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Application of modern survey and cartographic methods for documenting and presenting existing and historical workings of the UNESCO heritage site: Silver mine in Tarnowskie Góry

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Abstract. In this article, contemporary survey and cartographic methods were employed to document and present both the existing and historical workings of the UNESCO World Heritage Site, the Silver Mine in Tarnowskie Góry. Terrestrial laser scanning was utilized to capture detailed point clouds, which were then processed for advanced 3D applications. Due to the mine's limited man-made roof supports, traditional vectorization methods were found to be impractical. Instead, ContexCapture Bentley software was used to create a detailed mesh model, overcoming the limitations of standard mesh algorithms in capturing intricate interior details. The project also integrated historical and current maps, orthophotos, and a digital terrain model to enrich the dataset. For georeferencing, fixed church locations were used, and vector layers were developed to map shafts, adits, water tunnels, and narrow-gauge railways, with each layer annotated with historical and geometric attributes. This approach not only preserves the mine's complex features but also enhances its usability for future analysis and educational purposes. The resulting data offers a comprehensive, interactive representation of the mine, providing valuable insights into its historical importance and its ongoing role in the region's mining heritage.

1 Introduction

Modern survey and cartographic methods have transformed the documentation and presentation of cultural heritage sites through advanced technologies. Tools such as 3D and 2D visual digital technologies, Geographic Information Systems (GIS), laser scanning, and photogrammetry have revolutionized the field by offering precise, detailed, and interactive means of capturing and sharing information about these places [1, 2]. These methods not only enhance the accuracy of the documentation but also facilitate a deeper understanding of the heritage through visual and spatial data [1 – 3].

Among these technologies, 3D and 2D visual digital technologies play a critical role in the conservation and monitoring of cultural heritage [1, 4]. They enable detailed documentation and visualization, which are invaluable for preservation and educational

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purposes [5, 6]. For example, 3D laser scanning and photogrammetry create accurate digital models that capture the intricate details of heritage sites. Geographic Information Systems (GIS) further complement these methods by managing and analyzing spatial data, allowing for comprehensive mapping and visualization of the geographical aspects of heritage sites [1, 3, 4, 7]. This integration of various data types – such as maps, photographs, and textual information – provides a holistic view of the historical and current conditions [8].

The application of these modern methods extends to various benefits, including enhanced conservation and restoration efforts, improved public engagement, and advanced research opportunities [9]. Detailed data from modern surveys support targeted conservation strategies, while interactive digital models and maps enhance public education and appreciation of cultural heritage [10]. However, challenges such as managing large volumes of data and integrating modern techniques with traditional methods must be addressed to fully realize the potential of these technologies [11, 12]. Despite these challenges, the advancements in survey and cartographic methods continue to significantly enrich the documentation and presentation of UNESCO heritage places, fostering greater understanding and preservation of our cultural heritage [13].

Located in the Silesian province (Fig. 1) The Silver Mine in Tarnowskie Góry has been on the UNESCO World Heritage list since 2017, with a history dating back to the Middle Ages [14]. Records of mining in Tarnowskie Góry distinguishes two phases of development. The first phase, in the 16th century, when the mine was one of the most important silver mining centres in Europe and played a crucial role in the economic development of the region. In the second phase, during the industrial revolution, mine was modernized mine using steam technology for underground water drainage and the production of zinc, which met half of the global demand. The mine's UNESCO listing is due to its unique drainage and water supply system, which is exceptional on a global scale [15]. The Tarnowskie Góry mine was a pioneer in using groundwater for human consumption purposes.

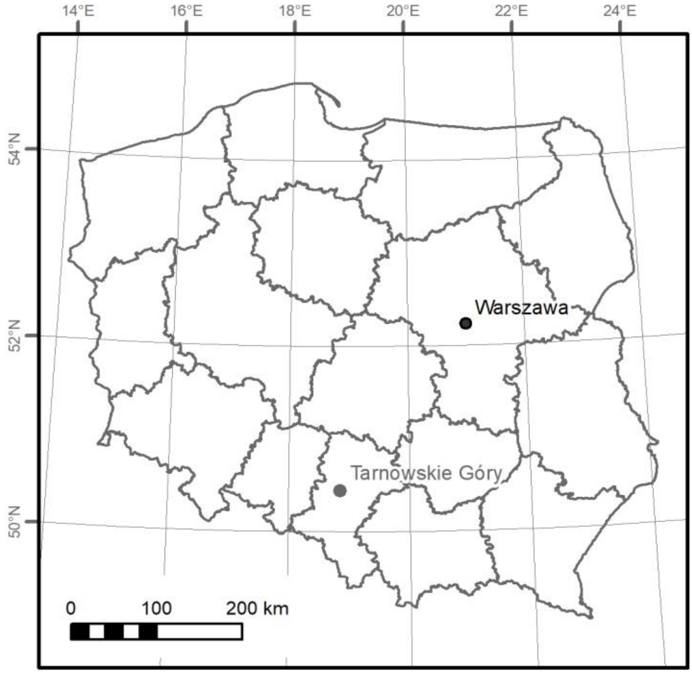

Fig. 1. Location of Tarnowskie Góry with a background of the administrative subdivision of Poland.

Mining activity in Tarnowskie Góry in Upper Silesia, located in the Bytom region, can be divided into two stages. The first stage began in the first half of the 16th century near Bytom. Under Tarnowice (now Stare Tarnowice, a district of Tarnowskie Góry), calamine and galena were extracted, from which lead and silver were smelted. During this period, the town of Tarnowskie Góry was founded in 1526 and was granted the status of a free mining town, the first in the Bytom region. It became necessary to unify German and Polish mining regulations and customs. For this reason, George Hohenzollern and Jan II Dobry established the "*Ordunek Gorny*". Its aim was to regulate the organization of work in mining and to establish the Mining Office as an authority overseeing mining operations and the registration of shafts.

A factor hindering extraction, sometimes making it impossible, was water retention in mining excavations. Attempts to address it were made using wooden drainage devices powered by water and horses, known as "kunszty". These solutions required continuous human labour and supervision, leading to the initiation of drainage adits. These adits allowed for the drainage of workings above them using gravity. The first example was the St. James adit, whose construction began in 1563. In the following decades, additional adits were dug, including the unfinished Kraków adit (drilled between 1568 – 1579) and the Gotthelf adit in the first half of the 17th century [16].

Due to the depletion of deposits in drained areas and the movement of troops through Silesia during the Thirty Years' War in the first half of the 17th century, mining in Tarnowskie Góry declined. In the late 18th century, two Prussian officials, Heinitz and Reden, decided to resume mining and unlock the potential of the still existing deposits. To this end, they decided to drill exploratory shafts. One of these was the Rudolfina shaft, where a vein of galena was discovered. As a result of this discovery, the Royal Friedrich Mine was established in 1783.

In the early years of the mine's operation, horse-driven drainage machines were used. This solution, along with the existing shallow adits, proved insufficient. To improve water pumping, a steam engine was imported from Great Britain in 1787, the first of its kind in the region of present-day Poland. A total of eight steam engines were installed at the mine. However, steam engines turned out to be a temporary solution. A more efficient method for draining mine water was continuously sought. Consequently, in 1834, the last adit, named the Fryderyk Głęboki Adit, was completed. It was located at the lowest point of the workings, allowing water to flow from the rest of the mine into the adit and then to the surface through 4.5 km of gravitational flow at a slight incline.

The operations of the Fryderyk Mine significantly impacted the development of the eastern part of Upper Silesia. The demand for coal to power steam engines stimulated the growth of the coal mining industry, including state-owned mines such as the König mine in Königshütte (now Chorzów) and the Königin Luise mine in Zabrze.

One consequence of the drainage system was the shortage of drinking water in local wells. In 1884, waterworks were established in Tarnowskie Góry, supplying potable mine water through pipelines to Bytom and Königshütte. The unique underground water management system led to the listing of the site as the Historic Silver, Lead, and Zinc Mine and its underground water management system on the UNESCO World Heritage List in 2017 [16, 17].

1.1 Background and contributions

In 2023 and 2024, students from the KNGK Geoinformatica student research club at the Faculty of Geo-Data Science, Geodesy, and Environmental Engineering of the AGH Kraków University had the opportunity to visit the Silver Mine in Tarnowskie Góry. The purpose of the trip was to carry out the Rector's Grants projects. The Okrężny Passage and Silver chamber which they scanned, are among the most distinctive parts of the mine. The laser scanning was carried out using the modern Leica BLK 360 scanner and Faro Focus scanner.

The scanning conducted by the students aimed not only to document the technical condition of the passage but also to develop a 3D model [18, 19].

The above-mentioned Rector’s Grants have two distinctive aims that would contribute into documenting existing and historical workings of the Tarnowskie Góry mine. The first contribution is scanning and georeferencing of some of the existing old maps of both the excavations and the terrain. Second contribution is work on creating a 3D documentation of the object suitable for becoming a base both for a digital twin and virtual tours. Both of those contributions required editing existing methods for underground environment and needs of UNESCO heritage object [19 – 21].

2 Methods and materials

2.1 Digitalizing existing old maps and creation of a GIS data base

The inventory of historical mining-related objects, encompassing both existing and non-existent features, was meticulously compiled using archival cartographic materials from the State Archive in Katowice and the Silesian Digital Library [22]. This comprehensive inventory leveraged a range of historical maps and documents, which provided critical insights into the mining infrastructure. The process involved careful analysis of these sources to ensure accurate documentation of each object’s historical context and spatial information. By integrating these archival resources, the project was able to create a detailed and reliable record of the mining heritage:

– German topographic map from 1883, Sucha Góra system, scale 1:10000 (Specialkarte der Oberschlesischen Bergeviere unter Angabe der Lage der verliehenen Bergwerke);

– German topographic map, scale 1:10000 (Sucha Góra system) from 1901, covering the area from Sosnowiec to Zabrze and from the vicinity of Tarnowskie Góry to the vicinity of Mikołów (Topographie zur Flözkarte vom nordlichen Teil des Oberschlesischen Steinkohlenbeckens);

– German topographic map, scale 1:10000 (Sucha Góra system) from 1930 –1935 (Topographie zur Flözkarte des Oberschlesischen Steinkohlenbeckens);

– German topographic map, scale 1:25000 from 1893, Messtischblatt, Tarnowitz sheet, 3258 (Fig. 2);

– Topographic map, scale 1:100.000 (Borowa Góra system) of the Military Geographic Institute from 1924 – 1939;

– Topographic map, scale 1:5.000 (Borowa Góra system) from 1958 – 1961.

Fig. 2. A fragment of the German topographic map 1:25000 with marked objects related to Tarnowskie Góry mining (Source: Silesian Digital Library: https://www.sbc.org.pl/en/dlibra/publication/4997/edition/4617).

Fig. 3 displays a detailed view of the geoportal layers, highlighting the newly documented mining workings. This visualization provides a comprehensive overview of the updated geographic information, showcasing the integration of recent data into the geoportal. The layers illustrate the spatial distribution and characteristics of the newly recorded mining features, offering valuable insights for further analysis and interpretation.

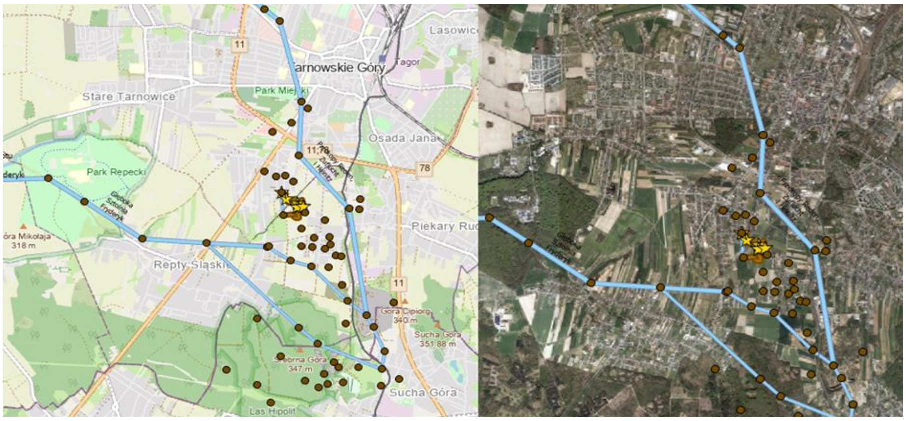

Fig. 3. The view of layers of the created geoportal showing newly documented mining workings (source: own work).

Georeferencing of old maps was based on the location of objects that had not changed their position and were recognizable on the map. Vectorization of the objects was done on already georeferenced maps. In the vector format, the locations of shafts, adits, water tunnels, the “Deep Fryderyk” adit, the “Boże Wspomóż” adit, adit outlets and discharges, as well as segments of the Upper Silesian Narrow-Gauge Railways were marked. Each object includes information in the attribute table with the original German name, year of establishment, and whether the object is listed as a UNESCO World Heritage [23]. Depending on the presented data, geometric parameters such as length for tunnels and adits, or depth for shafts were also added. The collected information not directly related to the location allows for filtering of objects based on selected parameters. These were added to enable displaying the state of mining in the area for a specific year as determined by the stakeholder.

In addition to the vector layers, raster data was also collected in the form of the previously mentioned maps, as well as an orthophotomap and a digital terrain model. The entire geoportal was made available using the ArcGIS Online platform.

2.2 Terrestrial laser scanning, and creation of basic mesh-type models

Documentation of detailed geometry of the workings of the mine was done in 2023 and 2024 with the use of two stationary laser scanners: Faro Focus 3D and Leica BLK360. The TLS (terrestrial laser scanning) process provides a point cloud of the surface of scanned objects. The point cloud file consists of lines of XYZ point coordinates on the object’s surface. In this case, additional data were also provided, such as: I – intensity of a laser beam coming back to the scanner and RGB – data on the object’s colour in measured points [24 – 26]. The point cloud can be vectored to create 2D projections of the object or to create a 3D model. Another option is to create a meshed fully textured model sometimes referred to as reality-mesh [27].

Both scanners used for TLS are considered medium range stationary laser scanners of medium accuracy and density of resulting point clouds. Faro Focus 3D is a white light scanner with 0.6 m – 120 m indoor or outdoor range, with ranging error of 2 mm and ranging noise up to 2.2 mm at 25 m. It has a camera with automatic adaption of brightness built inside it. A single scan takes up to a few minutes. Faro Focus instrument provides scans within 320 vertical and 360 horizontal fields of view, with up to 1 – 3 mm resolution. Leica BLK 360 is a the smallest and lightest currently available scanner with 155 mm of height, 80 mm id diameter, weighing 0.85 kg. Its accuracy is described as ±4 mm/10 m for a single 3D point. The working range of this scanner is 0.5 m to 45 m. The range and accuracy of this scanner are lower than FARO, however with time of scanning including taking RGB images of around minute for single station it seems to be ideal for this kind of relatively short rage survey.

The registration, alignment of the point clouds was done with the use of targets (ground control points) in the shape of 11 cm spheres and a few black and white 20×20 cm chessboards. Each pair of scans was connected by at least 4 targets. The registration of point clouds done in 2023 and 2024 was done with the use of natural GCP, in this case elements of mining supports and sculptures (Fig. 4).

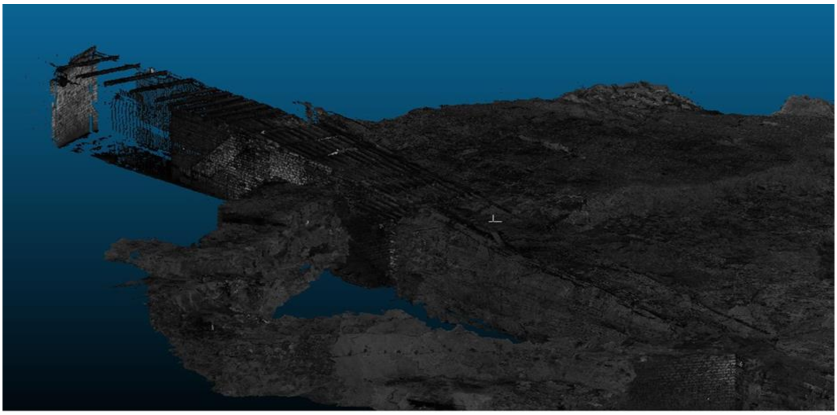

Fig. 4. Raw point cloud based of Faro Focus data.

3 Results and discussions

The result of the first part of the project was a set of maps that have been calibrated into a common coordinate system and an inventory of existing and historical workings. We managed to localize and create vector representations of 3 adits, 3 adits discharges, 3 water crosscuts/digs 2 Adit outlets and over 60 shafts. In addition, 5 km of Upper Silesian narrow-gauge railways was vectored. Currently the ArcGIS database is being transferred to ArcGIS online and will be available to the public (Fig. 5).

The point clouds obtained with terrestrial laser scanning are a valuable source of metric data; however, they require further processing to be usable in more demanding 3D applications. The most obvious option would be to vectorize the mine. However, since this particular mine has limited roof supports, this process would be time-consuming and not effective. This is why we opted for a different approach. The model was meshed, creating an object easier to manage with 3D software. However, this is not a straightforward procedure, as many mesh algorithm implementations are not designed for such data. Most commonly, they stitch up the holes, creating smooth, flat surfaces, which do not work properly for the insides of objects and interiors such as a mine. As a result, ContexCapture Bentley software was used, as it provided a slightly different algorithm that used the scan positions to establish relations between the objects (Fig. 6). This software also allows the creation of photorealistic textures on top of the mesh [28, 29]. However, in the current instalment, it is impossible to properly export them.

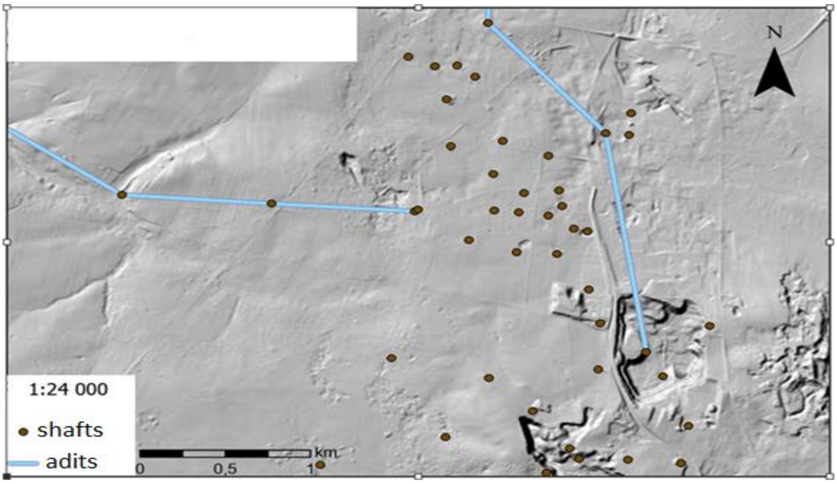

Fig. 5. Localisations of shafts, adits and water tunnels. Map of the working on the background of digital terrain model.

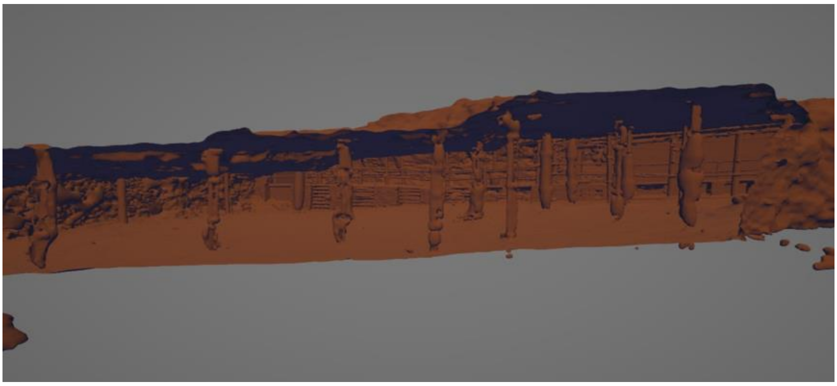

Fig. 6. OBJ model.

A mesh model was created based on the point cloud. Saved in OBJ format, it was exported to UNITY software, where an interactive application was made. The user of the application can move in a virtual “Silver Chamber”. Basic controllers were used to simulate the movement of a human person. This approach allows the user to see the chamber from a perspective normally inaccessible to visitors. The ability to see objects normally distant from the tourist route up close increases and broadens visitors’ perception of the mine space. An additional benefit of the development of the digital twin-interactive application is that it makes a virtual tour of parts of the mine available to people who are excluded due to disabilities that prevent them from visiting the mine. In the future, it is planned to develop models with the inclusion of texture, as well as with the possibility of interaction with the environment, which will increase immersion (Fig. 7).

The creation of a mesh model from the point cloud, exported to UNITY, has enabled the development of an interactive application allowing users to explore the virtual “Silver Chamber” from an otherwise inaccessible perspective.

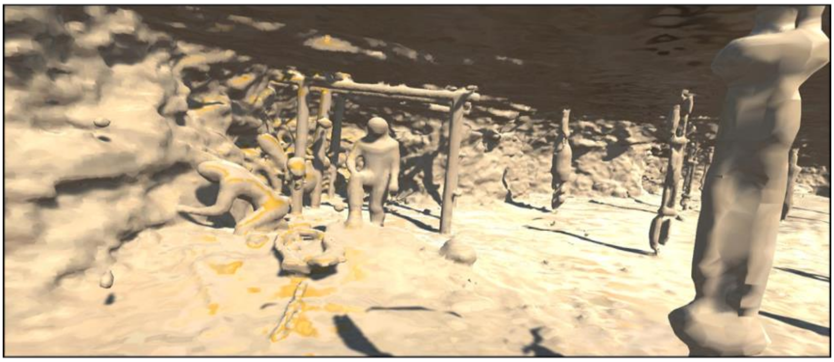

Fig. 7. An interactive application with the ability to move around the orbit.

This approach enhances visitors' understanding of the mine by providing close-up views of features typically out of reach. Additionally, the digital twin-interactive application offers virtual access to the mine for individuals with disabilities, and future plans include adding textures and interactive elements to further enrich the immersive experience.

4 Conclusions

The research project achieved several notable outcomes. The initial phase involved the development of a comprehensive set of maps, calibrated to a common coordinate system, and an inventory of both existing and historical workings. This phase successfully produced vector representations of 3 adits, 3 adit discharges, 3 water crosscuts/digs, 2 adit outlets, and over 60 shafts, along with mapping 5 km of Upper Silesian narrow-gauge railways. These data are currently being transferred to ArcGIS Online and will soon be accessible to the public.

For the second phase, point clouds obtained through terrestrial laser scanning provided crucial metric data but required additional processing for advanced 3D applications. Although vectorizing the mine was initially considered, the limited roof supports made this method impractical. Instead, a meshed model was created using ContexCapture Bentley software, which managed the complex interior data and allowed for photorealistic textures. However, limitations in current technology hindered the proper export of these textures.

The meshed model, saved in OBJ format, was then imported into UNITY software to create an interactive application. This application enables users to explore the virtual "Silver Chamber", offering a perspective typically inaccessible to visitors. Basic controllers simulate human movement, improving the visitor experience by providing close-up views and accommodating those unable to physically visit.

Future development plans include adding textures and interactive features to enhance user immersion. Ultimately, this project has resulted in a new interactive GIS database for an important UNESCO site in Poland. The next steps will involve visually verifying the found objects to assess their historical value and potential public safety risks. Additionally, while the project has laid the groundwork for a virtual tour, further work is needed to convert 3D point clouds into more photorealistic mesh models, a task that proved too costly and time-consuming within the current project scope but is planned for future efforts.

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References

1 Haddad, N. (2022). 3D and 2D Visual Digital Technologies and Cultural Heritage Documentation for Conservation and Monitoring: A Critical Review and Assessment. *Optoelectronic Devices in Robotic Systems*, 257-288. https://doi.org/10.1007/978-3-031-09791-1_10

2 Stylianidis, E., Evangelidis, K., Vital, R., Dafiotis, P., & Sylaiou, S. (2022). 3D Documentation and Visualization of Cultural Heritage Buildings through the Application of Geospatial Technologies. *Heritage*, *5*(4), 2818-2832. https://doi.org/10.3390/heritage5040146

3 Serain, C. (2016). The Contribution of Digital Technologies to the Mediation of the Conservation-Restoration of Cultural Heritage. Digital Heritage. *Progress in Cultural Heritage: Documentation, Preservation, and Protection*, 283-289. https://doi.org/10.1007/978-3-319-48974-2_32

4 Russell, B., & Wrisley, D.J. (2023). The UX of DH Workshops. *Digital Humanities Workshops*, 162-171. https://doi.org/10.4324/9781003301097-18

5 Polyanska, A., Pazynich, Y., Poplavska, Z., Kashchenko, Y., Psiuk, V., & Martynets, V. (2024). Conditions of Remote Work to Ensure Mobility in Project Activity. *Lecture Notes in Mechanical Engineering*, 151-166. https://doi.org/10.1007/978-3-031-56474-1_12

6 Wrisley, D.M. (2007). Balance testing and training. *Geriatric Rehabilitation Manual*, 409-414. https://doi.org/10.1016/b978-0-443-10233-2.50068-7

7 Villa, C., Jorkov, M.L., Madsen, C.K., & Jensen, J.F. (2022). 3D Documentation of Stone Sites at Ilulissat, West Greenland. Visual Heritage: *Digital Approaches in Heritage Science*, 115-132. https://doi.org/10.1007/978-3-030-77028-0_7

8 Reckziegel, M., Wrisley, D.J., Hixson, T.W., & Jänicke, S. (2021). Visual exploration of historical maps. Digital Scholarship in the Humanities, *36*(Supplement_2), ii251-ii272. https://doi.org/10.1093/llc/fqaa059

9 Dychkovskyi, R., Falshtynskyi, V., Ruskykh, V., Cabana, E., & Kosobokov, O. (2018). A modern vision of simulation modelling in mining and near mining activity. *E3S Web of Conferences*, (60), 00014. https://doi.org/10.1051/e3sconf/20186000014

10 Georgoula, O., Stamnas, A., Patias, P., Georgiadis, C., & Fragkoulidou, V. (2013). Historical coastal urban landscapes digital documentation and temporal study with 2D/3D modeling functionality: The case of Thessaloniki, Greece. *Journal of Cultural Heritage*, *14*(5), 396-402. https://doi.org/10.1016/j.culher.2012.10.007

11 Psyuk, V., & Polyanska, A. (2024). The usege of artificial intelligence in the activities of mining enterprises. E3S Web of Conferences, (526), 01016. https://doi.org/10.1051/e3sconf/202452601016

12 Kovacheva, S. (2016). Presentation of UNESCO Bulgarian Cultural Heritage Sites as Knowledge System in a Learning Environment. *Digital Presentation and Preservation of Cultural and Scientific Heritage*, (6), 179-188. https://doi.org/10.55630/dipp.2016.6.17

13 Paganoni, M.C. (2016). Reclaiming heritage for UNESCO: Discursive practices and community building in northern Italy. *Making Publics, Making Places*, 75-94. https://doi.org/10.20851/publics-05

14 Koch, H., Pawlak, Z., & Widera, B. (2020). *Memoriał na uroczystość stulecia istnienia Królewskiej Kopalni Ołowiu i Srebra Fryderyk.* Tarnowskie Góry, Poland: Stowarzyszenie Miłośników Ziemi Tarnogórskiej, 223 s.

15 Wagner, M. (2024). Szczęśliwe zwycięstwo Lwa Lechistanu. *Historia i Świat*, (13), 527-534. https://doi.org/10.34739/his.2024.13.32

16 Filak, M., & Pawlak, Z. (2017). *Tarnowskie Góry UNESCO. Obiekty pogórnicze wpisane na Listę Światowego Dziedzictwa UNESCO.* Tarnowskie Góry, Poland: Stowarzyszenie Miłośników Ziemi Tarnogórskiej, 76 s.

17 Hasterok, M., Piegza, M., & Dębski, P. (2021). Fibromyalgia from a psychiatric point of view. *Psychiatria i Psychologia Kliniczna*, *21*(2), 128-133. https://doi.org/10.15557/pipk.2021.0014

18 Lewińska, P., Róg, M., Żądło, A., & Szombara, S. (2022). To save from oblivion: Comparative analysis of remote sensing means of documenting forgotten architectural treasures – Zagórz Monastery complex, Poland. *Measurement*, (189), 110447. https://doi.org/https://doi.org/10.1016/j.measurement.2021.110447

19 Dzięgiel, M. (2021). The geotouristic attractiveness of the underground trails in Zabrze, Dąbrowa Górnicza and Tarnowskie Góry towns (Silesian Upland). *Geotourism/Geoturystyka*, *1-2*(60-61), 23-38. https://doi.org/10.7494/geotour.2020.1-2(60-61).23

20 Sztwiertnia, D., Ochałek, A., Tama, A., & Lewińska, P. (2021). HBIM (heritage Building Information Modell) of the Wang Stave Church in Karpacz–Case Study. *International Journal of Architectural Heritage*, *15*(5), 713-727. https://doi.org/10.1080/15583058.2019.1645238

21 Kalwara, P. (2017). Grzegorz Szymborski, Wyprawa Fryderyka Augusta I do Inflant w latach 1700-1701 w świetle wojny domowej na Litwie, Wydawnictwo Inforteditions, Zabrze-Tarnowskie Góry 2015. In Gremium. *Studies in History, Culture and Politics*, (11). https://doi.org/10.34768/ig.vi11.238

22 Szombara, S., Lewińska, P., Z˙adło, A., Róg, M., & Maciuk, K. (2020). Analyses of the Pradnik riverbed shape based on archival and contemporary data sets-old maps, LiDAR, DTMs, orthophotomaps and cross-sectional profile measurements. *Remote Sensing*, *12*(14), 2208. https://doi.org/10.3390/rs12142208

23 Maciuk, K., Apollo, M., Mostowska, J., Lepeška, T., Poklar, M., Noszczyk, T., Kroh, P., Krawczyk, A., Borowski, Ł., & Pavlovčič-Prešeren, P. (2021). Altitude on Cartographic Materials and Its Correction According to New Measurement Techniques. *Remote Sensing*, *13*(3), 444. https://doi.org/10.3390/rs13030444

24 Grilli, E., Farella, E.M., Torresani, A., & Remondino, F. (2019). Geometric features analysis for the classification of cultural heritage point clouds. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, (XLII-2/W15), 541-548. https://doi.org/10.5194/isprs-archives-XLII-2-W15-541-2019

25 Lenda, G., Lewińska, P., & Siwiec, J. (2019). Accuracy of Merging Point Clouds at the Maximum Range of a Scanner with Limited Possibilities of Target Placement. *Archives of Civil Engineering*, 65(4). https://doi.org/10.2478/ace-2019-0057

26 Prizeman, O.E.C. (2015). HBIM and matching techniques: Considerations for late nineteenth- and early twentieth-century buildings. *Journal of Architectural Conservation*, *21*(3), 145-159. https://doi.org/10.1080/13556207.2016.1139852

27 Skarlatos, D., & Kiparissi, S. (2012). Comparison of laser scanning, photogrammetry and SfM-MVS pipeline applied in structures and artificial surfaces. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, (1-3), 299-304. https://doi.org/10.5194/isprsannals-I-3-299-2012

28 Park, H., & Lee, D. (2019). Comparison between point cloud and mesh models using images from an unmanned aerial vehicle. *Measurement*, (138), 461-466. https://doi.org/https://doi.org/10.1016/j.measurement.2019.02.023

29 Krawczyk, A. (2022). Proposal of Redefinition of the Terms Geomatics and Geoinformatics on the Basis of Terminological Postulates. *ISPRS International Journal of Geo-Information*, *11*(11), 557. https://doi.org/10.3390/ijgi11110557