Unified Expression and Standardized Treatment of Railway Supergene Geological Disaster Risk Information

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Abstract. Aiming at the problem that railway supergene geological disaster risk data are scattered and heterogeneous, and it is difficult to unify and centralize management and fusion analysis, the multi-source and heterogeneous supergene geological disaster risk data are standardized and integrated, and based on ontology theoretical knowledge, the digital model of main risk factors such as geography, geology, facilities and meteorology and their relationship is constructed to realize the unified expression of geological disaster riskinformation; Then, a standardized processing method of geological disaster risk data is proposed to realize three-dimensional modeling of geography and geology of railway facilities, and accurately extract multi-factor semantic features of disasters such as location and scope, and gather multi-source dynamic monitoring data such as displacement and meteorology, which provides key data support for scene analysis and visual expression of railway supergene geological disasters. Finally, landslide geological disasters around typical railway lines are selected for experimental verification and analysis, which proves that this method is reasonable and effective.

Keywords: railway geological disasters; Unified expression model; Standardized treatment; Geo-geological modeling; Disaster feature extraction.

1. Introduction

China's railway network is large in scale, busy in transportation organization, and has the characteristics of wide distribution, long mileage and various types of equipment and facilities. Moreover, the surrounding environment along the railway is complex and diverse, facing a variety of geological disaster risks such as landslide, debris flow, rock burst, water inrush and mud inrush, high ground temperature, etc. Among them, there are many types of supergene geological disasters such as landslide, debris flow and collapse [1]. Due to the coupling effect of deep-surface multi-factors in the complex and dangerous environment of railway, the potential disasters and disaster trends are unclear, which has become a major engineering hidden danger faced by railway construction and operation. With the rapid development of Internet of Things and sensor technology in recent years, multi-sensor stereo comprehensive detection and dynamic observation technology in remote sensing, geophysics, hydrogeology and other multidisciplinary fields have been widely used, which continuously provides multi-source dynamic observation data of the whole chain of disaster chain and multi-factors for the analysis of hidden dangers of geological disasters. The existing research on the risk analysis of supergene geological disasters along the railway often independently deals with the multi-source observation data decentralized by relevant departments, and the cross-modal multi-source observation data are heterogeneous, and the characteristics of disaster-pregnant environment are unclear, which makes it difficult to realize the unified integrated management and deep fusion analysis of geological disaster risk data; At the same time, the visualization of geological disaster scenes is often limited to the expression of disaster dynamic process, and lacks the overall enhanced visualization expression of all factors such as geographical and geological environment, important infrastructure and meteorology around geological disaster scenes [2], which seriously restricts our awareness of complex environmental disaster risks.

Therefore, this paper breaks through the limitation of single analysis of geological disaster data, analyzes the geometric, semantic and temporal characteristics of multi-source and multi-modal geological disaster data covering the wide-area three-dimensional space of railways, constructs a digital model of unified expression of major risk factors such as geography, geology, facilities and meteorology, and forms a semantic-level standardized processing method of multi-source heterogeneous disaster risk information, establishes a geographical and geological model of railway facilities, accurately extracts multi-factor characteristics of disasters, and provides comprehensive and standardized data support for hidden danger analysis of railway geological disasters and enhanced visual expression of disaster scenes.

2. Data of risk elements of railway geological disasters

In a wide area, railways are faced with a variety of supergene geological disasters and the disaster scenarios are complex, resulting in different spatial and temporal scales, diverse modes, complicated semantics and different data storage formats. Therefore, geological disaster risk data are mainly divided into geographic data, geological data and multi-source dynamic monitoring data according to the elements that constitute disasters.

2.1 Geographic data

Including basic geographic information data, high-resolution satellite image data, digital elevation model, tilt photography data, railway facilities three-dimensional model results data, etc.

2.1.1 Basic geographic information data

It is mainly divided into national basic geographic elements and railway basic geographic elements data, which are mostly stored in vector form. The national basic geographical element data includes various spatial data related to topography, natural resources, social, political and economic conditions, including administrative divisions, water systems, residential areas and facilities, transportation, pipelines, topography, vegetation and soil quality, etc. Railway basic geographical element data refers to railway lines (including kilometer marks), stations, pipe boundaries and residences, land red lines, railway notes, public works (subgrade, track, bridges and culverts, tunnels, security facilities, etc.), electrical services (communication, signals, etc.), power supply and water supply (catenary, traction substation, power, water supply, etc.), housing construction (houses, structures, ancillary equipment, etc.), others (crossing and flat corridor, safety monitoring, vehicle maintenance, information room, railway land, etc.)

2.1.2 High-resolution satellite image data

High-resolution remote sensing image data of railway lines and surrounding areas obtained by high-resolution satellites. The data types are DOM image (. tiff), geological boundary (. dwg, etc.), and the resolution is better than 0.1 m.

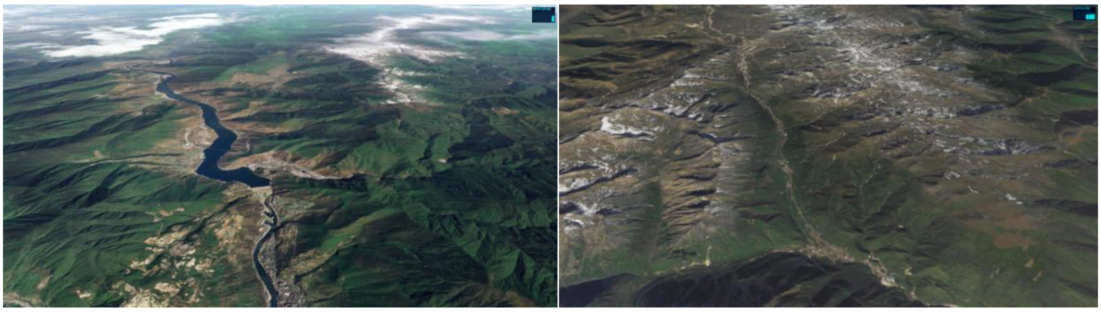


Fig. 1 Remote sensing image data

2.1.3 Digital Elevation Model (DEM)

Digital simulation of topography and geomorphology is realized through terrain elevation data, that is, digital expression of terrain surface morphology, which describes ground elevation through a group of ordered numerical arrays. The data formats are mainly GeoTIFF and TIFF.

Three-dimensional topographic map can be obtained by superimposing DEM and remote sensing image.

2.1.4 Tilt photogrammetry data

Tilt photogrammetry is an effective way to establish a high-precision single real-life 3D model of large-scale complex terrain and features. The ground resolution of UAV tilt images can reach up to 3cm, which can provide terrain and features data for fine engineering survey. The commonly used data formats of real 3D models are osgb, obj, 3dtiles, fbx and so on. The high-precision real-life three-dimensional model can effectively assist geological workers to judge the unfavorable geology.

Fig. 2 Oblique photography real scene model

2.1.5 Three-dimensional modeling results data of railway facilities

Including three-dimensional modeling results data of railway infrastructure such as stations, subgrade, bridges, tunnels and culverts. The commonly used three-dimensional model data formats are osgb, obj, 3dtiles, fbx and so on.

2.2 Geological data

Including regional geological map, geological mapping data, geological modeling results data and comprehensive geological survey results data.

2.2.1 Regional geological map

By collecting basic geological data such as regional geological map, structural outline map and hydrogeological map, the data format is generally dwg and jpg.

2.2.2 Geological mapping data

The purpose of engineering geological mapping is to provide true and accurate geological data for route scheme comparison, engineering geological evaluation of engineering construction site and engineering design. The contents of engineering geological mapping include stratum boundary, unfavorable geological boundary, fault, stratum lithology, geological structure, borehole information, etc.

2.2.3 Geological modeling data

The geological model is established based on the hierarchical structure of elements, which is composed of points, lines and planes and has accurate spatial coordinates of strata, faults, hydrogeological interfaces and exploration holes. All elements of the geological model need to be combined into a file, and the file format should be rvt, dae, obj, dgn and other general formats.

2.2.4 Comprehensive results data of geological survey

Including overview, general situation of natural geography, stratum, structure and earthquake, hydrogeological characteristics, engineering geological characteristics (unfavorable geology, special rock and soil, erosion evaluation, geological conditions and evaluation of major projects and suggestions on engineering measures), etc.

2.3 Dynamic monitoring data

Including layout data of geological disaster monitoring points and real-time monitoring data of geological disasters.

2.3.1 Monitoring and layout data of geological disaster points

Including design plan, section drawing, detail drawing, design description, project quantity table, monitoring and layout plan and section drawing of geological disaster point prevention and control engineering.

2.3.2 Real-time monitoring data of geological disasters

The monitoring content should include deformation monitoring information, including cracks, surface displacement, deep displacement, etc.; Physical field monitoring information, including stress, earth pressure, infrasound, etc.; Monitoring information of influencing factors, including rainfall, air temperature, soil temperature, etc.; Macroscopic phenomenon monitoring information, including video, mud level, radar, etc.

3. Unified expression of railway geological disaster risk information

Railway geological disaster data are heterogeneous in structure and semantics, so it is necessary to build a unified digital expression model of multi-source heterogeneous geological disaster risk elements for rapid access and effective management of multi-source heterogeneous data, which lays a foundation for integrated management and fusion analysis of multi-source heterogeneous disaster risk elements. This paper constructs a unified ontology-based digital expression model for railway geological disaster big data. Ontology is a descriptive tool that can effectively express concepts and relationships. By classifying and describing the concepts in the field of geological disasters, the temporal and spatial and semantic associations of elements in the field are defined, which makes the knowledge of geological disasters change to standardization [3].

The disaster data ontology model is expressed by triples:

$$O_D = \langle T, F \mid R\text{S} \rangle$$

Disaster data consists of three elements: type T (type), Feature F (Feature) and disaster scene relation RS.

Type: Data type marks data from a qualitative point of view, and each data set has multiple type labels: data can be summarized into the above-mentioned disaster risk factor data categories from the perspective of overall type; Divide the data into real-time data and historical data from the perspective of acquisition time; From the perspective of existence form, the data is divided into grids, vectors, texts, tables and so on.

Characteristics: The dominant characteristics and depth characteristics of disaster data are comprehensively listed from the aspects of time, space and attributes. Explicit features include coverage, date, temporal resolution and spatial resolution, etc. These features come from metadata description. Depth information is to obtain depth information after preliminary analysis and processing of data, such as slope height and slope extracted from DEM data, disaster range and disaster location extracted from remote sensing image data, etc. In order to manage metadata with structural and semantic differences uniformly, an extensible field mapping dictionary is established to unify field expression and solve semantic ambiguity such as "synonymy of different words" and "polysemy".

Disaster scenario relationship: Describes the relationship between data and disaster scenarios. This paper describes the correlation with disaster scene from two angles of type and temporal and spatial characteristics, and gives the qualitative and quantitative relationship distance, which provides the basis for disaster scene-oriented disaster data aggregation and fusion.

In order to build ontology model better, ontology editing tools are usually needed. Protege is a very popular free and open source ontology building tool at present. It provides a visual and interactive ontology development environment with the advantages of simple and quick operation rich plug-ins and modular design support. In this paper, Protege ontology modeling tool is used to build disaster data ontology model, as shown in Figure 3.

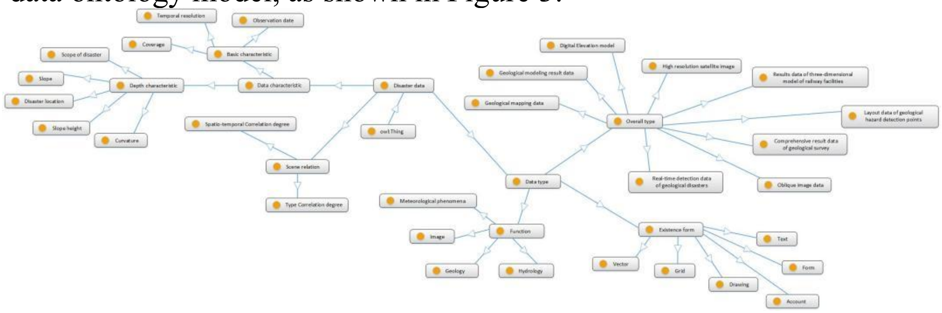


Fig. 3 Disaster data ontology modeling based on Protege

4. Standardized processing of railway geological disaster risk data

In order to analyze the evolution process of supergene geological disasters and enhance the visual expression of disaster scenes, it is necessary to study the semantic-level standardized processing method of disaster risk information, extract the semantic features of multi-factors of disasters, and form standard spatio-temporal data of railway geological disasters. Integrated processing of geographical and geological data, establishing a three-dimensional geographical and geological model of railway infrastructure; For remote sensing images, the characteristic information such as geological disaster scope and disaster location is extracted by means of remote sensing image interpretation; Gathering and accessing multi-source dynamic observation data, meteorological data and other supergene geological disaster monitoring data information.

4.1 Geographical and Geological Modeling of Infrastructure

4.1.1 Geographic modeling

There are many methods to make three-dimensional geographical model of railway facilities. This paper uses two-dimensional vector data and drawing file data which are easily obtained on railway to build three-dimensional geographical model by interpolation and transformation of two-dimensional vector data or drawing file, which provides three-dimensional modeling data source for visual display of geological disaster scene.

When using two-dimensional vector data interpolation transformation mode, first of all, the triangulation irregular network (TIN) model is established by using the top surface elevation data, and the representative Kriging interpolation algorithm [4] is used to interpolate the two-dimensional vector data, and a series of two-dimensional vector data elevation values are obtained to form the three-dimensional spatial elements of equipment and facilities. Kriging interpolation algorithm is based on the research results of geostatistics, taking regional transformation as the starting point, using covariance function and variance function as tools, and making unbiased estimation with minimum variance for regional variation in interpolation area. When the drawing file is made by equal ratio, the equipment and facilities in the drawing are made by equal ratio to form three-dimensional model data, and the three-dimensional data are stored in the model base, and then the unified storage and management of the data are realized through the model base. Finally, the three-dimensional spatial elements and three-dimensional model data are stretched, rotated, segmented, mapped and replaced, and the three-dimensional geographical model of railway facilities is constructed. In order to display the spatial information more intuitively, the image data and DEM data around the elements are superimposed with the equipment and facilities model, and finally the railway three-dimensional facilities scene is formed. The geographical modeling process of railway infrastructure is shown in the following figure.

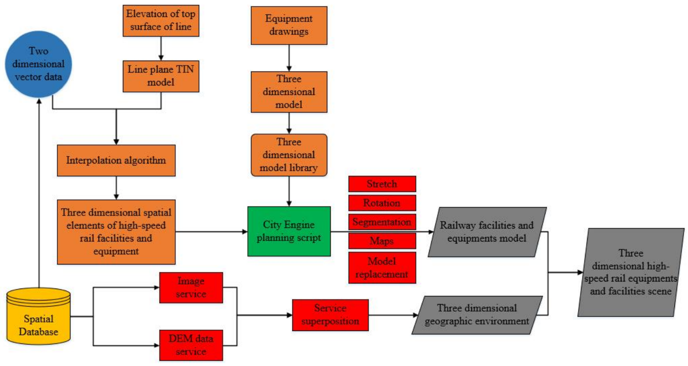


Fig. 4 Geographic modeling process of railway infrastructure

4.1.2 Geological modeling

Railway engineering geological exploration data are often discrete and rough. Firstly, projection transformation and data transformation are needed to collect railway multi-source engineering geological data, and then Kriging interpolation algorithm is used for spatial interpolation to obtain spatial coordinates and attribute values of points to be interpolated. Then the Delaunay triangulation algorithm is used to generate the digital elevation model (DEM) based on the triangulation irregular network (TIN), and then the railway infrastructure surface model is constructed, which can express the stratum morphology with different level resolutions. Triangulation Irregular Network (TIN) uses interconnected but non-intersecting and overlapping irregular triangles to simulate topographic relief, folds and unevenness in geological surfaces [5]. Through the infinite triangle subdivision to approximate the real stratum surface, to achieve the accurate expression of topographic structure, forming a nearly smooth stratum model. After generating the triangulation surface stratum model, Kriging interpolation algorithm is used to interpolate the triangulation network again, thus generating a new and finer triangulation surface model. Then, based on the surface Delaunay triangulation surface, the delaminated triangulation surface is built layer by layer according to the formation information of actual borehole and interpolated virtual borehole. Finally, the triangulation network of upper and lower geological interfaces in the same stratum is cut and stitched. When cutting, the intersection detection and elevation treatment are carried out on the DEM models of each layer. When stitching, a triangle in the triangulation surface of the stratum is taken as the starting point to judge whether it is the common boundary of the surface and establish the topological relationship. All triangles of the surfaces of each layer are traversed one by one to complete the stitching process, and finally the skeleton part of the geological model is formed. Finally, the middle essence of the curved surface model is filled, and finally the railway engineering geological body model is formed. The three-dimensional geological modeling process of railway infrastructure is shown in the following figure.

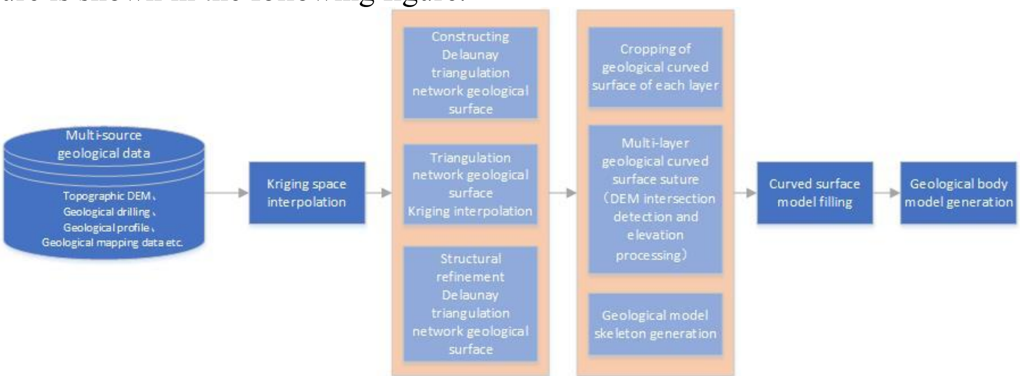


Fig. 5 Geological modeling process of railway infrastructure

4.2 Interpretation of Remote Sensing Images

Geological disaster scope refers to the intersection of geological disaster occurrence place and administrative area. The influence scope of disaster occurrence scene is extracted by multi-stage remote sensing image recognition, and the determination methods mainly include visual interpretation and automatic recognition [6]. Artificial visual interpretation needs to be assisted by remote sensing image interpretation mark database, through discriminant analysis of the differences in tone, shape and texture between disaster scene and its background environment, combined with the measured data on the ground, so as to determine the disaster impact range. Automatic recognition is to use computer technology to simulate artificial visual interpretation to recognize and classify image objects, which can be divided into two types: pixel-based classification and object-oriented classification. Pixel-based classification methods are generally used in low-and medium-resolution remote sensing image classification, including change detection, support vector machine and so on. Object-oriented classification is mainly used to extract information from high-resolution remote sensing and identify object information of specific disaster scenes [7]. In this paper, the object-oriented method is used to extract the information of geological disaster range and disaster location from remote sensing images.

Object-oriented recognition and extraction of post-disaster information in the study area. Firstly, the pre-processed post-disaster remote sensing image data and DEM elevation data are used to segment the image, and then the feature rule set is constructed to classify the segmented image. The disaster information recognition and extraction of post-earthquake image is realized by layer-by-layer classification of disaster feature rule set. The process of post-earthquake disaster information identification and extraction based on object-oriented classification technology is shown in the figure.

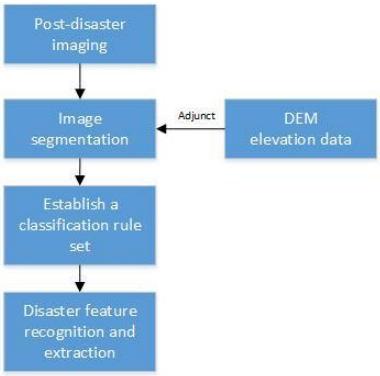


Fig. 6 Disaster feature extraction based on object-oriented classification

4.3 Dynamic Monitoring Data Access

Web Service interface can use common data format to exchange data in different systems in the form of service. Generally, according to the principle of "take on demand" [8], it is often used for structured data in established fields, and is suitable for scenes with high real-time data and small amount of data. Therefore, this paper uses WebService to access data periodically, analyze the data, and import it into the database for storage after preliminary treatment.

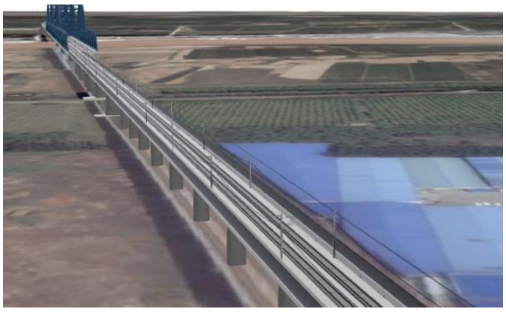
Table 1. Specific contents of multi-source dynamic monitoring data

Data content	Data description	Interface description	Data format
Meteorological monitoring	1. Obtain relevant information of meteorological monitoring sites and longitude and latitude data; 2. Obtain weather conditions, including time, temperature, relative humidity, wind speed, rainfall, snowfall and other data.	Meteorological monitoring data records provide data queried according to meteorological monitoring points, monitoring equipment codes and time periods.	json
Earthquake monitoring	Obtain earthquake early warning information, which is divided into earthquake quick report and common early warning information, including longitude and latitude position, time, earthquake grade, focal depth and other data.	Earthquake early warning data records provide data queried according to earthquake early warning sites and time periods.	json
Beidou displacement deformation monitoring	Obtain relevant information of Beidou monitoring site, longitude and latitude, monitoring equipment data, etc.; Based on Beidou high-precision positioning service, the monitoring data of workpoint displacement and deformation, including its displacement in vertical and horizontal directions, are obtained.	Beidou displacement and deformation monitoring data record provides data queried according to Beidou monitoring points, monitoring equipment codes and time periods.	json

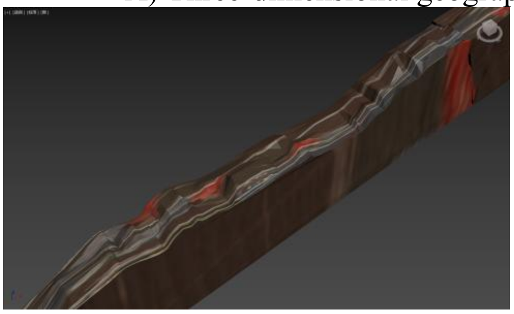
Multi-source dynamic monitoring data comes from various types, models and batches of monitoring sensors and business systems built in multiple periods and uses. Web Service interface can use common data format to exchange data in different systems in the form of service. Generally, according to the principle of "take on demand" [8], it is often used for structured data in established fields, and is suitable for scenes with high real-time data and small amount of data. Therefore, this study uses WebService to access the data interface periodically, return json data, parse the json data, and import it into the database for storage after preliminary processing. The following table shows the specific contents of dynamic monitoring access data. The accessed monitoring data is stored in Mysql database.

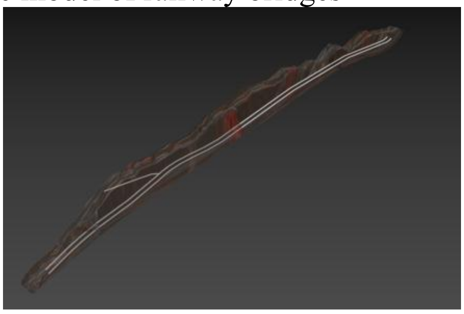
5. Test and analysis

In order to verify the effectiveness of standardized processing of geological hazard data proposed in this paper, a certain research area is selected to process railway geography and geological modeling data and remote sensing image data. Based on City Engine modeling software, the three-dimensional geographical model of railway bridge is constructed by means of equal ratio of drawing files, as shown in Figure 7 (A). According to the railway three-dimensional geological modeling process, the geological models of railway surrounding topography and railway tunnel in the study area are constructed. It can be seen that the internal layers of the geological model are distinct, which can better restore the geological lithology information of the outer layer of the tunnel and lay the foundation of geographical and geological scenes for enhancing the visual expression of geological disaster scenes, as shown in Figures 7b) and c). Using object-oriented remote sensing image interpretation method, aiming at the geological disasters in the study area, the information such as geological disaster scope and disaster location are effectively extracted, and the disaster scope is represented by yellow coverage, as shown in Figure 8. In addition, according to the digital elevation model (DEM), the characteristic information such as slope, slope height and curvature is accurately extracted, which provides disaster multi-factor characteristics for hidden danger analysis of geological disaster scenes.



A) Three-dimensional geographic model of railway bridges





b) Railway topographic and geological model; c) Geological model of railway tunnel

Fig. 7 Three-dimensional geographical and geological model of railway

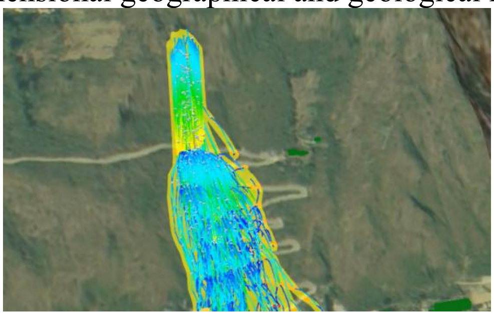


Fig. 8 Identification and extraction results of geological disaster range

6. Conclusion

There are many kinds of data of railway geological supergene disaster risk elements, scattered storage, multi-source heterogeneity, which make it difficult to unify and effectively integrate management and fusion analysis. At the same time, it faces some problems such as unclear disaster risk characteristics, unclear disaster evolution scenarios and inaccurate disaster assessment. Based on this, this paper puts forward a unified expression and standardized processing method of railway supergene disaster risk data, which realizes the unified expression of multi-modal disaster risk element data, realizes three-dimensional modeling of railway geography and geology, feature extraction of remote sensing image and access of multi-source dynamic monitoring data, provides key data for railway geological disaster scene analysis and enhanced visual expression, and then provides scientific and effective analysis and decision-making basis for railway engineering implementation such as disaster prevention and mitigation, emergency rescue, etc., and supports railway safety construction and operation.

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