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Remote Sensing Applications in Monitoring, Assessment and Decision Support for Disaster Emergency

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Abstract. Remote sensing technology has become a core method in modern disaster emergency management because of its wide coverage, rapid response capability, and objective observation advantages. This paper systematically reviews the key role of remote sensing throughout the monitoring–assessment–decision support chain in disaster emergency response. In disaster monitoring, remote sensing has gradually shifted from single post-disaster observation to integrated space-air-ground collaborative observation, supporting multi-disaster, dynamic, and continuous early warning. In disaster assessment, artificial intelligence and image interpretation algorithms have promoted the transformation from traditional manual visual interpretation to automated and quantitative intelligent assessment, improving the efficiency and accuracy of disaster loss evaluation. In decision support, remote sensing products have evolved from basic situation maps into intelligent decision-making tools embedded in emergency command systems, providing spatial evidence for rescue deployment, risk zoning, and resource allocation. This paper further compares the characteristics, advantages, and limitations of optical, Synthetic Aperture Radar, and thermal infrared remote sensing. Finally, it discusses current challenges in multi-source data collaboration, model generalisation, real-time processing, and operational integration, and proposes future directions for more intelligent disaster emergency applications.

Keywords: Disaster emergency response, Remote sensing technology, Disaster monitoring, Disaster assessment, Decision support

1. Introduction

Global climate change and urbanisation are both advancing. Together, they put huge pressure on traditional disaster management. Earthquakes, floods, and other natural disasters are becoming more frequent. The traditional emergency response system faces problems, including delayed responses, insufficient information, and an inadequate decision-making basis, which easily lead to mismatches in rescue resources, missed golden 72-hour optimal rescue window, and exacerbation of personnel casualties and property losses. How to quickly obtain accurate information in complex, dynamic disaster scenarios has become a core problem in modern emergency management.

The introduction of remote sensing technology provides a systematic solution to the above problems. Relying on its unique advantages of wide-area coverage, rapid response and objective

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observation, remote sensing can obtain spatial information of the disaster area immediately after its occurrence, supporting the transformation of emergency command from passive response to active perception. As a type of spatial information infrastructure, remote sensing can not only break the spatial limitations of ground-based observations but also serve as a smart eye for decision-making, connecting disaster-stricken areas with the command centre under extreme conditions such as interrupted communication and paralysed transportation [1, 2].

The application of remote sensing technology in disaster management has undergone an evolving process of deepening. In the early stages, it relied primarily on a single satellite platform for post-disaster image acquisition and visual interpretation, with relatively limited functionality. With the development of technologies such as Interferometric Synthetic Aperture Radar (InSAR), high-resolution optical satellites and unmanned aerial vehicles, remote sensing has gradually extended to the full cycle of prevention - preparation - response - recovery, forming an integrated air-ground monitoring system [3, 4]. In recent years, the integration of artificial intelligence and big data has further promoted the automation and intellectualisation of disaster information extraction, and remote sensing is evolving from an auxiliary tool to a core supporting means for emergency response [5, 6].

2. Working principle of remote sensing technology and its application in disaster emergency

Remote sensing obtains information from electromagnetic waves emitted or reflected by objects on the Earth's surface without direct contact. Different objects have different spectral fingerprints because of their material composition and surface structure. For example, healthy vegetation strongly reflects near-infrared light and absorbs red light, while water absorbs near-infrared radiation. Damaged and undamaged buildings also show different radar backscatter characteristics. By capturing these differences, remote sensing sensors can help identify disaster locations, assess damage severity, and monitor disaster development.

Three major types of remote sensing are commonly used in disaster response. Optical remote sensing uses visible and near-infrared bands and provides images that are easy to interpret. High-resolution satellites such as Gaofen-2 and Ziyuan-3 can identify collapsed buildings, damaged roads, and landslide boundaries, but optical images are limited by clouds, rain, and night conditions. Synthetic Aperture Radar (SAR) actively emits microwave signals and can work day and night in almost all weather. InSAR can further detect millimetre-level ground deformation, making it useful for monitoring landslides, earthquake faults, and subsidence. However, SAR images are more difficult to interpret. Thermal infrared remote sensing detects surface temperature changes and is useful for fire monitoring, volcanic activity, and thermal anomalies, though its spatial resolution is usually low. Therefore, multi-source fusion is often needed for more reliable disaster assessment.

3. Dynamic disaster monitoring: from post-disaster observation to collaborative early warning

3.1. Working modes of remote sensing technology in dynamic disaster monitoring

Disaster monitoring is the start of the emergency response, and this paper is the first to learn about the disaster. Given the development of this area so far, it can be concluded that there has been a change. This paper has only observed the damage in the past. This paper will focus on early warning at all times during the disaster now. Now, this paper does not have a single platform but uses many systems in conjunction. At present, the whole technical system of disaster monitoring based on remote sensing has been established.

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Now, the three-dimensional observation network for disaster monitoring at the platform level is composed of Space, Air and Ground. The high-temporal-resolution satellite constellation in China, for instance, the Gaofen series and Fengyun satellites, can observe the same area of the world multiple times a day or even several times an hour. Therefore, this paper will address the problems of rapid development promptly. SAR Satellites are Active Microwave Imagers. They will not be able to get pictures of the disaster area in bad weather. Therefore, now people are hired to monitor floods and earthquakes in real time for emergency management [4]. Drones and Aircraft are Mobile and Flexible Backups. They will be able to get to the damaged areas quickly after the disaster. They can take high-resolution pictures and build a 3D model of it at the centimetre level. It will meet people's desire to watch the little world in high definition [7]. Ground-based radars and Mobile Survey Systems are relatively new. They can help us feel what is happening on the surface more directly.

When it comes to monitoring methods, dynamic tracking relies on comparing images taken at different times. By aligning images from before and after a disaster and identifying changes, this paper can measure how the landscape has evolved. For example, this paper can see floodwaters spreading, landslides, or buildings going from standing to collapsed. For slow-moving disasters, InSAR analyses phase differences across multiple SAR images. This allows us to detect surface movement down to the millimetre. It is widely used to spot landslides early and track land subsidence over time [3].

The other places where the data come from are generally stable. Optical Images are relatively easy to see and understand. SAR images are not affected by bad weather and can still work. The other is low temperature. The three together will support and correct one another. Remote sensing data and field observations of the climate, water resources, geology, etc. It can help us build a numerical model of the process of a disaster. Then this paper can simulate and predict the path of the flood, the flow direction of the landslide, or how the fire will spread [2].

Usually, the method of dynamic monitoring is as follows: First of all, if there is an emergency, tasks will be issued and distributed among the satellites. Fast Data Processing and Normalisation. Next is the extraction of modifications. Update Maps and Products for Different Purposes Next. Finally, forward the new disaster information to the emergency command centre. It will continue to provide the basis of the above supervision and decision-making.

A New Complex System has also been formed. The main problem is how to build an all-encompassing and intelligent early warning system that collects data from all sectors of society at various stages [8]. If there is a serious accident that cuts off communication and electricity, this paper still needs to be able to gather and transmit the relevant monitoring data on time. This paper needs to solve the corresponding technical and engineering problems in practice.

3.2. Case study: UAV-based dynamic monitoring in the Bulgarian flood

In September 2023, the city of Tsarevo on the Black Sea coast of Bulgaria experienced extreme rainfall. This led to severe flooding. Multiple infrastructure facilities were damaged. Communications and traffic were disrupted. In this emergency response, UAV remote sensing played a key role [7]. It vividly demonstrated the dynamic monitoring concept described in this chapter.

Recently, more people have begun using DJI Matrice-series multirotor UAVs. Put the visible-light camera and the thermal-infrared sensor in place. The Flying height will be between 100 m and 200 m. An orthomosaic of 5cm or smaller ground resolution has been acquired by means of UAVs. An Oblique Shot is taken to obtain the 3D point cloud data. A thermal-infrared sensor is used to find

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the area of the low-temperature anomaly caused by standing water. Therefore, there will be no floodwater. All the data sources are, in fact, the monitoring methods listed above.

First of all, the raw images obtained by the UAV in the dynamic monitoring workflow are quickly stitched and geometrically corrected with Pix4Dmapper. An orthophotogrammetry image and a Digital Surface Model (DSM) of the flooded area were obtained. Thermal infrared data were obtained and overlaid on the orthophoto. There were some low-temperature, waterlogged places. Narrow the Scope of Flooding further. All of the processing work was done in six hours after the disaster. The first edition of the flood situation map has been released. It can be seen from the first two that there is dynamic monitoring, rapid response and continuous updating.

4. Accurate disaster assessment: from visual interpretation to intelligent quantification

4.1. Workflow of remote sensing technology in accurate disaster assessment

The first time remote sensing data was used after a disaster was to estimate the damage. It should be able to identify the amount of damage in a large number of disaster pictures quickly and accurately. With the development of artificial intelligence and big data in recent years, research has also changed rapidly. At present, the evaluation mode is being updated to be more automated, and artificial intelligence data processing and deep learning algorithms have begun to be applied [5].

First of all, the data for assessment work need to be obtained from many places in remote sensing. A space satellite will send us all-weather pictures of the disaster. Medium- and High-Resolution Optical Images are used to find damage in its early stages. High-resolution optical images of 1 metre or more can be acquired to see particular damage in a single building or road obstruction. SAR satellites can be used in bad weather too. A change in backscatter coefficient is caused by changes in the structure of the surface, and therefore can be used to identify floodwater and building collapse. UAV-based aerial remote sensing can obtain centimetre-scale images and 3D point clouds to assist in the high-precision analysis of important areas in the city [9]. Historically, the image archive before the disaster is used as the reference for change detection. The following are the preprocessing steps: Geometric Registration and Radiometric Normalisation.

At the methodological level, semantic segmentation and object detection based on deep learning have become mainstream tools for automatically extracting disaster damage elements from remote sensing imagery. Convolutional neural networks (such as U-Net, DeepLabV3+, and Mask R-CNN) are trained on large-scale labelled samples. They can perform pixel-level tasks, including building collapse identification, road damage detection, and water body segmentation [10]. A Change Detection Network is fed two images. A probability map of the changed region can also be exported. Therefore, it will be faster to grade. Some places that have undergone such changes are used as the subjects of these studies. Get some optical spectra. SAR imagery can be collected in all weather. Thermal Infrared Data Show Temperature Anomaly Fields. The three sources of data are in agreement and consistent with one another in this case. Based on the remote sensing images, combine the areas with physical damage and socio-economic data with social media data to carry out an all-round assessment of the impact of the disaster on society and the economy [11]. According to the oblique photographs and LiDAR data from UAVs, some high-precision 3D models have been created for analysis. The above are the calculations of landslide volume, simulation of flood depth and estimation of building volume loss. Time-series Remote Sensing Technology Analysis of Multiple Post-Disaster Images. This provides a good basis for the continuing supervision of the recovery and reconstruction work [12].

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After the above processing, remote sensing data at the product level have finally been converted into standard assessment products for emergency decision-making. Rapid assessment products are maps showing the extent of the disaster, statistics on the area of inundation and preliminary counts of damaged buildings; detailed assessment products are maps of building damage classification, road accessibility maps and landslide accumulation volume estimates; dynamic assessment products are those that show changes in the disaster and recovery progress [9]. The above types of products are generally available in the form of themed maps, statistics sheets and 3D scenes. They are sent to all the emergency command centres in the country via a cloud service.

Although the development speed of intelligent assessment technology has been high, it is not yet fully mature or widely applied. The first problem is model generalisation. A good model trained on data from a certain area will have a relatively low recognition rate in a new disaster area because the landform and buildings are different. Second, given the very high cost of sample annotation for a small sample and also considering that there are numerous types of damage and severe occlusion in urban areas, the robustness and accuracy of algorithms still need to be improved [13]. Finally, this paper still has the problem of how to rapidly translate the cutting-edge algorithms developed in the lab into stable, reliable and operating automated assessment pipelines that can achieve the goal of transforming research innovation into practical applications.

4.2. Case Study: intelligent assessment in the Sichuan Luding M6.8 earthquake

On September 5, 2022, there was a magnitude-6.8 earthquake in Luding County, Sichuan Province, and many people were injured or killed, and property was damaged. After the earthquake, the Institute of Earthquake Forecasting of the China Earthquake Administration worked with the Institute of Engineering Mechanics of the China Earthquake Administration to conduct joint air-ground building damage simulation assessments in a timely manner. Therefore, there will be a model for the intelligent evaluation of data acquisition - method application - product generation.

A building extraction model and an intelligent extraction system have been built in the team to obtain data from high-resolution satellite images of China's Gaofen-2 and Beijing-2 satellites. In a short time, more than 40,000 sets of building information for Luding, Shimian and other areas have been collected. The above data are from the main townships in the earthquake-damaged area. It provided the basis for the spatial data of the following assessments and showed that space-based satellites have the advantage of wide-area coverage.

The way the team at the level of methodological application did it was combined air-ground. First, they took some pictures from the air to get a look at the buildings. According to the earthquake damage simulator provided by the Institute of Engineering Mechanics, various ground-motion and structural conditions have been introduced to assess how much damage will occur to the buildings. To confirm that the evaluation results of the simulation are correct, high-resolution UAV remote sensing images of Moxi Town have also been obtained by the team. Based on the UAV pictures, some of the buildings have been damaged.

5. Emergency decision support: from information products to actionable knowledge

5.1. Workflow of remote sensing in emergency decision support

Optimisation of Resource Allocation in Disaster Emergency Decision-making. It will happen in a very uncertain and time-limited way. Finally, the biggest hope for remote sensing technology is that a large amount of observation data will be turned into practical intelligence for commanders at all

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levels. The following are the steps of change and display. At the same time, in accordance with the trend of standardisation of information products, customised analytical services and intelligent decision support, continuous development is also being carried out. At the level of general design, China's plan for the emergency disaster reduction satellite and application system in the 14th Five-Year Plan period is to improve the capability of turning data into decisions [10].

At the beginning of the emergency response, the first function of decision support is to quickly produce standardised products that show the general situation of the disaster. For instance, in the first few hours after a disaster, a basic situation map of the affected area, road closure points and potential risk zones will be provided to the command centre to help it quickly grasp the general situation of the disaster. Some rescue work has been carried out so far, and therefore the support requirements are particular. At this stage, customised thematic products are needed, including building damage classification maps, optimal material delivery route analyses, and temporary shelter suitability assessments. These directly serve the formulation of specific action plans for rescue teams.

To ensure that remote sensing information flows efficiently and accurately into the decision-making chain, innovation in organisational and coordination mechanisms is crucial. Building an efficient remote sensing satellite network cloud system is a technical guarantee for achieving rapid generation of warning information and issuance of response instructions [11]. At the international level, the International Charter on Space and Major Disasters cooperation mechanism has established a standardised process for urgently mobilising satellite resources from multiple countries in the event of major disasters. Its effectiveness has been verified in numerous global disaster responses [2, 14]. Domestically, exploring a coordinated service model for civil and commercial satellites under national coordination aims to stimulate the vitality of the commercial space sector, forming a civil-commercial synergy observation capability that is more agile in response and more diverse in data sources. Furthermore, through cloud-based computing power and standardised algorithmic models, automated assembly-line production, from data to products, is achieved. Through application programming interfaces (APIs), information services are seamlessly embedded in emergency command information systems at various levels, thereby realising integration from technology to operations [15].

5.2. Case Study: the Space-Air-Ground integrated decision support system in Shennongjia Forest District

Shennongjia Forest District is an important ecological function area in China and is also exposed to geological hazards such as landslides and debris flows. In 2025, its space-air-ground integrated monitoring, early warning, and emergency command system was recognised by the Ministry of Emergency Management, making it a representative case of remote sensing application in disaster response.

The system integrates InSAR satellite remote sensing, high-altitude video monitoring, and ground-based sensors to build a three-dimensional monitoring network for key hazard points. Real-time data are transmitted to the command centre, where emergency plans can be generated according to monitoring results. Multiple backup communication channels, including satellite phones and 370 MHz handheld radios, ensure that communication remains available when the main network fails.

At the decision-support level, remote sensing data are embedded into a closed-loop emergency process. Once an early warning is issued, the platform automatically generates disposal suggestions and sends them to relevant departments for confirmation and action. Thus, remote sensing

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information is transformed from situation maps into direct operational instructions, such as evacuation and emergency response activation.

During the 2025 flood season, the system detected slight mountain displacement through InSAR and ground sensors, issued landslide and debris-flow warnings, and supported timely evacuation, effectively preventing casualties.

6. Conclusion

Organise and present the applications of remote sensing technology at all links of the monitoring - assessment - decision support process in the paper on disaster emergency response. Recently, remote sensing technology has begun to be applied in other areas besides disaster relief and is now an essential part of the whole-weather early warning system that leverages cooperation among space, air and ground. Many places now work together to provide live updates. At present, artificial intelligence-based automatic quantitative intelligent assessment is used for the evaluation of assessments, and it has replaced the former method of visual inspection. Enhancements in the Performance of Deep Learning for Damage Information Extraction. Previously, the decision-support mechanism of the Emergency Command System was a general view of the situation based on remote sensing data; now, it is an all-weather, high-performance intelligent decision-support system that has gradually become the norm. Recently, a few combinations of optical, SAR and thermal infrared remote sensing systems have been employed to increase the efficiency of disaster relief.

There are still some problems now. Real-time integration of all kinds of data from various sources is still to be achieved. The Algorithm's Generalisation Ability Is Poor. New ways must be found to increase the stability of the small-sample environment and improve the accuracy of damage-type recognition in dense urban areas. There is a fusion gap at the link between remote sensing products and the emergency system. Different Standards Cause Poor Information Dissemination. The following are the future directions of work. Development of Cross-modal Data Fusion Algorithms for Real-time Intelligent Collaborative Processing. Improve Model Generalisation Ability. Exploration of Small-Sample Learning and Domain Adaptation Methods. Promote the Combination of Products and Operating Systems. The Same Rules and Requirements. Improve emergency communication and public aid. Promote innovation in the civil-commercial synergy service model. Build a more resilient national disaster remote sensing emergency system.

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