ISSN: 2664-9640

A rview of Image Processing and Machine Learning Technology in Flood Control and Emergency Management

Yu Fan [1, a], Hongquan Liu [1, b,*], Yongtao Zhu [2,c], Guoxing Zhang [2,d], Lijun Ma [3,e], Meng Yang [2,f]

[1] College of urban and rural construction, Hebei Agricultural University, Baoding 071001, China;

[2]Department of Water Resources of Hebei Province, Shijiazhuang 050000, China;

[3] College of resources and environmental sciences, Hebei Agricultural University, Baoding 071001, China.

[a]fy835960612@163.com, [b]50081999@qq.com

Abstract

With the rapid development of urbanization, flood disaster has become one of the most serious natural disasters affecting people's life. In order to minimize the loss caused by flood disaster, it is particularly important to build a complete and mature flood risk management system.The prediction of flood area map, flood depth and flood prone area is a very important part of flood risk management. In recent years, the development of image processing and machine learning technology provides a better choice for flood risk management.This paper expounds the application of image processing and machine learning technology in flood area mapping, flood depth measurement and flood sensitivity simulation, and discusses the future research direction on the basis of summarizing the existing research results at home and abroad.

Keywords

Flood management,Image processing,Machine learning,Research progress.

1. Introduction

Flood is one of the most serious natural disasters affecting urban economy,culture and people's life in the world.In recent years, both developing and developed countries have been facing flood risk.Recent studies have shown that with the rapid development of urbanization and the sharp increase of cement buildings and hardened pavement, the ability of cities to regulate flood and waterlogging has also been greatly reduced[1],In addition to the change of global climate, many cities in China and even the world have suffered from flood and waterlogging disasters since 2021,How to reasonably build an effective flood risk management system under the circumstances of climate change and human impact urgently needs in depth research[2].

The prediction of flood area and depth has always been a very important part of flood risk management. With the rapid development of science and technology, there are some effective methods and means for the study of the regularity of flood itself, information collection and transmission, the correct prediction and calculation of flood and the scientific optimization of dispatching methods[3]， For decades, satellite systems and remote sensing systems have been important data sources for flood prediction and flood management. However, because flood is a rapidly changing dynamic process, satellite and remote sensing systems have a certain lag, which is unfavorable for quickly mapping flood range, capturing and predicting flood process[4].

In recent years, with the development of image processing and machine learning technology, it can be combined with satellite and remote sensing systems to better predict the flood process and better manage the flood risk, which is important for carrying out targeted emergency measures in flood fighting and rescue and minimizing the economic and social impact of flood on cities and people The harm to life and even personal safety is of great significance. This paper summarizes the existing research results at home and abroad, and discusses the possible research direction in the future on the basis of the existing research results.

2. Application of image processing and machine learning technology in urban flood fighting and rescue

2.1. Flood range mapping

Image processing technology can be used to predict the flood range and approximate development process before and at the initial stage of flood.Huang Chang proposed a spatio-temporal analysis method of floodplain flood inundation based on time series observed discharge data and MODIS data, gave full play to the respective advantages of the two types of data, and realized the analysis of the temporal and spatial characteristics of large-scale flood inundation[5].On the basis of MODIS data, Zhang Na and others modified MODIS by using myd09ga surface reflectance data to realize the spatial detail location of flood inundated sub-pixel level. The sub-pixel mapping algorithm has higher accuracy and can well maintain the spatial detail characteristics of water body. The accuracy of sub-pixel location results after DEM correction is further improved[6].Researchers have combined space synthetic aperture radar (SAR) technology with automatic depth learning technology to accurately identify flood range and draw flood inundation map quickly and on a large scale[7].

2.2. Determination of flood depth

The traditional flood depth measurement method uses the data of water depth sensors and wells preset in the city. Researchers also use hydrostatic pressure, mechanical float system, thermal conductivity and radiation-based water level measurement methods. However, these preset sensor devices have limited coverage and high failure rate in rainstorm, so they have strong limitations. Recently, researchers combined u-net technology with flood depth prediction and proposed a device for predicting urban flood disaster in a short time using neural network under high resolution, When 28 million parameters are input, it can predict an area of 1280×1280m2 in 1 second[8].On the basis of urban rainfall data, the researchers also established a regression model for depth prediction of urban flood area by using the Gradient Boosting Decision Tree (GBDT) depth learning algorithm[9].SAR technology and machine learning technology can also be used to predict flood depth. Based on Synthetic Aperture Radar (SAR) and Digital elevation model (DEM), this technology can quickly predict flood depth[10].

2.3. Flood sensitivity simulation

Shi Rong et al. Simulated the flood sensitivity of dahongmen drainage area in Beijing by using the urban stormwater runoff management model (SWMM). The model used discrete spatial parameters to describe the regional hydrological variation characteristics, and quantitatively analyzed the impact of model parameters on the simulation results by Morris screening method. The results show that the model can better simulate the flood process in this area[11].Khabat Khosravi et al found that NBT model is an ideal tool for assessing flood prone areas and can properly plan and manage flood disasters[12].Zhaobo et al. Used the semi-automatic machine learning model—The weakly labeled support vector machine (WELLSVM) to evaluate the urban flood sensitivity, and carried out verification and comparison. The results show that WELLSVM model can make better use of spatial information and is better than all comparison models[13].

3. Research progress at home and abroad

3.1. Domestic research progress

China began to use satellite remote sensing system for flood monitoring very early. Flood monitoring system with NOAA satellite remote sensing data reception equipment was used in the lower reaches of the Yellow River many years ago. At the same time, the system also used subsystems which can provide geographical information and image processing functions to improve the mapping accuracy of satellite images[14].Several years ago, the emergence of GIS system provided new possibilities for flood forecasting and management. Jiang Li and others built and implemented a flood risk management system based on open-source GIS system with Lishui area as the research area on the basis of GIS. The system combines geographical location and related attributes, and has unique spatial analysis function and visual expression.[15].In recent years, Tong Jinping and others have proposed an XGBoost-based machine learning model to assess the risk of flooding in the core cities of the Yangtze River Delta. The predictive performance and accuracy of this machine learning model are higher than other common machine learning models[16].

3.2. Foreign research progress

There are many researches on image processing and machine learning technology abroad. In recent years, researchers have proposed many new machine learning technologies to simulate and predict flood more effectively.For example, Mahfuzur Rahman et al,combined hydrodynamic modeling with machine algorithm development to establish a disaster time assistance system, which can quickly generate flood disaster map and mark high-risk areas[17]。Alizadeh Kharazi et al,used the depth neural network method to detect the submerged parking signs in the photos of submerged roads and intersections, and combined Canny edge detection and probabilistic Hough transform to calculate the rod length and estimate the flood depth[18],This method is suitable for urban areas, and plays a great role in solving the problems of complex urban traffic and inconvenient prediction of flood depth.Mohammad Zare et al,studied how to use machine learning (ML) and deep learning (DL) technology to process satellite images. They found that ML model is mainly used to identify and predict submerged pixels and non submerged pixels in images, but there are still important problems in recognition accuracy[19].The research of Yu Feng et al,shows that the volumented geographic information (VGI) system can be used as a supplement to the remote sensing observation of flood range mapping, and this system is particularly beneficial when applied in urban areas[20].

4. Research prospect

This paper systematically expounds the application of image processing and machine learning technology in flood risk management and the existing research results. In the review process, the following problems are found to be further studied.

(1) Generally speaking, the research on flood risk management in China began very early, but in recent years, there is less research on image processing and machine learning technology in flood prediction and flood map drawing, and some foreign countries with many flood disasters have more research in this regard.

(2) The application of in-depth learning technology in urban flood control is also worthy of in-depth study.

(3) In terms of image processing technology, China can further develop the function of SAR technology in flood area and flood depth prediction, and combine depth learning technology and computer modeling technology to quickly and accurately draw flood area map at the initial stage of flood and even before flood.

Acknowledgments

This work was financially supported by the Applied Research Project of Water Safety Assessment of Hebei Province.

References

[1] Zhu Mingzhuan, Jiangzhonglin, Zhang Sihui. Urban Flood Risk Management Technology . Fujian Building Materials,Vol.12(2019): p11-2+30.

[2] Liu Bojun, Lei Xiaohui, Quan Jin, et al. Construction and Application of Regional Flood Risk Management Model. Rural Water Resources and Hydropower in China, Vol. (2016): p72-6.

[3] Bao Jianjie, Liu Zhuo , Zhang Cheng. Discussion on Construction of Flood Risk Map System in Liaoning Province. Water Resources and Hydropower in Northeast China, Vol.29(2011):p 52-3.

[4] MUNAWAR H S, HAMMAD A W A, WALLER S T. A review on flood management technologies related to image processing and machine learning . Automation in Construction, 2021, p132.

[5] Huangchang. Research on flood inundation analysis and modeling method of flood plain based on remote sensing and GIS; East China Normal University, 2014.

[6] Zhang Na, Wang Ping, Sang Huiyong, et al. MODIS Data Subpixel Mapping for Flood Submergence. Science of Surveying and Mapping, Vol.44(2019): p164-70.

[7] JIANG X, LIANG S, HE X, et al. Rapid and large-scale mapping of flood inundation via integrating spaceborne synthetic aperture radar imagery with unsupervised deep learning [J]. ISPRS Journal of Photogrammetry and Remote Sensing,Vol.178(2021): p36-50.

[8] LöWE R, BöHM J, JENSEN D G, et al. U-FLOOD – Topographic deep learning for predicting urban pluvial flood water depth. Journal of Hydrology, Vol.603(2021) : p126898.

[9] WU Z, ZHOU Y, WANG H, et al. Depth prediction of urban flood under different rainfall return periods based on deep learning and data warehouse. Science of The Total Environment, Vol.716(2020): p137077.

[10] HAO C, YUNUS A P, SIVA SUBRAMANIAN S, et al. Basin-wide flood depth and exposure mapping from SAR images and machine learning models. Journal of Environmental Management,Vol. 297(2021):p113367.

[11] Shi Rong, Pang Bo, Zhao Gang, et al. Sensitivity Analysis of SWMM Model Parameters in Urban Rainfall Flood Simulation. Journal of Beijing Normal University (Natural Science Edition),Vol. 50(2014): p456-60.

[12] KHOSRAVI K, SHAHABI H, PHAM B T, et al. A comparative assessment of flood susceptibility modeling using Multi-Criteria Decision-Making Analysis and Machine Learning Methods. Journal of Hydrology, Vol. 573(2019): p311-23.

[13] ZHAO G, PANG B, XU Z, et al. Assessment of urban flood susceptibility using semi-supervised machine learning model. Science of The Total Environment, Vol. 659(2019): p940-9.

[14] Li Shengyang, Zhaoyang , Zhang Fang. Satellite Remote Sensing Monitoring and Evaluation System for Regional Flood Disasters in the Yellow River Basin. Yellow River, Vol.04(2000): p13-4.

[15] Jiang Li, Jin Jing, Meng Jie. Design and implementation of mountain flood risk map drawing and management system based on GIS Technology. Zhejiang Hydrotechnics, Vol.45(2017): p20-4.

[16] Tong Jinping, Zhang Hanju, Liu Hui, et al. Risk assessment and influencing factors analysis of waterlogging in core cities of the Yangtze River Delta based on XGBoost. Hydraulic and Hydropower Technology (English and Chinese): p1-15.

[17] RAHMAN M, CHEN N, ISLAM M M, et al. Development of flood hazard map and emergency relief operation system using hydrodynamic modeling and machine learning algorithm. Journal of Cleaner Production,Vol.311(2021): p127594.

[18] ALIZADEH KHARAZI B, BEHZADAN A H. Flood depth mapping in street photos with image processing and deep neural networks. Computers, Environment and Urban Systems, Vol.88(2021): p101628.

[19] ZARE M, SCHUMANN G J P. Chapter 15 - Emerging Techniques in Machine Learning for Processing Satellite Images of Floods//SCHUMANN G J P. Earth Observation for Flood Applications. Elsevier. 2021: p321-36.

[20] FENG Y, BRENNER C, SESTER M. Flood severity mapping from Volunteered Geographic Information by interpreting water level from images containing people: A case study of Hurricane Harvey. ISPRS Journal of Photogrammetry and Remote Sensing, Vol.169(2020): p301-19.