DEVELOPMENT AND APPLICATION OF A SMART EMERGENCY RESPONSE PLATFROM FOR EARTHQUAKE DISASTERS BASED ON MULTI-SOURCE MONITORING DATA

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ABSTRACT: Because of the characteristics of the strong suddenness of disasters, many secondary disasters, and high requirements for response timeliness, the development of integrated disaster monitoring with space-air-ground (SAG) multi-source data is a key scientific issue to deal with natural disasters and ensure the safety of people's lives and properties. However, the existing technical methods of emergency response information extraction and collaborative monitoring and evaluation are slightly weak, and the application service capability needs to be improved. Based on the formation mechanism and evolution law of earthquake disasters, this paper studies the SAG multi-source collaborative monitoring method. Using multi-source data, we not constructed the algorithm model of disaster evolution process simulation and risk dynamic assessment, but realized rapid disaster emergency assessment and intelligent emergency decision-making. At the same time, it has developed an integrated platform for earthquake disaster monitoring and smart spatial information services, which realizes the integrated expression of elements such as rapid access to multi-source spatiotemporal information, smart service models, and disaster monitoring information. We provide a task-driven software-hardware cooperative service application. In this way, the emergency response capability of regional earthquake disasters can be improved, the development of disaster prevention, mitigation, and relief emergency industries can be accelerated, and scientific and technological support can be provided, which ensures national development.

KEY WORDS: Earthquake disaster, Intelligent emergency, Collaborative monitoring, Platform development, Space-air-ground data.

1. INTRODUCTION

1.1 Research Backgrounds

In December 2021, the "14th Five-Year Plan for National Emergency Response System" pointed out that disaster prevention, mitigation and relief work should be done well, and the modernization of emergency. Since the beginning of the 21st century, earthquakes and geological disasters have occurred frequently, seriously threatening the safety of people's lives and property. Compared with the "12th Five-Year Plan" period, during the "13th Five-Year Plan" period, the number of deaths and missing persons due to natural disasters, the number of collapsed houses and the proportion of direct economic losses in the gross domestic product (GDP) decreased by 37.6%, 70.8% and 38.9% respectively. During the "14th Five-Year Plan" period, China's development is still in a period of important strategic opportunities, which also provides a major opportunity to solve the long-standing outstanding problems in disaster emergency management and to promote the modernization of emergency management systems and capabilities [①,②]. But at the same time, it should be noted that China is one of the countries with the most serious natural disasters in the world. There are many types of disasters, wide distribution, high frequency and heavy losses. Safety production is still in the period of climbing and crossing the threshold, and various safety risks and hidden dangers are intertwined and superimposed. Production safety accidents are still prone to occur frequently.

Fortunately, with the rapid development of earth observation technology and the emergence of new technologies such as Cloud Computing, Internet of Things, Big Data, and Smart Cities, multiple observation methods are playing an increasingly important role in the monitoring and assessment of earthquake and geological hazards. If we want to achieve rapid monitoring, accurate assessment and efficient decision-making of emergency response to earthquake, geological and natural disasters, it is urgent to realize the integration and efficient application of technical methods for integrated SAG coordinated monitoring (DeVries et al., 2020; Xu et al., 2019). At the same time, it is encouraged to develop a three-

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① Gazette of the State Council of the People's Republic of China, 2022: "14th Five-Year" National Emergency System Planning, (6). http://www.gov.cn/gongbao/content/2022/content_5675949.htm.

② Bulletin of the Gansu Provincial People's Government, 2021: Gansu Province "14th Five-Year" Emergency Management System Construction Plan. (112). http://www.gansu.gov.cn/art/c103795/2022/682/202203/1982165.shtml.

dimensional rapid emergency response capability for natural disasters from the surface to the near-Earth space. In this way, it can provide guarantee for national security and the implementation of major national strategies (Lorincz et al., 2004; Pei et al., 2012; Abdalla and Esmail, 2018; Feng and Cui, 2021; Du et al., 2022). At present, China has initially established the following service systems: First, space infrastructure represented by terrestrial, meteorological and marine satellites. Second, aerial remote sensing platforms represented by manned aircraft and unmanned aerial vehicles (UAV). Third, the ground monitoring network represented by earthquake research. In addition, the era of big data artificial intelligence has arrived. It is also pointed out in the research on the social application and intelligent processing of Spatio-temporal Big Data (STBD). We need to use surveying and mapping, remote sensing and geographic information technology. In other research, we should carry out intelligent processing and mining of STBD. To maximize its integration into social applications (Li, 2016).

The study pointed out that STBD should be linked by time and space. It can integrate urban multi-source data to realize the convergence, integration, interconnection and sharing of spatio-temporal data. In this way, it has the capabilities of spatio-temporal analysis and dynamic visualization. If so, in the ubiquitous STBD. The data of surveying and mapping results will be relied on by all walks of life because of the spatial nature of the data. Its dependencies are also increasing (Li, 2017; Zhu and Fu, 2017). As the basis of urban development, surveying and mapping data can provide services for urban management departments according to its unique information characteristics. In order to solve the problem of electronic, informatization and sharing of surveying and mapping results data and natural disaster monitoring. The standardization, storage management, sharing, data utilization and updating of the surveying and mapping results data we have established coexist. At the same time, it is very meaningful to use the thematic map to strengthen the information service system network cloud platform of ecological environmental protection policies and measures.

1.2 Research Purpose

It is comprehensively found that there are major needs for emergency response decision-making such as emergency rescue, emergency rescue and disaster relief for earthquake disasters and disaster chains. To this end, our research includes establishing a monitoring method and application system driven by the disaster event process. It is used to break through the technical bottleneck of intelligent emergency response such as integrated SAG integrated monitoring and evaluation of earthquake disasters, and realize accurate extraction of disaster information. It is possible to study the production technology of earthquake disaster emergency products in complex disaster-pregnant environment, and promote its effective application in different decision-making stages (Li et al., 2021). Finally, in order to realize the integrated application capability of multiple heterogeneous information services, a smart spatial information service platform can be built (Abdalla and Esmail, 2018).

At the same time, an integrated governance system of "Space, Air and Ground" has been formed, which is "watching from the sky, shooting in the air, and inspecting on the ground". On the one hand, with the spatial information service driven by the earthquake disaster task as the core, a disaster emergency system is constructed to solve the problem of resource integration and collaborative service. On the other hand, carry out research on collaborative services for earthquake disaster monitoring and emergency response. Ultimately, through the research results, we will strive to provide scientific and technological support for the protection of national security and development, so as to improve the emergency response capability of regional earthquake disasters.

2. RESEARCH CONTENT

2.1 Emergency Response Method

We study the SAG collaborative emergency monitoring method for the evolution process of the disaster chain. At the same time, an emergency assessment and dynamic decision support route based on multi-source heterogeneous data is also constructed. A spatial sampling acquisition method for UAV emergency monitoring is formed. The construction of disaster target features based on imaging mechanism and the rapid extraction method of disaster elements are used in the collaborative emergency production of SAG data of disaster information products in complex disaster-pregnant environments.

2.1.1 SAG Joint Scheduling and Collaborative Observation Technology Method for Disaster Emergency Response

It is necessary to combine the information obtained at the first time after the disaster and the dynamic simulation results of the evolution of the disaster chain (Shao et al., 2016). In order to achieve rapid coverage of disaster areas, we need the following information when building an air-space-ground collaborative monitoring resource planning system: multi-satellite collaboration, aerospace and UAV collaboration, multi-space-time resolution combination, multi-sensor, etc.

2.1.2 Spatial Sampling Acquisition Method for UAV Emergency Monitoring

In response to the decision-making requirements of emergency command, the following limitations need to be overcome in the research on spatial sampling methods for UAV emergency monitoring in disaster-stricken areas: First, the on-site spatial scope, satellite and aerial remote sensing cannot effectively cover the disaster area. Second, disaster targets need to focus on high-precision observations. Third, the disaster mechanism and other information. According to this model, it can effectively support the collection of monitoring disaster information and disaster assessment of sampling points, so as to make emergency disaster reduction decisions timely.

2.1.3 Disaster Target Feature Construction and Rapid Extraction Method of Disaster Situation Elements

In this research, we combined the SAG collaborative monitoring resources to carry out remote sensing feature analysis of core disaster targets for emergency response and rescue decision-making. In this way, a feature dimension space that fully expresses the disaster target can be formed. Finally, organize and build a systematic disaster target feature library. On this basis, various feature recognition algorithms are closely combined with technical means such as machine learning (Almalki and Angelides, 2020). Furthermore, prior knowledge and data assimilation methods are incorporated. This can improve the monitoring efficiency of disaster elements and provide information support for emergency decision-making.

2.1.4 Manufacturing Methods of Emergency Products for Disaster Information of Different Levels

We focus on the dynamic decision-making needs of disaster emergency response. The research on the emergency production method of disaster information products for collaborative monitoring of SAG data under the background of complex disaster-pregnant environment is carried out (Wang et al., 2011). It is equivalent to studying the technical methods of rapid integration, aggregation and expression of multi-type background information and field information, including: integrating disaster area images, combining disaster brief information, historical data and long-term regional land surface ecological environment remote sensing products.

2.1.5 A collaborative assessment method for earthquakes and their secondary geological hazards

Research on the collaborative assessment technology of earthquakes and their secondary geological disasters can realize the rapid dynamic assessment of earthquake impact fields and earthquake disasters (Shi and Yuan, 2014; Shan et al., 2019; Wu et al., 2020). Therefore, we need to integrate the following information into the rapid detection results of earthquakes and their secondary geological disasters by integrating air-space monitoring data, earthquake dynamics, space-time distribution of aftershocks, focal mechanism solutions, earthquake rupture inversion, and earthquake scene quickly produced by seismic network observations. The typical disaster-bearing body types and damage information obtained from the emergency sampling survey, as well as the topographic, geographic and socio-economic data and other space and ground information, are based on multi-factor impact risk assessment technology. On this basis, we can realize the system design of the collaborative evaluation software module (Table 1) and the underlying construction of the platform (Figure 1).

Item	Method	Earthquake			
		Region	Intensity	Casualties	Etc.
Report Disaster Information	Situation Analysis				
Monitoring Evaluation	Space Stacking Population Density Contextual Analysis				
Vulnerability Assessment	Seismic Damage Estimation Method for Structural Vulnerability Update Update Method of Monitoring Data Vulnerability Matrix Damage Assessment of Vulnerability Matrix				
Comprehensive Disaster Information	Composite Index				
Disaster on Site	Sample Survey				
Deduction of Historical Disasters	Related to Historical Disasters				

Table 1. Evaluation model of earthquake disaster.

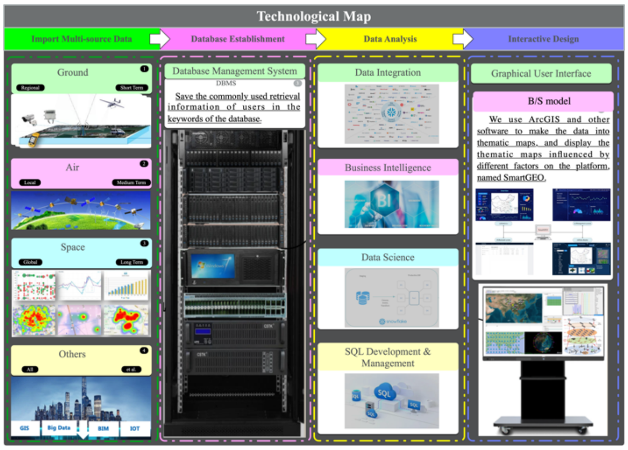

Figure 1. Research and application of platform.

2.2 Software development process of emergency platform

Based on cloud computing architecture and big data technology, combined with monitoring data required for disaster emergency monitoring and decision-making resources for disaster monitoring anomaly detection, evaluation and early warning. Research the data model and organizational mechanism of emergency spatiotemporal information resources and the description model of disaster tasks, and construct a comprehensive expression of spatial information such as disaster relief monitoring spatial data, disaster situation judgment and emergency rescue (Sharma et al., 2022). According to the semantic analysis of emergency response tasks, a disaster task combination model is constructed to quantitatively describe the data characteristics of abnormal events of disaster information elements. In addition, we also use machine learning theory, research tasks and spatio-temporal information resource mapping models to drive on-demand aggregation of different resources and active services to improve the speed of emergency response at different stages of disasters. On this basis, the rapid access of emergency information, real-time interaction method and dynamic focus service mode of multi-source spatio-temporal information at different stages in the disaster chain are studied, and a service chain management engine is designed to realize the coordinated processing of multi-source spatiotemporal information.

At the same time as we develop disaster emergency monitoring and intelligent space information service platform. We analysis the hierarchical relationship between disaster emergency monitoring and service systems, the basic process of system task execution and the logical relationship between functional modules. By studying the function and module division of the disaster monitoring and spatial information service integration platform, integrating general models and disaster emergency business models such as earthquake disaster information extraction and analysis, and designing service interfaces and interoperability methods. In addition, it is the unified encapsulation of atomic services of various models, which realizes the rapid integration of common models and the integrated integration of different models, and supports plug-and-play of different functional modules. For earthquake disaster emergency response business, we realize the dynamic combination of disaster emergency response business chain, and support parallel processing and collaborative services for disaster information extraction, analysis and decision-making. Finally, on the basis of data and model integration, this research sssearch and management, which can provide platform support for typical demonstration applications.

This platform aims to meet the planning needs of earthquake disaster collaborative monitoring and intelligent emergency response. The content includes: the architecture, function, interface and database of the design system. It generates data and models for seismic hazards. At the same time, it also provides the ability of secondary development, and integrates the platform for unified code management. We also use software testing sessions to improve the software (Figure 2).

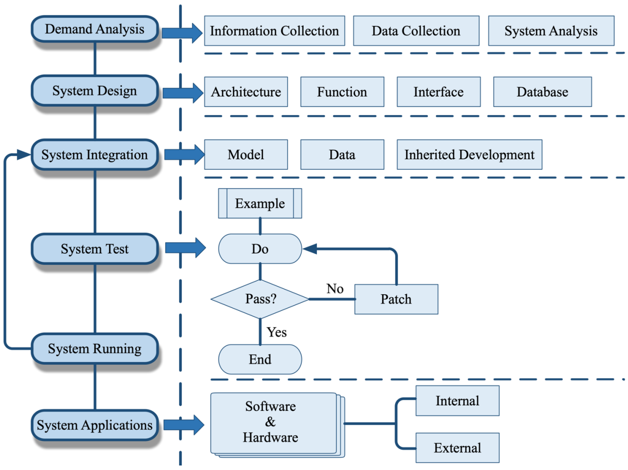

Figure 2. Flowchart of research and development.

The feasibility of platform development is shown in Figure 2. Platform development is mainly divided into six stages:

a. The stage of demand research and analysis, that is, to clarify the main problems and construction goals to be solved by the platform. We collected relevant information such as data and model algorithms, etc., and compiled a demand analysis report.

b. The stage of platform design: design the overall basic framework for the underlying development platform for disaster information acquisition, disaster analysis, disaster assessment, disaster relief decision-making and other disaster services. In the research, we built a platform architecture based on core technologies such as spatial database, high-performance computing, disaster model, and multi-dimensional visualization for platform integration.

c. The stage of platform research and development integration: According to the platform design scheme, the platform is developed with a unified development environment and a unified code management mechanism for disaster emergency applications.

d. The stage of platform testing: the system can be optimized and adjusted according to the test results.

e. The stage of platform trial operation: After the test is passed, the platform goes online for trial operation. It can be continuously updated and improved according to the feedback problems.

Figure 3. Platform logo.

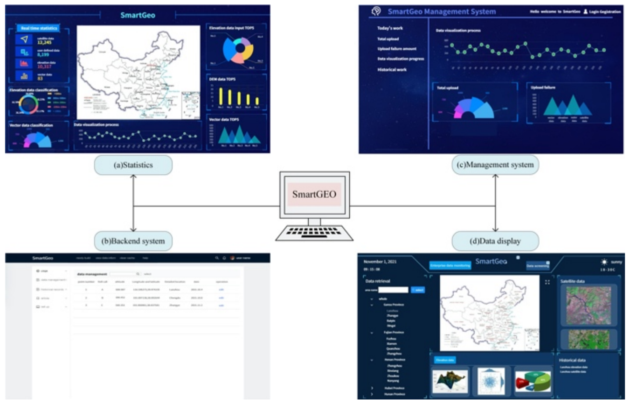

Figure 4. The interface of the platform.

The main purpose of developing this mode is to display the static data based on the Android mode and the C/S mode, and strive to display the potential value of the data in a dynamic form. Maps are one of the mediums of information exchange (Li et al., 2019). We use ArcGIS and other software to make the data into thematic maps, and display the thematic maps influenced by different factors on the platform, named SmartGeo (Figure 4) (Li et al., 2022). Figure 4(a) shows the surveying and mapping data through different forms of charts to extract hidden information; Figure 4(b) is the back-end management system that controls the display of front-end data, enabling real-time update of surveying and mapping results; Figure 4(c) It is the standardized management of data, which improves the standardization and sharing of surveying and mapping results data, and makes data storage and management more convenient; In Figure 4(d), a network platform is built to provide a display space for geographic information products.

3. RESULT

In the process of research and development of earthquake disaster emergency monitoring and intelligent space information service platform. We study the rapid access, real-time interaction technology and dynamic focus service mode of multi-source spatio-temporal information in different stages of the disaster evolution process, investigate the needs of disaster monitoring and emergency response planning, and form technical methods and integrated platform applications. Based on existing data and model methods, develop collaborative monitoring and rapid assessment of earthquake disasters, and form new method models. At the same time, the coordinated monitoring of earthquake and geological disasters and the integration of multiple elements of emergency response are realized. Finally, we have built a software platform for earthquake disaster monitoring and spatial information service to form data acquisition, processing and intelligent information service capabilities. Subsequently, regional application promotion was carried out in the research, which can provide decision support services for relevant departments and institutions.

The "Highlights" of this platform are reflected in the following three aspects: (i) Full-time, real-time perception. (ii) Full cycle, real-time monitoring. (iii) Real-time evaluation of all elements. Therefore, it is one of the important goals of the platform to realize the intelligent emergency evaluation of all elements of earthquake disasters. Here, we have established an intelligent iterative system of "perception-physical examination-assessment-warning-update", which is the "Smart" of the new intelligent emergency platform.

3.1 SAG collaborative emergency monitoring methods in the process of disaster evolution

In the case of incomplete satellite data, we scientifically design and carry out UAV sampling monitoring, high-precision repeated monitoring and rapid extraction of disaster information in hard-hit and sensitive areas around the specific requirements of on-site information for emergency command, rescue and search and rescue decision-making. In this way, the effective application of disaster monitoring products in different emergency decision-making stages can be guaranteed.

In addition, we also found that the regional disaster-pregnant environment is the earth's surface anomaly system composed of disaster-pregnant environment, disaster-causing factors and disaster-bearing bodies. In the research, if we can fully understand the occurrence, development and evolution mechanism of earthquake geological disasters, we can understand the hazard of disaster-causing factors, the stability of disaster-pregnant environment and the vulnerability of disaster-bearing bodies. In this way, a better monitoring and evaluation model of earthquake and geological hazards can be constructed.

We also propose two feasible research options:

a. Research on disaster evolution simulation for disaster process and disaster-causing mechanism. We can make comprehensive use of multi-source collaborative observation data such as space-based, space-based and ground-based to analysis the disaster-causing process and mechanism of disasters. In terms of methods, we can use mathematical model, dynamic simulation, empirical statistics, etc., which can be used to build a disaster process simulation model for earthquake disasters.

b. Research on dynamic risk assessment methods in the process of disaster evolution. On the basis of disaster process model, we can analysis and simulate the evolution process of the disaster-causing factors of earthquake and geological disasters. In this way, it is possible to simulate the evolution process of earthquake disasters, or to comprehensively study the dynamic assessment of risk.

In addition, it is necessary to recognize the formation process of secondary disasters caused by earthquake and geological disasters with the thinking of disaster chain, so as to realize the simulation of the disaster-causing process and the dynamic risk assessment of the earthquake and geological disaster chain. This research is based on the theory of disaster system, and we analysis the mechanism of disaster formation and the evolution law of disaster chain. It is integrated into the "theory-method-technology-application" system of emergency response to earthquake and geological disasters, which is an important scientific issue in disaster emergency response.

3.2 Development of an integrated platform for earthquake disaster smart information services

Earthquake disasters are characterized by sudden and dynamic changes. Therefore, extremely strong timeliness is required. This means that when carrying out disaster rescue and relief, it is necessary to mobilize air-space-earth observation resources within an effective time to obtain monitoring data quickly and continuously. At the same time, in terms of monitoring technology, in order to quickly identify the affected areas and objects, a mature and stable target identification method is required.

The smart emergency platform has the following capabilities: spatial interconnection; real-time observation; virtual and real compatibility. In addition, the platform can simulate and synchronize the real-time earthquake disaster information in various ways, and the monitoring model and evaluation model can be used as the carrier for the aggregation, analysis and presentation of multi-source monitoring data. Finally, the research has formed an emergency monitoring and management system that is synchronized with entity information.

4. CONCLUSION

4.1 The SAG collaborative emergency monitoring method is feasible in the evolution of earthquake disasters

This research focuses on dynamic decision-making needs such as earthquake disasters and disaster emergency response. At the same time, the technical method of spatial sampling for emergency monitoring is studied, which can be used to ensure the timeliness of emergency decision-making. This is mainly based on the characteristics of on-site information demand for emergency decision-making. To briefly summarize, the research covers the following points: (i) Collaborative planning of SAG monitoring resources for earthquake emergency tasks. (ii) Acquisition of emergency monitoring spatial sampling for multi-source data in earthquake areas. (iii) Analysis and extraction of disaster-pregnant factors of earthquake disasters.

4.2 The earthquake disaster smart emergency response platform has effective applicability

The construction of the air-space-ground integrated monitoring and emergency platform involves: the application level; the architectural level and the technical level. SmartGeo is based on visualization, Cloud Computing and Deep Learning technology system. Its compatibility and integration capabilities provide a foundation and guarantee for emergency monitoring of earthquake disasters. The service capacity of disaster emergency monitoring, evaluation and decision support has also been improved. It may be a good service tool for intelligent emergency response to earthquake disasters.

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