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[1] S M M Naidu*
[2] P S Oza
[3] O N Wagh
[4] Nitin Alzende
[5] Prashant Ahire
[6] Apurav Divekar
[7] Omkar Papade
[8] Virendra Mali
[9] Yuvraj Khelkar
[10] V M Diwate

Instrumentation for Water Level Monitoring System and It's Software Development

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Abstract: - The Water Level Tank Monitoring and Prediction System presented in this project harnesses advanced sensor technologies and predictive algorithms to address the critical issue of efficient water management, with depleting water resources and the growing demand for sustainable practices, real time monitoring of water levels in storage tanks becomes imperative. This system integrates ultrasonic sensors, microcontroller (ESP32), and data analysis techniques to monitor water levels in tanks accurately and predict future levels based on historical data. The system begins by continuously collecting real-time data from ultrasonic sensors placed inside water tanks. These sensors measure the water level accurately and transmit the data to a central microcontroller unit. The microcontroller processes the incoming data and sends it to a database for storage and analysis. Using sophisticated algorithms, historical water usage patterns are analyzed to predict future water levels. Machine learning techniques, such as regression analysis and neural networks, are employed to forecast water consumption trends, enabling proactive decision-making. The Water Level Tank Monitoring and Prediction System offers several significant advantages. Firstly, it provides real-time monitoring, ensuring that water levels are constantly observed. This real-time data is crucial for immediate action in case of leakages or sudden increases in demand. Secondly, the predictive analysis facilitates informed planning by anticipating water needs based on historical patterns. This proactive approach helps in optimizing water distribution, minimizing wastage, and ensuring a consistent water supply. In addition to its practical applications for households, industries, and municipalities, the system contributes significantly to water conservation efforts. By promoting efficient use of water resources and reducing unnecessary wastage, it aligns with the global goal of sustainable water management.

Keywords: Automation, Software, Hardware, Machine Learning, Microcontroller, Network/connectivity, Internet of Things

I. INTRODUCTION

This project introduces a robust and cost-effective solution employing cutting-edge technology to address the critical need for water management. By harnessing the power of ESP32 microcontroller and ultrasonic sensor technology, we have developed a Water Level Monitoring System that provides real-time data on water levels in overhead tanks. This data will be seamlessly transmitted and logged in the PostgreSQL database, and displayed on

[1] Professor and Head, Electronics and Telecommunication, International Institute of Information Technology (I2IT), Pune, MH, India. Email: mohans@isquareit.edu.in & POYV PVT LTD, Pune, India

[2] Computer Engineering, International Institute of Information Technology (I^2IT), Pune, MH, India. & POYV PVT LTD, Pune, India

[3] Electronics and Telecommunication, International Institute of Information Technology (I^2IT), Pune, MH, India. & POYV PVT LTD, Pune, India

[4] Computer Engineering, International Institute of Information Technology (I^2IT), Pune, MH, India

[5] Electronics and Telecommunication, International Institute of Information Technology (I^2IT), Pune, MH, India

[6] Computer Engineering, International Institute of Information Technology (I^2IT), Pune, MH, India

[7] Computer Engineering, International Institute of Information Technology (I^2IT), Pune, MH, India

[8] Electronics and Telecommunication, International Institute of Information Technology (I^2IT), Pune, MH, India

[9] Computer Engineering, International Institute of Information Technology (I^2IT), Pune, MH, India

[10] POYV PVT LTD, Pune, India

a user-friendly GUI offering users a convenient and accessible platform for monitoring and analysis. The system not only empowers users with precise information about water levels but also incorporates intelligent features such as threshold-based alerts and notifications via the frontend application. This ensures that potential is- sues like tank overflow or depleted levels are detected and addressed proactively, mitigating potential damage and conserving this precious resource. The fundamental goal is to significantly improve the efficiency and sustainability of water management practices. By continuously monitoring the
amount of water used and providing real-time statistics, this system ensures that administrators and users have access to crucial data for informed decision-making.

II. Methods of Water Level Monitoring

2.1 Existing Systems

2.1.1 Advantages

In the landscape of water management, the transfer of water from lower to higher-level tanks is fundamental in various settings, utilizing traditional electric or diesel-powered pumps, sump pumps, and gravitational systems. These mechanisms traditionally function with manual control and limited automation. However, the integration of water level monitoring technologies with these systems has introduced a new paradigm in water management, offering an array of benefits and promising solutions for more efficient and sustainable resource utilization. These pumping systems, though diverse in their applications, often rely on conventional methodologies for moving water. Traditional pumping systems harness mechanical power to transport water, while sump pumps are predominantly employed to eliminate accumulated water, and gravitational systems capitalize on the force of gravity for water transfer between different elevations.

The integration of water level monitoring technologies revolutionizes these systems by providing continuous real-time tracking through various sensors like ultrasonic or pressure-based instruments. This monitoring allows for not only the observation of water levels but also the prompt detection of anomalies that may signal potential leaks or irregularities in the system. Another significant advantage is the availability of real-time statistical analysis derived from the data collected by these monitoring systems.

2.1.2 Disadvantages

The maintenance of these sensors poses a continuous challenge. Exposed to water and ever- changing environmental conditions, the sensors demand regular upkeep to ensure consistent and precise readings. This ongoing maintenance incurs additional operational costs, impacting the overall efficiency of the system. The current systems may lack user-friendly, real-time data visualization capabilities. Accessible and intuitive visualization tools are vital for users to comprehend water level information effectively, aiding in prompt decision-making and action. In addition to these limitations, existing systems lack advanced functionalities that could enhance their adapt- ability to varying user roles and preferences. Features such as customizable threshold settings and user access control are crucial for tailoring the system to meet specific user needs, which might be lacking in the current setup.

2.2 Proposed System

Our system focuses on integrating a variety of works done to develop a water tank level monitoring system along with adding our unique methods and ideas to make the system more feasible, cost-efficient and society(public) oriented. Our system emphasizes not only the utilization of economical sensors such as ultrasonic sensors but also the comprehensive functionality of the system facilitated by our uniquely crafted dashboard interface. The advantage of the system is use of non- intrusive technique to measure water along with using simple microcontroller-based automation to reduce complexity. Our system also contains alerts as well as future predictions which makes it a full-fledged system for all conditions.

The disadvantages of our system currently includes power supply and Wi-Fi connectivity is- sues. The sensor box requires a continuous power supply for real-time monitoring and the Wi-Fi also needs to be connected for data logging. We are currently working on these problems.

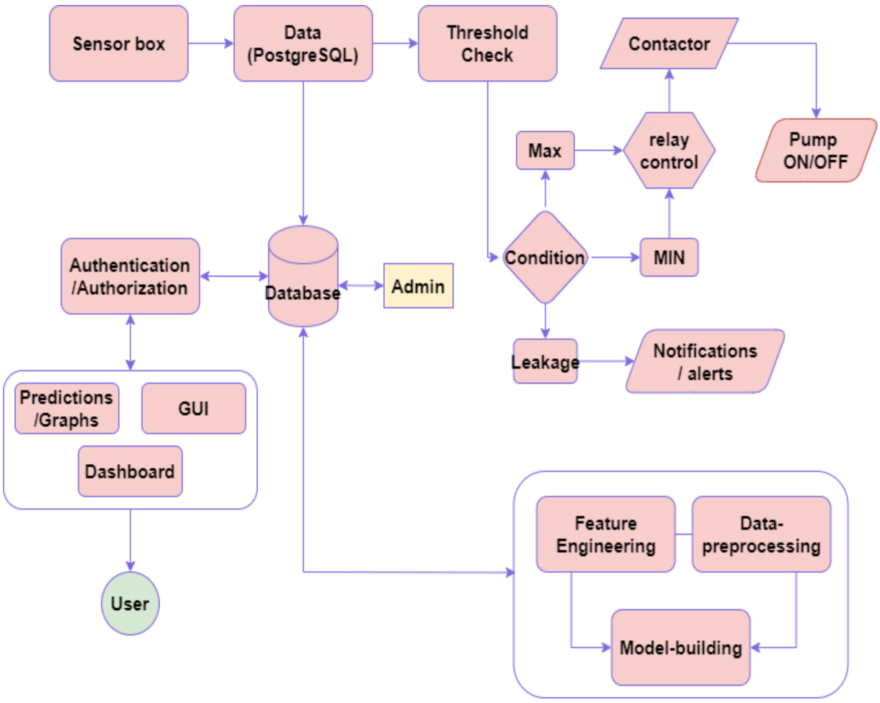


Fig 1 Detailed System Architecture

III. PREDICTION MODEL

3.1 Introduction

The process of model building in machine learning typically involves several key steps such as model selection, validation, etc.

Timestamp-based algorithms, are a class of algorithms used in distributed systems to establish a temporal order of events or transactions. These algorithms are crucial for achieving consistency, synchronization, and ordering of events in a distributed environment where multiple entities or processes may be working concurrently and independently.

3.2 Types of timestamp algorithm

ARIMA:ARIMA (AutoRegressive Integrated Moving Average) stands as a widely recognized and versatile method for time series forecasting. Given its well-established nature, it serves as a logical choice when predicting variables like water levels in a tank, relying on historical data for accurate forecasts.

Exponential Smoothing Methods: Holt-Winters Exponential Smoothing: This method extends exponential smoothing to handle time series data with seasonality.

Prophet: Developed by Facebook, Prophet is a forecasting tool designed for forecasting data with daily observations that display patterns on different time scales, such as holidays and seasonality. Seasonal Decomposition of Time Series (STL): STL decomposes time series data into seasonal, trend, and remainder components. It’s particularly useful for analysing and visualising seasonal patterns.

Long Short-Term Memory (LSTM) Networks: Deep learning techniques like LSTM networks are used for time series forecasting when dealing with sequences of data. They can capture complex dependencies and are suitable for univariate and multivariate time series.

Gated Recurrent Unit (GRU) Networks: Similar to LSTMs, GRU networks are used for time series forecasting and are known for their efficiency in capturing long-range dependencies in sequences.

3.3 Model building

In our work, we have used the ARIMA (AutoRegressive Integrated Moving Average) model as they are specifically designed for analyzing and forecasting time series data. Dependencies: ARIMA models are built on the idea that data points in a time series are not independent but exhibit temporal dependencies. ARIMA models are versatile and can be adapted to handle more complex time series analysis scenarios. One such adaptation is the inclusion of exogenous features or external variables. The accuracy of the model can be increased by using the combinations of above-mentioned models with ARIMA model as data increases and seasonality becomes a significant variable for prediction.

3.3.1 Mathmatical Model

Let S be the water level monitoring system. S = I,O,P,F,R
Here
I = Input of the system (Water level sensor) O = set of all Outputs
O = O1,O2,O3,O4
where,
O1 = level of water in cm O2 = Threshold alert
O3 = Prediction of water level O4 = Liters of water in the tank F = set of possible failures
F = F1,F2, F3
where,
F1 = Sensor failure F2 = Network failure
F3 = power supply down P = set of all functions f(I) → Outputs Failures
P = P1, P2, P3, P4
where,
P1 = gives water level from the sensor P1 : f(I) → O1 O4 (F1)
P2 = predicts water levels from the data
P2 : f(I) → O3 O4 (F1 F2 F3)
P3 = Send alert At threshold P3 : f(I) → O2 (F1 F2 F3)
P4 = Predicts volume of the water
P4 : f(I) → O4 (F1 F2 F3)

IV. FRONTEND

The Frontend refers to the part of a software or web application that users interact with directly. It is the user interface and user experience (UI/UX) design of a website or application, encompassing everything that users see, touch, click, and interact with. Frontend development involves creating the visual elements of a website or application and ensuring that they are responsive, intuitive, and user-friendly.

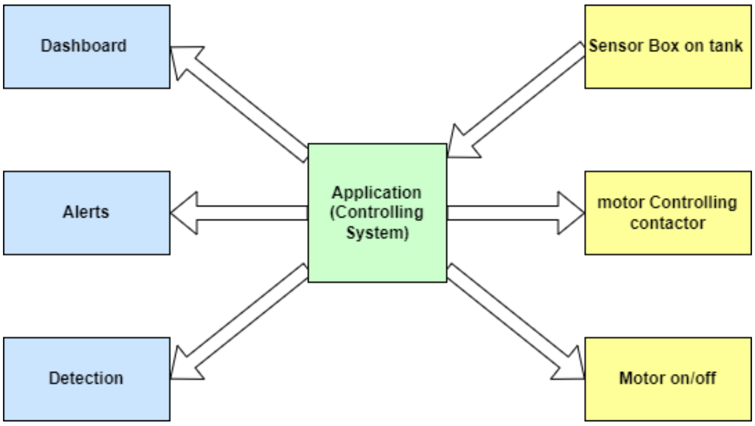


Fig 2 Application-Control system

We plan on using the react.js framework for the dashboard development. The dashboard will have graphs, input bars for prediction purposes, and various different functionalities based on roles such as super admin, organization admin, etc. The dashboard will have alerts and the latest data values and added users, etc will all be visible to the person based on the roles allotted. The Auto/Manual button will also be visible to the users but the hierarchy of decisions will be maintained by sending approval requests to higher authorities. The modes would not be implemented until the higher authorities approve the requested decision.

V. BACKEND

Backend development involves crafting the logic, managing database interactions, and configuring servers for websites or web applications. This area of development focuses on the behind-the- scenes functionality, ensuring seamless communication between the frontend and backend components of a website or application.

5.1 Nest JS

Nest JS is a framework for building server-side applications using TypeScript, which is a superset of JavaScript. NestJS is built on top of popular and mature JavaScript/TypeScript runtimes like Node.js.

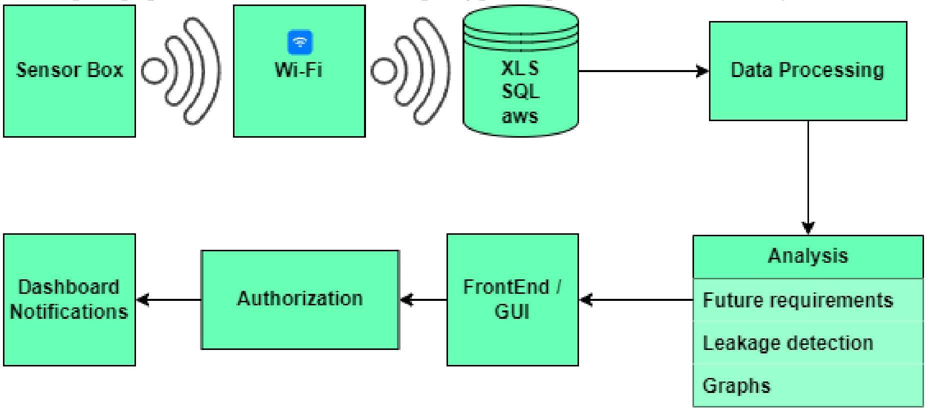


Fig 3 Software architecture

Login / Logout : The login/logout page would be connected to database and after user input, NestJS will be used for user authorization and login will only be possible if the data is correctly filled.

Alert messages: The system would constantly be recording the sensor data and storing it in the database, a threshold would be set at a certain level by the client, once the water level hits that particular threshold an alert message would be generated by the NestJS from the database using "Triggers" and a notification would be sent to the client. In case the tank is full the system will automatically turn off the water motor. To retrieve the data and perform the above operations NestJS plays an important role.

Client operations from the database: The retrieving of data from the database for adding, deleting, editing certain data bu client is done by nest js using various APIs. The functionality of nest js will help us connect with frontend with the database.

VI. HARDWARE AND AUTOMATION

Hardware and automation play a critical part in this project. The hardware consists of various components such as an ultrasonic sensor, ESP 32 microcontroller, contactor, relays, and wirings to connect it all. The system is integration of these devices and implements various IoT mechanisms.

6.1 Device Box

The device box consists of the ultrasonic sensor and ESP 32 interfacing along with proper covering for protection purpose. The box is then fit inside the tank on the inner side of the tank lid with the ultrasonic sensor eyes facing towards the water. The code and interfacing makes it possible to get right data and log it into desired database.

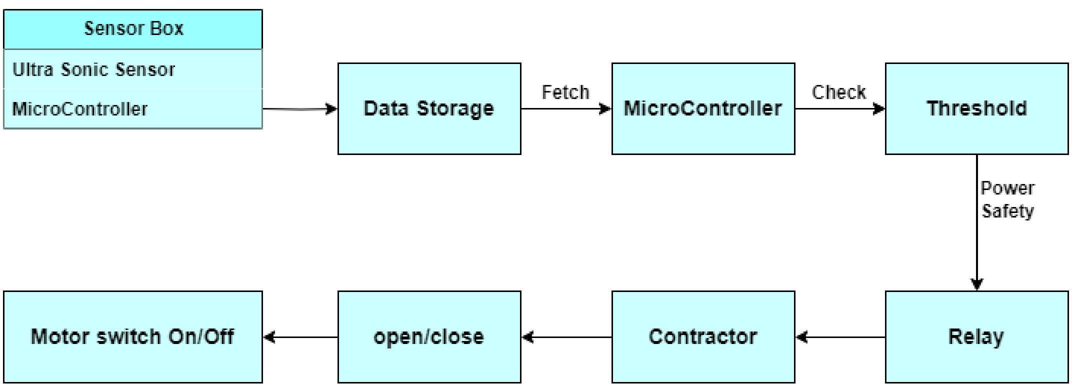


Fig 4 Hardware architecture

6.2 Contactor and Relay working

The contactor is a special type of relay used to interface 3-phase AC supply to smaller loads such as 5-volt microcontroller. The contactor is connected to the AC supply on one end and the other end is connected to a relay which further is connected to the ESP 32 microcontroller. The microcontroller fetches data from the database and based on decided threshold the relay orders the contactor to switch on or off the pump or motor. The microcontroller fetches data from overhead as well as lower head tank to make sure the motor is not switched on if water in lower head tank is not enough.

VII. LITRATURE SURVEY

7.1 Background

The primary objectives of this project revolve around the development of a water level monitoring system that delivers real-time data on water levels in tanks. This system not only aims to monitor the water levels but also endeavors to detect water leakages in tanks or pipes and predict future water levels. Such capabilities are essential in ensuring the early identification of issues, promoting proactive interventions, and optimizing the usage and conservation of water resources.

The project also aims to provide department officials with digital access to monitor water levels, offering the flexibility of an Auto/Manual system and incorporating alarms for various warnings, including tank overflow. Additionally, the project emphasizes monitoring water usage and wastage during off-peak timings, ensuring a comprehensive understanding of consumption patterns.

7.2 Literature Survey

Panpan Jiang et al.(2020) [1] presented a high-level water tank monitoring system based on the Internet of Things (IoT) to ensure the safety and stability of water supply in high-rise buildings. The system could also automatically control water levels and raise alarms in case of water pollution, ensuring the quality and continuity of household water supply.

Mehwash Farooqui et al.(2018) [3] presented a paper titled "Smart Monitoring of Water Tanks in KSA." The study addressed the critical issue of water scarcity in Saudi Arabia by developing an Android application based on the Internet of Things (IoT) concept for monitoring water levels in tanks. The application employs a wireless sensor, typically an ultrasonic sensor, to continuously monitor water levels in tanks and send alerts to users when the water level falls below a threshold or is empty.

Jyotirupa Malakar et al.(2019) [4] tackled the growing concern of water scarcity and inefficient water management by introducing an innovative automatic water tank level and pump control system. This system employs an ultrasonic sensor and a flow meter to continuously monitor water levels within both the overhead and main tanks. Using an Arduino Uno microcontroller, the system can autonomously manage the water pump, thereby preventing it from running dry, averting water overflow from the overhead tank, and conserving electricity.

Dr. Manjunath Kotari et al.(2019) [5] presented an innovative solution to address water wastage and inefficiencies in water tank management. The paper highlights the common challenges faced by residential water tank users, including the risk of running out of water and the potential for tank overflow due to inadequate monitoring. To tackle these issues, the authors introduce a Water Tank Monitoring System that utilizes sensors to track water levels in the tank. When the water level reaches a certain threshold (empty tank condition), the system sends a notification to the user through an Android application.

VIII. RESULTS AND ANALYSIS

The research for this project included the available components and systems for monitoring water levels and automatically switching on or off the motor. Through this, we understood that available systems use invasive sensors to sense the water level. We also realized that these systems do not have flexibility or customization facilities based on user requirements. Our aim was to build a full-fledged system that can be used for various applications along with customizable components.

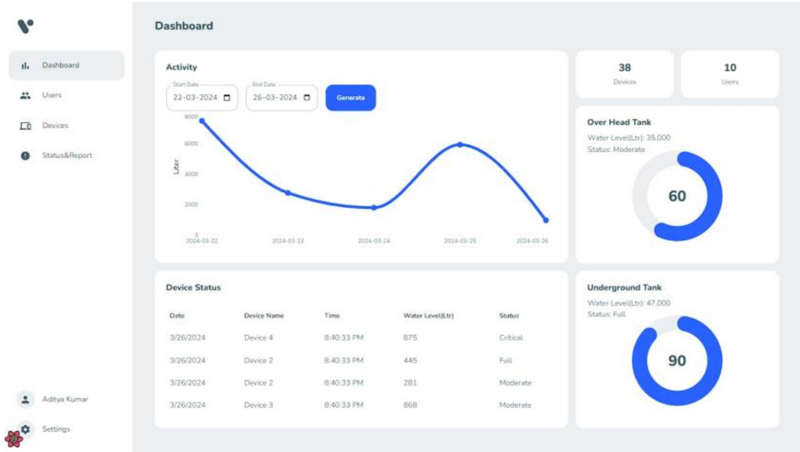


Fig 5 Dashboard

The result of this project focuses on the significance of analytics and automation for optimized water level management in tanks. It helps us monitor the water levels and accordingly use the water. The implementation of automation within the system contributes to a decrease in both human labor requirements and the occurrence of errors. This helps avoid overflow as well as helps to monitor water usage.

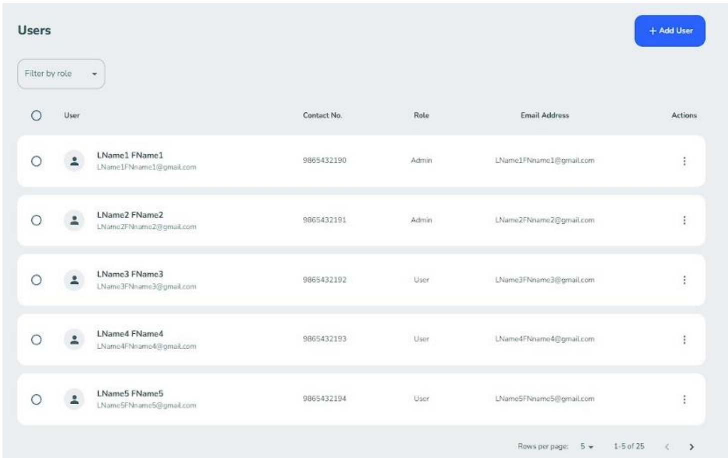
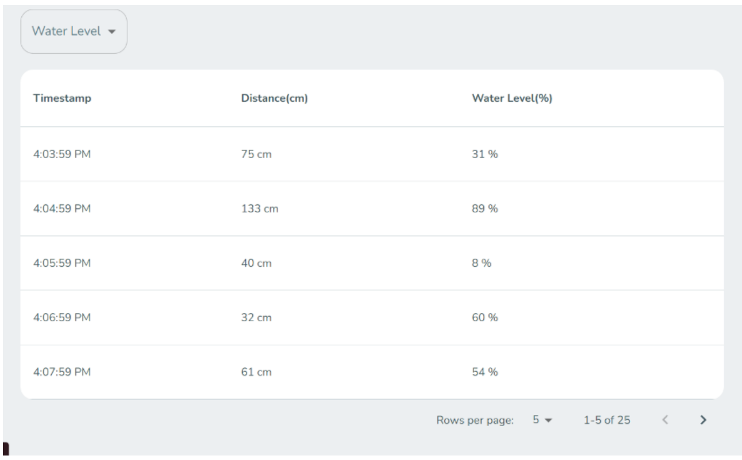


Fig 6 Users list in an organization

The data right now is logged onto a Supabase which is a frame work built on postgreSQL, and
based on overhead and upper head tank conditional values the prototype to switch on or off the motor is also ready. The prediction model to predict future water levels based on historical data is also tested and would be combined in the final system.



Water Level

Timestamp	Distance(cm)	Water Level(%)
4:03:59 PM	75 cm	31 %
4:04:59 PM	133 cm	89 %
4:05:59 PM	40 cm	8 %
4:06:59 PM	32 cm	60 %
4:07:59 PM	61 cm	54 %

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Fig 7 Device table

The front-end development for the system involves various complex components for a smooth user experience through the dashboard. The web application is dynamic in nature.

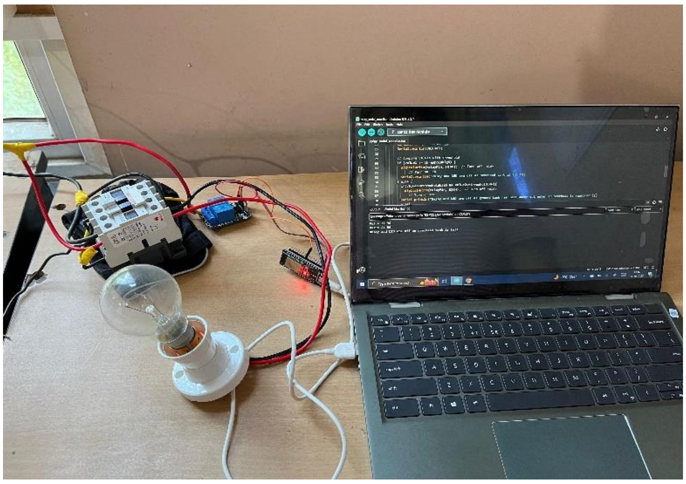

Fig 8 Bulb Off for low levels of the lower head tank and when the upper head tank is full

We are now working to develop this system further so it can have a wide variety of applications in various domains. Water level monitoring itself has various applications. The scope of the project can be expanded to other liquids as well where monitoring and automation are a must and play a critical role.

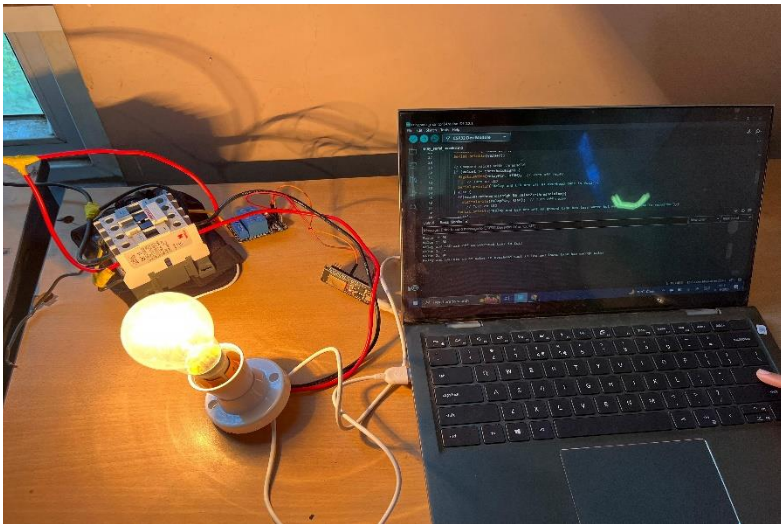

Fig 9 Bulb On for low level of upper head tank and sufficient level for lower head tank

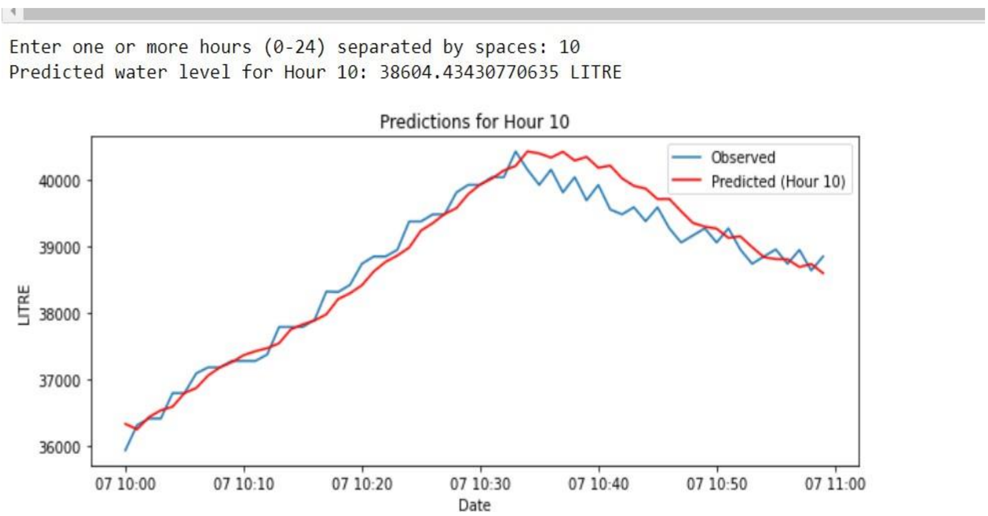

Fig 10 hourly prediction graph vs real values for given hour as input

IX. CONCLUSION

Real-time water level monitoring along with automation is a vital tool in various industries such as agriculture, fluid monitoring systems, dam or reservoir monitoring, etc. This system helps con- serve water by preventing overflows, and leakages as well as by providing analytics for observing water usage patterns. To conclude, the proposed system is an efficient way to optimize water monitoring and usage. The system is partially implemented but has scope in various industries with minimal changes. The system can also be improved using different evolving technologies for it to be of utmost efficiency along with modern compatibility.

This system also has a positive impact on the environment as it helps conserve water and also makes the user realize the need to change water usage patterns as they see the visuals of usage over the dashboard. The partially developed system is customizable which helps fulfill various societal requirements. The prediction of future levels of water using machine learning algorithms is helpful to satisfy the water requirements in various organizations on any given day. This can also be helpful to have flood alerts and warnings when the system is installed over various water bodies.

Real-time monitoring, leak detection, predictive analysis, and the potential integration of various parameters ensure a more sustainable, efficient, and future-ready approach to water resource management. This fusion enables better resource utilization, reduced wastage, and improved decision- making for both domestic and commercial water management scenarios.

Financing

The cost of developement was beared by POYV Pvt Ltd and the cost of publication is beared by Sir S.M.M. Naidu.

Conflict of interest

None

REFERENCES

[1] Canzong Zhou, Panpan Jiang, “A design of high-level water tank monitoring system based on internet of things”, University of South China, Hengyang, Hunan Province, China, July 2020, IEEE Xplore. (https://ieeexplore.ieee.org/abstract/document/9356829)

[2] M. Reza Hidayat, Susanto Sambasri, Firman Fitriansyah, Atik Charisma, Handoko Rusiana Iskandar, “Soft Water Tank Level Monitoring System Using Ultrasonic HC-SR04 Sensor Based On ATMega 328 Microcontroller”, Universitas Jenderal Achmad Yanu, Cimahi, May 2020, IEEE Xplore. (https://ieeexplore.ieee.org/abstract/document/8978229)

[3] Konstantinos Loizou, Eftichios Koutroulis, Dimitrios Zalikas, Georgios Liontas, Georgios Liontas & Co. E.E., Katerini, Greece, “A Low-cost Capacitive Sensor for Water Level Monitoring in Large-Scale Storage Tanks,” School of Electronic and Computer Engineer- ing, Technical University of Crete, Chania, Greece, 2015, IEEE. (https://ieeexplore.ieee.org/abstract/document/7125295)

[4] Nasro Min-Allah, Mehwash Farooqui, Abrar Alwashmi, Sarah Almahasheer, Malak Alsu- fayyan, Najla Altulaihan Department, “Smart Monitoring of Water Tanks in KSA”, College of Computer Science and Information Technology, Imam Abdulrahman Bin Faisal Univer- sity, Dammam, Saudi Arabia, 2018, IEEE. (https://ieeexplore.ieee.org/abstract/document/8947809)

[5] M. S. Godwin Premi, Jyotirupa Malakar, “AUTOMATIC WATER TANK LEVEL AND PUMP CONTROL SYSTEM”, School of Electrical and Electronics Engineering, Sathyabama Institute of Science and Technology, Chennai, India, 2019, IEEE. (https://ieeexplore.ieee.org/abstract/document/9065438)

[6] K. Chetpattananondha, T. Tapoanoib, P. Phukpattaranonta, N. Jindapetcha, “A self-calibration water level measurement using an interdigital capacitive sensor,” Sensors and Actuators, vol. 209, pp. 175-182, 2014.(https://www.sciencedirect.com/science/article/abs/pii/S092442471400051X)

[7] D. Moret, M. V. Lopez and J. L. Arrue, “TDR application for automated water level mea- surement from Mariotte reservoirs in tension disc infiltrometers,” Journal of Hydrology, vol. 297, pp. 229-235, 2004.(https://www.sciencedirect.com/science/article/abs/pii/S0022169404002069)

[8] M. Parashar, R. Patil, S. Singh, V. Mohan, K. Rekha, “Water Level Monitoring System in Water Dispensers using IoT”, Volume 05, Issue: 04, 2018. Retrieved October 15, 2018.

[9] Priya J, Sailusha Chekuri, “Water Level Monitoring System Using IoT”, International Re- search Journal of Engineering and Technology (IRJET), Volume: 04 Issue: 12, Dec-2017.

[10] J. Mounika, N. Siva Kumar Reddy, “Water Monitoring System Based On GSM”, Interna- tional Advanced Research Journal in Science, Engineering, and Technology, vol. 3, issue 7, July 2016. (https://iarjset.com/recent-issue-july-2016/)

[11] Authorship Contribution

1. Conceptualization: P.S. Oza, O.N. Wagh, Y.A. Chavan, V.M. Diwate
2. Data curation: O.N. Wagh, P.S. Oza
3. Formal analysis: Y.A. Chavan, V.M. Diwate
4. Acquisition of funds: S.M.M. Naidu
5. Research:P.S.Oza, O.N. Wagh, Apurav Divekar, Omkar Papade, Virendra Mali, Yuvraj Khelkar
6. Methodology: P.S. Oza, O.N. Wagh, Y.A. Chavan, V.M. Diwate, Virendra Mali, Yuvraj Khelkar,Apurav Divekar, Omkar Papade

7. Project management:P.S. Oza, O.N. Wagh, Y.A. Chavan, V.M. Diwate
8. Resources: SIR discussion
9. Software: Apurav Divekar, Omkar Papade, P.S. Oza
10. Hardware: O.N Wagh, Virendra Mali
11. Supervision: S.M.M Naidu, Y.A. Chavan
12. Validation: Y.A. Chavan
13. Display: SIr discussion
14. Drafting - original draft: P.S. Oza, O.N. Wagh
15. Writing - proofreading and editing: Ahire Sir