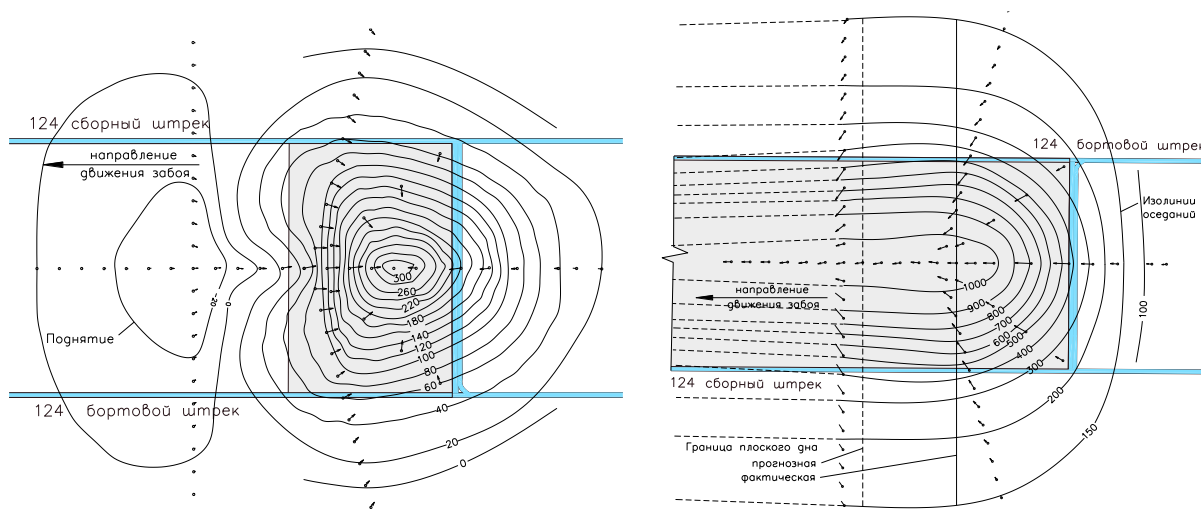


Figure 5. Isolines of subsidence of the earth's surface at the time of the 3th and 4th observations.

Based on the results of geodetic observations of the displacement of the earth's surface and subsequent processing in the SAMARa system, models of the surface of the displacement trough were formed. This model was obtained as a result of mathematical subtraction of topographic surfaces before the start of the displacement process and at the time of the observation. The term "model" in this case should be understood as a three-dimensional surface which in addition to the absolute mark can have an arbitrary number of other parameters (for example: maximum inclines, curvature, etc.) at each nodal point of the model. Each model is loaded into the computer's RAM and it is written to the database after work completion.

Primary generation can be implemented:

- by direct conversion from AutoCAD objects (3DFACE and POLYMesh) while maintaining the topology of elements;
- by reading from an ASCII file containing a description of nodes and their parameter values, as well as a topological description of the network;
- by automatically generating a model based on an array of irregular marks (pickets) with an arbitrary number of parameters.

In the case under consideration the model was created on the basis of elevations imported from the list of observation results into the AutoCAD system. Each node of the model, in addition to spatial coordinates, contains all five types of displacements and deformations based on the results of office processing of each observation (subsidence; maximum values of inclines, horizontal displacements, curvature, and horizontal deformations). Visually, the model is a network of irregular triangles, the vertices of which are nodes (figure 6).

Using the created models, you can determine the parameter values at any node or arbitrary point (in this case, the parameter value will be calculated by interpolation). With models you can perform various mathematical operations: addition, subtraction, merging, etc. Thus, having models of subsidence of the earth's surface from the influence of two adjacent mine workings, you can get a total general model. When considering the consequences of flooding the earth's surface with the help of models of the earth's surface, the surface of subsidence and the level of groundwater, the problem of establishing the boundaries of flooding is easily solved. In this case, the contour of the flood zone can be drawn as the result of the intersection of the groundwater level surface and the difference between the earth's surface and the subsidence surface. To solve such a problem in the conditions of a particular mining enterprise that develops a group of coal seams, subsidence models can be obtained based on the results of forecasting using the methodology of the current standard [7].

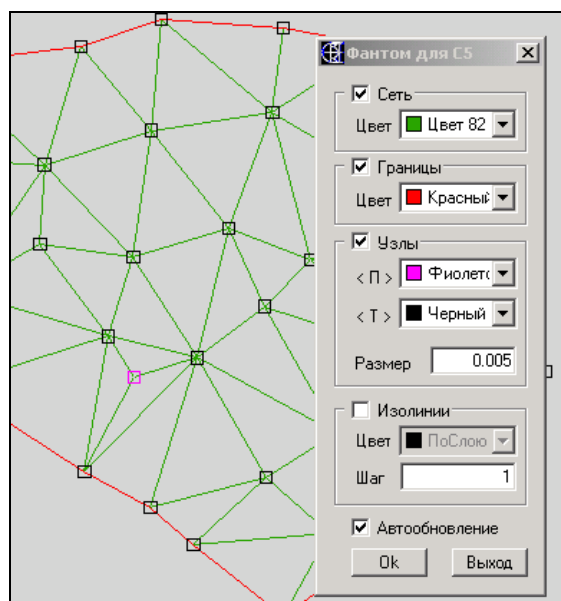


Figure 6. An example of model visualization in the SAMAR application.

To visualize the process of the earth's surface displacement, spatial models of changes in the topographic surface influenced by mining operations were built (figure 7). To do this, off-scale networks were created using the AutoCAD 3DFACE primitive and the “Build a Network” command.

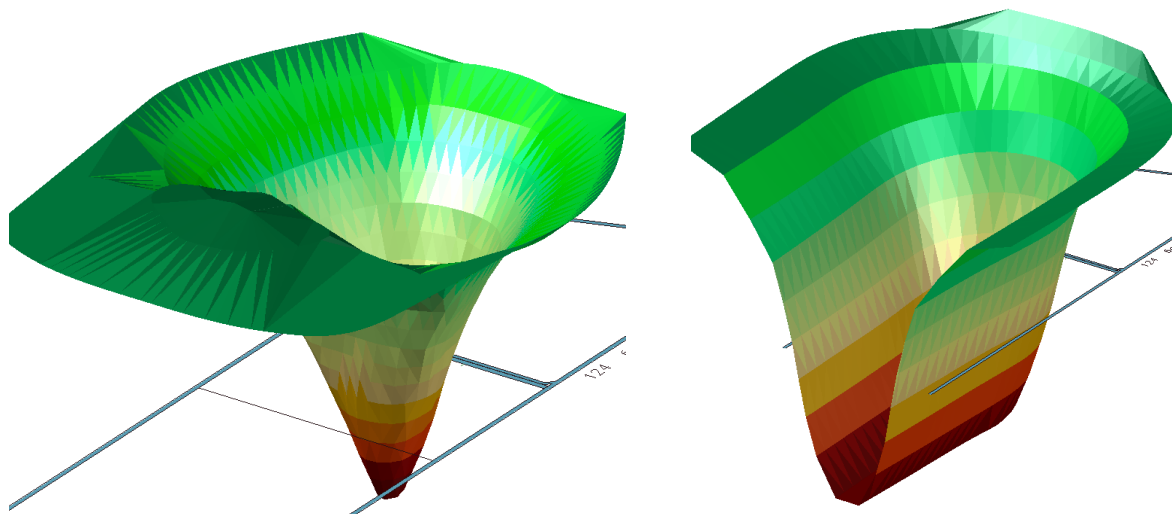


Figure 7. Computer spatial model (off-scale) of the earth's surface subsidence at the time of the 3th (left) and 4th (right) observations.

4. Conclusions

The presented models will allow determining the values of subsidence, inclines, and horizontal displacements of the earth surface deformations at arbitrary points of the displacement trough. This task is relevant due to the location of high voltage power lines installed on metal truss structures in the zone of mining influence. The most dangerous types of deformations for this type of engineering communications are the inclines of the earth's surface.

The presented computer modeling method can be used not only to analyze the results of observations, but also to predict the impact of underground mining on the earth's surface and objects located on it. In this case, the models are built based on the results of calculating the expected values of displacements and deformations.

This article discusses the methodology for producing mine surveying and geodetic observations of the earth's surface displacement, their office processing using the SAMARa software package (Ukraine), and presents the possibilities of analyzing and applying three-dimensional models in order to predict the negative environmental consequences of the development of coal deposits.

References

- [1] Grishchenkova E.N. 2014 Justification of the conditions for the use of electronic tacheometers for instrumental observations at mine surveying observation stations *Problems of subsoil use: Collection of scientific papers. Part I. National Mineral and Raw Materials University "Gorny" St. Petersburg* 157-159.
- [2] Kuchin O.S., Chemakina M.V. and Balafin I.E. 2017 Displacement of undermining rock mass above the moving longwall *Scientific Bulletin of National Mining University* **1** 55-60.
- [3] Kuchyn O. S. 2021 Analiz tochnosti vyznachennia obiemiv korysnykh kopalyn na skladakh z vykorystanniam suchasnykh prykladnykh prohram. Natsionalnyi hirnychyi universytet *Zbirnyk naukovykh prats Dnipro : NTU «Dniprovskaya politekhnika»* **65** 16-27.
- [4] Kurmanbaev O.S., Kirgizbaeva D.M. and Nurpeisova M.B. 2015 Research of geographic information systems at creation 3D models *15th International Multidisciplinary Scientific Geoconference SGEM, Bulgaria* 281-290.
- [5] Mikhailov V. I. Sobolevskaya S. N. and Bogdanova E. V. 2019 Deformation monitoring of buildings and structures located in the zone of technogenic subsidence of the earth's surface of the Soligorsk industrial area. Problems and prospects for the development of highways in the CIS *[Electronic resource]: materials of the International Scientific -practical conference dedicated to the 90th anniversary of Leonovich Ivan Iosifovich / Minsk: BNTU* 150-157.
- [6] Panzhin, A.A., Sashurin, A.D., Bolikov, V.E., Ruchkin, V.I., Efremov, E.Yu. and Panzhina, N.A. 2016 Features of geodynamic monitoring at Uzelginskoye field *Problems of Subsoil Use* **4** 81–88.
- [7] SSTU 101.00159226.001-2003 Rules for tampering with buildings, structures and natural objects during underground coal mining: *Industry standard Ministry of Energy of Ukraine* 2004 127 p.
- [8] Y. Wang, J. Zheng, and H. Wang 2019 Fast mesh simplification method for three-dimensional geometric models with feature-preserving efficiency *Scientific Programming* 1-12.
- [9] Dongdong Yanga, Haijun Qiuab, Shuyue Maa, Zijing Liua, Chi Dua, Yaru Zhua and Mingming Caoa 2022 Slow surface subsidence and its impact on shallow loess landslides in a coal mining area *CATENA* **209** 1 105830. <https://doi.org/10.1016/j.catena.2021.105830>
- [10] Yastika P.E., Shimizu N. and Abidin H.Z. 2019 Monitoring of long-term land subsidence from 2003 to 2017 in coastal area of Semarang, Indonesia by SBAS DInSAR analyses using Envisat-ASAR, ALOS-PALSAR, and Sentinel-1A SAR data *Advances in Space Research* **63** Issue **5** 1719-1736. <https://doi.org/10.1016/j.asr.2018.11.008>
- [11] Ebrahim Fathi Salmi, Majidreza Nazem and Murat Karakus 2017 The effect of rock mass gradual deterioration on the mechanism of post-mining subsidence over shallow abandoned coal mines *International Journal of Rock Mechanics and Mining Sciences* **91** 59-71.
- [12] Shaokun Ma, Jinmei Li and Zhuofeng Li 2022 Critical support pressure of shield tunnel face in soft-hard mixed strata *Transportation Geotechnics* **37** 100853.
- [13] Huayang Daiab, Peng Lia, Nurpeisova Marzhanc, Yueguan Yanab, Chongliang Yuand, Tursbekov Serikce, Junting Guof, Yryszhan Zhakypbekce and KonbaySeitulyc 2022 Subsidence control method by inversely-inclined slicing and upward mining for ultra-thick steep seams *International Journal of Mining Science and Technology* **32** Issue **1** 103-112.
- [14] Hengfeng Liua, Jixiong Zhanga, Baiyi Lia, Nan Zhoua, Xin Xiaob, Meng Lia and Cunli Zhua 2020 Environmental behavior of construction and demolition waste as recycled aggregates for backfilling in mines: Leaching toxicity and surface subsidence studies *Journal of Hazardous Materials* **389** 121870.

- [15] Behrooz Ghabrai, Gang Ren, Xiangyang Zhang and John Smith 2015 Physical modelling of subsidence from sequential extraction of partially overlapping longwall panels and study of substrata movement characteristics *International Journal of Coal Geology* **140** 71-83.
- [16] Jinfeng Ju and Jialin Xu 2015 Surface stepped subsidence related to top-coal caving longwall mining of extremely thick coal seam under shallow cover *International Journal of Rock Mechanics and Mining Sciences* **78** 27-35.
- [17] Bubnova O. 2024 Regularities of subsidence development during multiple underworking of the earth's surface in the Lviv-Volyn coal basin conditions *IOP Conf. Ser.: Earth Environ. Sci.* **1348** 012065. DOI 10.1088/1755-1315/1348/1/012065
- [18] Zberovskyi V., Bubnova O. and Babii K. 2018 Specifics of hydro-loosening of coal seams with account of rocks displacement parameters *Ukrainian School of Mining Engineering* **60 (00025)**. <https://doi.org/10.1051/e3sconf/20186000025>
- [19] Chetveryk M., Bubnova O. and Babiy K. 2017 The rate of deformation development in the rock massif on the basis of surveying monitoring on the earth surface *Mining of Mineral Deposits* **11(1)** 57-64. <https://doi.org/10.15407/mining11.01.057>
- [20] O. Shashenko, V. Shapoval, O. Kovrov, A. Skobenko, O. Tiutkin, K. Babii, O. Samorodov and S. Slobodyanyuk 2019 Determining the influence of physical nonlinearity of soil strength properties on the estimated base resistance *Eastern-European Journal of Enterprise Technologies* **6/7(102)**. <https://doi.org/10.15587/1729-4061.2019.184946>