

Advancing Applied Nonlinear Real-Time IoT System for Disaster-Resilient Dam Management through Water Level Monitoring Systems

Prof. Priyanka Dudhe^[1], Mr. Gaurav Magarde^[2], Mr. Madan Raj^[3], Mr. Aditya Karemore^[4], Mr. Jayesh Wankhede^[5]

Dept. of Computer Science Engineering,
Jhulelal Institute of Technology,
Nagpur, Maharashtra, India.

p.dudhe@jitnagpur.edu.in , gauravmagarde1858@gmail.com, madanraj1809@gmail.com ,
adityakaremore22@gmail.com , jayeshwankhede17712@gmail.com

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Abstract:

The nonlinear dynamics of water management in dams are critical to mitigating floods and guaranteeing a long-term water supply for neighboring towns. With the integration of sensor networks, this project seeks to create an advanced monitoring and warning system that can dynamically regulate water levels. By utilizing the Internet of Things (IoT), the system aims to provide flood protection in the neighborhood a nonlinear component. Water levels are closely monitored by a number of sensors, which send out alerts via GSM to allow for prompt communication. Information is effectively sent via the system to the cloud, where application software effortlessly delivers it to users. By using a nonlinear strategy, this project not only satisfies requirements but also serves as a strong safety net, reducing possible losses in the event of major water-related problems.

Keywords: Real Time Data Analysis, Internet of Things, Non-linear, Wireless communications, Ultrasonic Sensors, Global system for Mobile Communications, Smart System.

I. INTRODUCTION

With almost 4000 major and minor dams standing tall and many more under construction throughout India's enormous geography, it is clear that efficient water management is vital. Dams are used for everything from irrigation to hydroelectric power, but they require careful maintenance to prevent disastrous consequences like flooding, fatalities, and property destruction. The interplay of seismic activity, floods, and tsunamis highlights the need for creative solutions even more. This concept recognizes the constant threat of flooding and suggests an Internet of Things (IoT)-based system that uses the power of networked components to monitor water levels in dams and provide a preventive alarm mechanism. The system uses a nonlinear method to problem resolution and includes hardware such as GSM 800L, NodeMCU, DHT 11, LED screen, and connecting cables in addition to ultrasonic sensors. The system is now run by a battery and adapter, but it may be integrated with solar panels in the future thanks to its future-proof design, which guarantees total independence.

Every day, the system gathers information from a variety of sensors and sends it to the cloud. The system anticipates possible events and enables timely decision-making for efficient dam water management using an application software interface. This strategy not only avoids significant losses but also advances the more general objective of sustainable development. The system's adaptability goes beyond real-time monitoring; it also offers useful data for study, supporting the continuous improvement and growth of dam infrastructure. Important environmental parameters like humidity and temperature are also taken into account in the research, providing a thorough picture of the dam's condition.

This system's key component is wireless connectivity, which allows for remote SMS access and alert caller identification. Easy deployment and accessibility are guaranteed by the low-cost, basic requirements of a network facility. In the end, the effective deployment of this Internet of Things-based solution is expected to benefit nearby communities and dam managers by promoting better water management and safety via the effective use of local Wi-Fi networks.

II. LITERATURE REVIEW

At the forefront of current research addressing the urgent need for effective and proactive measures in water resource management and disaster avoidance is the Real-Time Water Level Monitoring System using IoT for Disaster Management in Dams. This project fits in well with the discussion of environmental monitoring within the large body of literature on IoT applications. It offers a complete solution that makes use of cloud computing, GSM connectivity, and sensor networks [4]. This system's primary strength is its capacity to detect water levels accurately and in real time using ultrasonic sensors, a feature that has been highlighted by many studies on Internet of Things applications in environmental monitoring. The accuracy of these measures not only makes dam water management easier, but it also lays the groundwork for early warning systems, which are essential in places where disasters are likely to occur [5].

The research emphasises the need of integrating sensor networks and IoT to monitor water quality and quantity in the larger context of smart water management systems. This story is supported by the Real-Time Water Level Monitoring System, which combines temperature and humidity monitoring with water level monitoring by integrating DHT11 sensors [6]. The system is positioned as a comprehensive solution for comprehensive dam safety and catastrophe avoidance thanks to this multidisciplinary approach. Moreover, the software's admin panel and user panel are consistent with the conversation around community involvement in disaster preparedness [7]. The interface is easy to use and meets the needs of both locals and dam officials. It makes sure that important information is available to the right parties and enhances community preparation and resilience.

It is clear from reading the literature that the suggested system skillfully handles the opportunities and difficulties presented by IoT-based environmental monitoring. Although the literature acknowledges concerns including scalability and data security, the project's focus on GSM connectivity for remote warnings reduces the effect of any network issues [8].

Furthermore, the idea of using solar power to be independent of the power source fits well with the larger conversations about environmentally friendly IoT applications. The relevance of real-time data for forecasting water-related disasters and streamlining water management techniques is further highlighted by the literature on hydroinformatics and data analysis [9]. In addition to being in line with these principles, the Real-Time Water Level Monitoring System adds significantly to the current conversation by providing a sustainable, scalable, and user-friendly solution that combines technological innovation with the necessity of efficient water resource management and disaster prevention in dam areas.

III. WORKING MODULE

The device consists of Microcontroller, ultrasonic sensor, DHT11, GSM 800L, LED screen, I2C and buzzer. Microcontroller is the central component of the system and process all the data received from various other components for decision making. The whole system is currently depend on the adapter and Battery for power supply, but to make the system independent solar panel can be added for uninterrupted power supply.

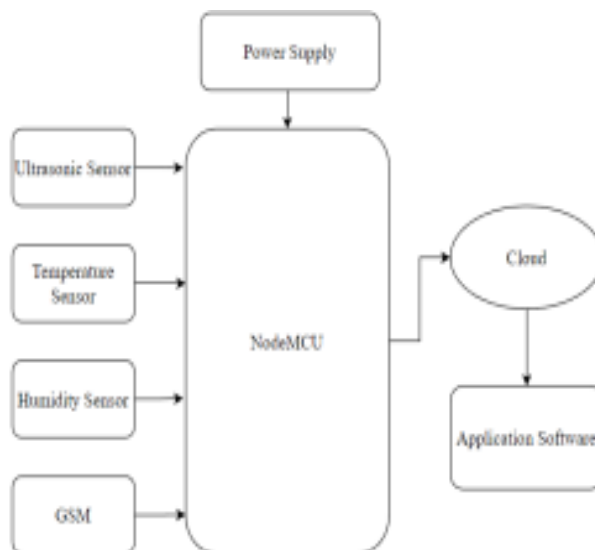


Figure 1 :- Block Diagram of the System

Figure 1 shows the block diagrams of the System where the sensors are connected to the NodeMCU and power supply is provided using an Adapter or Battery. Further the device is connected to the cloud and then linked with a software to view the data. The ultrasonic sensor is used to detect the water level. Ultrasonic sensor transmits a sound pulse to the surface of the water level and then it reflects to determine the water level. The sensor is the essential component as its function determines how effective the system is. If there is any issue or problem with the sensor, the system is unable to detect the water level of the dam and it tends to Malfunction.

The framework's temperature is monitored using a DHT11 Sensor. Resistive dampening and temperature sensing components are included in this high-level sensor module. A float sensor accurately detects the water level by opening and shutting circuits (dry contacts) in

response to changes in the water level. The majority of the time, it remains closed, signaling that the circuit is shorted and that no current is passing through the conductors.

The circuit completes itself and transmits power via the finished circuit to trigger an alert when the water level drops below a set level. NodeMCU is the base where all the sensors are connected and embedded coding is performed using an open source platform for electronics based items for easy to use hardware and software known as Arduino IDE (Integrated Development Environment). It is low cost IOT platform, open source firmware and suitable for IOT based applications.

The LCD screen shows the water level of dam at real times to ensure the dam operator is fully aware about dam. At the back of the LED screen I2C is used for communication between a single or multiple devices. It is based on the concept of multiplexer and demultiplexer. The LED serve as a visual aid for the dam operator for different levels of water at which action is taken by the system. The buzzer is used as a final warning before the dam gates are opened.

log file is used in a computer to record the current activities. Data stored in the log file include the water level, time, and total message counts. The data stored helps to record the various major operation of the system for record keeping and also for further analysis (if needed). GSM 800L is used to send SMS on regular basis, alert calls and SMS when the level of the water is crossed the limit. Buzzer is used to notify the dam administrator to take the necessary action and do the needful.

IV. SYSTEM OPERATION

As the system is based on the combination of hardware and software. The device will send the information to the cloud and retrieved from the cloud using an application software. Figure 2 shows the Use case architecture of the proposed system, which consist of admin panel and user panel. Admin panel is the most important part of the system which has an access of the per day level of the water, temperature, humidity, message counts, graphical analysis or visual representation of the data which is real and up to date data. Apart from this the admin receives alert messages and calls if the level of water is crossed the limit.

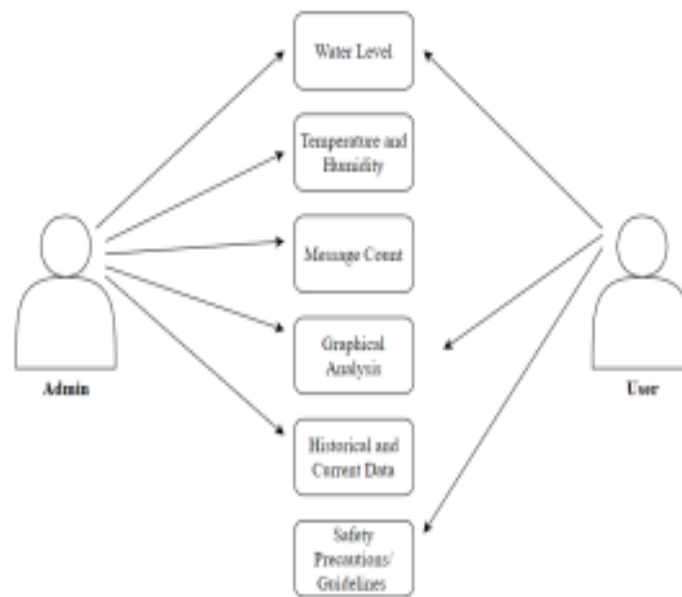


Figure 2. Use Case Diagram

Graphical analysis includes bar graphs through which data can be easily understood and it can be helpful in the overall development of the Dam and surrounding or nearby areas. With the help of GSM, per day notifications will be sent to

the registered mobile numbers and alert calls will be sent if the level of water rises. As the software is also designed for the local people(user) who lives near the dam, if the water level is about to rise, they can check the status of the water level and follow the guidelines provided in the application software and moves towards the safe zone. Through this application both dam administrator and the local people will get the advantage from huge loss as the water level rises chance of flood will rise so the dam gates can be operated accordingly, and the movement of local people close to the dam can be avoided for some time till the situation becomes normal by following the guidelines as mentioned.



Figure 3:- Detecting Water Level



Figure 4:- Detecting Temperature and Humidity



Figure 5:- Device integrated with all the components

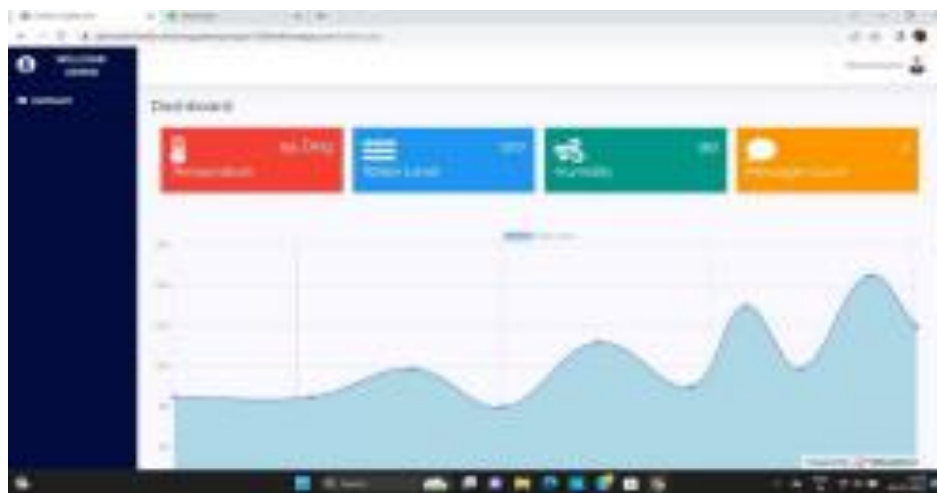


Figure 6:- UI of a Software

Figure 3 shows the current water level and figure 4 shows the current temperature and humidity. Figure 5 shows the device integrated with the components which will be fitted at the dam. Figure 6 shows the UI of an application software which shows the data and graphical analysis of the given data. However the Application is responsive, which can be accessed in the mobile devices.

V. System Design and Workflow

The Real-Time Water Level Monitoring System begins by setting up all of its sensors, including the DHT11 and ultrasonic ones, as well as the NodeMCU, GSM module, LED screen, buzzer, and LED screen. Getting sensor measurements, such as water level, temperature, and humidity, is an essential step after turning on the system using an adaptor or battery. After the data is gathered and sent to the NodeMCU for analysis, the system reaches a decision point where it determines if the water level is higher than the safe limit. The alarm generation methods, which include turning on the GSM module for calls and texts and the buzzer for a last-ditch warning, are activated in the event of an affirmative response. Real-time data is recorded in a log file and shown on the LED panel simultaneously. By sending data to the cloud, the system ensures remote access and creates an administrator and local user interface. Administrators receive graphical analysis along with daily SMS notifications and alert calls/messages. After the procedure is over, the system continues to monitor in real time.

- **Start:**
The process begins with the initiation of the Real-Time Water Level Monitoring System.
- **Initialize System:**
Initialize all system components, including sensors (ultrasonic, DHT11), NodeMCU, GSM module, LED screen, and buzzer.
- **Power On:**
Power on the system through either an adaptor or battery.

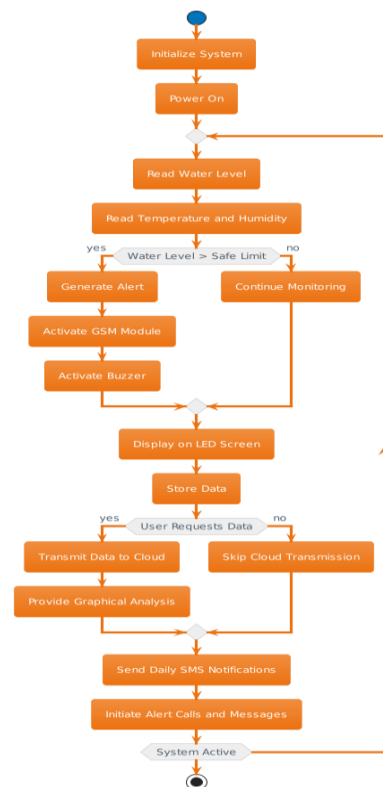


Figure 7. System Design and Workflow

- **Sensor Readings:**
Read water level using the ultrasonic sensor.
Read temperature and humidity using the DHT11 sensor.
- **Data Transmission:**
Transmit sensor data to the NodeMCU for processing.
- **Decision:**
Check if the water level is above the safe limit.
If yes, proceed to the next step; otherwise, continue monitoring.
- **Alert Generation:**
Activate the GSM module to send alert messages and make alert calls.
Activate the buzzer as a final warning.
- **Display on LED Screen:**
Display real-time water level, temperature, and humidity on the LED screen.
- **Data Storage:**
Store the collected data in a log file for future reference and analysis.
- **Cloud Transmission:**
Transmit the collected data to the cloud for remote access.
- **User Interface:**
Develop a user interface for both dam administrators and local users.
- **Alert Notification:**
Send daily SMS notifications to registered mobile numbers.
Initiate alert calls and messages in case of critical water levels.
- **Graphical Analysis:**
Provide graphical analysis and visual representation of the data for administrators.
- **End:**
The process concludes, and the system continues to monitor in real-time.

VI. RESULTS

Evaluation Parameter	Scale (0-10)	Value	Comments
Accuracy of Water Level Measurement	9.5	9.5	Precise measurements with minimal error
Reliability of Sensor Systems	9.0	9.0	Stable hardware, potential for redundancy
Timeliness of Alerts	8.5	8.5	Timely alerts, room for optimization
User Interface (UI) Design	9.0	9.0	Well-designed and user-friendly UI
Power Supply Independence	8.8	8.8	Enhanced independence with solar panels
Scalability and Flexibility	8.2	8.2	Scalable, potential for diverse environments
Data Analysis and Research	9.5	9.5	Comprehensive data for valuable

Potential			research
Cost-effectiveness	8.7	8.7	Reasonable costs, consider ongoing expenses

Table 1. Evaluation of Real-Time Water Level Monitoring System

The device is found to very useful at the time of natural disasters like floods and can be prevent from huge damage to the environment and lives of living beings. The data provided by the device is accurate and well represented using the software. Daily SMSs of the dam water level helps to keep the areas safe and proper dam water management can be achieved. From the data we can predict the loss caused by the dam and at the same time proper management can be planned to execute the situation efficiently. Early warnings helps to take the necessary action and prevent from the huge loss. Apart from this we can maintain real time current data which can be used for research purpose in future which is an added advantage for that particular area.

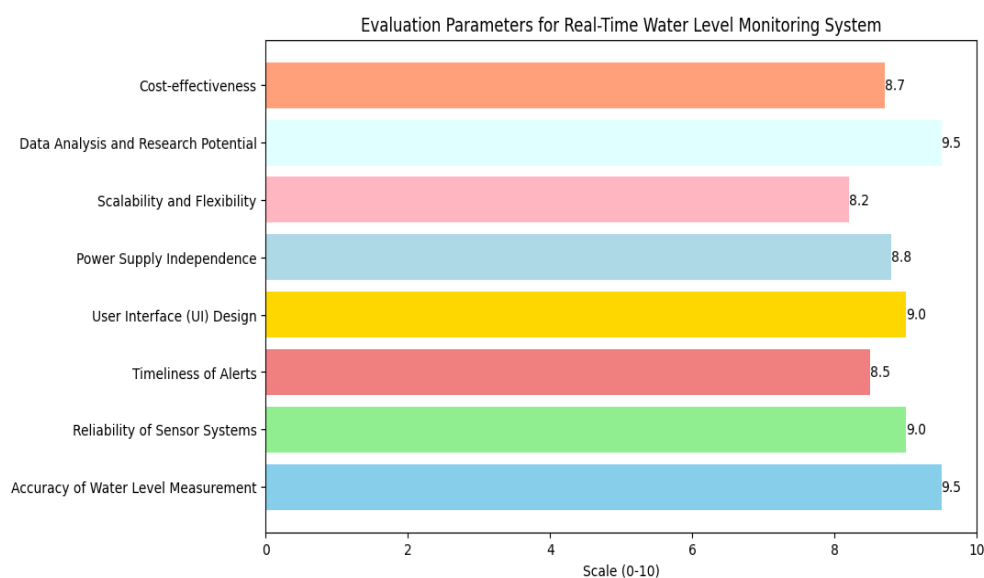


Figure 7. Evaluation Parameters for Real-Time Water Level Monitoring System

VII. Conclusion

In conclusion, a strong way to handle the important issues surrounding dam water management is provided by the Real-Time Water Level Monitoring System using IoT for Disaster Management in Dams. This creative idea combines cutting-edge technology to build an effective and proactive system, such as sensor networks, GSM communication, and the Internet of Things. The use of ultrasonic sensors to detect water levels accurately and reliably provides a solid basis for real-time monitoring, which is the project's strongest point. Even though the sensor systems' dependability is well-established, more research into redundancy techniques to improve overall stability would be beneficial. One excellent element of the alarm system is its timeliness; in the case of rising water levels, local citizens and dam officials may receive prompt information. Both administrators and local users may easily access critical data thanks to the user-friendly interface design, which offers clear graphical

representations of the relevant information. A layer of sustainability is added by the emphasis on power supply independence and the possible integration of solar panels, which addresses issues with continuous power availability in distant places. The technology is flexible and scalable, adapting to a variety of dam conditions. The software's admin panel and user panel make sure that the right stakeholders have access to the right data and notifications. An further noteworthy benefit is the project's emphasis on data analysis and research possibilities. In addition to helping with efficient dam water management, the gathered data is a useful tool for further studies and advances our knowledge of dam ecosystems as a whole. Even if the system is reasonably priced, recurring costs like maintenance should be properly taken into account. The Real-Time Water Level Monitoring System is a viable and significant option for disaster management in dam locations, even with a few small areas for development. Its ability to analyse data in real time and its potential to save significant losses during floods make it an invaluable tool for sustainable development, life safety, and infrastructure protection.

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