Slope Ranking and geohazards correlation analysis for Combined Open-Underground Mining area

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Abstract—**Geohazards in mining areas are mainly ground subsidence, slope landslides and ground cracks, surface cover degradation and environmental ecological pattern destruction. The classification and rank of terrain slope and the feature area extraction of the slope are the important content for the correlation analysis with the geohazards. The slope classification and rank index system for soil and water conservation, land use and man-made ground disasters was analyzed. According to the characteristics of open pit and underground associated mining area, we comprehensively analyzed the spatial correlation between different ground disaster and terrain features and landform types, and propose a new slope ranking index, dividing slope zones and forming slope classification map. Especially slope area of 35-45 degrees and more than 45 degrees was extracted, and the relationship between regional geohazards and slope zone was analyzed. The application of terrestrial laser scanning technology to establish open-pit high precision digital elevation model, extraction of slope, slope type, gully density characteristic factor, topography factor data sets are established, and correlation analysis, to enhance disaster information content.**

I. INTRODUCTION

By using the open pit and underground combined mining mode (or combined mining mode), giving the full advantages of underground and surface mining, coordinating each other and assisting each other, greatly improve the resource mining rates[XU Zhiyuan, 2015]. Open pit mining completely destroys the original terrain, geomorphology, soil structure, and the ecosystem of the mining area. The area of ground deformation and disasters in the coal mine area is large and the situation is complicated. Deformation may include subsidence and displacement. Typical ground hazards include subsidence, ground crack, landslides, instability of construction and surface degradation, and environmental and ecological pattern damage. The mode of coal mining in Pingshuo is combined open-underground mining in the original mining area and the adjacent two open-pit slope in mining would appeared ground disasters (ground subsidence, slope displacement, landslide and collapse). Combined mining is a complex process, there are many disturbances and complex deformation mechanism, due to the mining induced ground subsidence, open-pit slope and stability of dump ground disaster problems directly affect the safe production of mines [Franke, R., 1982; Liu Xianquan, 2008; Cai Qing Xiang, Zhou Wei, Shu Jisen, et al.,2008], a wide range of existing land cover and ecological degradation pattern of damage [LI Jinchuan, BAI Zhongke, CHAI Shujie, et al, 2009].

The large open pit and underground mining geohazards area is divided into three categories, one is the cracks, subsidence, building instability, two is the landslide, open-pit mining end caving, dump collapse, the three category is the coverage of vegetation degradation and ecological environmental pattern damage. Topographic factor is an important part of mine geohazards evaluation, especially the classification of terrain slope and the extraction and analysis of slope zone.

The comprehensive control plan of soil and water conservation specification that the land area of small watershed is divided 6 grades by different slope. The slope ranking standard is: the lower gentle slope is less than 5 degrees, the gentle slope is 5 degrees -8 degrees, the gentler slope is 8 degrees -15 degrees, the lower steep slope is 15 degrees -25 degrees, the steep slope is 25 -35, the high steep slope is more than 35 degrees.

Slope is divided into five levels for investigation of land use present situation, that is less than or equal to 2 degrees, 2 degrees to 6 degrees, 6 degrees to 15 degrees, 15 degrees to 25 degrees, >25 degrees. Less than 2 degrees, 2 degrees to 6 degrees for flat farmland, 6 to 15 degrees, 15 to 25 degrees for slope farmland, >25 degrees for steep slope farming The different levels of the ground slope have different effects on the utilization of farmland. Less than or equal to 2 degrees without soil erosion; 2 degrees to 6 degrees can be mild soil erosion, should pay attention to soil and water conservation; Moderate soil erosion can occur at 6 degrees to 15 degrees. Soil and water conservation should be strengthened by building terraced fields and planting at equal height; 15 to 25 degree soil erosion is serious. Comprehensive measures such as engineering and biology must be adopted to prevent soil erosion; >25 degrees is land reclamation limit area, that is not allowed to land reclamation

planting crops, has been cultivated, gradually returning farmland to forest and grassland.

It is necessary to carry out comprehensive investigation and renovation of man-made geohazard caused by high and steep slopes (height greater than 15 meters, slope greater than 45 degrees) and unreasonable slope cutting [ZHAO Qian，ZHANG Jin, 2012; LI Chongrui，ZHANG Jin，XIAO Jie,2016].

II. NEW SLOPE GRADING INDEX AND CORRELATION ANALYSIS OF TOPOGRAPHIC FEATURE IN MINING AREA

A. New slope ranking index

Based on comprehensive analysis of different ground disasters and terrain, landform, land cover spatial relationships, we suggested a new slope grading index for division of slope zone, that is 0-6 degrees and 6-15 degrees, 15-25 degrees, 25-35 degrees, 35-45 degrees, 45 degrees, a slope classification map can be formatted. The features polygon of the 35 degree -45 slope are extracted and the features of the topographic environment of geohazards can be revealed. We further analyze the relationship between geohazard points and slope zone region. According to the four types of geomorphmetry, such as plain, terraced, mountainous and hilly, the number and distribution of geomorphic geohazards are counted.

B. Data acquisition and terrain feature analysis of surface laser scanning in open pit

Using RIEGL VZ-4000, three targets were placed on the ground around the scanner about 6M, which ensured that the scanner could scan the target in the scanning process, and the position of the target center was accurately measured by RTK GPS. The scanner is set to 1000 meters, density of 20 cm vertical and horizontal angle of view, local scanning, scan time is about 15 minutes, the operation mode is manual scanner HMI airborne touch screen control method for data storage, automatic storage to external USB memory and built-in memory scanning instrument.The maximum plane error of the modeling parameters is set to 0.015 meters, and the nearest distance and the maximum triangle border length are set, and the value can be defined according to the actual needs. After the model is set up, the data is merged and the coordinate system is corrected by the automatic merging module.

The triangulation surface is generated. According to the auxiliary grid, the group analysis is carried out to find the area in the low inclined triangular mesh, that is, the characteristic line, and calculate the point cloud disconnection near the boundary. Along the boundary part in forward and backward direction of the track, the calculated slope and the slope of the bottom line.

C. Correlation analysis of topographic feature in mining area

From the perspective of spatial morphology, terrain features and image features, we can depth understand geohazards multi-dimension features in mining area, and build the geo-location, morphology, attribute, semantics, structure, process, and relationship of disaster information map spectrum. A multi-dimensional feature based geohazards data sensing model integrating time, space, semantics and relations is constructed to realize multi field information, multi granularity analysis and location based information aggregation method in disaster area.

D. Figures

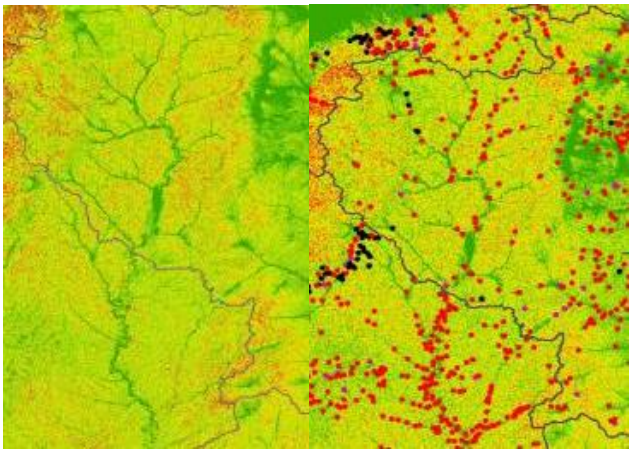

Figure 1. New Slope ranks and Geohazards Point Association

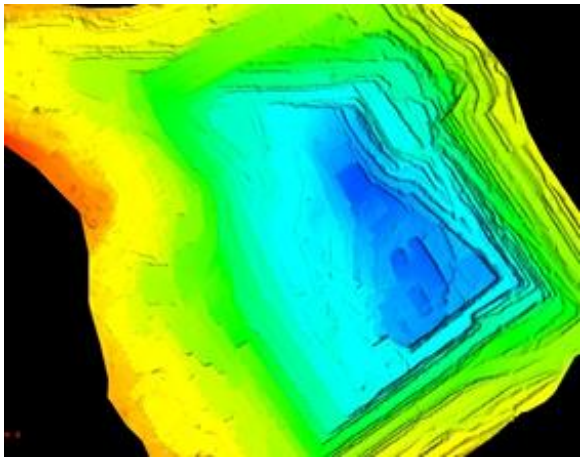

Figure 2. Open pit DEM

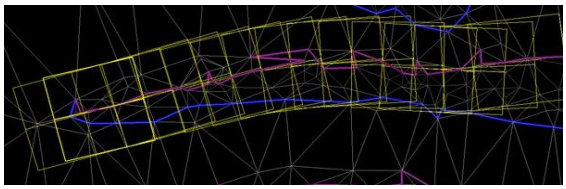

Figure 3. The top and bottom line of slope

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CONCLUSIONS

The existing classification and ranking specification of slope for geohazard analysis cannot meet the application demand, a new classification and ranking index system of slope for geohazard analysis corresponding with flat area, slope area, more slope area, steep slope area, high steep slope area and cutting gully area are suggested in this research, which the geometric features of the slope (e.g. the length, width, shape), surface coverage characteristics are considered and feature slope zone is formatted by merging slope cell according to slope ranking index system.

This paper studies and propose a new slope ranking index for large-scale terrain analysis in mining area, and the high-precision digital elevation model based on the ground laser scanning technology, and further studies the correlation analysis method of extracting the slope characteristics and ground disasters

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