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Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management in Carrascal Municipality

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Abstract:
This study introduces an innovative flood monitoring solution powered by Internet of Things (IoT) and SMS notifications aimed at transforming disaster management in Carrascal, a flood-prone municipality. Utilizing ultrasonic sensor technology, the system continuously tracks water levels and promptly sends SMS alerts to relevant authorities, enabling swift and coordinated responses. The system is developed using an Iterative Development Model, incorporating Arduino-based hardware, MySQL database management, and PHP programming alongside an Online Programming Platform, ensuring flexibility and scalability. The findings confirm the system's high efficiency, security, and ease of use, alongside its maintenance-friendly nature, making it a valuable asset for local residents and municipal personnel. The system is highly recommended for integration by the Municipal Disaster Risk Reduction and Management Office (MDRRMO) in Carrascal, aimed at enhancing flood detection, monitoring, and rapid emergency response.

Keywords: IoT, Ultrasonic Sensing, Flood Monitoring System, SMS Alerts, MySQL, Disaster Risk Management

Introduction:
Flooding is a devastating natural disaster that often strikes without warning, causing significant damage to both lives and properties. In the municipality of Carrascal, a region frequently affected by floods, a Smart IoT-Enabled Flood Monitoring System with SMS Alerts has been developed to provide timely, real-time alerts to both residents and local authorities. This system continuously monitors water levels using ultrasonic sensors, identifying fluctuations in water levels and sending instant notifications when thresholds are breached, ensuring prompt action can be taken.
According to Vinothini et al. (2019), floods are catastrophic events that result in severe destruction, particularly during heavy rainfall or when waterways overflow. Despite their unpredictability, floods can be effectively managed with the right technological intervention. This project aims to fill the gap by providing a reliable flood monitoring solution through IoT. The system incorporates three sensors to track temperature, humidity, and water levels at various stages, ensuring comprehensive monitoring of flood conditions. These sensor readings are processed using a PIC Microcontroller and transmitted via a Wi-Fi module to a cloud platform for real-time monitoring.

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By implementing a Decision Tree Algorithm, the system achieves 99.6% classification accuracy, ensuring reliable flood detection and decision-making. The Minimum Mean Square Error of the algorithm further improves its prediction capabilities, outperforming alternative methods like the HyperPipes Algorithm. One of the primary challenges in flood management has been the lack of real-time, accessible information for the general public. Traditional systems often focus on limited data points, leaving communities unaware of imminent risks. This IoT-based flood monitoring system addresses this gap by providing a continuous stream of data and instant SMS alerts to keep residents informed and safe. The integration of IoT in flood monitoring not only enhances disaster preparedness but also plays a crucial role in risk mitigation.

The system is designed to be user-friendly and easily accessible, ensuring both residents and administrators can monitor flood conditions effectively. For those living in flood-prone areas, this technology provides a proactive approach to flood prevention, helping to reduce risks during natural disasters. Simple, quick, and reliable, this system aims to revolutionize flood management and protection in Carrascal, ultimately improving disaster response and safety for the entire community.

Conceptual Framework

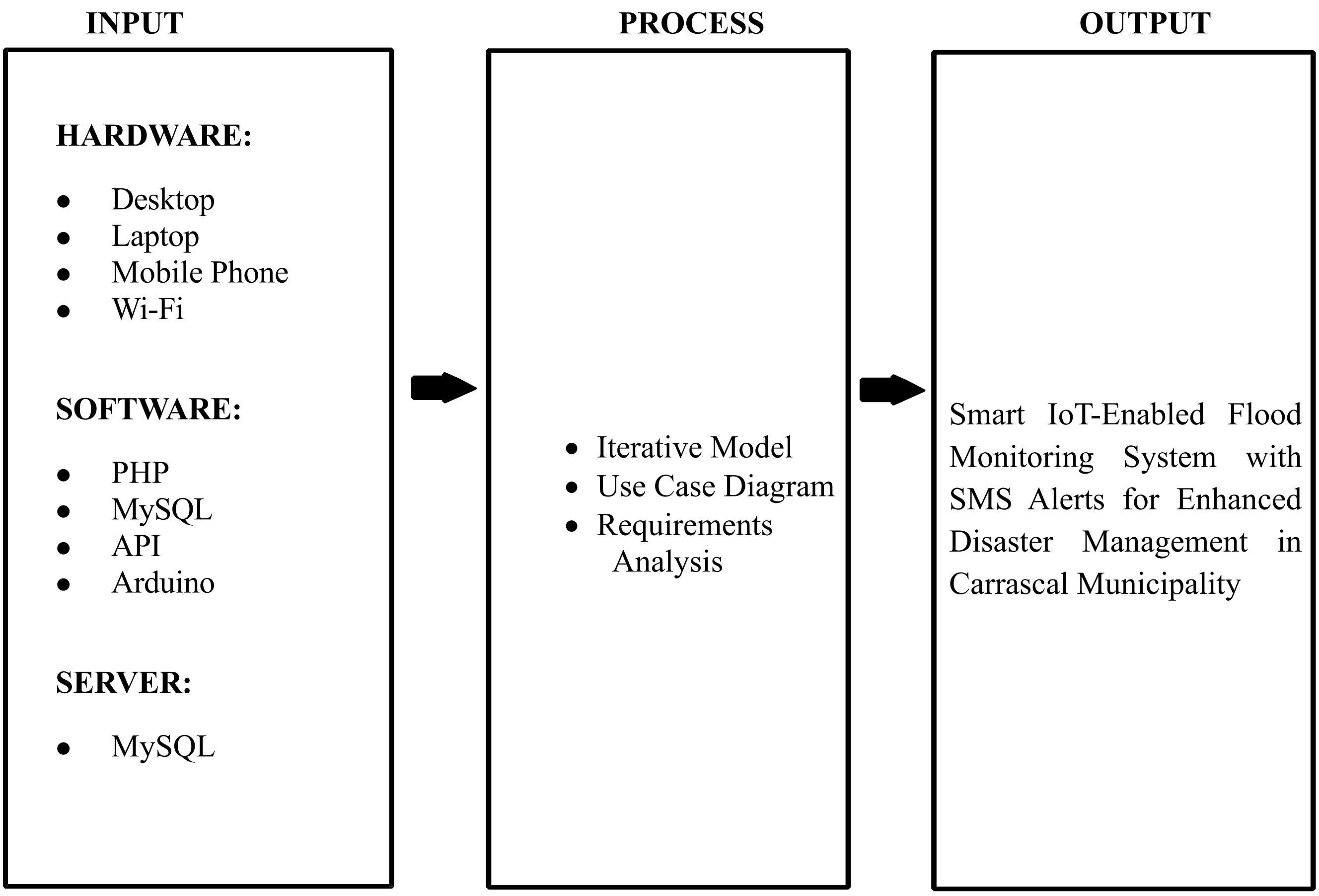

Figure 1.0 IPO Diagram of the Study

Figure 1.0 shows the conceptual framework of the study, which illustrates the process of developing the IoT-Based Flood Monitoring System with SMS Notification in the Municipality of Carrascal. The system utilizes hardware components such as desktop, laptop, mobile phones, and Wi-Fi to access the design and codes of the system. The programming language used in the system is a general-purpose scripting language designed to develop dynamic and interactive applications. The software stack also includes PHP, MySQL, and Arduino, which enable seamless integration for real-time data processing. The system uses the MSSQL database to store all the data inputted by users and collected from sensors. The Iterative Development Model ensures continuous refinement and adaptation of the system, while the Use Case Diagram and requirements analysis guarantee that the system meets the needs of both residents and municipal authorities. Ultimately, the system produces real-time SMS alerts, improving disaster management and flood response in Carrascal.

Statement of Purpose and Objectives

The purpose of this study is to develop and implement an Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management in Carrascal Municipality to enhance disaster preparedness and flood risk management in the Municipality of Carrascal. This system serves as a proactive solution, monitoring real-time water levels and sending instant SMS alerts to the community when a flood is imminent. By providing timely notifications, the system helps minimize the risk of property damage and loss of life, offering a crucial tool for flood-prone areas. This solution leverages the power of Internet of Things (IoT) technology to create an accessible, efficient, and effective means of addressing natural disasters.

The specific objectives of this research are as follows:

- To design and develop an Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management in Carrascal Municipality, specifically tailored for monitoring flood-prone areas.
- To create a system that relays real-time flood information to both residents and administrators, helping store critical data and ensuring the timely dissemination of flood alerts.
- To implement a user-friendly system that allows community members to easily receive alerts and act accordingly, enhancing the overall disaster response and risk mitigation efforts in Carrascal.

By achieving these objectives, this study aims to provide a comprehensive, scalable, and reliable solution that not only improves flood monitoring but also contributes to the safety and resilience of the community.

Scope and Limitation

The scope of this study is centered on the development and implementation of an Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management specifically for the Municipality of Carrascal, located in Surigao del Sur, an area that is highly vulnerable to flooding and landslides. This research aims to reduce the risks posed by flooding, especially in light of climate change, by providing real-time flood monitoring and early warnings to residents. The system leverages Internet of Things (IoT) technology to help protect the lives and properties of those living in flood-prone areas by offering proactive, timely interventions.

Scope:

The study focuses on residents of Carrascal, Surigao del Sur, who are at high risk of flooding and landslides, aiming to reduce the dangers associated with these natural disasters through a real-time IoT-based flood monitoring system.

The objective is to equip the community with a reliable early warning system, providing SMS alerts that help mitigate the adverse impacts of flooding.

Limitation:

The research is geographically limited to the Municipality of Carrascal, Surigao del Sur, and does not extend to other areas or regions.

The Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management in Carrascal Municipality requires a stable internet connection to send real-time alerts, limiting its use in areas with poor connectivity.

The system also requires a computer or laptop to power and operate the device, restricting its implementation in environments without access to such equipment.

Despite these limitations, the study aims to provide an efficient, adaptable solution for flood management that could potentially be expanded to other regions in the future.

Significance of the Study

This research holds considerable value for various stakeholders:

Administrators: The system enables quick and effective updating of data concerning flood-prone areas, facilitating informed decision-making for disaster response and management.

Community: Residents in flood-affected areas will have direct access to accurate, real-time flood data. The SMS notifications offer them timely alerts to take preventive action, minimizing potential damage and safeguarding lives.

Researchers: This study contributes to a deeper understanding of IoT technology in disaster management, allowing researchers to explore the integration of real-time monitoring systems in response to natural hazards.

Future Researchers: The outcomes of this project serve as a valuable reference for future studies in disaster management and climate change adaptation, providing a timely and relevant foundation for further exploration of IoT-based solutions in vulnerable communities.

Related Literature

Foreign Studies

Early warning systems for flood events can save lives and minimize property damage. With the advent of the Internet of Things (IoT), which is accompanied by the widespread availability of affordable sensors, IoT-based flood monitoring systems have become an essential tool in disaster management. A comprehensive survey of various IoT implementations for flood monitoring reveals significant advances in hardware development, sensor integration, and installation methods. In particular, IoT systems use ultrasonic sensors for water level detection, microcontrollers for data processing, and wireless communication for real-time transmission. These systems enable reliable and timely flood warnings, providing cost-effective and practical solutions for mitigating the impacts of floods. Furthermore, the use of artificial intelligence (AI) and machine learning for predictive flood forecasting is an emerging trend, with IoT systems being combined with these technologies to improve accuracy and reliability. Mamat, Nor Hana, et al. (2021) emphasize the importance of waterproofing sensors, particularly ultrasonic devices, to withstand harsh environmental conditions, as well as the integration of additional sensors for comprehensive hydrological, meteorological, and geological data collection.

Additionally, Polymeni, Sofia, et al. (2022) discuss the growing impact of the IoT, where devices are interconnected not only for human interaction but also for continuous data monitoring. IoT networks, equipped with sensors and actuators, allow real-time data collection and communication, making them ideal for environmental monitoring. These advancements make IoT an essential tool for tracking natural disasters such as floods.

Further supporting the role of IoT in flood monitoring, Saragih, Yuliarman, et al. (2020) present a case study on floodgate control systems. Using IoT sensors for real-time water level monitoring, their system integrates stepper motors to control sluice gates, facilitating effective flood mitigation. Their study reported high accuracy in data transmission and real-time flood level monitoring, offering promising solutions for flood control mechanisms.

Shah, Wahidah Md, et al. (2018) focus on IoT platforms that can detect water levels and the rate of water rise, providing earlier warnings to communities. Their flood warning system is based on an IoT framework that sends SMS alerts to mobile phones, offering practical flood mitigation tools. This approach emphasizes the importance of real-time notifications in saving lives by allowing timely evacuations.

The feasibility and effectiveness of IoT-based solutions for flood management are further explored by Gabriel, Piñeres-Espitia, et al. (2022), who assess the viability of 6LoWPAN protocols in flood monitoring systems. Their research emphasizes the capability of TelosB mote devices in flash flood scenarios, proving that IoT technology can significantly reduce the impact of floods through early warning and preparedness.

In conclusion, the integration of IoT technology in flood monitoring systems presents a transformative approach to disaster management, offering real-time data collection, enhanced prediction accuracy, and immediate notification systems, significantly improving flood response efforts.

Local Studies

Flooding is a common issue in tropical countries such as the Philippines, exacerbated by rainfall and clogged drainages. Parilla, Rio Allen G., et al. (2020) explore a garbage monitoring system in Manila, which uses ultrasonic sensors to measure garbage levels in drainages. By integrating IoT technology, the system helps monitor and prevent flooding caused by garbage accumulation. The results of their study demonstrated that the system, although reliant on internet connectivity, was effective in real-time monitoring and alert notifications.

In the northern regions of the Philippines, Natividad, J. G. (2018) presents a real-time flood monitoring system using ultrasonic sensors. This system provides alerts to concerned agencies via SMS and facilitates public inquiries regarding water levels in flood-prone areas, enhancing community involvement and preparedness.

Amagsila, Gervy Andrew, et al. (2017) develop an Android-based flood monitoring application that provides flood reports to vehicle owners. This system utilizes Arduino for flood detection and integrates GPS for real-time flood status updates, ensuring users can avoid hazardous flood zones.

Panganiban, E. B. (2017) focuses on flood predictions in the Metro Manila area using a predictive model that gathers rainfall data and flood levels. The system, built on a Raspberry Pi platform, processes real-time data and forecasts potential flood scenarios, offering a user-friendly interface for flood risk management.

Beltran Jr, Angelo, et al. (2021) proposed a disaster management system that integrates multiple sensors for detecting various natural calamities, including floods. The system, designed with an Arduino-based prototype, sends alerts to mobile phones upon sensor activation, improving real-time disaster preparedness.

Synthesis and Review

The reviewed literature confirms that IoT-based flood monitoring systems can significantly enhance early warning capabilities, reduce damage, and improve flood management. Key components like ultrasonic sensors, SMS alerts, and real-time data transmission are critical to ensuring timely responses. The integration of artificial intelligence for flood prediction, combined with wireless communication networks, offers a promising solution for disaster resilience. Moreover, studies suggest that incorporating additional environmental sensors—such as those measuring temperature, humidity, and wind speed—can further enhance flood forecasting and preparedness, leading to more effective disaster management strategies.

The role of community engagement is pivotal in ensuring that these early warning systems are effective. It is essential that these technologies not only inform authorities but also empower residents by providing them with the necessary information to take preventive actions. Future developments should focus on improving internet connectivity, making these systems more reliable in remote and underserved areas, and enhancing the accuracy of flood predictions through advanced machine learning algorithms.

System’s Analysis

A use case diagram is an essential tool that visually represents the interactions between users (actors) and the system, summarizing the various roles and functions within the Smart IoT-Enabled Flood Monitoring System. It highlights the events and activities users engage in when interacting with the system, clarifying the flow of information and decision-making processes. This approach ensures that each actor’s role is well defined, enhancing the system's usability and efficiency.

This chapter outlines the research strategy and methodologies employed to develop the system, with a focus on an iterative development process. The proponents adopted the traditional Software Development Life Cycle (SDLC) to define, refine, and address challenges identified during the study. By continuously reviewing and improving each phase, the system was optimized for real-world application. This approach not only ensures the system’s adaptability but also guarantees that it remains responsive to emerging challenges, thus improving its functionality and reliability in flood risk management. The iterative nature of this methodology is crucial in delivering a robust and scalable system that can evolve with technological advancements and community needs.

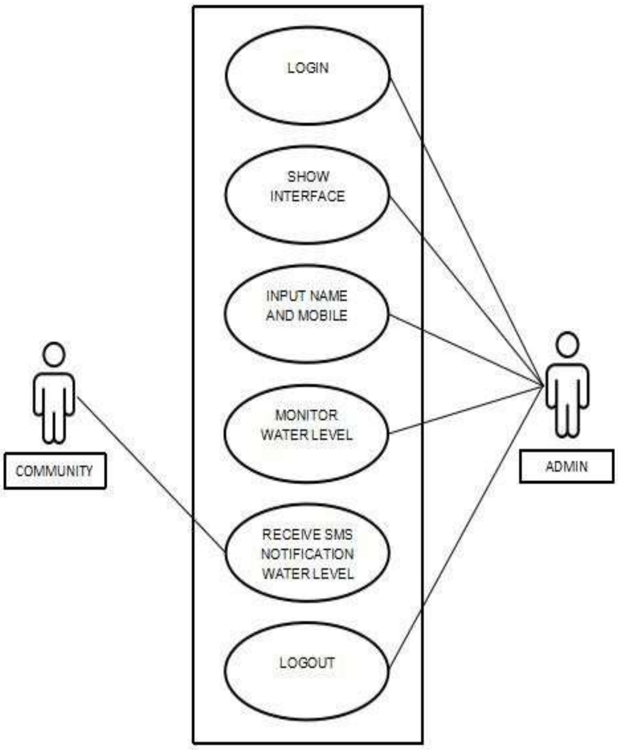

Figure 2.0 Use Case Diagram

Figure 2.0 presents the use case diagram of the proposed system, titled "An IoT-Based Flood Monitoring System with SMS Notification in the Municipality of Carrascal." This diagram illustrates the roles and interactions of various system actors, providing a clear overview of how users and administrators engage with the platform.

The process begins with the admin, who creates an account to log into the flood monitoring application. Upon successful registration, the admin gains access to real-time updates on flood-prone areas. The flag team plays a pivotal role in approving new registrants, ensuring that only authorized users can participate in the system. Once members are approved and join the system, they can pose questions and request information specific to their location, helping them understand whether their area is at risk of flooding.

The system administrator holds the responsibility of maintaining the platform, ensuring regular updates and resolving any bugs to keep the system functioning smoothly. After logging in, users are presented with an intuitive interface that provides real-time updates on flood risks in Carrascal, empowering them to monitor water levels and receive SMS notifications when a flood event is imminent.

This diagram highlights the seamless flow of interactions, ensuring that the system remains both user-friendly and responsive to the needs of the community. The IoT-based flood monitoring system not only facilitates real-time monitoring but also ensures that the local authorities and residents are well-prepared and informed during flood events, significantly enhancing disaster preparedness and community resilience.

System Design

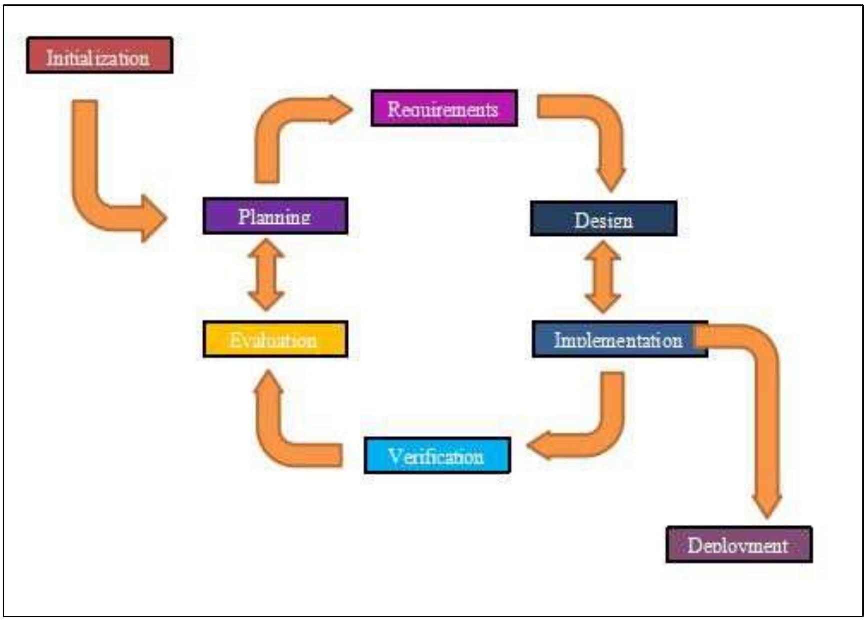

Figure 2.1 Iterative model

The Iterative Model was selected by the proponents for its ability to refine the software through continuous cycles of design, development, and testing, ensuring that the system evolves progressively with each iteration. This approach not only facilitates flexibility but also allows for the incorporation of additional features, adjustments, and improvements as the development progresses. The iterative process ensures that the final product is robust, user-centered, and capable of meeting the dynamic needs of the community it serves.

The Iterative Model divides the development process into distinct, manageable phases, each contributing to the gradual completion of the system. These phases are outlined as follows:

Initiation Phase – During this phase, the proponents focused on identifying potential titles for the proposed system. After selecting a title, they presented it during a proposal hearing to gather initial feedback and refine the focus of the project.

Planning Phase – The proponents collaborated with experts and local stakeholders in Carrascal, focusing on flood-prone locations. This phase involved defining the core problem, establishing system requirements, and formulating a plan that would guide the development of the IoT-Based Flood Monitoring System with SMS Notification. It was during this phase that the research objectives were solidified, setting the stage for the system's functionality.

Requirements Phase – In this phase, the proponents conducted detailed research, gathering specific data related to flood-prone areas in Carrascal. This information was instrumental in identifying the exact needs of the users and administrators, ensuring the system would address the most pressing concerns effectively.

Design Phase – With the requirements in place, the proponents moved on to creating the software design. A solution was crafted to integrate all the necessary features, including flood monitoring and SMS notifications. The design was built to meet both functional and technical requirements, ensuring that the system would be scalable and adaptable.

Implementation Phase – Once the planning and design were finalized, the actual coding began. During this phase, the proponents integrated all previously defined specifications and design documents into the system. The coding process aligned closely with the system requirements, ensuring the flood monitoring system was built according to the planned functionality.

Verification Phase – This phase focused on verifying the system's effectiveness through rigorous testing. The proponents conducted a series of evaluations, gathering feedback from clients to confirm that the system's methods and processes were sound. Security checks and functionality assessments were also completed to ensure the system's reliability.

Evaluation Phase – The software underwent extensive testing to determine if it performed as expected. The user requirements and system specifications were reviewed, and recommendations for improvements were made. Adjustments and new features were suggested to better meet user needs.

Deployment Phase – In this final phase, the system was officially deployed. After confirming that the system was operating as expected, the IoT-based flood monitoring platform was made available for use, offering a reliable means of storing and monitoring flood information for flood-prone areas. The system's effectiveness in real-world scenarios was validated during this stage.

Project Plan – The proponents followed a structured Software Development Life Cycle (SDLC), which consisted of six key phases. Initially, all the system's requirements were identified and analyzed. The hardware and software choices were determined, and interviews with management were conducted to clarify expectations. Upon gathering the necessary data, the system design was created, ensuring that every requirement was addressed. The coding phase followed, and during the final cycle, the system was thoroughly tested for bugs and errors, ensuring the system's success and reliability.

By utilizing the Iterative Model, the proponents were able to incorporate feedback and make adjustments at each phase, ensuring the final system is both functional and user-friendly. This method also allowed the researchers to adapt quickly to challenges, improving the system incrementally and delivering a solution that truly meets the needs of Carrascal Municipality. The result is a reliable, flexible system that provides timely flood warnings to help protect lives and property.

Results and Discussion

This chapter gives the result and discussion of the parameters in accordance with the stated objectives. The development of IoT Based Flood Monitoring System. This included the essential operations and activities that the system must be able to perform.

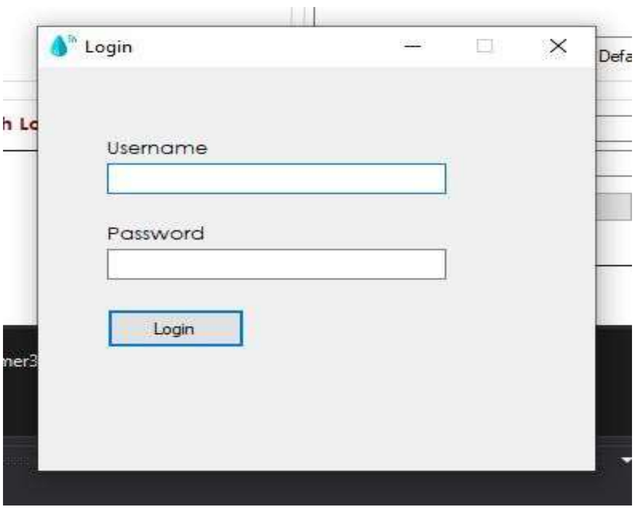

Figure 3.0 Login Form

Figure 3.0 displays the Login Form for users accessing the Smart IoT-Enabled Flood Monitoring System with SMS. This form is designed to allow easy access for all users, enabling them to engage with the system seamlessly. The login process does not require an internet connection for users to sign in. However, internet connectivity becomes essential once users are logged in, as it is required to send real-time flood alerts to their devices. After successfully clicking "Log In", the system automatically transitions to the User Interface, where users can interact with the system's various features, including monitoring flood conditions and receiving instant notifications. This streamlined access ensures that users can quickly receive critical flood information, enhancing their ability to respond to potential flood risks effectively.

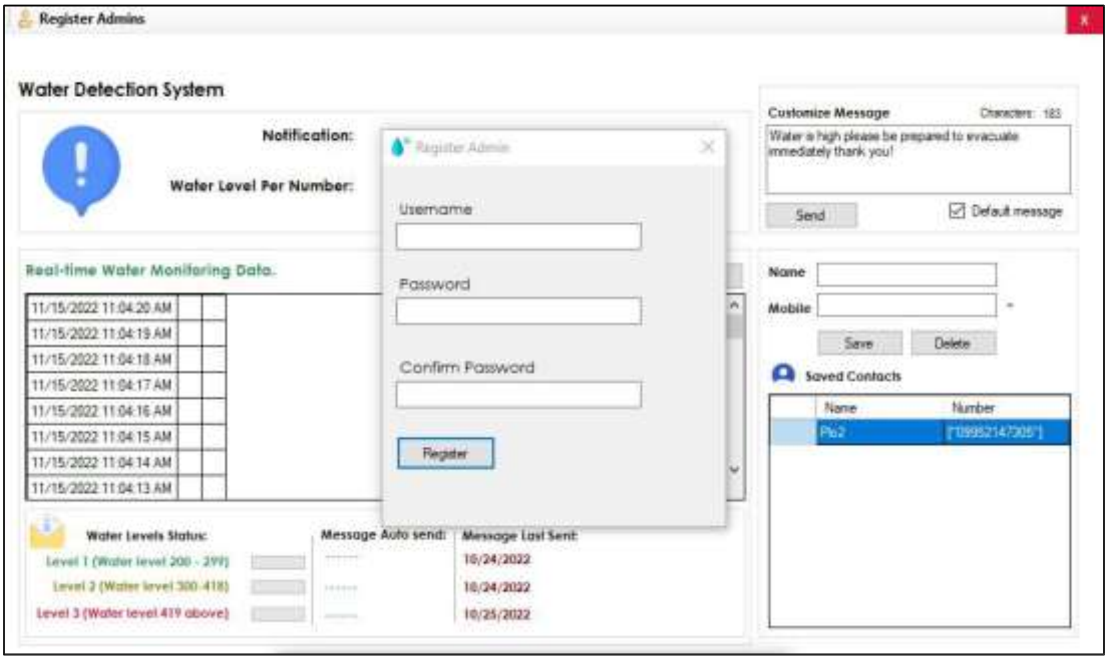

Figure 3.1 Administration Registration Form

Figure 3.1 illustrates the Register Admin functionality, allowing the system to manage and add new admin users to ensure smooth operation and oversight. Upon selecting the "Register Admin" option, a registration form appears, prompting the user to input their username and password in the designated fields. To confirm the registration and grant access, the user must click the "Register" button. This feature is crucial for maintaining a secure and organized structure within the system, enabling the administrators to effectively manage user access, monitor flood data, and ensure the system runs seamlessly. By providing easy and secure admin registration, this functionality ensures reliable system management, enhancing the overall efficiency of flood monitoring and notification processes.

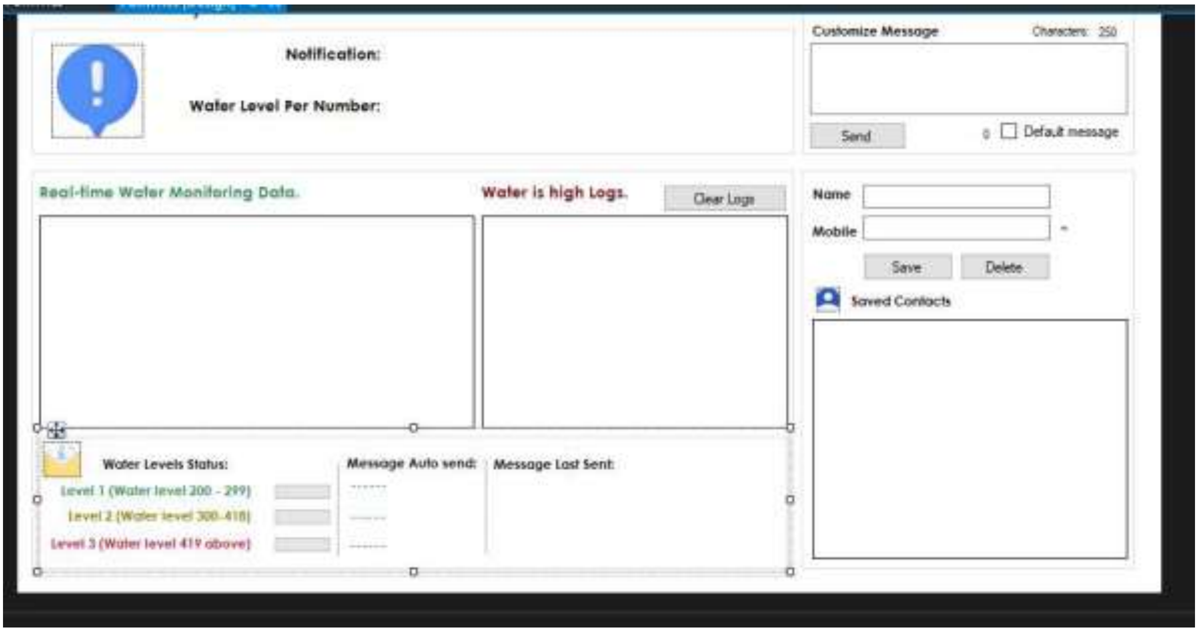

Figure 3.2 System User Interface

Figure 4.2 showcases the System User Interface of the Smart IoT-Enabled Flood Monitoring System with SMS, providing a clear and intuitive view of the real-time water monitoring data. This interface displays the most recent time and date of the water level readings, updated every 20 seconds, ensuring that users always have access to the latest flood information. The system logs high water levels and automatically registers when the water reaches critical levels. When the water level surpasses a predefined threshold, the system sends instant alerts to individuals listed in the saved contacts, ensuring timely notifications for emergency responses.

To manage the contacts, the admin can input names and mobile numbers into the system and click “Save” to store them. Should the need arise to delete a contact, the admin can simply click on the contact name and select “Delete.” In the Customized Message section, the admin has the flexibility to input personalized messages, tailoring notifications to specific recipients as necessary. This feature allows the admin user to send manual alerts, ensuring that the flood warning system is adaptable to changing circumstances. By offering an easy-to-use interface with customizable notification capabilities, this system empowers the admin to maintain an effective, responsive flood monitoring and communication process, safeguarding lives and property in flood-prone areas.

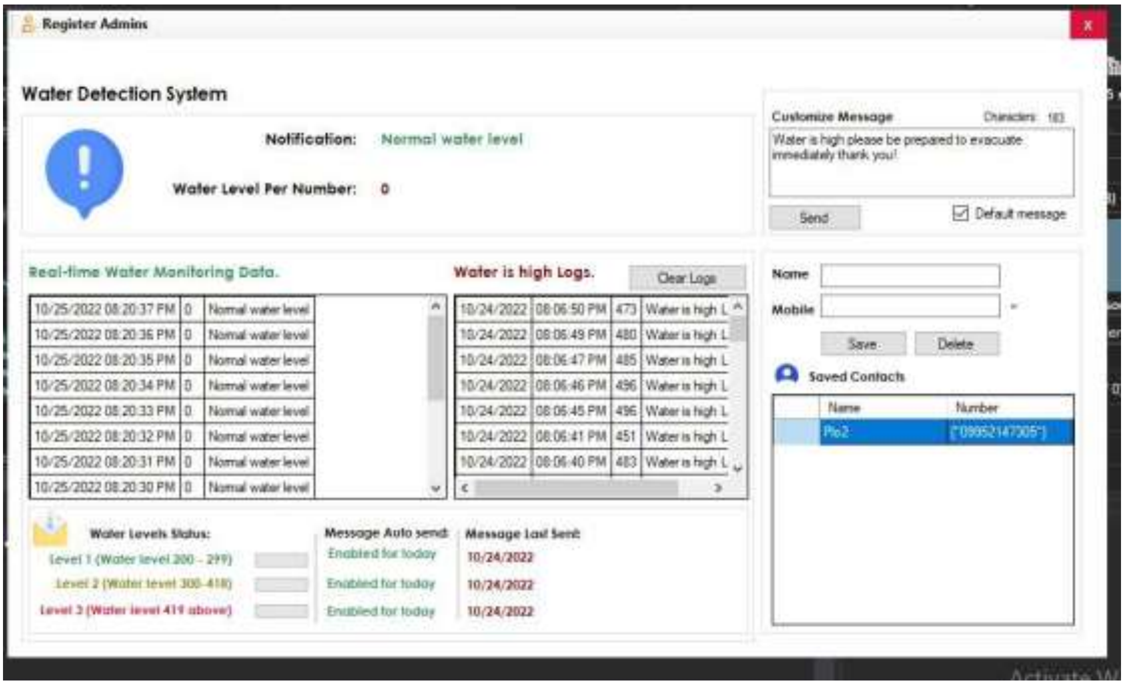

Figure 3.3 User interface Dashboard

Figure 3.3 illustrates the dashboard of the Smart IoT-Enabled Flood Monitoring System, showcasing the complete procedure and functionality of the system. The real-time water monitoring feature displays the current water levels, indicating normal levels as well as higher thresholds. When the water level reaches Level 3, signaling a high water alert, the system triggers an immediate notification to the community, urging them to evacuate promptly. This dynamic and responsive interface ensures that users are kept informed and prepared, enabling swift action to mitigate the impacts of flooding. By providing real-time updates and timely evacuation alerts, the system plays a critical role in protecting lives and property during flood events.

Summary, Conclusion, and Recommendations

This chapter provides an overview of the study's findings, draws conclusions based on the results, and presents recommendations for future improvements.

Summary of Findings

The Municipality of Carrascal is committed to improving the quality of life for its residents, yet one of the most recurring natural disasters—flooding—poses a significant threat, leading to environmental damage, loss of life, and property destruction. Despite the inevitability of such natural disasters, the impact can be mitigated with effective monitoring and early warnings. To address this challenge, the researchers propose an Smart IoT-Enabled Flood Monitoring System equipped with SMS notifications. This system is designed to provide crucial real-time alerts, ensuring that the community receives immediate emergency messages to take the necessary safety precautions. The system meets all requirements to deliver accurate flood data and offers innovative solutions that can enhance both performance and reliability during flood events.

Conclusion

The development of the Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Dis aster Management the Municipality of Carrascal demonstrates that the integration of real-time data and automated alerts is an effective approach to ensuring public safety. The system's ability to monitor water levels and environmental conditions allows for early detection of flood threats, enabling prompt response actions. Additionally, the SMS notification feature ensures that residents are immediately informed about rising flood risks, providing them with ample time to evacuate if necessary. The success of this system reflects a significant advancement towards a safer, more resilient community. By incorporating such technologies, Carrascal takes a proactive step in reducing the risks associated with flooding, ensuring better protection for its residents.

Recommendations

Based on the study's findings, the researchers recommend the implementation of the Smart IoT-Enabled Flood Monitoring System with SMS Alerts for Enhanced Disaster Management the Municipal Disaster Risk Reduction and Management Office (MDRRMO) of Carrascal. The system's utility, effectiveness, and convenience make it a vital tool for enhancing flood risk management. The following recommendations are offered:

For the Municipality of Carrascal:

- Implement the IoT-based flood monitoring system across all flood-prone areas to ensure real-time monitoring and immediate alerts.
- Ensure community involvement through training programs to familiarize residents with the system, enabling them to act quickly in case of flood alerts.

For Future Researchers:

- Cloud Integration: Future researchers may consider integrating a cloud server for storing critical data, ensuring easy access and long-term storage of flood-related information.
- Data Reporting: It is recommended that regular water level reports be published on a weekly or monthly basis, providing the community with valuable insights into flood risks and water conditions.
- System Enhancement: Future studies could focus on enhancing the system by adding more sensors, predictive algorithms, and integrating additional weather data, further improving the system's ability to forecast floods and enhance community resilience.

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