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EFFECTIVENESS EVALUATION OF EMERGENCY RESCUING PLANS ORIENTED TO URBAN WATERLOGGING BASED ON A NEURAL NETWORK MODEL

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ABSTRACT

In response to the significant impact of urban waterlogging on residents, the economy, and urban infrastructure in recent years, this study introduces an innovative wargame-based evaluation approach for emergency rescue plans. The primary goal of this research is to improve emergency rescue capabilities while minimizing costs and identifying gaps in existing emergency rescue plans. To effectively evaluate these capabilities, we extract specific content related to OODA (Observe, Orient, Decide, Act) dynamics in rescue actions. Furthermore, a comprehensive index system is developed to evaluate emergency rescue capabilities in the context of urban waterlogging scenarios. To address the challenges associated with intelligent optimization and evaluation of such systems, we employ a radial basis function neural network and conduct wargame experiments to obtain data and measure capability indices. The evaluation model is trained using data samples to ensure robust performance. In addition to the proposed model evaluation and analysis framework, we also present an evaluation and analysis method for RBF (Radical Basis Function) neural networks and compare the prediction results with those obtained from GRNN (Generalized Regression Neural Network), PNN (Product-based Neural Network), and BP (Back Propagation) neural network algorithms. This model efficiently processes and fits data by simulating expert experience for evaluation purposes. Such an approach takes advantage of machine learning’s sensitivity to data characteristics, effectively avoiding the influence of human factors while stably reflecting the mapping relationship between indicators and performance outcomes. This research presents a novel solution with significant implications for the development of urban emergency rescue systems that address the challenges posed by urban waterlogging incidents.

I.INTRODUCTION

The city, acting as a crucial regional center in the realms of politics, economics, and culture, continues to be susceptible to diverse calamities. Human activities often undermine the city’s capacity to prevent and withstand disasters, thereby diminishing its safety resilience and exacerbating the impact of natural calamities. Revealing the persisting challenge, despite remarkable advancements in science and technology, lies in accurately predicting certain abrupt natural disasters such as waterlogging. This inherent challenge significantly complicates disaster management efforts. The acceleration of urbanization has led to an increased frequency of urban waterlogging disasters and subsequent losses, posing a substantial threat to the socio-economic fabric of cities [1]. Given the intricate nature [2], unpredictable characteristics [3], and extensive damage potential [4] associated with urban waterlogging disasters, urban emergency management faces multifaceted challenges encompassing establishing a harmonious and stable urban environment, judicious utilization of limited resources, and enhancing the emergency management department's ability to promptly respond to crises while mitigating risks. Adopting a scientific approach is imperative for disaster mitigation. Currently, both domestic and international researchers have conducted extensive research on disaster management, focusing on various technical aspects such as communications, computers and networks, geographic information systems (GIS), global positioning systems (GPS), among others [5], [6], [7]. Notably, significant contributions have been made in the development of advanced machine learning and optimization algorithms in this field. For instance, a novel approach for real-time monitoring of Automated Guided Vehicles (AGVs) against cyber attacks has been proposed using an integrated Internet of Things (IoT) architecture and a developed Deep Neural Network (DNN) with rectified linear units [8]. This innovative method enables effective detection of potential cyber-attacks on AGVs. Furthermore, in [9], a fault detection and correction approach based on IoT and deep learning was proposed to detect bearing faults during motor operation by analyzing vibration signals. A novel system based on IoT and deep learning, as presented in [10], demonstrates real-time detection of cyberattacks and accurate classification of various cutting conditions, enabling online monitoring for CNC machines. In this study, we propose a novel approach that utilizes convolutional neural networks and an innovative image mixing method for data augmentation to achieve precise and reliable measurement of Vickers hardness value directly from high-resolution images of SCM 440 steel specimens, as described in [11]. The authors in [12] introduce a deep learning strategy utilizing a convolutional neural network (CNN) with two convolutional layers and two pooling layers for disease detection and classification of tomato plants. Furthermore, [13] introduces Bash Bunny, a novel tool designed to assist military personnel, law enforcement agencies, and penetration testing teams in successfully extracting data from air-gapped networks using specific techniques that yield exceptionally high success rates. As previously indicated in the literature [14], [15], [16], the implementation of a situational emergency response program can significantly enhance the reliability and efficiency of emergency operations. Numerous research studies have focused on urban flood emergency response [17], [18], [19]. In a recent investigation [20], the

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utilization of urban flood soldier chess projection combined with dynamic Bayesian networks was explored for contingency analysis in disaster systems. Power system contingency strategies were examined in another study [21] to assess the effectiveness of artificial neural network-based analysis for rapid decision-making. Additionally, an architectural strategy for a disaster management simulation exercise platform was proposed by [22] to enhance support for verifying decision-making activities related to command and control as well as resource allocation. Considering that flood disasters are characterized by urgent situations and limited access to information, incorporating neural network technology into the design and development of an emergency decision support system enables quantitative decision support for on-site emergency command and dispatch. In the literature [23], a multi-criteria decision model was used to evaluate critical factors for cost reduction in solar power plants.

II.METHODOLOGY

A) SYSTEM ARCHITECTURE

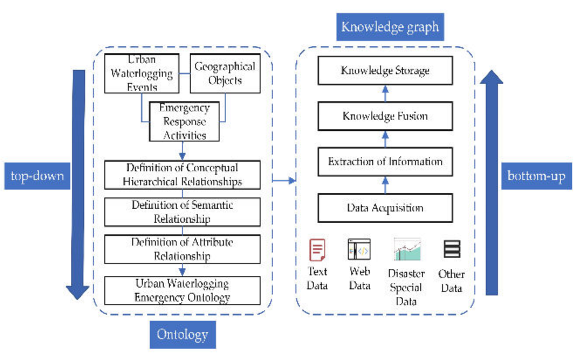

Fig1.System Architecture

The system architecture for evaluating emergency rescue plans for urban waterlogging using a neural network model is designed to integrate real-time data from various sensors, urban planning databases, weather forecasting systems, and emergency management frameworks. The core of the system consists of multiple layers that provide data input, processing, and output for decision-making support.

Data Collection Layer: This layer is responsible for collecting real-time data from various sources, including satellite imagery, IoT-based environmental sensors, weather stations, and mobile applications. Data related to rainfall levels, water accumulation, geographical features, population density, infrastructure status, and traffic conditions are gathered.

Preprocessing Layer: The data collected undergoes preprocessing to remove noise and handle missing or incomplete data. Feature engineering techniques are used to extract relevant features from the raw data, transforming it into a usable format for the neural network. This includes normalization, scaling, and encoding categorical data.

Neural Network Layer: This is the heart of the system, where the core analysis takes place. A deep neural network (DNN) or a more specialized network, such as a convolutional neural network (CNN) for spatial data or recurrent neural network (RNN) for sequential time-series data, is employed to predict the effectiveness of different rescue plans. The model is trained on historical data that includes past

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waterlogging events, their severity, and the effectiveness of previous rescue strategies. The network evaluates multiple parameters, such as rescue team deployment time, response routes, the affected population, and available resources.

Decision-Making Layer: Based on the output of the neural network, the decision-making layer assesses the effectiveness of the rescue plans. It provides a set of recommendations for first responders, urban planners, and emergency management authorities. These recommendations may include optimal evacuation routes, resource distribution strategies, and suggestions for prioritizing affected areas.

Visualization Layer: The visualization layer integrates with the decision-making layer to provide a graphical interface for emergency personnel and authorities. Real-time dashboards, heat maps, and simulation models are used to visualize potential flood zones, rescue resource allocation, and response time. This helps authorities to react faster and more efficiently.

B) Proposed Neural Network Model

The proposed neural network for evaluating emergency rescue plans in urban waterlogging is designed to handle large amounts of diverse data inputs. A multilayer perceptron (MLP) is used for general predictive purposes, but advanced architectures like convolutional neural networks (CNNs) can be used for spatial data processing (e.g., satellite images of the affected areas). For time-series data, such as rainfall prediction or water level forecasting, recurrent neural networks (RNNs) or long short-term memory (LSTM) networks are employed due to their ability to handle temporal dependencies. The model is trained using labeled historical data, with features such as:

- Rainfall intensity and duration
- Historical water levels
- Evacuation times and locations
- The capacity of emergency services and transport routes
- Urban infrastructure vulnerabilities
- Population density in different areas

The neural network model is trained using supervised learning techniques and employs back propagation to minimize prediction error. The final model is evaluated using validation techniques, such as cross-validation

C) Dataset

The dataset for training the neural network model consists of a combination of real-time data and historical information related to urban waterlogging incidents. The data sources can include: Weather data: Rainfall, wind speed, temperature, humidity, and other meteorological factors. Geospatial data: Information about urban topography, flood-prone areas, and infrastructure vulnerabilities. Traffic data: Current traffic patterns, road closures, and bottlenecks during waterlogging events. Historical waterlogging data: Information from past waterlogging events, such as the affected area, response time, casualties, and the effectiveness of previous emergency plans. Emergency response data: Data on response team locations, evacuation times, available rescue resources, and evacuation efficiency. The dataset needs to be comprehensive, with the quality and accuracy of data being paramount to the success of the neural network model. Data preprocessing is necessary to standardize and normalize inputs to avoid discrepancies in learning patterns and ensure a reliable model.

D) Future Selection

The future development of this system will focus on enhancing its accuracy, scalability, and adaptability. Key areas for improvement include: Real-Time Data Integration: Future advancements in IoT and sensor technologies will enable real-time data feeds from various sources, such as drones, wearable devices, and mobile applications, further improving the responsiveness and accuracy of the system. Model Adaptation for Dynamic Environments: Urban waterlogging scenarios can vary greatly due to factors like climate change, urbanization, and infrastructure degradation. The system could incorporate reinforcement learning (RL) techniques to adapt to changing conditions and improve prediction and decision-making capabilities over time. Multi-Criteria Decision Analysis (MCDA): For more comprehensive decision-making, the system could integrate multi-criteria decision-making models that combine economic, social, and environmental factors alongside neural network predictions. This would allow authorities to make decisions based on a wider array of constraints and priorities. Collaboration with Autonomous Systems: In the future, autonomous vehicles, drones, and robots could be deployed to assist in urban rescue operations, with the system being integrated into these platforms for real-time decision-making. Interoperability: The system could be expanded to integrate with other urban management systems, such as traffic management, healthcare emergency systems, and environmental monitoring systems, ensuring more coordinated disaster response strategies.

III.CONCLUSION

The application of neural networks for evaluating the effectiveness of emergency rescuing plans in urban waterlogging scenarios is a promising approach. By combining real-time data collection, advanced machine learning algorithms, and decision support systems, such a system can significantly enhance the effectiveness of rescue operations, reduce casualties, and mitigate damages caused by waterlogging events. The ongoing improvement and adaptation of the neural network model, along with the integration of new data sources and technologies, will play a key role in ensuring that urban areas can respond efficiently to future waterlogging events.

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