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Original scientific paper

APPLICATION OF 3D POINT CLOUD DATA FOR CUT SLOPE MONITORING

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Abstract: This paper discusses the monitoring of slope instability during the construction of an expressway. As a basis, appropriate geological and engineering-geological investigations were carried out, supported by the application of practical sensing and analysis techniques, including drone-based imaging. The main goal is to present an example of the detection and monitoring of slope movements using a 3D point cloud obtained from the low-cost, remote, and precise SfM (Structure from Motion) technique, and appropriate software. The analyzed area represents a small part of a slope cut on the A2 Expressway Kriva Palanka-Stracin, in the Republic of Macedonia, which is under construction. The slope cut is excavated in albite-epidote-chlorite schists. In geological terms, it was found that this part of the cut has favorable conditions for the occurrence of instability. Four different point cloud sets were analyzed from four different surveys conducted over a total of five months, both before and after the occurrence of the instability. Multitemporal geomorphic changes in the unstable area were identified by comparing the SfM-derived point clouds in pairs. 3D distances were estimated with the multiscale model-to-model cloud comparison for each pair of point clouds. The results show that the displacements on the slope range up to 70 cm. Also, the five-month observation period shows that the instability is still active. Additional geometrical features that enable easier visualization of changes in the terrain were utilized. The obtained results show that these procedures for the detection and monitoring of displacements of unstable terrains can be used as a regular technique for such purposes. The advantages are many, including swiftness, high detail of prospecting, and the possibility of determining very small movements.

Key words: slope instability; 3D point cloud; SfM technique; monitoring

INTRODUCTION

Among the many geological hazards, landslides have the widest distribution and cause considerable losses to the national economy and property. The stability of road slopes directly affects local traffic and the safety of life and property for surrounding residents [1, 2, 3].

Monitoring loose rocky slopes along roads is quite important to provide a safe environment during the construction and exploitation of roads, especially when many roads are laid across mountainous areas in Macedonia.

In terms of on-site measurement and monitoring, many scholars have used monitoring devices such as displacement sensors, inclinometers, water content sensors, and pore water pressure sensors, combined with IoT (Internet of Things) technology and GNSS (Global Navigation Satellite System) technology to monitor slopes [4]. These monitoring devices improve monitoring efficiency [5]. However, this type of sensor equipment provides point-based monitoring and cannot achieve comprehensive coverage of the slope. The monitoring data comes from various scattered sensors, and there is little relevant monitoring information for non-sensor installation points [6].

The analyzed area represents a small local landslide. A slightly larger part of this area was host to a larger landslide that occurred before the current one. After the occurrence of the first landslide, appropriate engineering-geological investigations were conducted, and slope remediation included mitigating the slopes in that part of the cut. The EG investigations provided insight that the inclination of the foliation and joint systems of the present rock were prone to the possible occurrence of new instabilities.

The slopes were initially excavated with an angle of 1:1.5 (34°). After EG investigations adopted solutions for mitigating the first two slopes with an angle of 1:2 (27°), while the third slope (due to private property in the vicinity) remained with the angle of 1:1.5.

The new landslide occurred after remediation of the slopes, on the third slope, causing minimal changes in the slope appearance. During the entire period of excavations at this cut, the area was regularly surveyed using drones and SfM technology for calculations of BoQ (Bill of Quantities). After the occurrence of the new landslide, the idea was to review all available data, concluding that the movement of this part of the slope occurred before it was noticed on-site.

Unmanned aerial vehicles (UAVs) are emerging as effective tools in landslide hazard management, allowing rapid collection of imagery and production of high-resolution photomosaics to safely evaluate landslide deformation and activity. UAVs combined with Structure from Motion (SfM) photogrammetry have emerged as a new approach in recent studies for landslide monitoring [7]. The efficiency of SfM algorithms has been demonstrated in multiple studies for landslide monitoring [8].

Structure from Motion (SfM) [9] is now a powerful method for 3D reconstruction and point cloud generation. SfM applications, such as Smart 3D Capture, PhotoScan, and Pix4D, are popular for professional and/or non-professional operators of photogrammetry. These systems directly process a sequence of images and generate point clouds. Each point has a color index originating from the color of an original image pixel. By photographing loose rock and the surrounding environment, SfM software can calculate a point cloud that can realize a quantitative estimation of rock movement [10].

This research aims to implement already available data obtained for another purpose for this site in the context of monitoring and predicting the occurrence of landslides during the construction of road infrastructure. This makes it a low-cost and fast way of a new approach that replaces classic field prospecting, i.e., the previously mentioned monitoring methods. Previous practice involved monitoring a specific area after a hazard occurred. In this case, this method would be applied first, representing the earliest form of constant monitoring and detection of possible landslides. In this context, various papers have been published elaborating on similar problems using point clouds [11, 12, 13, 14].

STUDY AREA

The study area represents a small (60 m by 25 m) part of the cut at A2 Expressway Kriva Palanka–Stracin, section Dlabočica–Čatal, within the villages Petralica and Psača (Figure 1).

Fig. 1. Location of the research area (latitude, longitude 42.178670, 22.201061, Google Map)

It is excavated in hilly terrain where the ground gradually dips from the north towards the south part, which means towards the valley of the Kriva Reka river and the western and eastern sides towards the temporary streams which have flow direction from north towards south (towards Kriva Reka). The terrain in a geological sense is composed of metamorphic schistose rocks. After remediation of the slopes, they stayed stable for another year (Figure 2).

At the beginning of February 2023, there was a visual confirmation of the landslide occurrence on the third right slope of the cut.

In the subsequent period, the dimensions of this landslide increased, as a result of which additional amounts of rock material were falling off the slope (Figure 3).

Fig. 2. Aerial look at the cut before the occurrence of the new landslide, where the studied area is marked with a red circle

Fig. 3. Landslide condition on 27.09.2023

GEOLOGICAL AND ENGINEERING-GEOLOGICAL FEATURES

All phases of the geological development have had a final influence on the creation of the current state of the terrain, which is manifested in today's relief and the conditions for design and construction. The base of the terrain is composed of Rifey-Cambrian metamorphic rocks with low to medium crystallinity, which represent part of the Serbian-Macedonian massif.

After the occurrence of the first landslide, an EG mapping is done to determine the borders between the lithological units and to register all contemporary engineering-geological processes and appearances (Figure 4).

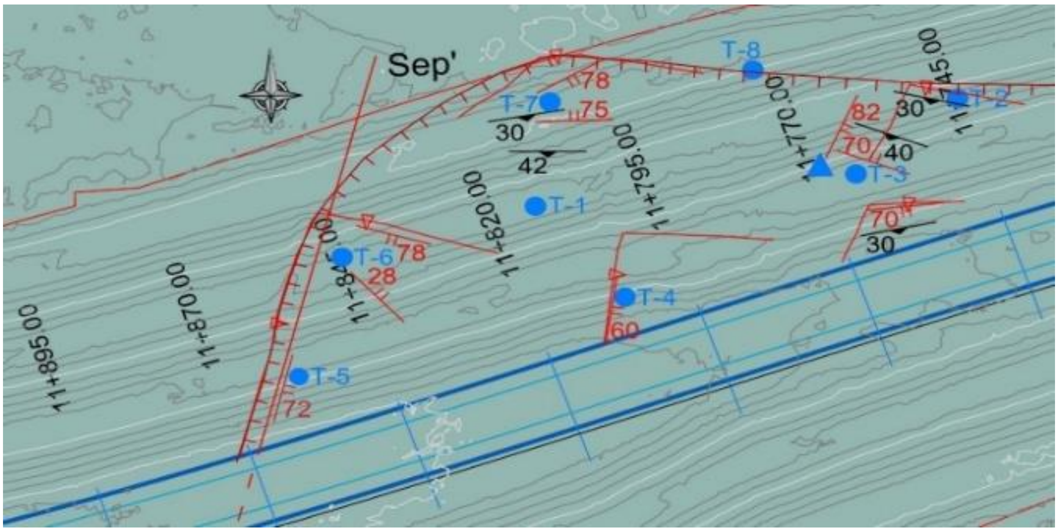


Fig. 4. Engineering-geological map for the designated part of the cut

With the performed detailed geological mapping it can be generally concluded that this part of the terrain, where the cut is designed and constructed, has a complex geological and structural-tectonic setting. The presence of Rifey-Cambrian metamorphic rocks is established such as albite-epidote-chlorite and albite-chlorite schists with different fracturing and weathering. They are characterized by a schistose structure, at some parts quite fractured, folded, and tectonized especially at the contact parts with fresher and stronger albite-epidote-chlorite schists.

The schists are characterized by clear schistosity, folding, and several joint systems oriented along the foliation, perpendicular to it or in different directions. They are quite friable along the fractures, and along them also locally intensively altered with the appearance of clay component, a product of surficial weathering, where they are soft and friable. Three or more joint sets were observed here whose dip direction and dip angle were measured using a geological compass (Figures 5 and 6). The surfaces of the fractures are mostly planar, slightly rough, squeezed, or have mm openings.

In Figure 5 there are two maximums with similar dip directions towards the south (169° and 187°) and diagonal dip angles (30° and 44°). Also, less present joint systems with gentler dip angles (DE = 46/28°) have been registered. From the following figures of the contour diagram and rosette plot, it can be seen that the foliation of the schistose metamorphic rocks has an unfavorable dip direction and unfavorable dip angle in relation to the road alignment, which at this part has direction 70°–250° (the line that goes through the center of the circle). The appearance of the new landslide takes place along the foliation plane of 180/42° at its upper part.

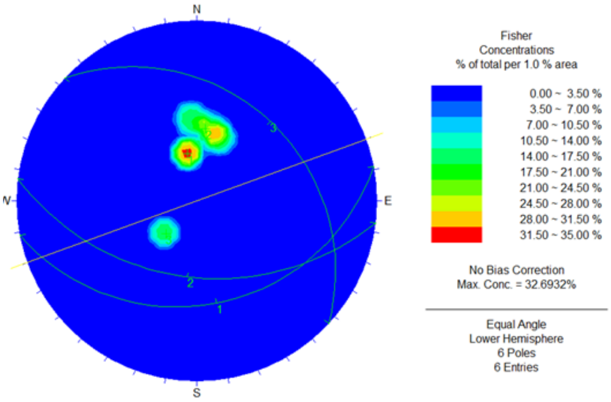


Fig. 5. Contour diagram of dip direction and dip angle of the foliation

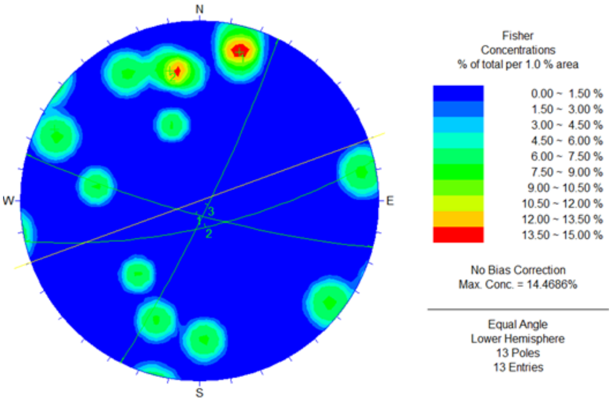


Fig. 6. Contour diagram of dip direction and dip angle of the joints

From the contour diagram (Figure 6) of the alignments of the maximums it can be seen that there are more joint systems with different orientations (strike), but most of them have steep to sub-vertical dip angles. Most joint systems have strike E-W, ENE-WSW, and ESE-WNW, with angles close to sub-vertical. Such strike and dip of the joint systems in relation to the main plane of the foliation, which is unfavorable to the pavement construction, further worsens the existing situation. It is about the appearance of a system of joints that cause fragmentation, that is, the separation of blocks and smaller parts of the schist to break off. In this case, we have ideal conditions for the occurrence of instability.

The geological composition of the medium greatly contributes to the creation of these unwanted appearances. The engineering activities accelerate their process and greatly influence their development. The process of surface weathering of rocks changes the composition and setting of the rock mass and leads to the destruction of the rock in the form of debris and larger rock fragments. These contemporary processes are anthropologically caused, i.e., they occurred after the undertaken construction activities for the alignment of the road and construction of the cut. Near this area tectonic zones (faults) are present as well as planar fractures and joint systems, so at many places unstable zones are found, and fallen rock masses with a tendency to fall and slide towards the lower parts of the slopes (Figure 7).

On the other hand, the morphology of the terrain, precipitation, oxygen, CO_2, temperature oscillations, ice, and the steep inclination of the slopes also contribute to the creation of landslides. The surface weathering of the rocks is expressed along the entire length of the open slope and is most pronounced on the contact parts between the schists and the fault structures. Because of the gravitational conditions, there is an occurrence of falling of small rock fragments and larger quantities of rock material.

The unfavorable dip direction and dip angle of the foliation, tectonic fracturing, intersection of fault structures with the foliation, and perpendicular fractures to the foliation, as well as precipitation, are significant factors for the creation of this state. It can be expected that smaller and local landslides can occur even with the mitigation of the slopes.

Fig. 7. The new sliding of the rocky material occurred on the upper part of the third slope with a dip direction and dip of the foliation of 180/42°

USED METHODS, HARDWARE, AND SOFTWARE

The traditional methods are based on physical access to the rock surface. Since the 2000s, remote sensing techniques have been applied to several fields, particularly to the characterization of rocky slopes [15]. The scientific community has shown a growing interest in the extraction of information on discontinuities from remote sensing-derived datasets. This is quite interesting as it enables the characterization of the discontinuities without access to the surface [16].

Structure from Motion (SfM) [17] is a photogrammetric range imaging technique for estimating three-dimensional structures from two-dimensional image sequences that may be coupled with local motion signals. It requires a digital camera and, if needed, a Remotely Piloted Aircraft System (RPAS). It can provide a 3D point cloud (3DPC) that can be further analyzed with different variety of software.

The data acquisition was performed using a low-altitude camera drone – Phantom 4 RTK [18]. It belongs to Low-Altitude Unmanned Aerial Vehicles which is employed to capture the ortho and oblique images during the flight (Figure 8a). The photo size is 5742 × 3648 pixels with horizontal and vertical resolution of 72 dpi.

Before scanning the area with the camera mounted on the drone, at least four reference points should be visibly marked which are surveyed with high precision GPS device and later used for point cloud georeferencing. With the SfM technique using the drone, the entire object was recorded by navigating the drone to take pictures and record all visible surfaces (Figure 8b). When recording, the drone positions itself using its coordinates.

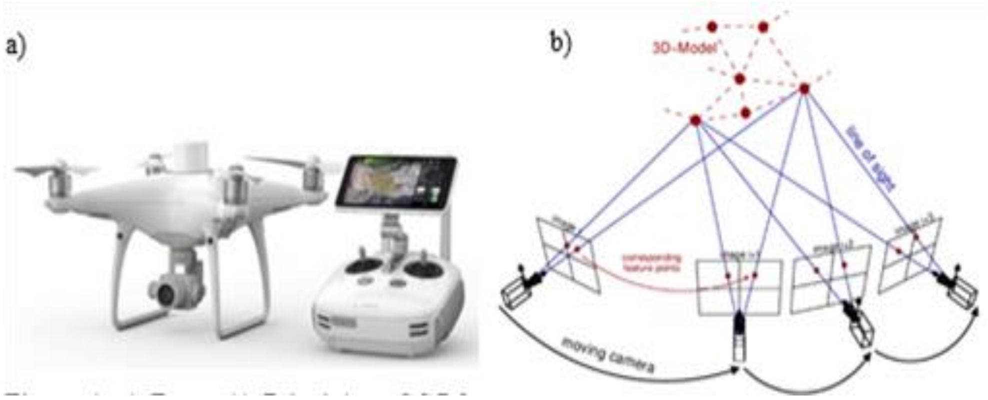


Fig. 8. a) Drone. b) Principles of SfM method

There are several approaches and algorithms to reconstruct camera orientation and geometry from images. Currently, one of the most used methods is based on the employment of Structure-from-Motion algorithms. These algorithms belong to the computer vision research field and together with stereo-reconstruction techniques provide the opportunity to create accurate 3D models from images without prior information about the location of image acquisition, or about the camera parameters used to perform the acquisition [19]. The 3D scene geometry and camera motion are reconstructed from a sequence of 2D images that are taken by a camera that moves around the scene. The SfM algorithm detects common feature points in multiple images and uses them to reconstruct the movement of those points throughout the image sequence. A conventional photogrammetric workflow starts with the acquisition of images with certain pre-defined rules. These rules are very important for a successful photogrammetric project, i.e., enough overlaps between images [20], the configuration of the image network [21], and photographic quality. With this information, the locations of those points can be calculated and visualized as a 3D point cloud (Figure 8b).

Four different surveys are made, and four different point cloud sets are prepared for this paper: The point cloud acquired before detected movement is the reference point cloud. During five months, four photogrammetric surveys were made. Multi-temporal geomorphic changes in the landslide area were identified by comparing the SfM-derived point clouds in pairs. 3D distances were estimated with the multiscale model-to-model cloud comparison for each pair of point clouds.

Two different software were applied. Pix4D mapper version 4.8.3 is commercial software specialized in photogrammetry [22]. It is used for the photos received from drone imaging to be turned into a point cloud. CloudCompare version 2.11.0 [15] is open-source software for working with 3D point clouds.

During the processing of the obtained images in Pix4D, a visualization of the exact positions of the camera while the photos were taken is obtained (Figure 9).

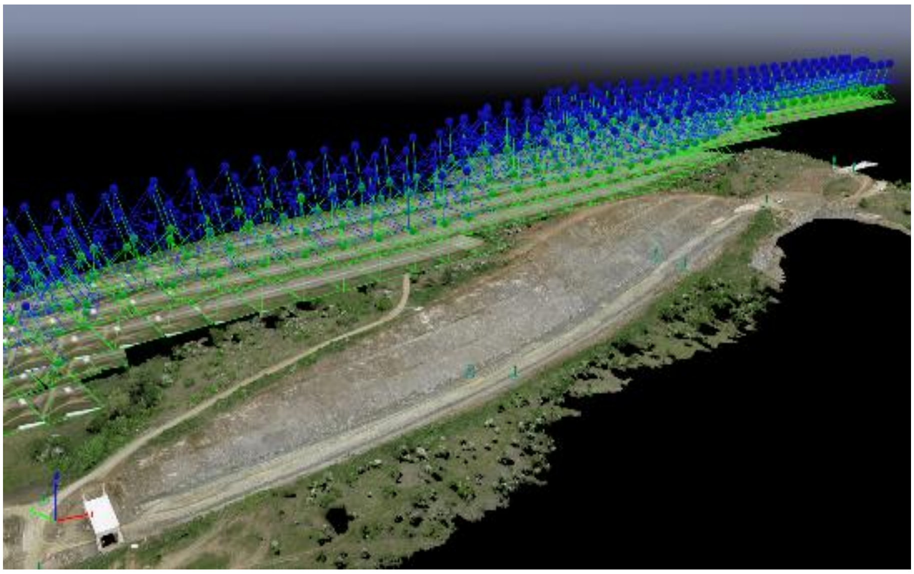


Fig. 9. Positions of the camera while surveying

Very high-density point clouds can be extracted from these photos, but to be able to work properly, an optimal point density number is chosen. With the complete processing, the model is obtained, i.e., the cloud of points. The resulting model is saved in one of the many available extensions: .las, .laz, .ply, .xyz, etc. (Figures 10, 11, 12, 13). The number of points for these four surveys is between 510.034 and 655.834 depending on the conditions when the survey was done.

The next step was georeferencing the point cloud and positioning it in a known coordinate system. Four control points from each point cloud had to be selected to align the point clouds together (Figure 14). The coordinates for these points were obtained previously using a GPS survey.

Fig. 10. First survey on 13.12.2022

Fig. 11. Second survey on 20.01.2023

Fig. 12. Third survey on 21.02.2023

Fig. 13. Fourth survey on 16.05.2023

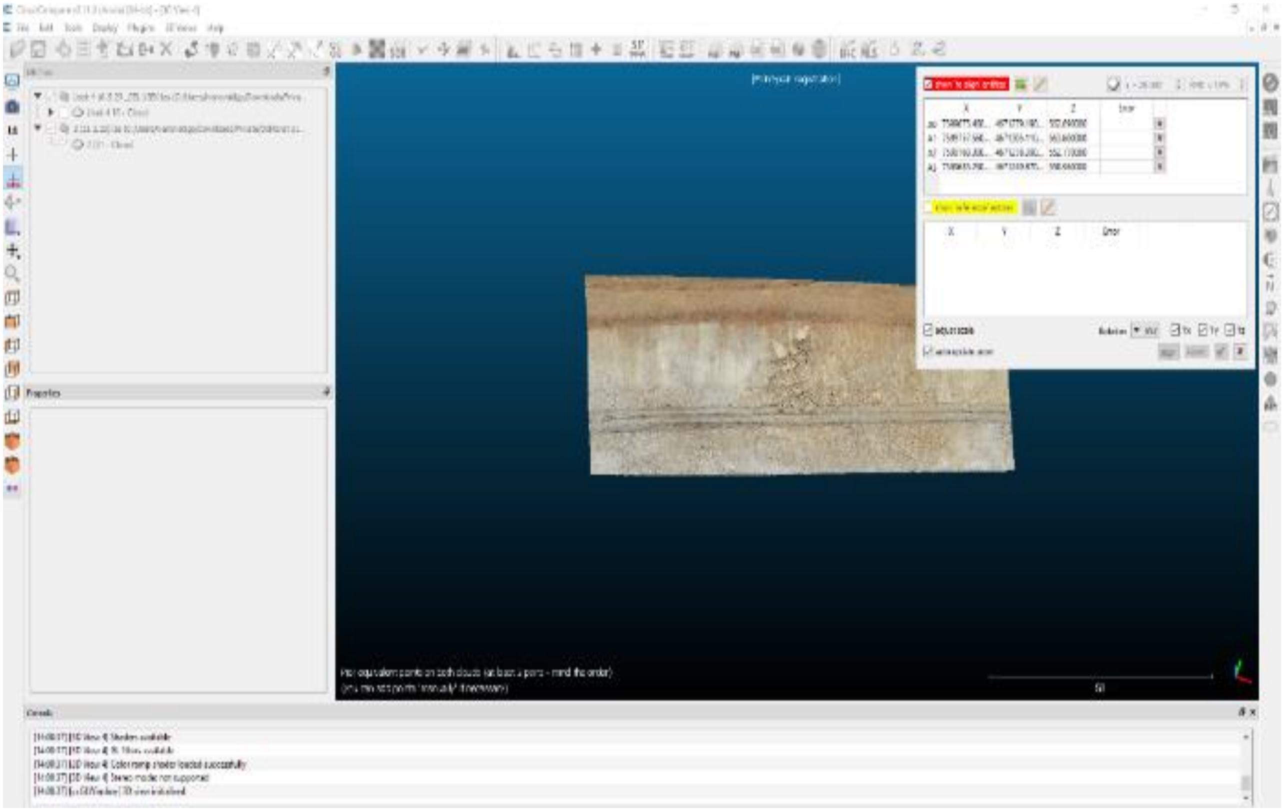


Fig. 14. Georeferencing the point cloud in CloudCompare software

RESULTS

The CloudCompare tool Cloud-to-Cloud (C2C) Distance computes the distances between two clouds. To launch this tool the user must select two clouds (and only two). Before displaying the tool dialog, CloudCompare will ask you to define the roles of each cloud: Which one will be used as a reference, and which one will be compared? In this case, the older cloud will always be the reference [23].

For each C2C distance computation method, CloudCompare software will compute four values for the distance which are the maximum distance, average distance, mean distance, and the standard deviation. In this case, the automatic data are not used because of the changes due to excavation at the vicinity of the landslide, a factor that influences the complete statistics. Instead, the detection of the largest differences is done manually using the tool Point picking.

The landslide was visually detected and confirmed on 21.02.2023. From this perspective, it can be said that the first and second surveys were made before visual detection of the landslide, that is, before noticing major changes in the slope. The third and fourth recordings were made after this period. Figure 15 shows the result of the comparison between the first and second surveys as seen on CloudCompare. The bright colors in the middle of the image indicate that there are some changes when comparing point clouds. The bright colors at the edges of the area indicate differences due to excavation that was done in the surrounding area between the two surveys and should be ignored.

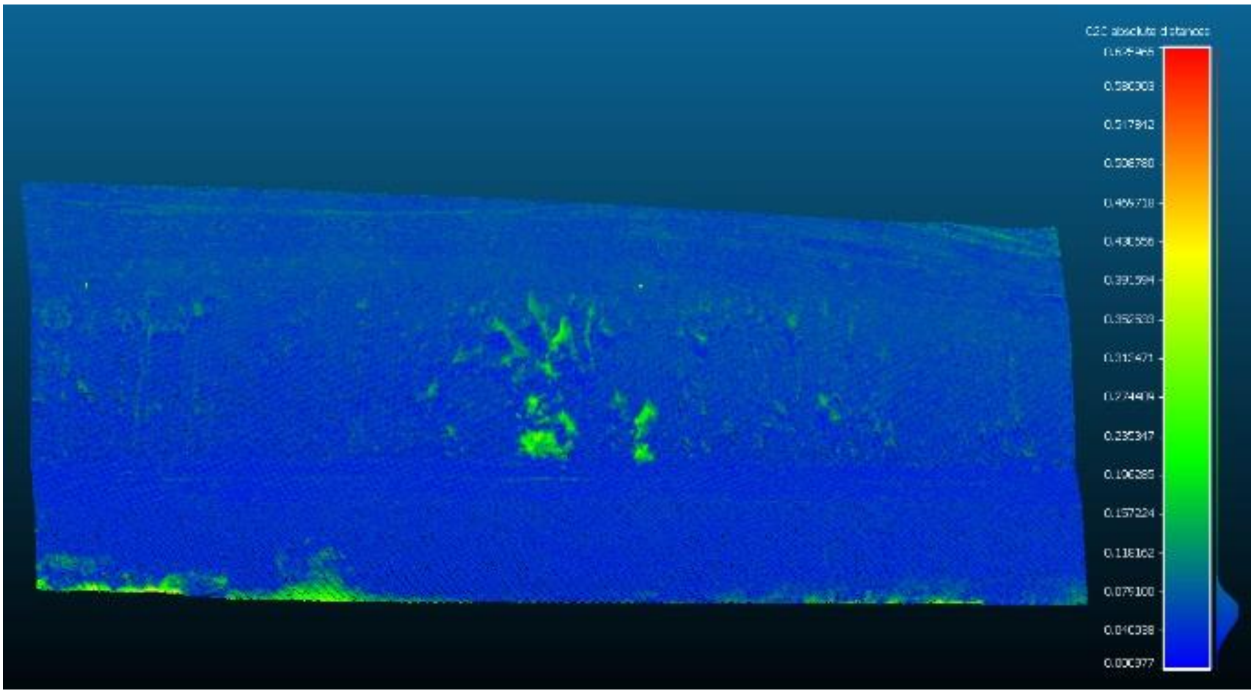
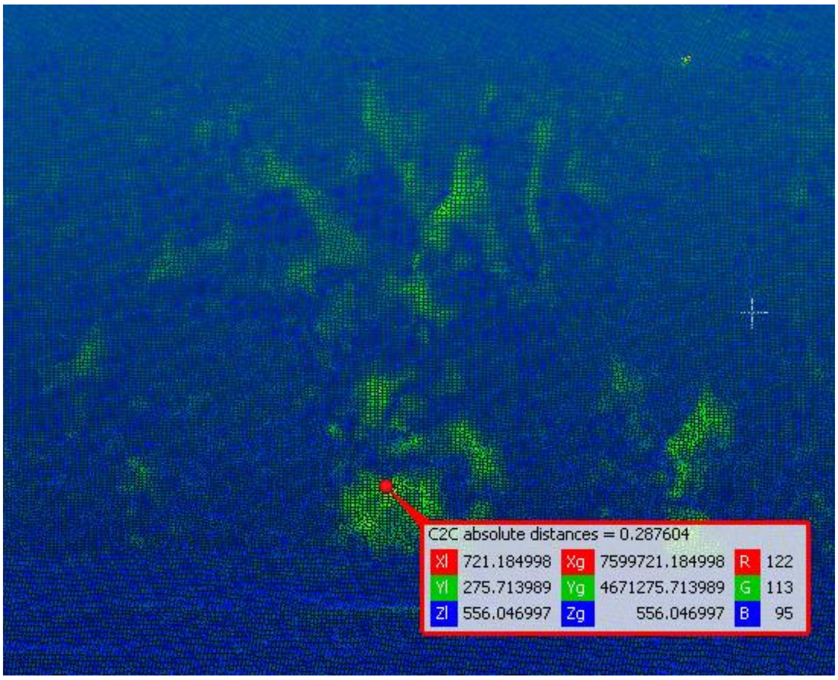


Fig. 15. Comparison between the first and the second surveys

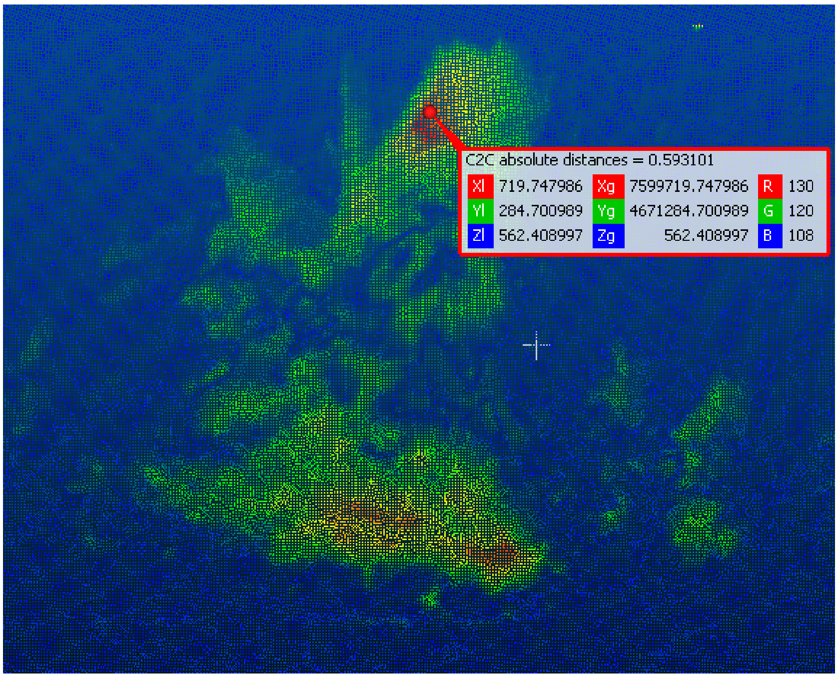
Comparing the first two surveys, it can be noticed that there was some kind of movement before the visual detection of the landslide (Figure 16). The biggest change in positions is 28 cm. It can be noticed that there are small differences around the study area, because of the small difference in positioning of the two point clouds (up to 3 cm) and from the erosion that was present at the moment. When comparing the first survey with the survey that was taken after the occurrence of the landslide, that is, the third survey, it can be said that the greater difference between the two clouds of points in the part of the researched area is already noticeable (Figure 17). Apart from the fact that this type of landslide is already observed on the spot, using CloudCompare, displacements can be measured in different places of the landslide, with the largest absolute displacement being 59 centimeters.



C2C absolute distances = 0.287604

Xl	721.184998	Xg	7599721.184998	R	122
Yl	275.713989	Yg	4671275.713989	G	113
Zl	556.046997	Zg	556.046997	B	95

Fig. 16. Comparison between the first and the second survey with the maximum absolute distance



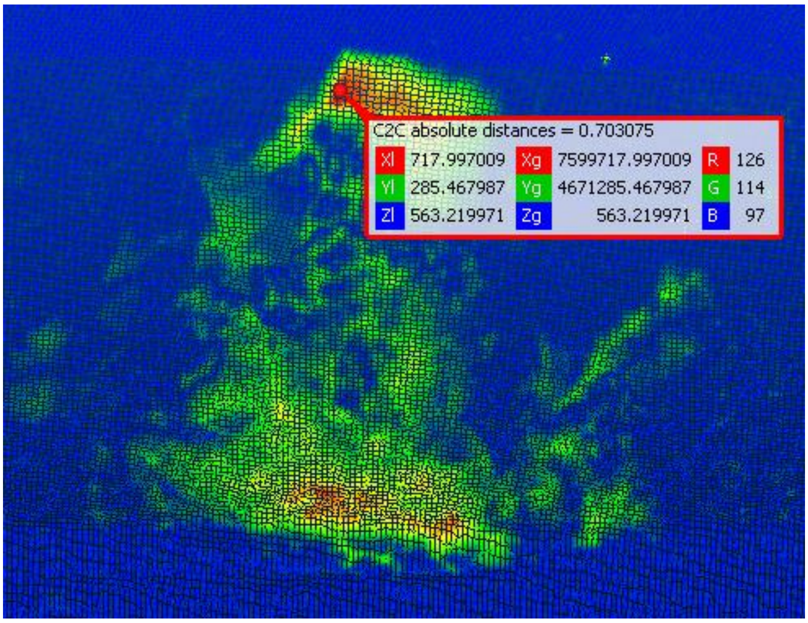
C2C absolute distances = 0.593101

Xl	719.747986	Xg	7599719.747986	R	130
Yl	284.700989	Yg	4671284.700989	G	120
Zl	562.408997	Zg	562.408997	B	108

Fig. 17. Comparison between the first and the third survey with the maximum absolute distance

When comparing the first with the fourth and the last survey (Figure 18), it can be noticed that the differences between the two point clouds are more significant and that they are spread over a larger area. The absolute maximum distance is 70 cm. It is noticeable that the absolute maximum distance is increasing, and the shape of the landslide as well is changing especially in the upper part of the landslide. This is because of the permanent erosion and landslide through the slope and redeposition of the rocky material and its bottom. It can be concluded that the real activity of the landslide is in its upper part.

A comparison of the penultimate (third) and the last recording (fourth) can also be used as a control measure (Figure 19):



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C2C absolute distances = 0.703075
Xl 717.997009   Xg 7599717.997009   R 126
Yl 285.467987   Yg 4671285.467987   G 114
Zl 563.219971   Zg      563.219971  B  97
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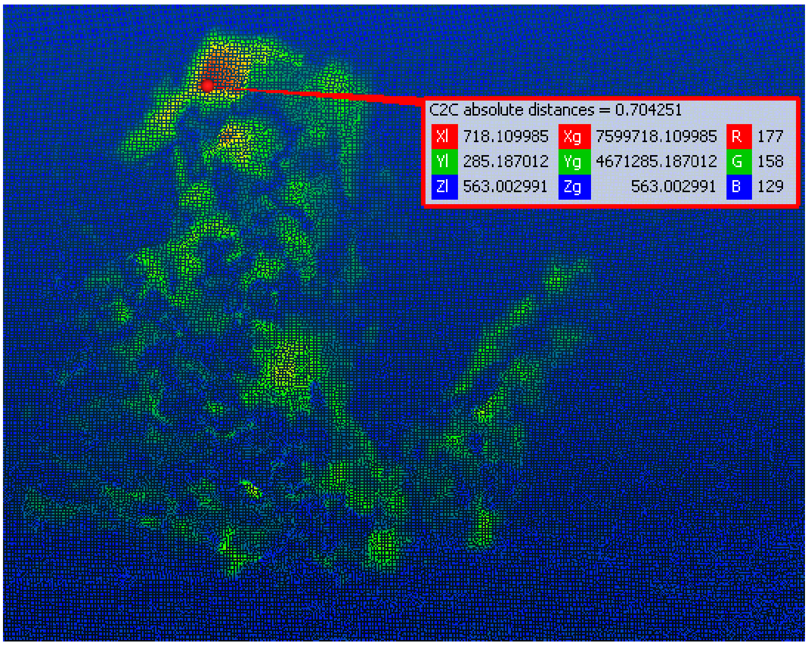
Fig. 18. Comparison between the first and the fourth survey with the maximum absolute distance



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C2C absolute distances = 0.704251
Xl 718.109985   Xg 7599718.109985   R 177
Yl 285.187012   Yg 4671285.187012   G 158
Zl 563.002991   Zg      563.002991  B 129
```

Fig. 19. Comparison between the third and the fourth survey with the maximum absolute distance

From the control measurement, it can be noted that by comparing the two images taken after the occurrence of the landslide, it is not settled and there are still certain movements, especially in its upper part. For this period, the largest distance between these two recordings is 70 cm. The maximum distance is the same as the maximum distance from the beginning of the landslide. It stays at 70 cm but is in another area of the landslide. It is due to the constant erosion, new rockfalls, and redeposition of the rocky material, which is changing its shape.

After this analysis, it can be concluded that these movements are the greatest in the part of the cut where the actual sliding occurs after the foliation of the schist in combination with the unfavorable conditions of the joints, i.e., in the upper part of the slope. This conclusion coincides with the data obtained from the performed geological surveys, where unfavorable parameters were obtained at the exact micro-location. The lower part of the landslide endures changes mostly due to redepositing the rocky material from the upper parts. The last comparison also shows that there is still movement on that part of the slope, that is, the landslide has not yet settled.

This same method can also be used to compare periodic recordings of the entire cut, which would be used for a quick and constant insight into the condition of the cut and relevant data would be obtained for the possible occurrence of any instabilities that would threaten the safety of workers and machines, as well as during operation of the expressway.

ADITIONAL GEOMETRICAL FEATURES

Apart from the method described above, the software used also contains several other options and tools that can contribute to a better understanding, visualization, and monitoring of various events during excavation (mine, roads, etc.). In the CloudCompare software package, we can calculate various geometric features such as Anisotropy, Eigentropy, Planarity, Surface variation, Surface roughness, Sphericity, Verticality, etc. These geometric features are mostly computed using Principal Component Analysis (PCA).

By using this technology when examining larger areas, any changes of any type can be very easily observed. In Figure 20, there are the differences between the recordings made on 13.12.2022 and 16.05.2023 at the entire cut.

In blue are the parts where there were no changes during that period. The areas with red color represent the sections of the cut where the most significant changes occur. The changes are most noticeable in the part of the road construction, positions where excavation was carried out in the meantime for remediation of the slopes, as well as on the periphery where there is a change in the vegetation. In the part of the slopes, you can notice a change, the landslide on the third slope on the right side of the cut (marked with the white arrow).

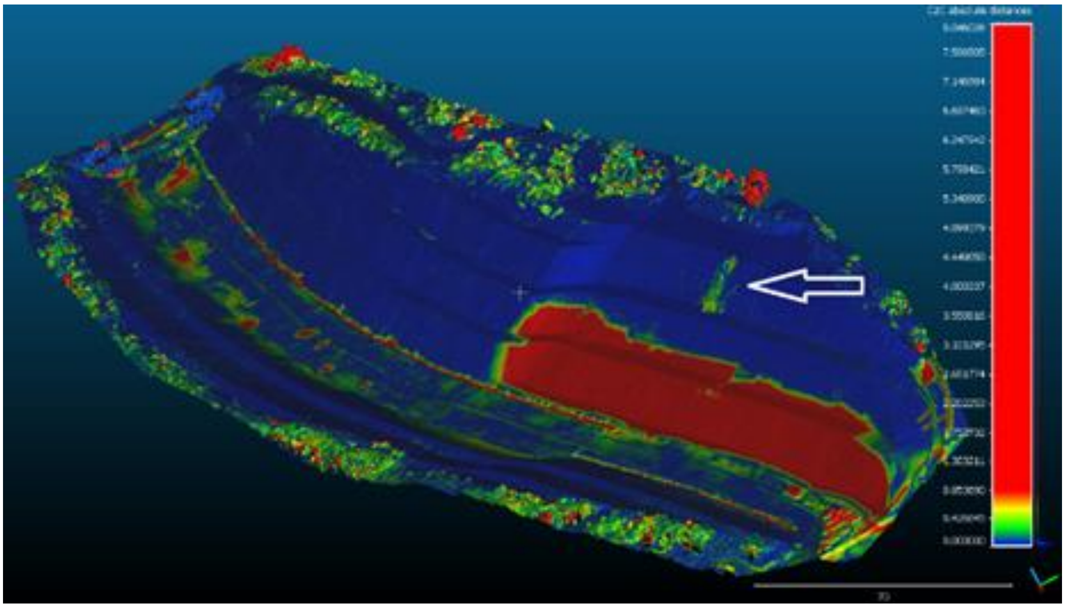

Fig. 20. Changes within 5 months at the cut

By monitoring deviations of the field surface from a perfect vertical, i.e., horizontal perspective, it is also possible to inspect the condition of the cut. The different nuances of colors give a solid perception of possible deviations that can indicate errors during execution (excavation), but also certain displacements of the terrain caused by landslides or rockfalls (Figures 21 and 22).

Verticality is well-suited for distinguishing between facade and horizontal planes, while planarity does the opposite. As per the equation shown in the workflow above, planarity is related to eigenvalues, while in the case of verticality, it is extracted using a normal *z* component from each 3D point. The smoothness of the surface, which is somewhat related to the roughness measure, can be described by planarity and the quality of plane fitting for normal vector estimation as well.

In CloudCompare, the feature "planarity" refers to the degree to which a surface or area in a point cloud dataset exhibits planar characteristics, meaning it is approximately flat or follows a plane (Figure 21).

Planarity is often measured as the deviation of points within a region from the best-fitting plane. Its tools can compute metrics such as the root mean square deviation (RMSD) or the coefficient of determination (R-squared) to quantify the planarity of surfaces. Additionally, CloudCompare can visualize planar surfaces by displaying them in different colors or by applying color gradients based on planarity values. Analyzing planarity in point cloud data can be useful for tasks such as detecting flat surfaces in architectural structures, identifying geological bedding planes, or assessing the quality of manufactured components. It helps users understand the geometric characteristics of surfaces and make informed decisions based on their planar properties.

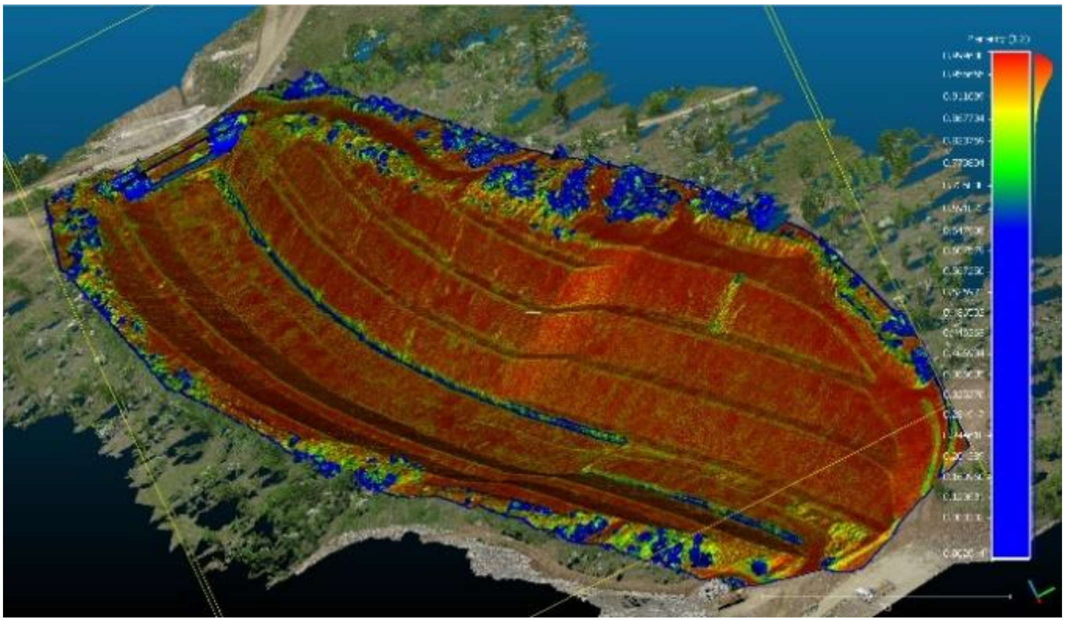

Fig. 21. Planarity of the terrain

In CloudCompare, the feature "verticality" refers to the degree to which a feature or object in a point cloud is oriented vertically, typically measured as the angle of inclination from the vertical axis (Figure 22).

This feature is useful for analyzing structures such as buildings, walls, or geological formations to determine their vertical alignment or deviation from the vertical direction. By analyzing the verticality of objects or structures, one can assess their stability, orientation, and alignment in relation to the vertical axis.

This information can be valuable for various applications, including architectural modeling, structural analysis, and geological mapping.

Observing the entire cut with the implemented planarity and verticality features, one can readily discern other changes at the cut, besides the landslide, which is the focus of this thesis. The most significant difference is that for both planarity and verticality, the colors used generally for gradual changes in the angle of slopes/planes are uniform in their transitions. A sudden change in those colors also indicates an irregular deviation in planarity and verticality, which except showing irregular excavation can also indicate the accumulation of unven material, that is, the occurrence of a landslide.

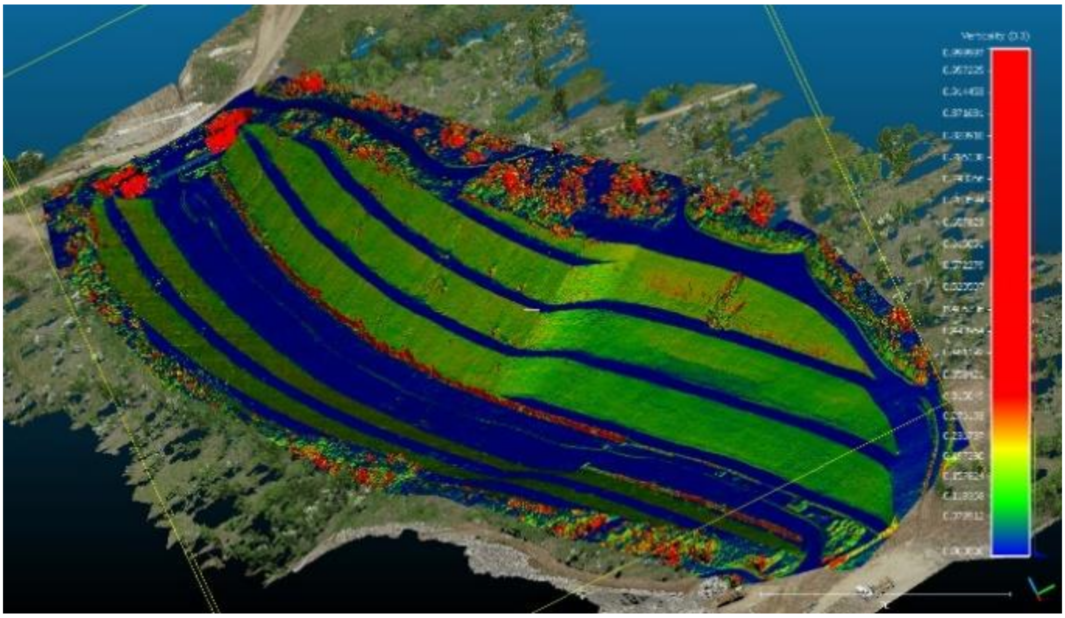

Fig. 22. Verticality of the terrain

CONCLUSION

The case study outlined in this paper focuses on a minor local landslide, yet it is imperative to recognize that the methodology showcased herein can effectively provide insights into various forms of movement, including the initiation of planar or wedge-shaped failures.

It was concluded that the source of the instability is one plain of the foliation of the host rock with dip direction/dip 180/42°, while the slope is being excavated at an angle of 34° and strike of 70 to 250°. Additionally, the dip direction and dip of some joint systems are unfavorable, and it further worsens the accelerated fragmentation of the rock. The field prospection conclusions are in correlation with the analyses obtained with the 3D point cloud data. Point cloud data also proves that the new landslide occurred mainly in the upper part of the cut slope, while the changes in its lower part are due to the redeposition of the fallen material.

It should be considered that this methodology does not represent the implementation of the latest innovations in technology, but rather the application of several software and hardware solutions used in engineering for years. Nevertheless, this case study serves as a tangible demonstration of the practical application of this methodology in real-world scenarios, showcasing its direct involvement during the construction of critical infrastructure such as an expressway.

Employing this form of prospecting and monitoring enables the early detection of instabilities, facilitating the timely implementation of appropriate measures to enhance the safety of both labor and machinery operating within specific areas. This procedure can also be recommended for monitoring slopes during the exploitation of the road.

Typically, instability is identified visually, prompting the search for solutions thereafter. However, through the proposed method, it becomes possible to detect potential minor or major changes even before visual observation, thereby offering opportunities to prevent or minimize significant damages.

Implementing such a procedure for monitoring road and mine slopes, utilizing surveys primarily intended for other purposes during the construction process, as demonstrated in the presented case, would be a commendable practice. This approach entails no additional costs, enhances the level of detail in prospecting, replaces time-consuming on-site inspections with quick processing of point clouds, and expedites the production of resulting graphics. Ultimately, this method boasts remarkable reliability, as evidenced by its capability to detect even the minutest processes during instability occurrences.

Leveraging the geometric features extracted from point clouds can facilitate continuous and secure monitoring of an entire cut or slope, aiding in the early detection of any undesirable incidents. The availability of multiple tools for comparing obtained point clouds can offer diverse insights into the analyzed area; if one feature fails to provide comprehensive insight, another may fill the gap.

Further advancements in the method are anticipated through the integration of artificial intelligence for the monitoring and prediction of landslides, as well as the automation of the procedure, facilitating coverage over larger areas and reducing evaluation time. However, it is essential to approach the use of this method with caution, considering changes in various aspects such as vegetation or progress in excavation, before commencing this type of analysis.

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Резиме

ПРИМЕНА НА ПОДАТОЦИ ОД ОБЛАК СО 3Д ТОЧКИ ЗА СЛЕДЕЊЕ НА КОСИНИТЕ НА ПАТОТ

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Клучни зборови: нестабилност на косина; облак со 3D точки; SfM техника; мониторинг

Во овој труд се разгледува следењето на нестабилноста на косини при изградба на експресен пат. На почеток беа извршени соодветни геолошки и инженерско-геолошки истражувања, поткрепени со употреба на практични техники за набљудување и анализа, вклучувајќи и снимање со употреба на дрон. Главната цел е да се прикаже еден пример на детектирање и следење на нестабилности на стрмните делови на косините со користење на облак со 3Д точки добиен со евтината, далечински контролирана и прецизна техника SfM (Structure from Motion), како и со употреба на соодветен софтвер. Анализираната површина претставува мал дел од една косина на експресниот пат А2 Крива Паланка–Страцин, во Република Македонија, кој е во изградба. Разгледуваниот дел на косината е ископан во албит-епидот-хлоритски шкрилци. Во геолошка смисла е констатирано дека во овој дел на косината има поволни услови за појава на нестабилности. Беа анализирани четири различни облаци со точки добиени од четири различни снимања спроведени во текот на пет месеци, пред и по појавата на нестабилноста. Мултивременските геоморфни промени во нестабилната област беа идентификувани со споредување на облаците со точки. 3Д-растојанијата беа проценети со употреба на повеќестепена споредба на два облака со точки. Резултатите покажуваат дека поместувањата во рамките на нестабилноста се движат до 70 cm. Исто така, петмесечниот период на набљудување покажува дека нестабилноста е сè уште активна. Искористени се и дополнителни софтверски геометриски карактеристики кои овозможуваат полесна визуализација на промените на теренот. Добиените резултати покажуваат дека овие постапки за откривање и следење на поместувањата во нестабилните зони на тлото можат да се користат како редовна технологија за таков вид проблеми. Предностите се многу, вклучувајќи ги и брзината на работата, високата прецизност на деталите и можноста за одредување на многу мали поместувања.