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IoT-Based Flood Detection and Management Systems in Urban Areas

Srinjoy Sengupta*

Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha, India; 22053383@kiit.ac.in.

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Abstract

Urban flooding poses considerable challenges due to its economic, social, and environmental repercussions, particularly in areas experiencing rapid urbanization. This paper reviews recent developments in IoT applications for flood detection and management. It underscores different IoT frameworks that are employed to gather and oversee data from sensors that track hydrological, geological, and meteorological metrics. Furthermore, the research investigates how Artificial Neural Networks (ANN) are integrated into smart flood prediction systems, which enhance the scalability and reliability of flood management initiatives by evaluating critical environmental variables. The fusion of IoT with cloud computing and data analytics services has bolstered data processing capabilities. Conversely, the integration of IoT with Synthetic Aperture Radar (SAR) data provides effective solutions for monitoring and early warning systems. By synthesizing current research and identifying emerging trends, this survey aspires to offer insights into the efficacy and efficiency of current flood management strategies and their implications for enhancing urban resilience.

Keywords: IoT-based systems, Flood detection, Urban areas, Real-time monitoring, Machine learning, Flood management.

1 | Introduction

Flood management has increasingly relied on advanced technologies, including the Internet of Things (IoT), remote sensing, and Machine Learning (ML). These innovations enable real-time monitoring, accurate flood prediction, and timely alerts, thereby improving disaster preparedness and reducing the adverse impacts of flooding on communities and infrastructure.

Corresponding Author: 22053383@kiit.ac.in

1.1 | Background on Urban Flooding and Its Impact

Urban flooding is a growing concern with significant economic, social, and environmental impacts. It is exacerbated by climate change, population growth, and rapid urbanization, especially in developing countries like India [1]. The causes of urban flooding include the expansion of impervious surfaces, altered drainage patterns, and the loss of natural features due to urban growth. These factors contribute to increased vulnerability and risk in urban areas. To address this issue, resilience thinking has become a key consideration for city planners and decision-makers. Recent advances in urban flood research have introduced novel modeling approaches, including hydraulic-hydrologic models that utilize modern computing architecture and Artificial Intelligence (AI) techniques. Understanding the impacts of flooding is crucial for building flood-resilient cities and implementing effective management strategies.

1.2 | Limitations of Traditional Flood Management Systems

Traditional flood management systems face several limitations. Conventional flood gates in water canals are often manually operated and lack real-time monitoring, leading to overflow and flash floods. Many existing flood monitoring systems have a limited range, are difficult to maintain, and offer insufficient data analysis capabilities. Flood control dams frequently fail to provide adequate protection due to violations of operational guidelines and encroachment on floodplains. Relying solely on hard-engineered measures is less sustainable and adaptable than integrated approaches incorporating nature-based solutions. Additionally, traditional knowledge systems, potentially contributing to disaster risk reduction, are often overlooked in existing disaster management policies and practices [2]. Integrating traditional knowledge with modern science and technology, such as IoT-based solutions, is recommended for a more comprehensive and practical approach to flood management to address these limitations.

1.3 | Importance of Adopting Modern Technology for Flood Detection and Management

Modern technology plays a crucial role in flood detection and management. Remote sensing, Geographic Information Systems (GIS), and AI have emerged as powerful tools for predicting, monitoring, and responding to floods. These technologies complement traditional hydrological methods, providing enhanced early warning systems and better decision support. ML and image processing techniques have been applied to various flood management tasks, including prediction, detection, mapping, and evacuation planning. However, there is still a need for more hybrid models that combine these approaches for improved outcomes. Additionally, modern technology can support post-disaster rehabilitation by offering services such as counseling to survivors [3]. Integrating these advanced technologies with disaster management practices is essential for developing comprehensive flood management strategies that address all phases, from prediction to recovery.

1.4 | Objectives and Contributions of the Research

The main objective of this research is to survey the current advancements in IoT-based flood detection and management systems, focusing on urban environments. This study aims to evaluate existing approaches, identify their limitations, and explore recent technological developments in IoT, ML, and cloud computing that can enhance flood prediction, monitoring, and response. The research contributes by providing a comprehensive overview of modern methodologies, assessing the integration of different technologies for real-time data collection and analysis, and highlighting the gaps in current solutions. Additionally, it aims to offer recommendations for future research directions and practical strategies for implementing more resilient flood management systems in cities.

2 | Literature Review

Research on flood management has highlighted the benefits of IoT, ML, remote sensing, and GIS technologies for improving prediction, monitoring, and response strategies [4]. IoT devices enable real-time data collection from sensors, while ML techniques enhance predictive accuracy. Remote sensing and GIS facilitate spatial analysis for mapping flood risks and assessing urban vulnerabilities. Integrating these technologies provides a comprehensive approach, offering valuable insights for developing more resilient flood management practices.

2.1 | Overview of Existing Flood Detection and Management Approaches

Flood risk management has evolved significantly over the past decade, transitioning toward a more integrated and strategic approach emphasizing whole systems and life-cycle thinking. This methodology encompasses a variety of activities and techniques, ranging from hydrological assessments to economic evaluations. Flood monitoring and warning systems (FMWS) are essential for mitigating the impacts of flooding; however, many existing systems face challenges related to range, maintenance, and real-time monitoring capabilities. Remote sensing technologies have become invaluable for flood management, providing timely and detailed information crucial for disaster response and damage assessment. Satellite and aircraft-based systems can effectively delineate flood-affected areas, evaluate damage, and enhance predictive modeling of flood vulnerability in both inland and coastal regions [5]. These advancements in flood risk management, monitoring systems, and remote sensing techniques collectively contribute to more effective flood detection, prevention, and response strategies.

2.2 | Previous Work on IoT Applications in Flood Management

Recent research has investigated the applications of the IoT in flood management. Proposed IoT architectures focus on collecting, transmitting, and managing flood-related data from various sensors that monitor hydrological, geological, and meteorological parameters. These systems aim to enhance the integration of data, sensors, and applications while providing collaborative tools for diverse end-users. A distributed cooperative IoT system has been developed to tackle the challenges associated with conventional server-centric IoT systems—such as increased network load and delays in feedback control. This approach employs event-driven data collection and edge computing to facilitate efficient real-time flood alerts. Field trials conducted in Vietnam have shown a significant reduction in network load for flood monitoring [6]. IoT-based flood monitoring systems can improve disaster prevention and management capabilities, especially for flash floods resulting from extreme rainfall events.

2.3 | Use of ML in Flood Prediction

ML techniques have become powerful tools for flood prediction, offering enhanced accuracy and cost-effectiveness compared to traditional methods. These algorithms can analyze large volumes of data to identify subtle patterns, making them particularly effective for predicting long-term and short-term flood events [7]. By leveraging ML models, stakeholders can contribute to risk reduction, develop policy recommendations, and minimize the loss of life and property damage. Various ML approaches have been utilized, including data decomposition, algorithm ensemble techniques, and model optimization. Flash floods, which can occur rapidly due to intense rainfall, present a significant challenge for prediction systems. Typically, ML-based flood prediction systems involve data preprocessing, variable identification, and model evaluation using metrics such as accuracy and confusion matrices. Despite the potential of ML techniques, challenges remain in developing models that are both more accurate and efficient for flood prediction.

2.4 | Recent Advancements in IoT Applications for Flood Management

IoT applications for flood management have demonstrated promising results in monitoring, prediction, and early warning systems. Proposed IoT architectures focus on collecting, transmitting, and managing flood-related data from various sensors that measure hydrological, geological, and meteorological parameters. Smart flood prediction systems that utilize IoT and Artificial Neural Networks (ANN) have been developed to enhance scalability and reliability in flood management [8]. To predict flooding using ANN algorithms, these systems monitor critical factors such as humidity, temperature, pressure, rainfall, and river water levels. Integrating IoT with cloud computing and data analysis platforms has further improved data processing capabilities, allowing for more efficient information management. Additionally, combining IoT with Synthetic Aperture Radar (SAR) data shows significant potential for developing robust flood monitoring and early warning systems. These advancements aim to provide more effective and efficient solutions for managing floods in flood-prone areas.

Table 1. Showing different IoT Technologies.

IoT Technology	Description	Applications in Flood Management	Advantages	Challenges
Ultrasonic Sensors	Measures water levels using sound waves.	Monitoring river levels, reservoirs, and urban drainage systems.	Low cost, reliable for level measurement.	Limited range, affected by obstacles or debris.
LoRa (Long Range)	Low-power, long-range communication.	Transmitting data from remote areas.	Long-range, low power usage.	Limited data rate, needs gateways.
Drones/UAVs	Collect high-resolution aerial imagery.	Inspecting flood damage, monitoring.	High spatial resolution, flexible.	Limited flight time and regulations.

3 | Current State of IoT-Based Flood Detection Systems

IoT-based flood detection systems have advanced significantly, incorporating a range of sensors such as water level, rainfall, and flow sensors for real-time monitoring. These systems utilize low-power communication technologies like LoRa and GSM for data transmission, ensuring extensive coverage and continuous data flow. However, challenges remain in ensuring data accuracy, optimizing power consumption, and improving integration with predictive analytics. Efforts are ongoing to address these limitations by developing more robust architectures, enhancing connectivity, and utilizing ML for better flood forecasting and decision-making support [9].

3.1 | Description of Existing IoT Architectures and Their Functionalities

IoT architectures play a critical role in integrating various components and ensuring the success of IoT applications. Numerous IoT architectures exist, including software, hardware, and general frameworks. Layered architectures are ubiquitous, with distinct services provided at each layer. A notable five-layered model has been proposed as a comprehensive IoT architecture. Additionally, domain-specific architectures cater to the unique requirements of different IoT applications. IoT platforms must effectively integrate heterogeneous components from multiple vendors, utilizing diverse protocols, data formats, and communication technologies [10]. Despite the variety of available architectures, IoT systems encounter scalability, reliability, and heterogeneity challenges. Understanding these architectures and their functionalities is crucial for researchers and developers in selecting the most suitable technologies for their IoT projects.

3.2 | Review of Sensor Technologies Used in Flood Monitoring

Flood monitoring systems have progressed significantly by incorporating various sensor technologies and data analysis methods. Remote sensing, including optical and radar satellite sensors, offers frequent and cost-effective capabilities for assessing floods. IoT-based sensors and computer vision techniques are increasingly employed for real-time flood monitoring, modeling, and early warning systems. Commonly used sensors in flood monitoring include depth, rainfall, and flow sensors, often integrated with wireless sensor networks and GSM technology for internet connectivity. Advanced systems utilize a combination of precipitation, flow velocity, water level, temperature sensors, and cameras to gather hydrological data and characterize flood events. Despite these advancements, many existing FMWS in developing countries face limited range, reliance on manual operations, and a lack of real-time data analysis [11]. Researchers advocate leveraging IoT technologies to overcome these limitations and enhance flood monitoring capabilities.

3.3 | Integration of Data Collection, Transmission, and Analysis

Data integration is essential for analyzing large volumes of diverse information from multiple sources in flood management. A practical integrated framework combines real-time data collection from various sensors with dynamic visualizations and simulations, facilitating improved planning and control of flood monitoring efforts. As the volume of sensor data increases, there is a need for enhanced data management and analysis techniques that can process both historical and live-streaming data simultaneously. This capability allows for faster analysis and better situational awareness during flood events. Data integration techniques can address queries that span multiple data sources, which is critical for effective flood response and management. These approaches aim to overcome the challenges of analyzing unique and complex datasets, reduce decision-making response times, and enable more efficient data analysis across diverse sources in flood-prone areas.

3.4 | Comparison of Centralized Versus Distributed Systems

Centralized systems provide streamlined management and easier control over data processing; however, they introduce single points of failure that can compromise system reliability during critical events. On the other hand, distributed systems enhance scalability and fault tolerance, making them well-suited for real-time flood monitoring across multiple locations. However, this comes at the cost of increased system design and maintenance complexity [12]. The choice between centralized and distributed systems ultimately depends on various factors, including the nature of the flood management application, scalability requirements, and the sensitivity of the data being processed. Careful consideration of these factors ensures effective flood detection and response strategies.

4 | ML Techniques in Flood Prediction

ML techniques such as decision trees, random forests, support vector machines, neural networks, and K-Nearest Neighbors (KNN) significantly enhance flood prediction by analyzing large datasets to identify patterns. These methods offer varying strengths, such as handling non-linear data or working well with high-dimensional spaces while having limitations like overfitting or high computational demands. Integrating these techniques allows for more accurate and timely flood predictions, crucial for effective disaster management.

4.1 | Overview of ML Approaches Utilized for Flood Prediction

ML approaches have become increasingly popular in flood prediction because they can analyze large datasets and identify complex patterns. Various ML techniques have been effectively utilized, including logistic regression, decision trees, naive Bayes, and support vector machines. These methods often provide enhanced performance and cost-effective solutions compared to traditional physical models. Decision trees, in particular, have shown promise, improving accuracy as more features are integrated into the models. Researchers are actively enhancing ML models through hybridization, data decomposition, algorithm ensemble, and model optimization strategies [13]. Despite the successes of ML in flood prediction, challenges persist, especially in generating accurate and timely predictions to mitigate the impacts of rapidly developing events like flash floods. Ongoing research is focused on refining ML techniques to enhance flood forecasting capabilities and address these challenges effectively.

4.2 | Evaluation of Model Performance Metrics and Methodologies

The evaluation of model performance is a critical aspect of flood prediction research. In this domain, assessing the effectiveness of various models involves ranking them based on their predictive accuracy for different flood-related variables. Metrics such as mean absolute error and root mean square error are commonly used to evaluate the performance of flood prediction models. In addition to traditional statistical measures, specialized metrics may be employed to capture the temporal significance of predictions, particularly for rapidly developing events like flash floods. While conventional evaluation methods can offer insights into model accuracy, they may also have limitations, such as sensitivity to specific data distributions and neglecting the uncertainty inherent in predictions. Emerging methodologies focusing on classification capabilities and performance comparison across diverse datasets aim to address these challenges [14]. These varied approaches underscore the importance of selecting appropriate metrics and evaluation methodologies for assessing model performance in the context of flood prediction.

4.3 | Discussion of Challenges in Predicting Flash Floods Using ML Techniques

ML techniques have become increasingly important in flood prediction because they can analyze large datasets and identify complex patterns. These methods provide enhanced performance and cost-effective solutions for predicting flash floods, which pose significant risks due to their rapid onset. Random forests and support vector machines are frequently employed among the various ML algorithms to assess flash flood susceptibility and generate early warning predictions. However, challenges remain, including optimization, improved internet connectivity, and solutions to data loss issues. Researchers are investigating strategies such as hybridization, data decomposition, algorithm ensemble, and model optimization to boost prediction accuracy. Future advancements may focus on incorporating sociodemographic, health, and housing data and considering climate change scenarios for long-term adaptation strategies [15]. Despite the existing challenges, ML models have shown high prediction performance, with metrics indicating robust accuracy.

4.4 | Analysis of the Effectiveness of Various ML Algorithms

The effectiveness of ML algorithms varies across applications, highlighting distinct strengths and weaknesses [16]. For water quality prediction, some algorithms demonstrate superior accuracy and lower error rates, while in hiring decisions, metrics like processing time, precision, and recall complicate the selection process. Classification algorithms, including Logistic Regression, Decision Trees, Support Vector Machines (SVM), and KNN, perform differently across datasets, for example, Decision Trees are intuitive but prone to overfitting, whereas SVMs excel in high-dimensional spaces with careful tuning. In medical contexts, models like Random Forests and Neural Networks handle complex data effectively but can lack interpretability [17]. Ultimately, the choice of algorithm should align with the specific application and desired outcomes.

Table 2. comparing various ML approaches.

ML Technique	Use in Flood Prediction	Strengths	Challenges
Decision Trees	Classifying flood risk based on hydrological data.	Easy to interpret, handles various features.	Risk of overfitting with small datasets.
Support Vector Machines	Identifying flood-prone areas using classification.	Good performance with small data samples.	Sensitive to tuning hyperparameters.
Random Forests	Predicting flood events by aggregating multiple data sources.	High accuracy, robust to noisy data.	Slower prediction times for large datasets.
Neural Networks	Modeling complex flood patterns with time-series data.	Captures nonlinear dependencies in data.	Requires substantial data and training.

5 | Remote Sensing and Geographic Information Systems

Remote sensing and GIS play a crucial role in flood management by providing data collection, analysis, and visualization tools. Remote sensing techniques, including satellite imagery and aerial photography, enable the detection of flood-prone areas and monitoring flood dynamics. GIS facilitates the integration of spatial data, such as topography and land use, allowing flood hazard maps and risk assessments to be created [18].

Together, these technologies support decision-making processes in urban planning and emergency response, helping to mitigate flood risks and enhance resilience.

5.1 | Role of Remote Sensing Technologies in Flood Management

Remote sensing technologies are essential for effective flood management at all stages: pre-flood, during, and post-flood. Utilizing tools like multispectral imaging, radar, and LIDAR, these technologies enhance flood prediction, risk assessment, and hazard analysis [19]. GIS complement remote sensing by improving flood disaster monitoring and management, offering significant advantages over traditional methods of hydrological parameter recording. They provide cost-effective and rapid access to spatial data, even in hard-to-reach areas, while facilitating hydrological modeling through data collection, analysis, and presentation. Remote sensing techniques are particularly valuable for delineating flood-prone regions, developing flood hazard maps, and estimating flood depths with [8] Digital Elevation Models (DEMs). Moreover, they can aid in assessing the impacts of urbanization on river flows and flood risks.

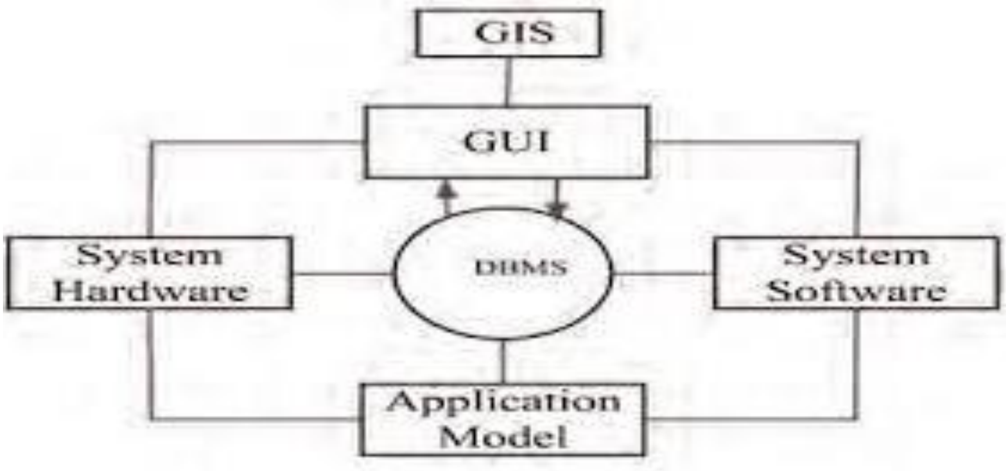

Fig. 1. Overview of geographic information system design.

5.2 | Application of GIS in Flood Mapping and Risk Assessment

GIS are essential for flood risk mapping and assessment, offering a range of applications from data management to creating flood hazard maps. GIS facilitates comprehensive flood risk assessments by integrating diverse datasets, such as topography, bathymetry, and flood defense infrastructure. Researchers have developed techniques to identify flood hazards and risk areas by analyzing rainfall, water characteristics, and population density. GIS overlay functions, combined with Digital Elevation Models (DEMs), enable the creation of classification maps for flood risk zones, guiding urban planners to avoid development in high-risk areas [13]. Additionally, integrating hydraulic simulation models, such as HEC-RAS, with GIS enhances spatial visualization and prediction of flood scenarios, significantly improving flood risk assessment capabilities. These methodologies highlight GIS's versatility and effectiveness in flood-related research.

5.3 | Case studies Demonstrating the Use of Remote Sensing and GIS in Urban Flood Scenarios

Through various case studies, remote sensing and GIS technologies have shown significant value in urban flood analysis and management. In Canada, high-resolution optical imagery was utilized to map floodwater distribution and evaluate the impacts of urban growth on flood risks. Similarly, QuickBird imagery and GIS-based hydrological modeling were employed in Ho Chi Minh City, Vietnam to identify areas vulnerable to rainfall-induced and tidal flooding. A study in Dhaka, Bangladesh, integrated GIS and remote sensing to develop flood prediction maps based on criteria such as elevation, flooding depth, and land use types [20]. In

Ahmedabad, India, these technologies were applied to analyze urban flooding and propose sustainable urban drainage solutions. These case studies illustrate the effectiveness of remote sensing and GIS in mapping flood extent, assessing risk factors, and facilitating informed decision-making for urban flood management.

Table 3. The table shows technologies like remote sensing and GIS utilized in flood management.

Technology	Use in Flood Management	Strengths	Challenges
Remote Sensing	Mapping flood extent using satellite imagery.	Provides large-scale, real-time data coverage.	Limited accuracy under cloud cover conditions.
GIS	Analyzing flood risk and creating hazard maps.	Enables integration of diverse datasets.	Requires high-quality data for accurate results.
LIDAR	Measuring flood depths and topography changes.	High-resolution data suitable for urban areas.	Expensive and resource-intensive data processing.
Radar Imaging	Monitoring rainfall and water levels remotely.	Penetrates through clouds for accurate readings.	Lower spatial resolution compared to optical sensors.

6 | Challenges and Limitations in Current Research

Current research in flood prediction and management faces several challenges and limitations. These include integrating diverse data sources, real-time data processing, and the scalability of IoT-based systems [21]. While effective, ML models often struggle with data quality issues and require significant computational resources for large-scale implementations. Remote sensing techniques may encounter limitations in spatial and temporal resolution, affecting the accuracy of flood mapping. Additionally, the lack of standardized protocols for data sharing and limited technical expertise in some regions further constrain the effectiveness of current approaches [15]. Addressing these challenges is essential for advancing flood resilience efforts.

6.1 | Identification of Gaps in Existing IoT-Based Flood Management System

Recent studies have highlighted several gaps in current IoT-based flood management systems. Issues such as inadequate hydraulic design of flood control structures, inaccurate forecasting, and insufficient maintenance of warning systems have exacerbated flooding in Metro Manila. While proposed IoT architectures for flood data management exist, there is a pressing need for more comprehensive and integrated approaches. A systematic review indicates slow progress in implementing systems thinking in flood risk management, revealing a significant disparity between developed and developing countries, especially in Africa. Limited technical expertise and resource constraints impede the adoption of advanced methodologies in many regions. To overcome these challenges, researchers advocate for transitioning from linear to holistic approaches that align with global disaster risk reduction and sustainable development frameworks [16]. Collaboration among researchers, institutions, and countries is essential for improving flood risk management efficacy.

6.2 | Limitations of Current Predictive Models and Technologies

Predictive models are extensively employed in flood management yet encounter several limitations. Current models often struggle to accurately account for the complex interactions between various environmental factors, leading to challenges in real-time flood forecasting. In hydrological modeling, oversimplifications and subjective assumptions can negatively impact the accuracy of predictions. Additionally, predictive models may not generalize well to different geographical regions or climatic conditions, particularly if developed using localized datasets, resulting in potential overfitting. In flood risk assessment, existing models frequently lack sufficient accuracy due to inadequate datasets and the absence of standardized metrics for evaluation. Researchers are increasingly integrating advanced technologies such as ML, AI, and remote sensing to overcome these challenges into next-generation flood prediction models. Furthermore, external validation of these models across diverse populations and settings is essential to enhance their reliability and effectiveness in flood management strategies.

6.3 | Issues Related to Data Integration, Real-Time Monitoring, and Maintenance

Data integration in flood management involves several challenges, particularly in unifying diverse data sources and managing real-time information from various sensors. Integrating hydrological, meteorological, and geological data is critical for effective flood prediction and risk assessment, yet the heterogeneous nature of these data sources complicates the process. Additionally, real-time monitoring systems must address interoperability issues, which are more complex than those found in traditional databases. In flood management, the quality and reliability of integrated data are essential for accurate decision-making. While conventional statistical methods may suffice for small datasets, data mining techniques can uncover valuable insights from large, dynamic datasets, enhancing the ability to manage flood risks effectively [17]. Addressing these challenges is vital for improving flood monitoring, prediction, and disaster response strategies.

7 | Future Directions for Research

Future flood prediction and management research should focus on several key areas to enhance effectiveness and resilience. Emphasizing the integration of IoT, ML, and remote sensing can improve data accuracy and timeliness. Developing standardized protocols for data sharing will facilitate collaboration across disciplines and regions. Researchers should explore hybrid models combining machine-learning techniques to enhance prediction accuracy and reliability. Investigating nature-based solutions and their impacts on flood risk reduction can provide sustainable management strategies [22]. Finally, incorporating community engagement and local knowledge into flood management frameworks will ensure solutions are tailored to specific regional needs and challenges.

7.1 | Recommendations for Enhancing IoT-Based Flood Detection and Management

IoT-based flood detection and management systems have emerged as vital tools for mitigating the impacts of flooding, potentially saving lives, and protecting property. These systems leverage various sensors, such as ultrasonic sensors for monitoring water levels, and utilize microcontrollers like NodeMCU ESP8266 or ESP32 for efficient data processing and transmission. Adopting low-power, long-range communication technologies, such as LoRa, can significantly extend the coverage area of these systems. Furthermore, integrating computer vision techniques with IoT sensors enhances real-time flood monitoring, modeling, and early warning capabilities. IoT frameworks can effectively monitor surface and groundwater levels, enabling timely alerts to vulnerable populations.

7.2 | Suggestions for Improving ML Models for Flood Prediction

ML models have made significant strides in flood prediction systems over the past two decades, enhancing performance and cost-effectiveness. However, there is still room for improvement. To optimize flood prediction models, several strategies should be prioritized. First, hybridizing existing models can leverage the strengths of different algorithms, increasing predictive accuracy. Second, data decomposition techniques can enhance model performance by breaking complex datasets into manageable components, allowing for more precise analysis. Third, employing algorithm ensemble methods can improve predictions by combining the outputs of multiple models to reduce errors. Also, model optimization through hyperparameter tuning can fine-tune model performance to specific datasets. Emphasizing real-time data integration and socioeconomic factors can also enrich model outputs, leading to better-informed flood management decisions [23]. By adopting these strategies, researchers and practitioners can significantly enhance the efficacy of ML models in flood prediction, ultimately contributing to improved risk reduction and disaster management efforts.

7.3 | Importance of Interdisciplinary Approaches in Flood Management

Interdisciplinary approaches are essential for effective flood management, given the complex interactions among natural, built, and social systems. These approaches enhance urban flood resilience and livability by integrating knowledge from diverse disciplines and stakeholders. Successful interdisciplinary research hinges on collaborative processes and team readiness, which can be evaluated through collaborative proximity and program assessment. Such collaboration is vital for effective disaster risk management, as evidenced by initiatives in tsunami hazard mapping and river flooding [24]. Implementing Nature-Based Solutions (NBS) for flood risk management necessitates a multi-actor, multidisciplinary strategy to maximize environmental, social, and economic benefits. Viewing NBS as a boundary concept can foster communication across disciplines and stakeholders, laying the groundwork for effective flood risk mitigation.

7.4 | IoT-Based Flood Monitoring Device

The IoT-based Flood Monitoring and SMS Alert system leverages advanced technology for effective flood management. It features a depth sensor installed in flood-prone areas to continuously monitor water levels. The collected data is transmitted to a central monitoring station via GSM and Wi-Fi networks. When the water levels reach a critical point, the system automatically sends SMS alerts to authorities and residents, providing real-time updates on potential flood risks [25]. This proactive flood monitoring strategy enables timely responses and strengthens disaster management, helping to reduce the impact on communities and infrastructure.

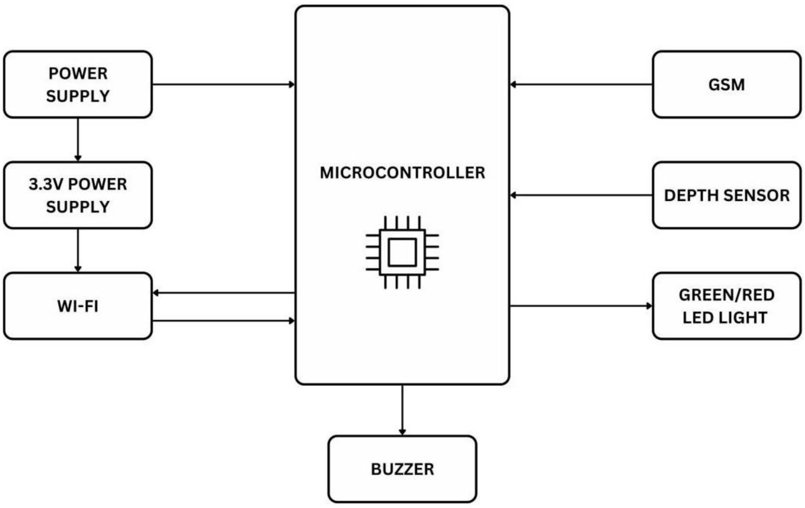

Fig. 2. Diagram of IoT based flood monitoring device.

8 | Conclusion

Integrating IoT, ML, and remote sensing technologies has significantly transformed flood management, enhancing predictive capabilities and real-time monitoring. While challenges persist, such as data integration and model optimization, ongoing research holds promise for developing more resilient flood management strategies. Future efforts should focus on interdisciplinary collaboration, community engagement, and exploring innovative solutions like nature-based approaches. By leveraging these advancements, communities can improve their preparedness and response to flooding, ultimately minimizing its impact on lives and infrastructure.

8.1 | Summary of Findings from the Survey

The survey on IoT and ML advancements for flood management reveals several key findings. IoT architectures, utilizing diverse sensors and communication technologies, have effectively monitored and predicted flood events, although challenges remain in integration and real-time data processing. ML models have significantly improved flood prediction accuracy, with strategies such as hybridization and algorithm ensemble vital for enhancing model performance. Interdisciplinary approaches are essential for effective flood management, integrating knowledge across various domains and stakeholders to foster urban resilience [25]. Lastly, remote sensing and GIS technologies have proven invaluable for mapping flood risks and supporting decision-making in urban environments. Integrating these technologies and collaborative strategies presents a promising pathway for enhancing flood management and response efforts.

8.2 | Implications for Urban Flood Management Strategies

The integration of IoT and ML in urban flood management enhances real-time monitoring and predictive capabilities. IoT devices facilitate swift data collection, leading to timely early warning systems that protect lives and property. ML analyzes complex datasets for improved flood prediction, allowing for proactive resource allocation and targeted interventions [26]. Additionally, interdisciplinary collaboration and nature-based solutions are essential for developing comprehensive strategies that restore natural water flow and enhance urban resilience against flooding

8.3 | Final Thoughts on the Future of IoT and Technology in Flood Resilience

The future of IoT and technology in flood resilience holds great promise for enhancing disaster preparedness and response. As IoT devices become more sophisticated, their ability to provide real-time data on hydrological conditions will improve, allowing for more accurate flood predictions and early warning systems. Advancements in ML and data analytics will enable the integration of diverse data sources, facilitating better decision-making and resource allocation. Furthermore, the synergy between technology and nature-based solutions will encourage sustainable urban planning and ecosystem restoration, fostering resilience in flood-prone areas. Collaborative efforts among governments, researchers, and communities will be crucial in leveraging these technologies to create adaptive strategies that mitigate flood risks and enhance overall community resilience.

Author Contribution

Srinjoy Sengupta study the data, write the original draft, contribute to the discussion of the limitations of the strategies, validate the results, and review the manuscript.

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Data Availability

The data used and analyzed during the current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest regarding the publications of this paper.

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