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The use of modern IT tools to acquire information about geographical space from archival maps

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Abstract. Rapid technological development observed for many years in Geographic Information Systems (GIS) has enabled the application of this system in many areas of life, including: administration, infrastructure management, in environmental protection, spatial planning, in real estate management, in crisis planning and in many branches of industry, including mining. According to [1], the Geographic Information System should be understood as a system for acquiring, processing, verifying, integrating, manipulating, analyzing and presenting data that are spatially referenced to the Earth. It usually includes a spatial database and appropriate software. The article presents an example of obtaining spatial data from archival maps, which are an important, and sometimes even the only source of information enabling tracking changes occurring in the geographical environment and determining the location of objects whose time of using has come to an end. Using the GIS class software, the author made a multivariate calibration of the archival situational and altitude map of the area of the inactive "Saturn" mine. On the basis of the obtained results, she indicated the most appropriate method for this type of task. The map prepared in this way was used to locate liquidated mine excavations connected to the surface. Acquiring reliable information about the location of this type of excavations is particularly important because of the risk associated with the possibility of outflow of gases adversely affecting the atmosphere and thus health of people staying near them (mainly methane and carbon dioxide) as well as due to the possibility of occurrence of so-called discontinuous deformations.

1. Introduction
Among the modern IT tools used more and more often, also in the mining industry [2, 3, 4, 5, 6, 7], GIS class software can be exchanged. This is called any program that allows entering, collecting, analyzing and visualizing data that are spatially referenced to the Earth. The software is, next to people, equipment, data and procedures of their processing and sharing, the basic element of geographic information systems (GIS - Geographic Information Systems). An example of this type of software is the QGIS program. It is an open, free and cross-platform GIS software (it works on GNU / Linux, Unix, Mac OSX and MS Windows platforms). It was created relatively recently (in 2002) and since then it has been dynamically developing [8, 9, 10].

Geographical information systems allow to collect huge amounts of data, both spatial and descriptive and in various forms (raster and vector), verify them, manage them and conduct various types of analysis (http://gisdisplay.pl/gis/programowanie-gis.html).

Despite the technological development related to, among others, with such fields as photogrammetry, remote sensing and GNSS measurements, very often an important role in obtaining
data supplying geographical information systems is still used in traditional maps. Sometimes, they are a source of information without which it would be impossible to perform analyzes related to, for example, the transformation of the environment. In the case of mining maps, they are particularly valuable in a situation when the mining plant is liquidated, and thus objects associated with their activity. As part of the work, the author used an archival mining map covering the area of the liquidated "Saturn" coal mine. Using the QGIS program, there were made several variants of this map calibration, choosing the best option in its assessment. Such calibrated map and information obtained from available services (Google maps) allowed the author to determine the location of mining excavations located in this area and having connection with the surface in the current spatial situation. Knowledge on this subject will increase the level of safety of users of this area because the presence of these excavations is associated with the risk of discontinuous deformations and the possibility of gas outflow (methane and carbon dioxide) [11, 12, 13, 14].

2. Characteristics of the area of the study
The study covered the mining area of the "Saturn" mine. This coal mine was created from the merger of three other mines: the "Czerwona Gwardia" mine, "Milowice" and "Czeladź". The first one was the "Milowice" mine (1822), then the "Czeladź" mine (1860) and the last of these three, the "Saturn" mine, which in 1951-1984 functioned under the name "Czerwona Gwardia". The mining area included the city of Czeladź, part of the city of Sosnowiec and Będzin (figure 1).

Figure 1. A fragment of the surface map with the boundary of the "Saturn" mining area marked out (materials obtained from the Archive of Mine Survey and Geological Documentation of the State Mining Authority in Katowice).
The limit of the mining area of the "Saturn" mine was 31 points. The coordinate system in which the mining maps were carried out was the Sucha Góra local system (table 1). In addition, these points had coordinates converted into the 1965 system.

**Table 1.** Coordinates of the refraction points of the mining area of the Saturn Mine (own elaboration based on materials obtained from the Archive of Mine Survey and Geological Documentation of the State Mining Authority in Katowice).

| No | Point number | Coordinate system „Sucha Góra” X | Y | No | Point number | Coordinate system „Sucha Góra” X | Y |
|----|--------------|---------------------------------|---|----|--------------|---------------------------------|---|
| 1  | 5403         | -8003.00                        | 12540.00 | 17 | 5419         | -13484.20                       | 14033.70 |
| 2  | 5404         | -8774.00                        | 12590.00 | 18 | 5420         | -14176.90                       | 14193.70 |
| 3  | 5405         | -10592.00                       | 12708.00 | 19 | 5433         | -14287.30                       | 14131.10 |
| 4  | 5406         | -10480.00                       | 12372.00 | 20 | 5434         | -14400.00                       | 14138.00 |
| 5  | 5407         | -12193.29                       | 12100.90 | 21 | 5435         | -14457.30                       | 14232.50 |
| 6  | 5408         | -12664.36                       | 12906.28 | 22 | 5436         | -14468.70                       | 14950.00 |
| 7  | 5409         | -12393.15                       | 12924.06 | 23 | 5450         | -14350.00                       | 15190.00 |
| 8  | 5410         | -12409.53                       | 13158.84 | 24 | 5451         | -14259.00                       | 15844.00 |
| 9  | 5411         | -12822.19                       | 13244.70 | 25 | 5452         | -14871.00                       | 16641.00 |
| 10 | 5412         | -12694.66                       | 13359.40 | 26 | 7302         | -15206.00                       | 16865.00 |
| 11 | 5413         | -12579.50                       | 13809.40 | 27 | 7301         | -13107.00                       | 17740.00 |
| 12 | 5414         | -12802.81                       | 13826.37 | 28 | 7251         | -12514.00                       | 17680.00 |
| 13 | 5415         | -13086.00                       | 14000.00 | 29 | 7129         | -12000.00                       | 17677.00 |
| 14 | 5416         | -13000.00                       | 14220.00 | 30 | 7053         | -8524.00                        | 17751.00 |
| 15 | 5417         | -13140.00                       | 14400.00 | 31 | 7054         | -8238.00                        | 14111.58 |
| 16 | 5418         | -13601.70                       | 14334.00 |    |              |                                 |   |

"Saturn" coal mine was put into liquidation by the decision of the Minister of Industry and Trade of October 5th, 1992, No. 168/92 / Org. In the area of the "Saturn" mine there were over thirty mine workings connected to the surface (mainly shafts). The shafts were deepened from 1855. Their liquidation was carried out at different times. The name of shafts and the year of their exploration and liquidation is presented in table 2.

**3. Source of materials**

According to the current regulations [15, 16] it is the responsibility of every entrepreneur to keep and update geological and metrological documentation during mining operations and after prior arrangement of this documentation, forwarding it to the President of the State Mining Authority. The ordering and completeness of the surveying and geological documentation is monitored by a mining surveyor or a mining geologist under the supervision of a competent local mining supervision authority [16]. The surveying and geological documentation includes documents: measuring, computational and cartographic presenting the geological and mining situation of the mining plant, as well as the state of the area within the boundaries of the mining area [15]. The types of documents included in the survey documentation are specified in detail in the regulation [16]. One of such documents is a mining map. According to the standard [17], mining map is a cartographic document prepared by authorized person, presenting the situation and relief, mining excavations situation, geological situation, prepared by geometric projections or a mapping method, intended for mining operations. This document is to ensure proper and safe operation of mining plant operations [17].
Table 2. List of liquidated shafts in the area of "Saturn" mine (own elaboration based on materials obtained from the Archive of Mine Survey and Geological Documentation of the State Mining Authority in Katowice).

| Shaft’s name          | Year of the exploration | Year of the liquidation |
|-----------------------|-------------------------|-------------------------|
| Wentylacyjny Nr 1     | about 1900              | no data                 |
| Rozalia               | before 1905             | no data                 |
| Wentylacyjny II       | before 1910             | about 1920              |
| Wentylacyjny III      | before 1905             | about 1920              |
| Milowice              | before 1919             | no data                 |
| „15”                  | no data                 | no data                 |
| Aleksander R-I        | no data                 | no data                 |
| „16”                  | before 1901             | 1958                    |
| Antoni                | before 1918             | 1958                    |
| XIII                  | no data                 | 1963                    |
| Feliks                | no data                 | 1956                    |
| Nr 3                  | no data                 | 1966                    |
| Korneliusz            | no data                 | 1966                    |
| Alfred                | 1908                    | 1975                    |
| Wiktor                | 1898                    | 1989                    |
| VI                    | 1956                    | 1980                    |
| Jan                   | 1908                    | 1980                    |
| Łoboda                | 1900                    | 1987                    |
| Wojciech              | 1890                    | 1986                    |
| Julian                | 1900                    | 1989                    |
| Pogoń-C               | 1954                    | 1993                    |
| V                     | no data                 | 1994                    |
| Anna                  | 1855                    | 1994                    |
| N-II                  | 1966                    | 1993                    |
| N-I                   | 1987                    | 1993                    |
| Abraham               | before 1900             | 1995                    |
| Kondratowicz          | 1924                    | 1995                    |
| Piotr                 | before 1900             | 1996                    |
| IV                    | 1927                    | 1996                    |
| Aleksander R-II       | 1880                    | 1996                    |
| Pogoń-M               | 1957                    | 1996                    |
| Hieronim              | before 1900             | 1996                    |

In the case of "Saturn" coal mine, after making the decision on its liquidation, the geological and metrological documentation (including cartographic documentation) went to the Archive of Mine Survey and Geological Documentation of the State Mining Authority in Katowice), from where the author obtained a map of the mining area of the mine. On its basis, it determined the location of liquidated mine workings connected to the surface. The obtained map was in the form of a raster image and therefore it was necessary to give it a spatial orientation (the calibration process was carried out).

The software used (QGIS program) allows to calibrate the map based on the coordinates of characteristic points or by indicating such points on a previously calibrated map, or on a layer shared in free services (Google maps, OpenStretMap, etc.).

In the case of a map of the surface of the "Saturn" mining area, the author calibrated it in two different ways. In the first of them the coordinates of selected breakpoints of the mining area were
used, in the second one a map from Google Maps was used. In both cases, the transformation was carried out using the Helmert method.

As already mentioned, the map of the mining area of the "Saturn" mine was conducted in the Sucha Góra local system. In addition, each of the points had specified coordinates in the 1965 layout. Due to the fact that the QGIS program does not allow the calibration of maps in local systems, coordinates in the 1965 system were used. Calibration was carried out based on several selected points (ten points were used in total the border of the mining area, evenly distributed over the entire map sheet). A fragment of the calibrated surface map is shown in figure 2.

![Figure 2. Fragment of the calibrated surface map.](image)

The transformation parameters are presented in table 3.

**Table 3. Parameters of transformation for points with known coordinates in the system 1965.**

| Shift x   | Shift y   | Scale x | Scale y | Rotation (degrees) | Medium error (map units) |
|-----------|-----------|---------|---------|--------------------|--------------------------|
| 243227.915 | 880737.730 | 1.70004 | 1.70004 | -1.03322           | 16.4102                  |

In the case of calibration based on map points obtained from the Google Maps service, it was necessary to identify them earlier on both layers (calibrated map and the layer loaded into QGIS from a given site). The fragment of the surface map and the corresponding area on the layer from Google Maps are shown in figure 3.

![Figure 3. Selection of points on the basis of which calibration will be carried out (area identification).](image)
Also in this case, the calibration was carried out on the basis of ten points evenly distributed on the map sheet. The fragment of the map of the "Saturn" mine surface with the points included in the calibration is shown in figure 4.

![Figure 4](image_url)

**Figure 4.** A fragment of the map of the surface of "Saturn" mine with the points included in the calibration.

The transformation parameters are presented in table 4.

| Shift x  | Shift y  | Scale x | Scale y | Rotation (degrees) | Medium error (map units) |
|----------|----------|---------|---------|--------------------|--------------------------|
| 243236.730 | 880751.465 | 1.70473 | 1.70473 | -1.13705          | 16.0016                 |

Table 4. Parameters of transformation for points located inside the border of the mining area.

An example of the shafts’ location against the current spatial situation is shown in figure 5 and figure 6.

![Figure 5](image_url)

**Figure 5.** Location of the Wojciech i Jan shaft on the background of the Google Maps map.
In both cases, the average calibration error obtained was at a similar level (around 16m). Considering the scale of the map and its quality, the obtained result should be considered satisfactory.

After giving the spatial reference map, it is possible to observe changes that occurred in the period from the liquidation of an excavation to the present day. For example, the effect of calibration is shown in Figure 8 and Figure 9. In the case of Jan and Wojciech shafts, the changes were small (Figure 8). In the case of the area on which the shaft Pogoń-M liquidated in 1996 is located, the changes were much larger. A truck car park is located above the dismantled shaft.

4. Threats related to the presence of abandoned shafts

Liquidation of mining excavations, having connection to the surface, can be carried out in several ways. One of them is cutting off the shaft with insulating stoppings on the pit bottom and filling the shaft pipe with a suitable material. The inlet of the shaft is additionally covered with a concrete or reinforced concrete slab on which the embankment is made. According to the authors of the report [11], this is the most appropriate and the most secure method. Another way is to secure the shaft tube with a plate or a platform on which the embankment is made. Liquidation of the shaft is also possible by damming inlets to the pit bottoms and covering the shaft pipe.

According to the information in Table 2, the liquidation of shafts in the area of "Saturn" mine has been carried out over seventy years. In the case of five shafts (Wentylacyjny Nr 1, Rozalia, Milowice, 15, Aleksander R-I) there is no information of the time of their liquidation. Very often documentation describing the manner of liquidation of such excavations has been preserved in a form that is insufficient to unambiguously determine whether it was carried out in a correct manner and does not threaten the use of these areas in later times.

After the shafts liquidation for their condition and their surroundings, the various processes taking place in the rock mass are inter alia: water circulation, corrosion, suffosion, embankment compaction, etc. [18, 19]. As a consequence, discontinuous deformations may occur, most often in the form of depressions [13, 20, 21]. As indicated by the authors of the works [12, 13, 14, 21], liquidated mine workings connected with the surface may also pose a threat to the atmospheric air, mainly due to the possibility of outflow from high amounts of gases such as methane or carbon dioxide. Reliable information about the location of this type of workings would allow to increase safety in their area.

5. Summary

The article discusses the issues related to the use of modern IT tools in the mining industry. Discussed is the method of obtaining information on the location of liquidated mining excavations, having connection to the surface, based on archival maps, using the GIS class software. Despite the rapid
The development of measurement techniques (e.g., GNSS, remote sensing, photogrammetry, etc.), traditional maps are still an important source of information, in particular for geographic information systems. Using the QGIS program, the author calibrated the map of the surface of the mining area of the liquidated „Saturn” coal mine. The prepared raster layer made it possible to reconstruct the location of shafts located in this area. The excavations were subjected to gradual liquidation from the beginning of the 19th century (e.g., Ventilation shaft II and Ventilation shaft III). For some of them there is no information about the year of liquidation. Very often there are no documents specifying their location (measurement documents) or they are dispersed in various institutions. In addition, documents constituting measurement and geological documentation in many cases (especially from the initial period of activity of a given mine) have been preserved in residual and incomplete form.

Locating places where excavations of this type had a connection with the surface is important because their presence is a threat due to the possibility of discontinuous deformations and the outflow of methane or carbon dioxide.

Knowledge about this subject will allow to label properly these places and keep up to date with the state of the excavations as well as their surroundings.

The author of the article showed that the QGIS program, belonging to the GIS class programs, easily allows obtaining information from archival maps, as well as has the ability to develop a database of this type of objects.

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