Smart Water Tank Monitoring System Using Conductive Sensors and LoRa Technology

By

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Motivation

- **Supporting Sustainable Practices**: Combining monitoring, predictive insights, and durable technology, the system empowers users to **conserve water** and make informed usage decisions.
- **Urban Water Scarcity**: Cities like Bangalore face **periodic water shortages** that impact daily life and economy. This project enables active water management to reduce waste and mitigate scarcity.
- **Predictive Analytics**: The system forecasts water needs based on historical and real-time data, allowing users to optimize usage and reduce reliance on emergency measures.
- **Durability with Conductive Wires**: Unlike traditional sensors, conductive wires reliably monitor water levels with minimal maintenance, offering a sustainable, long-term solution.

Introduction

The **Smart Water Tank Tracking System** aims to address the challenges of **water scarcity and inefficient water management**. By integrating **IoT sensors, LoRa communication**, and **machine learning**, the system provides a comprehensive solution to monitor and predict water usage in real time.

Key Objectives:

- **Automated Water Monitoring**: Track water levels in real-time using conductivity sensors and transmit data using **LoRa** for remote monitoring.
- **Predictive Analytics**: Use machine learning to forecast future water demand and optimize resource usage.
- **Efficient Resource Management**: Enable better water conservation by predicting usage trends and providing real-time alerts to avoid overflow or shortages.

Project Contribution

The **Smart Water Tank Tracking System** was collaboratively developed by the project team, with **key contributions** from each member:

Subhash:

- **System Design and Architecture** - Designed the system architecture with metal conductors and LoRa for accurate water level monitoring.
- **IoT and Communication Setup** - Configured ESP32 and LoRa for remote data transmission and receiver setup.
- **Database Integration** - Developed PostgreSQL database schema and logic for real-time updates of water level data.

Siva:

- **Machine Learning Model Development** - Developed and optimized the SARIMAX model for accurate water usage predictions.
- **Predictive Analytics and Model Evaluation** - Evaluated model performance and optimized predictions.
- **System Monitoring and Optimization** - Set up model retraining and data storage for continued accuracy.
- **Web Interface and Visualization** - Built a user-friendly interface for real-time tracking.

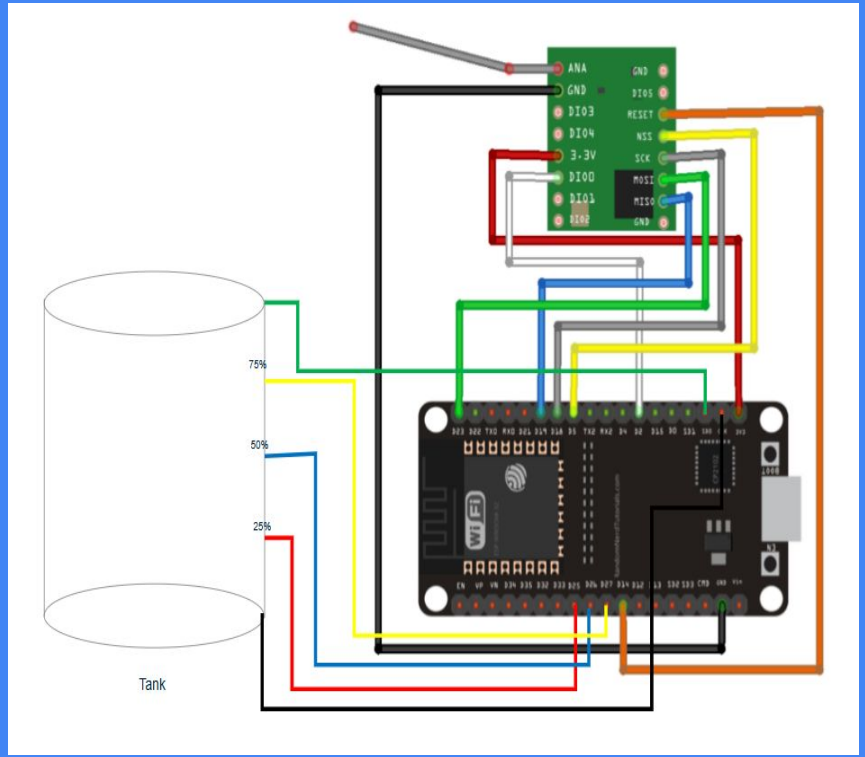
Methodology Used

System Design and Architecture

- **Hardware**: Metal conductors for 0%-100% water level detection.
- **IoT Integration**: ESP32 + LoRa (RFM95) for remote data transmission.
- **Database**: PostgreSQL setup for real-time water level data storage.

Water Level Monitoring

- **Sensor Placement**: Metal conductors positioned at key levels.
- **Data Transmission**: ESP32 sends data via LoRa to update the database.



Data Analytics

Data Collection and Preprocessing:

- **Data Gathering**: Collected water level and environmental data over time.
- **Data Cleaning**: Applied techniques like forward filling for missing values and scaling numerical features such as water level, temperature, and water usage.

Machine Learning Model Development:

- **Model Selection**: Used SARIMAX (Seasonal ARIMA with eXogenous variables) for time-series forecasting of water usage.
- **Feature Engineering**: Included relevant features like timestamp,current_water_level ,people_using_water,temperature, season, time_of_day, water_usage_last_hour, required_water
- **Training the Model**: Trained the model using historical data and evaluated its performance using metrics like mean squared error (MSE) and R-squared (R^2).

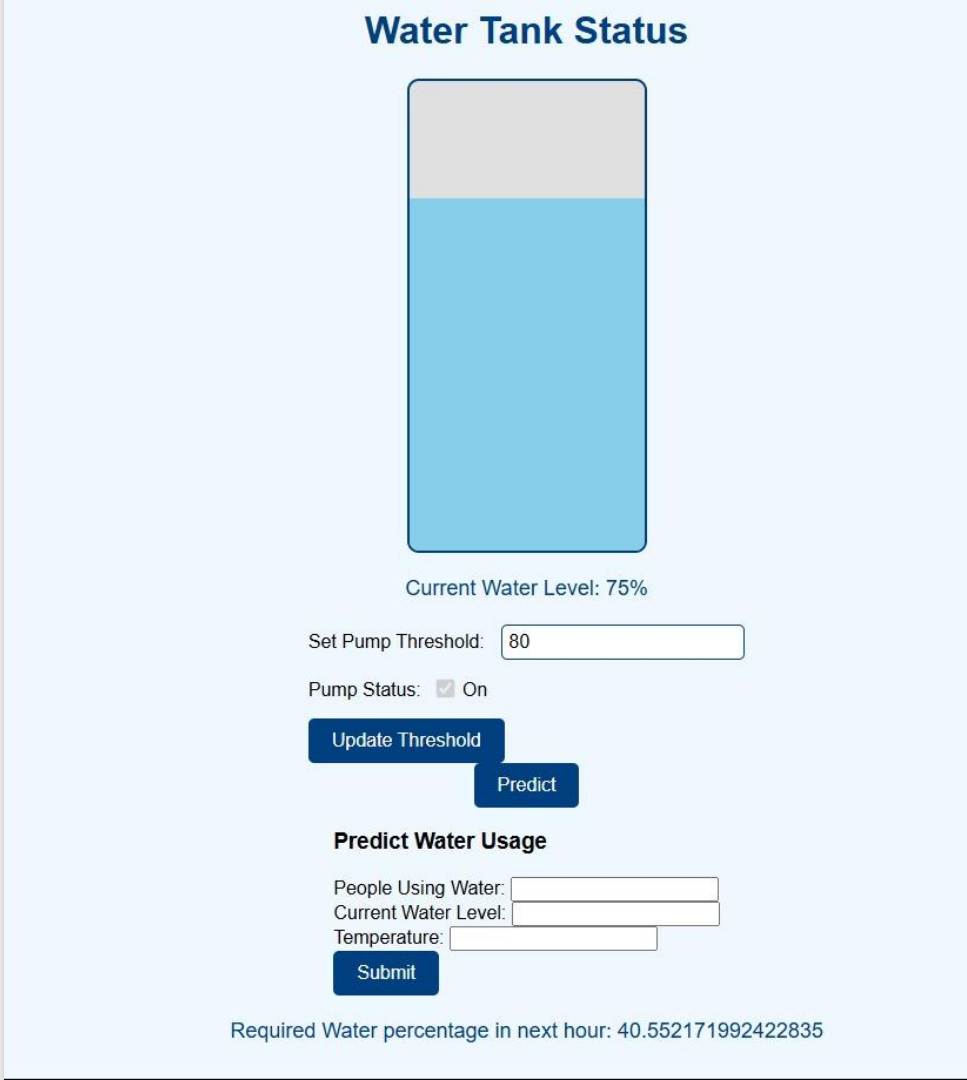
Importance and Benefits of SARIMA

- **Predicts Seasonal Trends:** SARIMA models are ideal for time series data with recurring seasonal patterns, such as monthly sales, weather, or water usage in smart systems.
- **Captures Long & Short-term Dependencies:** Combines autoregressive, integrated, and moving average components to handle both short-term noise and long-term trends effectively.
- **Transforms Non-stationary Data:** Through differencing, SARIMA makes non-stationary data stationary, improving model accuracy and forecast reliability.
- **Improves Forecast Accuracy:** By modeling seasonal behavior and dependencies, SARIMA provides more accurate forecasts for complex, cyclical data.

Website Development

- Designed a web interface to display real-time water levels and takes threshold value and notifies us whenever the water level crosses that, usage predictions , and historical trends.

- Integrated real-time data updates and alerts for users regarding water levels or abnormal consumption patterns.



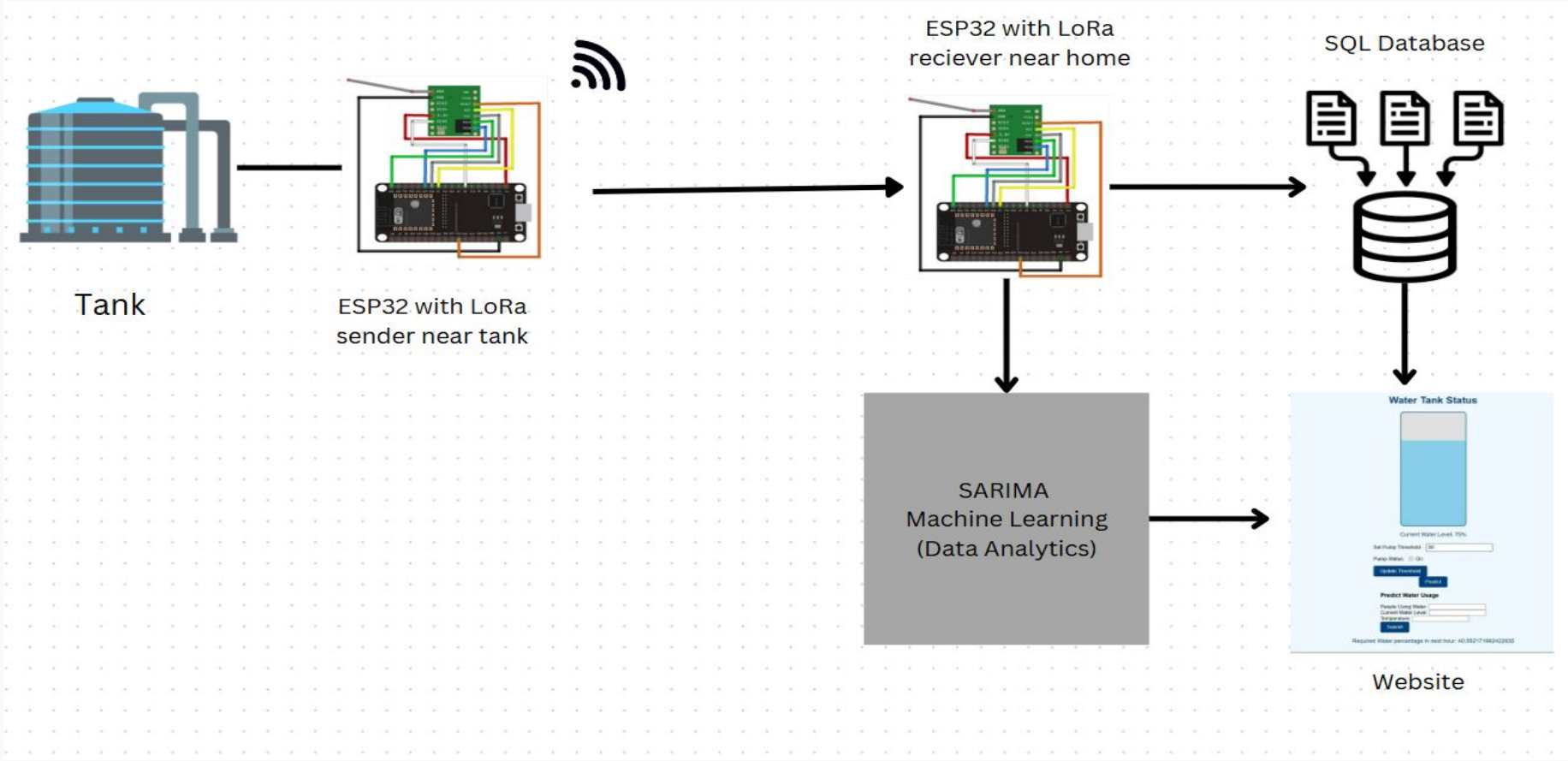
Process

- **Data Prep:** Collect data, encode categorical features (e.g., season), fill missing values, scale features.
- **SARIMA Configuration:** Use SARIMAX function.
- **Training & Saving:** Train the model and save parameters.

Parameter Selection:

- **Order (p, d, q): (1, 0, 1)**
  - **AR(1):** Captures recent dependency.
  - **MA(1):** Models recent noise.
- **Seasonal Order (P, D, Q, s): (1, 0, 1, 24)**
  - Period 24 for daily patterns.
  - Seasonal AR(1) and MA(1): Models 24-hour dependency and noise.

System Architecture



EXPERIMENTS AND TESTING RESULTS

Connection & Data Transmission

- Successfully established a reliable connection between **ESP32** and **LoRa** transmitter-receiver system.
- Real-time water level data transmitted to the **SQL database** and displayed on the **web interface** without delay.

Web Interface Updates

- Water levels on the website update automatically with **AJAX**, showing accurate, real-time tank status.
- Notifications triggered when water levels reach threshold values, ensuring prompt alerts.

Prediction Model Testing

- **SARIMAX model** accurately forecasts water usage based on historical patterns.
- Achieved reliable results with **Mean Squared Error (MSE)** and **R^2** metrics, enabling effective water usage predictions.

Conclusion: Successfully developed a fully integrated system for **remote water monitoring** and **predictive analytics**, providing efficient, automated water management.

CHALLENGES FACED

DELAY IN WEB UPDATES

Problem:

- Real-time water levels weren't immediately reflected on the web interface.
- Users had to manually refresh the page to see updates.

Solution:

- Implemented **AJAX** for **automatic updates**.
- Ensures **real-time updates** of water level diagram without manual refresh.

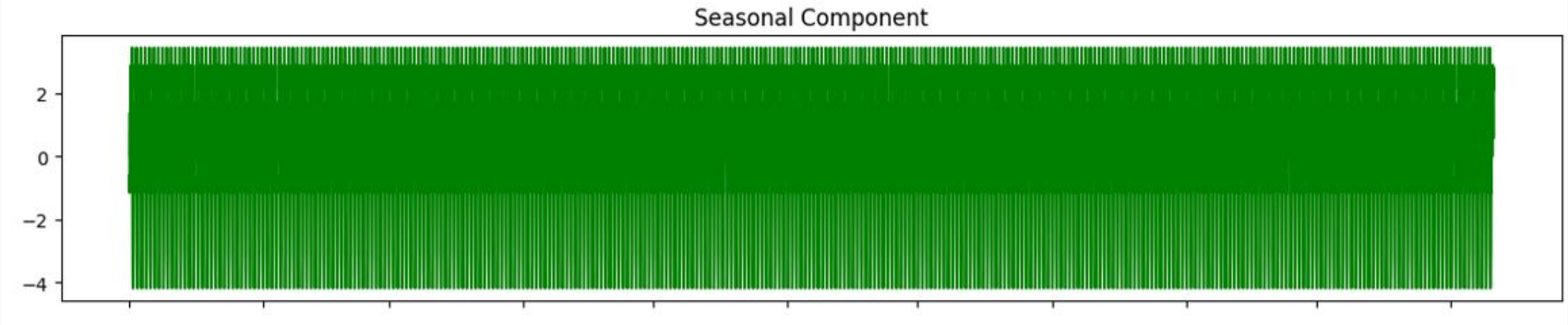
Outcome:

- Improved user experience with **instantaneous data reflection**.

MODEL SELECTION FOR PREDICTION

Problem:

- Accurately predicting water usage with **seasonal** and **daily** variations was challenging.



- Selected **SARIMAX** model to handle:
- Implemented **automated retraining** to maintain prediction accuracy over time.

Integrating ML Model with Django

Problem:

- Running hourly predictions without interrupting the user experience required **synchronization**.

Solution:

- Used **Django Background Tasks** to execute ML model predictions in the background:
  - Predictions are generated **every hour** without affecting the user interface.
  - Ensures **real-time forecasts** are displayed on the web without delay.

Implementation (Commands):

```
pip install django-background-tasks
```

Conclusion

The Smart Water Tank Tracking System provides an efficient solution for real-time water level monitoring, usage prediction, and resource management. Key highlights of the project include:

- **Innovative Sensing**: Metal conductors were used for durable, water-resistant level detection.
- **IoT and LoRa Integration**: Enabled remote, long-range data transmission from tank sensors to home-based receivers.
- **Predictive Analytics**: SARIMAX model accurately forecasted water usage by incorporating seasonal and daily patterns, helping in proactive water management.
- **User-Friendly Interface**: AJAX-powered web interface displayed live updates, historical trends, and alerts for optimal user experience.
- **Automated Retraining**: Background processes ensured continuous model accuracy, adapting predictions as new data was collected.

This system effectively addresses the challenges of water scarcity by providing a robust, scalable approach for managing water resources. Its predictive capabilities and real-time insights support sustainable water usage, making it valuable for both residential and agricultural applications.