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Abstract of the doctoral dissertation

Modeling of ground displacements caused by induced seismicity with the use of the machine learning method

The rapid development of industry and new technologies is associated with the growing demand for raw materials. This, in turn, forces exploitation in difficult mining and geological conditions. Exploitation disturbs the natural balance of the rock mass and causes induced seismic events. Currently, induced seismicity is a global problem and inspires the interest of the scientific community and industry, especially in the field of tremors prevention and minimizing the negative effects of seismic events. One of the effects of mining tremors is the displacement (deformation) of the ground, which is an important research and practical issue in terms of their characteristics and the spatial-temporal development process.

The main goal of this dissertation was to develop a model describing the relationship between the ground displacements caused by the tremors induced in the underground mining with mining and geological conditions using the machine learning method - Random Forest Regressor (RFR) approach. The Rudna mining area was selected as the research site, as it is a "living laboratory" for studies of mining tremors. There are several seismic events with an energy above 10^6 J registered each year. The research methodology included several stages, which made it possible to achieve the goals that have been set.

At the beginning, an extensive state of art review was conducted, that allowed for the definition of the direction of research. The second stage concerned the analysis of input data, including: basic information about mining tremors; review of maps of mining excavations, geological profiles, deformation maps. In the third stage, the LOS (Line of Sight) displacement detection was carried out using the DInSAR (Differential Synthetic Aperture Radar Interferometry) method and analogously with the SBAS method in the fourth stage (Small Baseline Subset) to obtain deformation data necessary for studies. Moreover, an analysis of the identified LOS displacements was performed with the use of spatial GIS (Geographic Information System) and descriptive statistics. In the fifth stage, the available geodetic levelling results were compared with the results of the SBAS method. In the sixth stage, a geodatabase of the LOS displacements, mining and geological conditions was developed for the research in the last stage. This stage concerned the modeling of LOS displacements and the determination of statistically significant predictors using machine learning regression technique. The last stage consisted of summarizing the research results and drawing up final conclusions.

As a result of the conducted research, it was confirmed that the use of the satellite derived LOS displacements, mining and geological factors for supervised machine learning allows for the modeling ground deformations caused by high-energy induced tremors in the

area of underground mining. The research made it possible to expand the knowledge on ground deformation caused by mining tremors. It has been shown that statistically significant predictors include: exploitation period, field area, goaf area, energy, average depth of exploitation, average fault slip value, distance from the exploitation level from the hypocenter. On the other hand, the optimal model was characterized by the coefficient of determination (R^2) at the level of 93%. In addition, the research has confirmed that the ground in the epicenter area: before the tremor is subject to a slow subsidence in connection with the ongoing exploitation; the tremor causes a sudden increase in deformation; after the tremor, it continues to slowly subsidence. It was also found that induced tremors accelerate the disclosure of deformations that would appear anyway as a result of the rock mass moving deeper into the post-mining void. Additionally, the developed deformation database can be used in the prevention of mining area protection.

This doctoral dissertation consists of 189 sequentially numbered pages. The study referred to 295 literature items, including 37 Polish and 258 English items, and to 4 items authored or co-authored by the PhD student. The doctoral dissertation contains: 105 figures (including 21 in the appendix) and 23 tables (including 10 in the appendix).

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