RESEARCH STATUS AND DEVELOPMENT TREND OF PHOTOGRAMMETRY AND REMOTE SENSING IN URBAN FLOOD DISASTERS

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ABSTRACT:

In recent years, urban floods occur frequently in China, and urban flood disaster has become one of the important reasons for the sustainable development of cities. Photogrammetry and remote sensing technology has the advantages of large observation range, large amount of information, fast speed, good real-time performance and strong dynamic. It plays an increasingly important role in flood control and disaster reduction, and has become an important support means for flood control and flood reduction in China. This paper mainly reviews the research status and development trend of photogrammetry and remote sensing technology in urban floods, summarizes the monitoring and evaluation of flood disasters, numerical simulation of flood disasters, and acquisition of hydrological characteristics, and prospects the future development of photogrammetry and remote sensing technology in flood disaster management in China.

1. INTRODUCTION

China is located in the east of Asia and the west coast of the Pacific, and the terrain is very complex. Affected by monsoon climate and tropical cyclones, there are huge regional differences in climate, uneven spatial and temporal distribution of precipitation, and frequent rainstorm and flood disasters. At the same time, China is one of the countries with frequent flood disasters in the world, about two-thirds of the land area may have different degrees and different types of flood disasters. According to statistics from the National Disaster Reduction Center of the Ministry of Water Resources and the Ministry of Emergency Management, between 1991 and 2020, there were an average of 2020 deaths or disappearances due to floods in China, totalling more than 60,000 deaths, with an average annual direct economic loss of 160.4 billion yuan, or about 4.81 trillion yuan.

Since the founding of the People's Republic of China, China has established a relatively perfect flood control engineering system, and also established non-engineering systems such as flood monitoring, forecasting and early warning. However, under the dual influence of rapid urban expansion and global warming, the frequency, intensity and duration of urban extreme climate events are increasing (Miller et al.,2008), and urban waterlogging disasters caused by urban rainstorm are also increasingly frequent (Zhang et al.,2014; Sun et al.,2014). The frequent occurrence of waterlogging disasters not only caused huge economic losses to China, but also seriously threatened the personal and property safety of residents, becoming an important factor restricting urban development (Zhang et al.,2014; Alderman et al.,2012).

The increase of rainfall frequency and intensity in urban areas is an important incentive for urban rainstorm waterlogging (Zhang et al.,2014). On the one hand, global warming has changed the local climate characteristics of cities, increasing surface evaporation and transpiration and accelerating water cycle, thereby increasing the frequency, intensity and duration of urban extreme rainstorms (Ciscar et al.,2011); on the other hand, urban heat island effect and aerosol emissions caused by urbanization also increase the frequency and intensity of urban rainfall (Hu et al.,2018; Xu et al.,2019). At the same time, urban construction has led to changes in all aspects of urban water cycle (Miller et al.,2008), especially the increase of impervious surface makes rainwater infiltration decrease, and water retention is difficult to discharge rapidly. The impact of these urbanizations is more pronounced in densely populated, highly sealed, poorly permeable and groundwater-recharged cities (Zhang et al.,2014).

Remote sensing technology has the advantages of large observation range, large amount of information, fast speed, good real-time performance and strong dynamic, which plays an increasingly important role in flood control and disaster reduction. In the related research of remote sensing earth observation, the remote sensing image data in urban areas have the characteristics of abundant resources, high spatial resolution, fast return visit cycle and high quality (Zhang et al.,2020). Therefore, it is an important development trend to deepen the application of remote sensing technology in urban hydrology and carry out the risk assessment of urban flood disasters by combining RS and GIS technologies to carry out the analysis of urban hydrological characteristics, prediction, monitoring and simulation of urban flood disasters (Zhang et al.,2020).

2. APPLICATION OF PHOTOGRAMMETRY AND REMOTE SENSING TECHNOLOGY IN FLOOD DISASTER MONITORING AND EVALUATION

Photogrammetry and remote sensing technology can be applied to the monitoring and evaluation of flood disasters. Its main monitoring and evaluation technical processes are shown in Figure 1. Its main advantage is that it scans the disaster area in a wide range, which is conducive to the first time to respond to disaster events. Especially in the case of large disaster area and inconvenient transportation, satellite remote sensing is almost the only means.

During the flood disaster, remote sensing technologies such as satellite remote sensing, aviation and UAV (ZHU et al.,2017: FENG et al.,2015) can be used to shoot images and quickly

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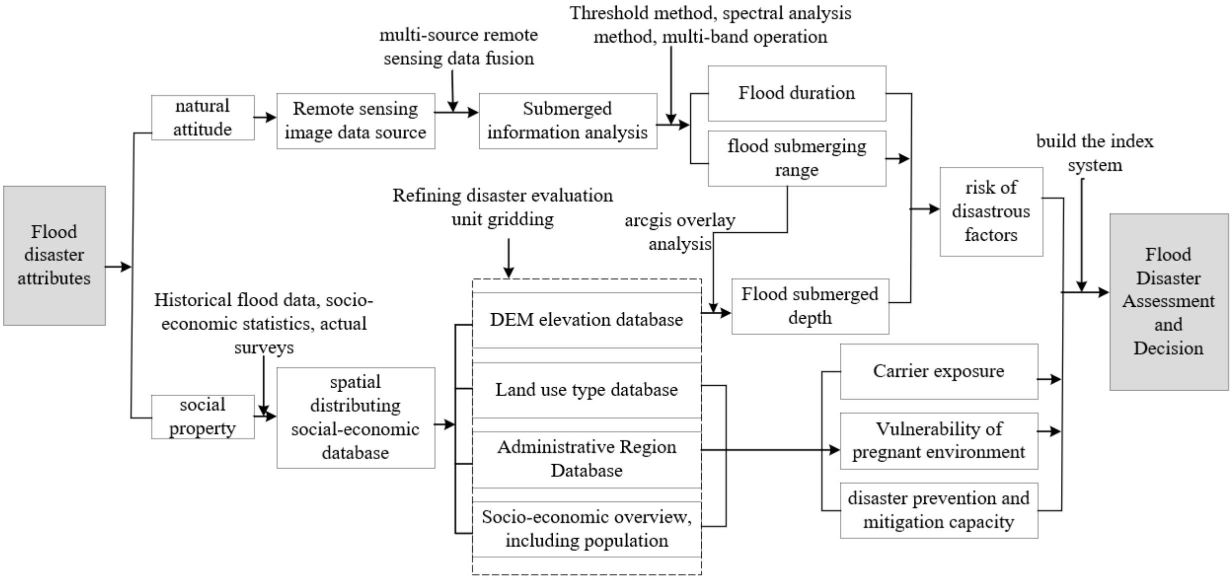

Figure 1. Flow chart of flood disaster monitoring and evaluation technology

Interpret the flooded area. Dai and others put forward the need for more space remote sensing in flood monitoring (Dai et al.,1996); meng et al. pointed out that solving the accuracy of water body identification, eliminating cloud interference, and dynamically monitoring flood cover are the main problems to be solved in remote sensing flood monitoring, and it is necessary to effectively combine ground hydrological data with remote sensing data, multi-sensor combination, and remote sensing data accuracy measurement system, which is an important development direction for the in-depth integration of remote sensing hydrological applications (Meng et al.,2012). Tanguy et al. proposed a method for drawing near-real-time flood inundation maps in urban and rural areas by combining Radarsat-2 satellite images and hydraulic data. The results of this method show that the flood area data with different return periods have good ability to overcome the limitations of flood detection based on SAR in urban environment and to achieve accurate mapping of suburban flood inundation maps by combining SAR data C-band images (TANGUY et al.,2017). Nandi et al., taking the optical / infrared images of Landsat8OLI / TIRS sensors before and after the 2014 flood disaster in Varanasi region as an example, based on NDWI and MNDWI classification of surface covered water distribution, combined with the support vector machine algorithm, the distribution map of flood area in the region was drawn (Nandi et al.,2017).

In the daily monitoring of flood disasters, it is necessary to solve the problem of providing information support for the city to understand its ability to regulate and store rainwater and resist flood disasters. Usually, the urban surface water cover area extracted from remote sensing images is used to characterize the natural storage entities such as rivers and lakes in the city. Zhou Yaohua and others in Wuhan City, the study found that giving full play to the potential of Wuhan lake storage is the most economical and feasible measures to alleviate waterlogging disasters in Wuhan City (Zhou et al.,2015). Combined with the major waterlogging disaster in Tangxun Lake water system in Wuhan in July 2016, Fang et al. proposed to implement the optimal scheduling strategy of multi-lake connectivity and lake storage capacity in Wuhan, so as to effectively improve the urban stormwater management capacity (Fang et al.,2017). Full remote sensing technology, extraction of a wide range of lakes, rivers, open channels and other storage facilities, combined with spatial information to study the connectivity characteristics between lakes, is the basis for the study of lake storage and utilization potential. Taking IKONOS panchromatic image as an example, Wang Ke designed a filter suitable for urban river edge characteristics and low-frequency information, and extracted urban river information in Qinhuai District and Baixia District of Nanjing City (Wang et al.,2011). However, it is conservation facilities such as ditches, channels and dams based on remote sensing data is still an open research topic (SANZANA et al.,2017)

Using remote sensing technology in the broad sense such as monitoring video (JIANG et al.,2019), smart phones (O'Grady et al.,2019) and big data (Wu et al.,2019) to obtain disaster information, and studying the prediction and prediction of flood disaster in a specific region or a specified range is also one of the important development trends of remote sensing technology applied to the study of flood disaster monitoring. Grady et al. corrected the historical data of flood inundation range observed by smartphones to regional remote sensing images, and used this data to correct the inundation results simulated by hydrological models, which effectively improved the accuracy of flood forecasting results (O'Grady et al.,2019); from the daily monitoring information of flow velocity, water level, rainfall and humidity sensors, Anbarasan et al. extracted the flood disaster big data according to the data extraction rules. On the basis of missing value processing and normalization processing, they used the attribute combination method to generate the regional flood probability prediction rules, and input the flood disaster big data and prediction rules into the convolution depth neural network model to obtain the flood disaster prediction results with high accuracy (ANBARASAN et al.,2020).

3. APPLICATION OF PHOTOGRAMMETRY AND REMOTE SENSING TECHNOLOGY IN NUMERICAL SIMULATION OF URBAN FLOOD DISASTER

With the development of 3S technology, the acceleration of urbanization also puts forward higher and higher precision requirements for flood simulation. Photogrammetry and remote sensing technology provide long time sequence, large area and high precision underlying surface information and urban hydrological and meteorological data for urban flood simulation, and provide data guarantee for the study of urban water cycle law.

The application of photogrammetry and remote sensing technology in flood simulation mainly includes two aspects: ① Meteorological and hydrological data based on remote sensing, such as remote sensing radar quantitative rainfall forecast, satellite remote sensing soil water inversion, remote sensing evapotranspiration inversion and flood process information (Schmugge et al.,2002);②Surface information based on remote sensing, such as fine terrain information, land use information, digital rivers and basins, and hydrological and hydraulic parameters information based on the above information extraction. At the same time, domestic and foreign scholars have also constructed a lot of numerical simulation models of flood disasters, which are better used in urban flood simulation experiments and provide reasonable decision results for cities.

3.1 Meteorological and hydrological data based on remote sensing

In the application of meteorological and hydrological data based on remote sensing, remote sensing technology can observe hydrological state variables in a wide range (Schmugge et al.,2002).

Quantitative rainfall forecasting based on space satellite technology has developed rapidly in the past decade, and its spatial and temporal resolution and accuracy have been continuously improved, which provides valuable information for large and medium-scale water cycle research and rainfall observation in ungauged basins. Researchers have carried out many works around global and local-scale hydrological simulation research (Haile et al.,2005; Naumann et al.,2012; Tang et al.,2015). Khan et al. drove CREST (coupled routing and excessive storage) hydrological model to simulate the flood process of a watershed in Lake Victoria, Africa, using the basic data of distributed hydrological models such as rainfall, land use and topography obtained by satellite remote sensing, and applied the flood range information obtained by remote sensing to verify the model, which showed good results and showed the wide application prospect of remote sensing data in areas with and without data (Khan et al.2011). Wang et al. evaluated the accuracy and applicability of the latest generation of TRMM3B42 - V7 satellite precipitation inversion data products in the Pearl River Basin using the ground rainfall station data, and the products showed good accuracy. The VIC hydrological model was calibrated using the data, and the effect was ideal (Wang et al.,2017).

Weather radar is a ground-based active microwave remote sensing technology, which is mainly used to monitor the short-term heavy rainfall information in the range of tens to hundreds of square kilometers. It has the characteristics of wide measurement range, strong timeliness and convenient maintenance, and is widely used in weather forecast and rainstorm flood forecast and early warning (Zhang et al.,1996; Li et al.,2008). Zhu et al. introduced the related research and application of rainstorm and flood prediction using radar rainfall data at home and abroad. It is considered that radar rainfall prediction data can improve the prediction period of rainstorm and flood model, and has great application prospects in urban flood simulation (Zhu et al.,2016). At the same time, it is pointed out that the reliability of radar rainfall prediction should be further improved. The advantages of wide detection range and high accuracy of C-band radar and the characteristics of high resolution and low cost of X-band radar should be used to improve the ability of urban flood control and disaster reduction.

Remote sensing soil water and remote sensing evapotranspiration inversion are mainly used for basin-scale water cycle research, farmland drought monitoring and urban heat island effect (Rajib et al.,2016; Nicolai et al.,2017; Kullberg et al.,2017; Coutts et al.,2016; Herman et al.,2018). Cheng et al. used MODIS satellite remote sensing vegetation index and surface temperature data to construct the inversion algorithm of vegetation canopy temperature based on VI~TS (vegetation index and surface temperature) feature space and linear mixed model. The estimated canopy temperature was consistent with the field measurement data of handheld infrared thermometer (Cheng et al.,2017). Wu et al. retrieved the surface brightness temperature based on Landsat TM/ETM +remote sensing, analyzed the spatial distribution characteristics and temporal and spatial evolution law of urban heat island in Harbin, and explored the internal relationship between urbanization and heat island effect (Wu et al.,2017). Liu retrieved land surface temperature using single window algorithm based on Landsat thermal band remote sensing data, and further calculated evapotranspiration for urban flood simulation (Liu et al.,2016).

In terms of flood process information based on remote sensing, flood range and water depth can be used for flood control and disaster reduction, as well as flood model verification and calibration (Schmugge et al.,2002; Sanyal et al.,2004). Many scholars have carried out a lot of research and application work in this regard (Horritt et al.,2002; Bates et al.,2004; Hostache et al.,2009). Mason et al. estimated the inundated area of a 150-year flood in Tewkesbury, UK based on Terra SAR-X synthetic aperture radar (SAR) remote sensing data, and identified the flood area in sheltered areas of houses and trees by airborne laser altimeter (LiDAR) technology (Mason et al.,2010). Compared with aerial images, the correct interpretation rate of flood in Terra SAR-X visible area was 76 %, and 58 % when the sheltered area grid was considered. The study suggests that the flood range obtained by remote sensing can provide more reliable information for flood model validation and calibration.

3.2 Land Surface Information Based on Remote Sensing

The surface information based on remote sensing mainly includes digital elevation information (DEM), surface coating classification information, and digital watershed information (Yang et al.,2015), which not only provides a large number of basic geographic information for hydrological models, but also provides data basis for digital hydrological simulation (Xu et al.,2013) and large-scale water cycle research. Digital hydrological simulation technology based on DEM technology provides the possibility for the study of distributed hydrological model based on physical mechanism (X). High-precision DEM and high-resolution, hyperspectral and multi-temporal remote sensing images provide an increasingly rich data source for the quantitative description of watershed spatial information. People have deepened their understanding of physical characteristics such as watershed topography, hydrology and biological processes (Wang et al.,2015), and great progress has been made in hydrological simulation and water cycle process research based on remote sensing technology (Zhao et al.,2006; Jiang et al.,2013; Xu et al.,2010). Gashaw et al. extracted land use from Landsat remote sensing images of different periods, and analyzed the impact of land cover change on hydrological

Model	The model characteristic	Time	Main R & D units
Flood Simulation Model	The coupling of urban ground flooding and pipeline is realized for the first time based on unstructured grid.	1997	China institute of water resources and hydropower research
Hydro Info	Numerical simulation of complex flow and transport process is provided.	2006	Dalian university of technology
Hydro MPM	Numerical method is used to simulate the dynamic process of water flow, water quality, sediment and its associated process.	2007	Pearl River Water Resources Research Institute
GAST	The Godunov format used to solve the two-dimensional Saint-Venant equations, and GPU parallel computing technology is used to accelerate the calculation.	2013	Xi'an university of technology
IFMS/Urban	Based on the self-developed GIS platform, a two-dimensional coupling calculation is realized.	2015	China institute of water resources and hydropower research

Table 1 Flood model of main cities in China

Model	The model characteristic	Development organizations
SWMM	Provides distributed hydrological module, one-dimensional hydrodynamic module.	EAP American Environmental Protection Agency
HEC-RAS	One-dimensional and two-dimensional hydrodynamic modules are provided.	American Army Engineering Corps Hydrology Engineering Center (HEC)
PCSWMM	SWMM as the core, provides pre-processing module, and can simplify the calculation of two-dimensional surface.	Canadian Institute of Hydraulic Calculation (CHI)
LISFLOOD-FP	Two-dimensional hydrodynamic module is provided.	Bristol University
InfoWorks ICM	High integration, comprehensive function, the realization of hydrological, hydrodynamic, water quality coupling simulation, and has a powerful pre-processing function.	UK HR Wallingford
MIKE	It includes MIKE URBAN, MIKE FLOOD, MIKE21 and other modules. Each module is relatively independent and has complete functions, which is widely used in various projects.	DHI Institute of Wheat Hydraulics
EFDC	Water quality module can simulate point source pollution, non-point source pollution, organic migration process.	Virginia Ocean Research Institute (VIMS)
Delft3D	Suitable for three-dimensional hydrodynamic water quality simulation, can simulate estuary, port hydrodynamic.	Delft Hydraulic Research Institute, Netherlands
FLO-2D	Two-dimensional hydrodynamic module, one-dimensional calculation embedded SWMM module.	FLO-2D Software Company
FLOW-3D	CFD software, provides three-dimensional hydrodynamic module, suitable for analysis of three-dimensional flow field.	Flow Science, the US

Table 2 Flood models of major foreign cities

processes (Gashaw et al.,2017). Zope et al. used multi-period Landsat/ETM remote sensing image data to analyze the impact of urbanization and land use change on runoff change and flood characteristics of the river basin in Mumbai, India (Zope et al.,2016). The results showed that the built-up area increased by 74.84% in the past 43 years, and the peak and total runoff changed little, but the range of high flood risk areas increased by 64%.

With the continuous advancement of global urbanization, some new urban water problems have emerged in recent years. Among them, urban flood problems have attracted more attention due to their complex formation mechanism and wide social impact, and relevant scholars have carried out a lot of research (Cheng T et al.,2018; Zhang J Y et al.,2016; Zhang J Y et al.,2017). Due to the complex distribution of urban surface features, buildings, roads, culverts, open channels and other interlaced, and the formation mechanism of urban flood is not clear, the simulation of flood in urban areas is facing great difficulties. In addition, hydraulic factors such as flood depth and speed are easily affected by urban surface features and micro-topography. Small terrain errors may lead to different simulation results. Urban flood models show high sensitivity to terrain data. Before the 1990s, it was difficult to obtain terrain data with low accuracy and rough spatial resolution (Wilson et al.,2005). In recent years, with the development of space remote sensing technology, the development of airborne laser altimeter, synthetic aperture radar interferometry and other technologies has significantly improved the accuracy and acquisition speed of terrain data. For example, airborne lidar can provide terrain data with millimeter-level resolution in a large scale (Teng et al.,2015), and in the urban scale, it can provide terrain data with millimeter or even millimeter-level. Evans et al. studied the use of fine LiDAR point cloud to carry out fine building contour extraction and micro-topography recognition, which promoted the rapid development of flood simulation models with high spatial resolution (Evans et al.,2008).

3.3 Flood Simulation Model

Remote sensing technology and GIS are widely used in distributed and semi-distributed hydrological models. De Almeida et al. showed that using high-resolution terrain data (e.g.,10m) to carry out numerical simulation of flood disaster based on two-dimensional shallow water equation can more accurately reflect the runoff characteristics, and show strong application potential in flood inundation, flood risk management, and improving the resilience of urban flood engineering (Evans et al.,2008).

The input data of urban flood model mainly include hydrological and meteorological data such as rainfall, runoff and water level, and urban basic information data such as topography, land type, river section and municipal pipe network, which are mainly obtained by manual field survey or urban monitoring stations. Due to the limitation of local complex terrain on measurement conditions, and the imperfection of urban monitoring technology and equipment, the data needed for urban flood research are still lacking. Tables 1 and 2 are the popular urban flood models in China and abroad.

Wang and Lu pointed out that remote sensing data were integrated into the hydrological model by providing data-driven, boundary conditions and state information for the hydrological model (Wang Wei et al.,2016). Xie et al. constructed a super-water level-drainage model framework to assess the risk of flood disasters caused by climate change in the northwest coast of the United States, which integrates meteorology, ocean and coastline (XIE et al.,2019). Taking the Avenue Basin behind the Skitoude seawall in Massachusetts as an example, combined with the water level collected by sensors and the water level information obtained by USGS lidar, according to the relationship between the basin area and water level, the super-top water volume was analyzed and the rationality of the evaluation results of the framework was verified. Zhou et al.studied the potential green roof transformation points in the Fifth Ring Road of Beijing by GIS and remote sensing, and evaluated the runoff reduction effect under three green roof transformation schemes under four comprehensive rainfall conditions by SCS-CN hydrological model (ZHOU et al.,2019). Herman M. R et al. applied the simplified surface energy model and the inversion model of atmospheric land exchange to SAWT (Soil and Water Assessment Tool) (Herman et al.,2018). The study showed that after using genetic algorithm and multi-parameter optimization algorithm to evaluate the influence of remote sensing data on simulated evapotranspiration, runoff velocity and flow results, remote sensing data could effectively improve the calculation accuracy of hydrological model.

With the in-depth integration of GIS technology, remote sensing technology and hydrological applications, a 'simplified hydrological model' is gradually developed to simplify the runoff generation and confluence relationship between grids or sub-confluence areas by moderately combining hydrological physical processes. Due to the lack of strict mathematical and physical significance of this kind of model, it is relatively limited in dam failure analysis, flood process evolution simulation and quantitative research of flood disaster with high accuracy requirements. However, the simplified hydrological model is widely used in the study of large-scale flood disasters in countries or regions due to its advantages of easy access to input parameters, simple model setting, short calculation time and acceptable calculation error. For example, the simplified hydrological model TOPMODEL uses catchment topology data and soil moisture initial conditions to generalize semi-physical process rainfall runoff parameters; the simplified hydrological model OBJTOP adopts the object-oriented idea to improve TOPMODEL, and the exponential decay function can be used to simulate the hydraulic conductivity and impervious surface area to predict the rainfall scenario of small watershed (Wang J et al.,2005). The simplified hydrological model HAND (Height Above the Nearest Drainage) is suitable for flood disaster simulation at continental scale (> 2000 square kilometers) (Rennó et al.,2008). Nobre A. D.et al. pointed out that the HAND model has a good application prospect in surface water literature, meteorology, ecology, carbon cycle, biology, environmental protection, land use and disaster assessment management (Nobre et al.,2011).

4. APPLICATION OF PHOTOGRAMMETRY AND REMOTE SENSING TECHNOLOGY IN HYDROLOGICAL CHARACTERISTICS ACQUISITION

Photogrammetry and remote sensing technology provide superior data sources and prerequisites for the research in the field of hydrology and water resources.

The distribution characteristics of impervious surface and water body in the basin are important parameters reflecting the hydrological response characteristics of urban runoff yield and concentration (BOYD et al.,1993). Since the 1990s, Schueler (SLONECKER et al.,2001; SCHUELER et al.,1994) and others have studied that impervious surface is a key factor affecting urban water ecological environment and urban flood disasters; Arnold and Gibbons believe that the ratio of impervious land area in the basin has a certain relationship with urban water infiltration. When the ratio is 10 %, it will have an impact on water quality. when the ratio reaches 30%, the water quality of the basin will decrease; excessive impervious surface ratio will lead to urban waterlogging (Amold et al.,1996); shao et al. carried out the research on the influence of impervious surface increase on hydrological process (Shao et al.,2019). In view of the problem that the existing research generally takes administrative divisions rather than watersheds as units and cannot consider adjacent watersheds, based on the division of urban multi-scale catchment areas and the analysis of hydrological systems by DEM, the influence of dynamic impervious surface ratio on regional runoff production and confluence characteristics was studied. It was found that when the impervious surface ratio in the catchment area changed from 4 % to 20%, the rainfall runoff in the region will increase by twice. Wang et al. studied the relationship between surface runoff yield and the corresponding impervious surface fraction (ISF) (WANG et al.,2020). LANDSAT images were used to monitor the growth of impervious area during urban development in Beijing from 1980 to 2015, and the corresponding impervious surface fraction was determined.

Remote sensing technology has also been widely used in the studies of soil moisture (PAN et al.,2015; Uebbing et al.,2017) and vegetation evapotranspiration (Yuan et al.,2006; Li et al.,2005) on the underlying surface, which solves the problem that hydrological state factors cannot be quantified in regional hydrological studies. Wei Zhaozhen studied the relationship between land use change and hydrological zoning types, the study showed that land use change will have a direct or indirect impact on the spatial distribution characteristics of hydrological types in the basin (Wei et al.,2014; Feng et al.,2013); studied the evapotranspiration characteristics of the Huaihe River Basin based on remote sensing technology (Shao et al.,2012).

5. DEVELOPMENT TREND OF PHOTOGRAMMETRY AND REMOTE SENSING TECHNOLOGY IN URBAN FLOOD

With the development of 3S technology, it provides new technical means for urban flood control. By introducing new technologies such as satellite remote sensing, UAV aerial photography, radar, laser and 5G communication, and integrating with the observation data of traditional ground stations, it forms an integrated intelligent perception system of space and ground (Huang et al.,2021), realizes the complementary advantages of multi-source data, and comprehensively and timely grasps the occurrence process of flood disasters and objectively counts the loss of disasters.

However, in the face of the new situation and new requirements of flood control and disaster reduction, there is still room for improvement and improvement in the application of remote sensing technology in flood disaster monitoring and evaluation. For example, the remote sensing data source in China is still insufficient, the overall monitoring elements are single, the monitoring frequency is insufficient, the timeliness of monitoring needs to be further improved, and the stereo monitoring and data fusion of sky and ground are insufficient. There is still a certain distance between remote sensing monitoring of flood disasters and engineering and business. The future development trend of photogrammetry and remote sensing technology in urban flood control is mainly reflected in the following aspects.

5.1 UAV remote sensing technology

Unmanned aerial vehicle remote sensing is an application technology that uses advanced unmanned aerial vehicle technology, remote sensing sensor technology, telemetry and remote control technology, communication technology, GPS differential positioning technology and remote sensing application technology to automatically, intelligently and specifically quickly obtain space remote sensing information such as resources, environment and disasters, and complete remote sensing data processing, modeling and application analysis (Liu et al.,2022). In recent ten years, with the rapid development of UAV technology, low altitude remote sensing has become an important supplement to satellite remote sensing and plays a unique role. Unmanned aerial vehicle (UAV) low-altitude remote sensing has unique advantages such as cloud operation, flexibility, emergency scheduling and high-resolution data acquisition, which can make up for the application bottlenecks of satellite remote sensing, such as the great influence of cloud, the difficulty in guaranteeing the timeliness of data acquisition, and the high cost of task customization. The combination of the two can more effectively realize the multiple information acquisition and disaster emergency monitoring of underlying surface.

The use of UAV remote sensing technology is of great significance in dike patrol and disaster monitoring services. The current dike inspection work relies heavily on manpower, low efficiency and high risk. Using high-tech means to accurately identify the embankment risk, reduce the workload and intensity of manpower to patrol the embankment, and improve the efficiency of patrolling the embankment is an extremely convenient and efficient means of flood control, and it is also one of the technical problems that need to be solved urgently in flood control work. Therefore, the use of UAV remote sensing is a promising means of flood control. In critical moments, UAVs equipped with optical, thermal infrared, radar and other types of sensors are used to conduct remote sensing imaging of dikes and flood disaster areas, providing scientific support for dike patrol (Wang Jun et al.,2021), disaster assessment and demonstration of flood storage and detention areas. Using thermal imaging technology, combined with centimeter-level high-precision visible image and radar signal, UAV remote sensing can effectively identify dike piping, leakage and other hazards. Compared with human inspection, UAV remote sensing can more quickly obtain a wider range of dam image information, find possible danger points, assist the embankment inspection work, and improve the efficiency of embankment inspection. In addition, in some areas with relatively complex terrain, the use of UAVs to patrol dikes can more effectively reduce the patrol risk.

Using UAV for disaster monitoring service and monitoring and collection of water conservancy information can greatly improve the accuracy and timeliness of the collection and transmission of rainfall, drought and disaster information. The timely prediction of its spread trend is of great significance for the formulation of flood control and drought relief scheduling scheme. In addition, the remote sensing image obtained by UAV can be used to judge the affected area, where landslides and debris flows may occur, and add obstacle factors to path analysis, so as to formulate a reasonable rescue path for rescue personnel.

5.2 short-time forecast and early warning

Real-time monitoring is not enough after floods. At present, the new generation of Doppler radar and satellite data with high spatial and temporal resolution are the main means of monitoring strong convective weather. Combining the monitored remote sensing data with GIS technology, three-dimensional grid jigsaw data and satellite jigsaw data are generated based on radar base data. With the help of big data artificial intelligence image recognition technology and machine learning algorithm, a short-term near prediction system can be developed, which includes strong convective cell recognition and tracking. Using this system can quickly provide the best rescue route information after the disaster, provide detailed and accurate data for taking effective measures for rescue work, and provide sufficient scientific basis for disaster prevention and mitigation decisions.

5.3 Fast Processing of Remote Sensing Big Data and Intelligent Extraction of Flood Information

Timeliness is the key indicator of flood emergency monitoring. At present, the field of remote sensing has entered a new era characterized by high precision, all-weather information acquisition and automatic and rapid processing. The space-space-ground integrated collaborative observation system formed by satellites, UAVs and ground monitoring stations provides multi-dimensional and high-frequency multi-source heterogeneous flood disaster observation data, involving different imaging methods, different bands, different resolutions, different observation scales, as well as different periods of pre-disaster, mid-disaster and post-disaster. The amount of data increases explosively. The traditional remote sensing image analysis and processing is time-consuming and inefficient, which is difficult to meet the needs of rapid emergency response for flood disaster monitoring. In the future, high performance computing technology is needed to develop efficient algorithms for remote sensing image processing and multi-source data fusion. The rapid development of artificial intelligence technology such as deep learning will also promote the deep mining of remote sensing data information and the intelligent extraction of flood information, further improve the efficiency and quality of data processing, and provide timely and accurate technical support for flood control and disaster reduction.

5.4 Joint Analysis of Flood Disaster by Multi-source Satellite Remote Sensing

Limited by remote sensing observation means and data information mining technology, it is difficult to meet the needs of multi-factor and multi-scale monitoring in the whole link of flood disaster only by satellite remote sensing and UAV remote sensing. With the development of space-space-ground integrated collaborative observation, space-space-ground multi-source heterogeneous data fusion and processing technology, sensors such as synthetic aperture radar, ground penetrating radar, laser radar, Doppler radar, thermal infrared, visible light and video based on satellites, unmanned aerial vehicles and ground mobile platforms are gradually realizing the multi-factor and multi-level information perception of rainfall (precipitation), water (water level, flow rate, flow rate, ice condition, water temperature, sediment concentration), danger (dam seepage, piping, cracks, landslides, etc.) and disaster (submerged duration, submerged area, submerged loss, etc.), breaking the limitation of single factor perception. By processing the acquired multi-remote sensing data and using the abundant observation information of meteorological satellite satellites, the disaster situation in the disaster area can be analyzed concretely and accurately, which provides important support for weather analysis, environmental monitoring, climate monitoring, resource assessment and disaster early warning.

5.5 Post-disaster loss estimation

Remote sensing technology can also conduct post-disaster loss estimation for us. After the disaster, the disaster losses are comprehensively approved based on historical remote sensing data, real-time remote sensing data and field survey data, and the living conditions of the victims are evaluated to provide decision-making support for the recovery and reconstruction of the affected areas and the relief arrangements for the lives of the victims. With the support of background database, GIS comprehensive analysis and statistical analysis methods are used to find out the occurrence location, large-scale disaster situation and disaster degree of flood disaster. At the same time, the detailed assessment of post-disaster losses of different land types such as cultivated land, forest land, residential area and industrial and mining enterprises is given. Qualitative, positioning and quantitative maps, summary data and statistical reports are generated according to administrative units at different levels of provinces, cities and counties, which are provided to relevant departments.

6. CONCLUSION

With the further advancement of urbanization, urban water problems have become increasingly prominent, especially urban floods. Urban flood simulation based on fine information is extremely important. At present, the basic information of remote sensing has been widely used in the study of flood simulation, but there is still room for improvement and improvement in giving full play to urban flood disaster management (Wang et al.,2021), which is mainly manifested in the following aspects : the remote sensing data processing is not timely and the degree of automation is low ; the use of UAV emergency monitoring has the problems of communication interruption and traffic obstruction in disaster areas ; the obtained satellite remote sensing data have low resolution and low timeliness.

With the continuous progress of photogrammetry and remote sensing technology in China, urban basic geographic information and related meteorological and hydrological information based on remote sensing can provide fine and comprehensive basic data for flood simulation, which lays a solid foundation for digital flood simulation and intelligent flood risk management. Based on the summary of the existing methods and technologies, several research directions worthy of attention in the future are summarized:①AI remote sensing improves the data processing ability. In the future, remote sensing technology and artificial intelligence technology are combined to develop efficient algorithms for remote sensing image processing and multi-source data fusion by using deep learning and high performance computing technology, so as to improve the ability of remote sensing data information recognition and intelligent extraction, improve the efficiency of data processing, ensure the accuracy of monitoring, and provide timely and accurate technical support for flood control and disaster reduction.②UAV multi-sensor applications enhance multi-source data acquisition capabilities. At present, the common sensors on UAV are orthophoto cameras and video sensors, which can quickly obtain high-definition orthophotos, 3D models and video data on the scene.

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