# Augmented Reality Based Water Level Monitoring

*Submitted in partial fulfillment of the requirements for the degree of*

**Bachelor of Technology**

in

**Electronics and Communication Engineering**

*by*


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**VIT, Vellore.**


April, 2025

# DECLARATION

I hereby declare that the thesis entitled "Augmented Reality Based Water Level Monitoring" submitted by me, for the award of the degree of *Bachelor of Technology in Electronics and Communication Engineering* to VIT is a record of bonafide work carried out by me under the supervision of Dr.Rohith mathur

I further declare that the work reported in this thesis has not been submitted previously to this institute or anywhere for the consideration of the degree/diploma.

Place : Vellore

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G.J J.Dhanush

**Signature of the Candidate**

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This is to certify that the thesis entitled "Augmented Reality Based Water Level Monitoring" submitted by **G.Hitesh-21BEC2087,Boga Vivek 21BEC2159, Dhanush-21BEC2344** VIT, for the award of the degree of *Bachelor of Technology in Programme*, is a record of bonafide work carried out by him / her under my supervision during the period, 13.12 2024 to 20.04.2025, as per the VIT code of academic and research ethics.

The contents of this report have not been submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The thesis fulfills the requirements and regulations of the University and in my opinion meets the necessary standards for submission.

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**Internal Examiner**

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To all those who played a part, directly or indirectly, we offer our deepest thanks. Your contributions have made this journey both meaningful and memorable.

**G Hitesh** **Boga vivek** **Dhanush**

# Executive Summary

This project focuses on building an **interactive water level monitoring system** that combines the power of **Augmented Reality (AR)** and the **Internet of Things (IoT)** to provide real-time insights in a visually engaging way. The goal is to make water level monitoring more efficient, accurate, and user-friendly—especially in settings where manual checking can be inconvenient or impractical.

At the heart of the system is an **ESP8266 microcontroller**, which reads data from an **ultrasonic sensor** to measure the water level inside a tank. This data is then sent wirelessly to the **Firebase Realtime Database**, ensuring live updates are available at any time. What sets this project apart is its use of **AR through Unity**, allowing users to scan a marker and instantly see a **3D model of the water tank**, complete with the current water level rendered inside it.

This real-time, 3D visualization offers a better and more intuitive understanding of the tank's status compared to traditional displays. It also opens the door for further enhancements like low-water alerts, automatic motor control, and mobile notifications.

Overall, this system shows how AR and IoT can work together to solve everyday problems. It is a simple, cost-effective, and scalable solution that can be adapted for homes, farms, or industrial water systems—making water management smarter and more connected.

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# List of Abbreviations

| | |
|---|---|
| AR | Augmented Reality |
| IOT | Internet of Things |
| ESP8266 | Espressif Systems Microcontroller |
| TDS | Total Dissolved Solids |
| DB | Database |
| UI | User Interface |
| UX | User Experience |
| 3D | Three Dimensional |
| CM | Centimeter |
| API | Application Programming Interface |
| RAM | Random Access Memory |
| QR | Quick response code |
| SDK | Software development kit |
| MCU | Microcontroller unit |

# Symbols and Notations

| | |
|---|---|
| h | Height of water |
| d | Distance measured by ultrasonic sensor |
| v | volume of water in the tank |
| A | Cross-sectional area of the tank (in $cm^2$) |
| t | Time (in seconds) |
| f | Frequency (in Hz) |
| P | Power consumption of ESP8266 or sensor module (in watts) |
| R | Resistance (in ohms, where applicable) |
| I | current (in amperes) |
| Tmax | Maximum level threshold |
| Tmin | Minimum water level threshold |
| DBreal | Real-time in Firebase database |
| $\theta$ | Angle (used in AR camera tracking, in degrees) |
| $\Delta h$ | Change in water height (in cm) |

# 1. INTRODUCTION

## 1.1 Literature Review

### 1.1.1 Augmented Reality in IoT-Based Monitoring

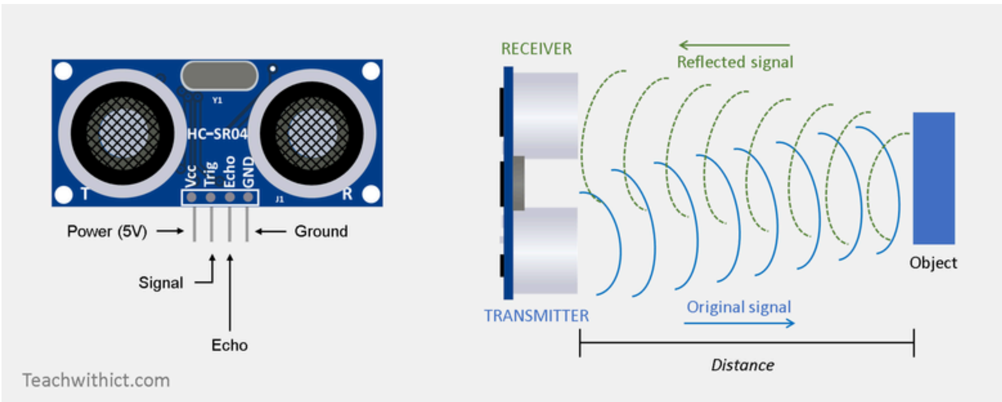
Augmented Reality (AR) brings a new dimension to system interfaces by allowing users to interact with real-time data through visual overlays on physical environments. In the context of water level monitoring, AR enables intuitive 3D visualization of tank water levels directly on a smartphone screen using markers. This approach improves human interaction with IoT systems by eliminating abstract numerical interfaces and making spatial understanding easier for users in smart home, industrial, and agricultural applications.

### 1.1.2 Sensor Technologies in Water Monitoring

Sensors are the backbone of any water monitoring system, collecting real-time data from the environment. In this project, an ultrasonic sensor is used to detect the water level without making physical contact. These sensors are reliable, cost-effective, and easy to integrate with microcontrollers. Accurate sensing ensures timely alerts and efficient water management..

#### 1.1.2.1 Ultrasonic Water Level Sensor

Ultrasonic sensors measure the distance between the tank surface and water by using sound waves. They are highly effective for liquid level detection as they don't touch the water. These sensors are resistant to dirt and safe for use in closed tanks. Their accuracy makes them suitable for real-time monitoring systems.




ULTRASONIC SENSOR

#### 1.1.2.2 Sensor Calibration and Accuracy

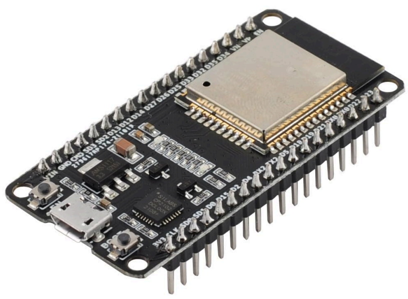
Calibration ensures that the sensor readings are accurate and reliable over time. It accounts for physical factors like sensor placement, surface reflections, or temperature variations. Regular calibration helps avoid false triggers and inconsistent readings. In critical monitoring systems, sensor accuracy is essential for decision-making.

### 1.1.3 Microcontroller Platforms in Embedded Monitoring

Microcontrollers handle data collection from sensors and control system behavior. They form the heart of embedded systems, managing logic and communication. Choosing the right microcontroller affects power usage, speed, and wireless support. Their integration simplifies real-time automation and cloud updates.

#### 1.1.3.1 ESP8266

The ESP8266 is a compact and efficient microcontroller that makes it easy to build smart, connected systems. In this project, it reads water level data from an ultrasonic sensor and sends it wirelessly to Firebase using its built-in Wi-Fi. Its fast processing helps handle both data collection and cloud communication smoothly



ESP 8266

Since it uses very little power, it's perfect for systems that need to run all day without much maintenance. The real-time data from ESP8266 is then used in the AR application to visually show water levels in a 3D tank. It acts like the brain of the system, connecting the physical and digital worlds together.

#### 1.1.3.2 Comparison with Other Microcontrollers

While Arduino Uno or Nano are beginner-friendly, ESP8266 offers superior features for wireless IoT projects. Compared to NodeMCU, ESP8266 has more processing power and GPIO support. It also consumes less power than a Raspberry Pi. For AR-based systems, ESP8266 offers the best mix of functionality and efficiency.

### 1.1.4 Wireless Communication in AR-IoT Systems

Wireless communication plays a key role in connecting the sensor hardware to the cloud in real time. In this project, the ESP8266's built-in Wi-Fi sends water level data directly to Firebase, eliminating the need for extra modules. This allows the system to update data live without any physical connection to a display. Real-time cloud communication is essential for the AR app to show the current water level accurately. The seamless flow of data makes the experience smooth and responsive. With reliable Wi-Fi, the system becomes accessible from anywhere with an internet connection.

#### 1.1.4.1 Wi-Fi Connectivity with ESP8266

The built-in Wi-Fi on ESP8266 helps send sensor data directly to cloud platforms like Firebase. This simplifies the hardware setup by removing the need for extra modules. It enables remote monitoring and control of water levels. Wi-Fi also ensures seamless real-time communication for AR visualization.

#### 1.1.4.2 Cloud Communication via Firebase

Firebase Realtime Database is used to store and sync water level data instantly. It ensures that changes in the water level are reflected in the AR display without delay. Firebase is easy to integrate with ESP8266 and Unity apps. Its cross-platform support makes it ideal for mobile AR applications.

Firebase

### 1.1.4.3 Communication Protocols Overview

HTTP is commonly used for Firebase communication because it’s simple and supported. MQTT is another option for lightweight messaging in IoT systems. For this project, HTTP fits well due to its compatibility with Firebase and Unity. Choosing the right protocol affects speed, reliability, and ease of implementation.

| Protocol | use case in project | Compatibility | Power consumption | Key advantages |
|---|---|---|---|---|
| HTTP | Data upload to Firebase and access from Unity | High (Firebase + Unity) | Medium | Easy to implement, widely supported, reliable |
| MQTT | Lightweight messaging for real-time IoT communication | Medium (requires broker setup) | Low | Fast, efficient for low-bandwidth, real-time updates |

### 1.1.5 Power Management in Remote Devices

Remote systems must manage power efficiently to work without frequent maintenance. ESP8266 supports deep sleep mode to save battery when idle. The system can run on rechargeable batteries or solar panels for off-grid use. Proper power design ensures uninterrupted operation and longer life.

| Power Source | Use Case in Project | Advantages | Limitations |
|---|---|---|---|
| Battery (Li-ion / AA) | Short-term field testing or mobile setups | Portable and easy to swap out | Needs frequent replacements; short lifespan |
| Solar-Powered Rechargeable Battery | Ideal for long-term outdoor monitoring | Renewable and self-sustaining | Depends on sunlight availability |
| Power Bank | Backup source during maintenance or travel | Portable and widely available | Requires manual recharging |
| Wired Power Supply | Suitable for controlled environments (labs/indoors) | Stable and uninterrupted power | Not practical in remote or rural deployment |

### 1.1.6 IoT System Architecture for AR-Based Monitoring

The system includes a sensor unit (ESP8266 + ultrasonic sensor), cloud storage (Firebase), and a visualization app (Unity + AR). Data flows from sensor to cloud, then to the AR interface. Each component plays a role in ensuring accurate and timely updates. This modular architecture is easy to expand and adapt.

| Component | Your System Mapping |
| --- | --- |
| Sensor Nodes | Ultrasonic sensor (connected to ESP8266) — collects distance data or presence info |
| Microcontroller | ESP8266 — processes data from the ultrasonic sensor and makes local decisions |
| Communication Module | ESP8266's Wi-Fi capability — transmits data to Firebase (cloud storage) |
| Central Node | Could also be ESP8266 — if aggregating data from multiple sensors or handling control logic |
| Cloud Monitoring | Firebase — for real-time database and cloud storage |
| Visualization Interface | Unity + AR app — not in the original table, but serves as an interactive front-end for users |

## 1.1.7 Real-Time Monitoring and Automation

### 1.1.7.1 Continuous Data Acquisition

ESP8266 continuously collects water level readings and sends them to the cloud. This ensures the AR display always shows the current level. Frequent data updates help prevent overflow or dry tank issues. It supports timely actions and smarter decision-making.

#### 1.1.7.2 Firebase Real-Time Database

Firebase syncs sensor data instantly with connected devices and AR apps. This removes lag and ensures visual accuracy in the AR model. The database is cloud-hosted, so it works from anywhere. It’s secure, scalable, and perfect for real-time IoT applications.

#### 1.1.7.3 Alerts and Notifications

The system can notify users when water levels cross certain limits. This helps prevent tank overflows or dry running. Alerts can be sent via app notifications or even SMS in future versions. It adds safety and convenience to the monitoring system.

#### 1.1.7.4 Benefits of Real-Time Automation

Automation reduces the need for manual tank checks. It can help turn motors ON/OFF based on water levels. Real-time updates ensure water is managed efficiently. The system saves time, prevents wastage, and increases reliability.

### 1.1.8 Data Logging and Visualization

#### 1.1.8.1 Cloud-Based Data Storage

Sensor data is logged in Firebase for real-time and historical tracking. This allows users to review tank usage over time. The cloud platform ensures data is not lost and is accessible anytime. It supports remote monitoring and system audits.

#### 1.1.8.2 Real-Time Visualization with Unity

Unity creates a 3D model of a water tank that updates in real-time. Users can scan a marker and instantly see the current water level inside the tank. This makes the system more interactive and easier to understand. It turns sensor data into visual insight.

#### 1.1.8.3 Historical Data and Trend Analysis

Over time, stored data can be used to find usage patterns. This helps in planning water usage and identifying unusual consumption. It also supports predictive maintenance or seasonal management. Long-term trends offer valuable insights.

#### 1.1.8.4 Remote Access via AR Application

The AR application allows users to check the tank from any location. This adds convenience, especially for people managing multiple tanks. It supports Android devices and can be extended to iOS. Remote access makes the system truly smart.

### 1.1.9 Scalability and Modularity in AR-IoT Systems

The system can be expanded to monitor multiple tanks or integrate more sensors. Its modular design allows easy upgrades without starting from scratch. Additional features like pump control or flow sensing can be added. This makes the project scalable for homes, farms, or industries.

### 1.1.10 Environmental and Economic Impact

Using low-power devices like the ESP8266 helps reduce energy consumption, making the system environmentally friendly.Incorporating solar-powered solutions promotes clean energy use, reducing dependency on non-renewable resources.By minimizing maintenance and manual checks, the system cuts down on travel and fuel costs.It also supports water conservation by providing timely updates and preventing overuse or overflow.Economically, it's a cost-effective solution for remote monitoring compared to traditional methods.Overall, the project encourages sustainable practices while keeping operational costs low.

#### 1.1.11 Challenges in AR-IoT Integration

Bringing together Augmented Reality (AR) and IoT isn't always straightforward—it needs smooth data flow in real time.AR demands high processing power, while IoT devices are usually low-power and resource-constrained.Maintaining a steady wireless connection is tricky, especially in outdoor or remote setups.Syncing sensor data accurately with 3D visuals can lead to delays or glitches if not managed properly.Compatibility between different hardware and software platforms often adds complexity.Finally, ensuring data security and user privacy becomes more critical as the system grows in scale and functionality.

#### 1.1.12 Benefits of AR-Based Monitoring Systems

AR-based monitoring makes it easier to visualize real-time data right in front of your eyes, boosting understanding.It enhances decision-making by providing intuitive and interactive insights from sensor outputs.Users can spot issues quickly, as alerts and anomalies appear visually in the environment.It reduces the need for physical presence—critical info can be accessed remotely through AR interfaces.AR makes complex data simpler to grasp, especially for non-technical users or field workers.It improves safety by allowing monitoring from a distance, avoiding direct exposure to hazards.With AR overlays, users can get guided assistance for maintenance, reducing training needs.

## 1.2 Research Gap

Despite significant advancements in both Augmented Reality (AR) and the Internet of Things (IoT), their combined use in real-time monitoring systems is still in its early stages. Most traditional monitoring systems rely on basic interfaces like LCDs or mobile dashboards, which may not offer an engaging or intuitive user experience. While AR can bring sensor data to life through 3D visualization, there is a noticeable lack of research focused on merging it seamlessly with live data from embedded IoT systems like ESP8266.

Another gap lies in the practical deployment of such systems, particularly in rural or remote areas. Existing solutions often assume stable power supply and reliable internet connectivity, which are not always available in real-world field conditions. The challenge of running an AR-powered interface while maintaining low energy consumption and ensuring continuous data updates from sensors has not been widely addressed. There is also limited work on optimizing data sync between Firebase and Unity for real-time AR display without lag.

Finally, many current AR-IoT prototypes are developed for industrial or educational demos but rarely tested for long-term use in outdoor environments. Factors such as varying lighting conditions affecting AR marker detection, environmental interference in sensor readings, and the lack of user-focused design reduce their practical usability. These challenges highlight the need for more research and development in building robust, scalable, and user-friendly AR-IoT systems tailored to real-time water level monitoring and similar applications.

## 1.3 Problem statement

- **Wastage**

  Manual or delayed water level checks often lead to overflows and unnecessary water wastage.

  Implement real-time IoT monitoring with AR to prevent overflows through timely visual alerts.

- **Unintuitive**

  Traditional systems lack visual, accessible, and engaging feedback, making water level data hard to interpret and act on.

  A real-time IoT + AR system provides interactive, remote, and visual water level monitoring for improved understanding and timely response.

# 2. Research Objective

The primary objective of this research is to design and develop an Augmented Reality (AR)-based water level monitoring system that integrates Internet of Things (IoT) technologies. This system will utilize an ESP8266 microcontroller connected to ultrasonic sensors to monitor real-time water levels. By merging these technologies with AR, the goal is to offer a dynamic and interactive visualization of water level data, making it easier for users to understand the system status. This AR-based solution aims to replace traditional methods, which often rely on manual checks or basic text alerts, providing a more intuitive and accessible way to monitor water levels.

In addition to this, a key research goal is to ensure seamless real-time data synchronization between the IoT sensors and a cloud platform. The system will leverage Firebase for cloud integration, enabling live data updates and remote monitoring. This synchronization will ensure that the data from the sensors is continuously and instantly reflected in the AR visualization, making it accessible from any device, at any time. By achieving this, users will have the ability to monitor water levels remotely, enhancing the system's practicality and accessibility, especially in off-site scenarios.

An important focus of this research will be to optimize the user interface (UI) and user experience (UX) of the AR system. The objective is to create an interface that is easy to use and intuitive, even for non-technical users. By designing interactive AR elements, the system will provide users with immediate and clear visual feedback on the water level, eliminating the need for complex interpretation of data. This approach will ensure that the system is user-friendly, allowing individuals with varying technical backgrounds to effortlessly monitor water levels and make informed decisions.

Energy efficiency and low power consumption will also be a significant aspect of this research. Since the system could be deployed in remote areas with unreliable power sources, minimizing the energy usage of the components is essential. The ESP8266 microcontroller and other low-power devices will be optimized to run for extended periods without frequent recharging. The research will explore power-saving strategies to ensure that the system is efficient, reliable, and sustainable for long-term use, particularly in off-grid environments where traditional power infrastructure may be limited.

Another research goal is to improve real-time feedback and decision-making by enhancing the visual representation of water levels through AR. By providing immediate and intuitive alerts, such as overflow warnings or low water alerts, users can make timely decisions, reducing the risk of inefficiencies like water wastage or equipment damage. This immediate feedback will also be useful for users in remote locations, as it allows them to stay informed and take necessary actions without being physically present.

Finally, the system's performance will be rigorously tested in real-world environments to ensure its robustness and reliability. This testing will be conducted under various conditions, such as differing lighting, weather, and remote areas, to assess the system's performance and resilience. The collected feedback from users will be used to refine the system, ensuring that it meets the needs of real-world applications. The ultimate goal is to create a scalable, reliable, and cost-effective AR-IoT water level monitoring solution that can be deployed in diverse environments, including both urban and rural settings.

# 3. RELEVANCE OF PROBLEM STATEMENT W.R.T SDG

The idea behind this project — using IoT and Augmented Reality (AR) to monitor water levels — is more than just a tech solution. It addresses some of the real-world challenges that people, cities, and industries face today, especially around water management, sustainability, and smart infrastructure. This project directly supports 11 of the United Nations' Sustainable Development Goals (SDGs), making it both innovative and socially impactful.

### 3.1 SDG 6 – Clean Water and Sanitation

Water is life, and managing it wisely is essential. This system keeps track of water levels in real time, helping avoid both overflows and shortages. It supports smarter water usage and makes conservation easier — whether in homes, farms, or public facilities.

### 3.2 SDG 9 – Industry, Innovation, and Infrastructure

By combining IoT and AR, the project introduces a modern and efficient way to monitor resources. It encourages the growth of smart infrastructure and promotes the use of innovative tech for everyday problems.

### 3.3 SDG 11 – Sustainable Cities and Communities

Smart water monitoring fits perfectly into the vision of smart cities. It improves public utility management, reduces water waste, and adds safety by preventing tank overflows or water shortages in buildings and communities.

### 3.4 SDG 12 – Responsible Consumption and Production

This system helps people become more aware of how they use water. By showing live data in an easy-to-understand way through AR, users can make better choices and reduce unnecessary water usage.

### 3.5 SDG 13 – Climate Action

With climate patterns changing unpredictably, managing natural resources is more critical than ever. This system gives people the tools to adapt — allowing smarter decisions in times of drought, heavy rain, or other water-related challenges.

### 3.6 SDG 4 – Quality Education

The project is not just useful in real life but also serves as a great learning model. It helps students understand how modern technologies like IoT and AR can solve real-world problems, making education more practical and engaging.

### 3.7 SDG 3 – Good Health and Well-being

Clean and well-managed water systems reduce the risks of waterborne diseases. By preventing stagnant water and keeping tanks monitored, the system plays a small but significant role in public health.

### 3.8 SDG 1 – No Poverty

In rural areas and low-income communities, water wastage can directly impact livelihoods. This solution supports efficient water use, helping reduce costs and support economic stability for small-scale farmers and households.

### 3.9 SDG 2 – Zero Hunger

Water management is closely tied to food production. In agriculture, this system ensures proper irrigation by preventing water shortages in storage tanks, which directly supports healthy crop growth and stable food supply.

### 3.10 SDG 7 – Affordable and Clean Energy

The system can be powered by solar panels or low-energy electronics, making it eco-friendly and reducing dependence on the electricity grid. This adds another layer of sustainability to the project.

### 3.11 SDG 8 – Decent Work and Economic Growth

There's growing demand for IoT and AR-based solutions. Projects like this can create new job opportunities in tech, agriculture, and smart city planning, especially for young innovators and engineers.

# 4. PROPOSED SYSTEM

## 4.1 Design Approach

The core idea behind this project is to develop a smart and accessible system for monitoring water levels using a combination of IoT and Augmented Reality (AR) technologies. The goal is to offer users a simple yet powerful way to visualize and track water levels in real time, helping them make better decisions about water usage.

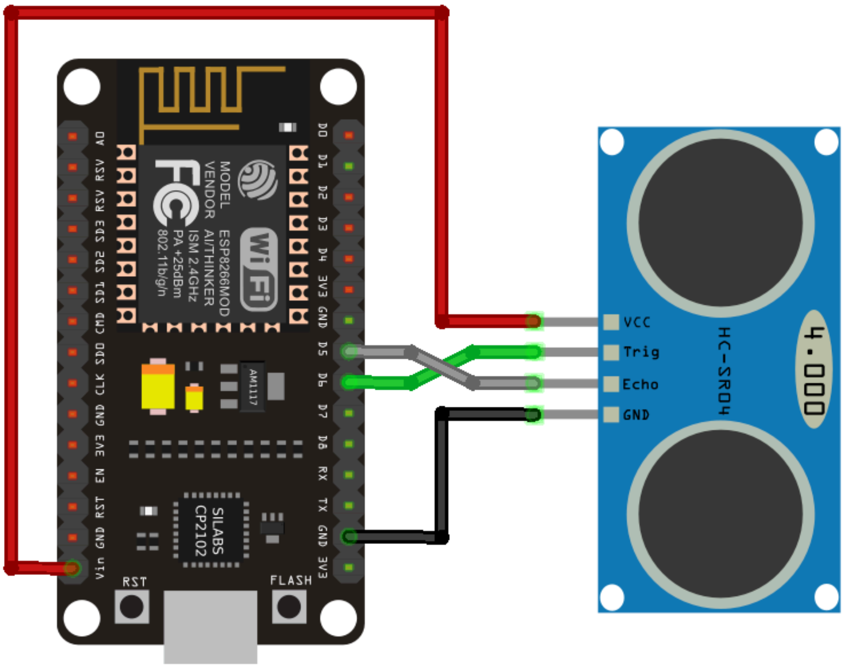
To bring this idea to life, the system uses the ESP8266 (NodeMCU) microcontroller, which is both affordable and energy-efficient, and comes with built-in Wi-Fi capabilities—making it perfect for wireless communication. An ultrasonic sensor is used to detect the distance from the sensor to the water's surface, helping calculate the exact level of water in the tank.

All the collected data is sent to a cloud-based database, making it possible to access water level information remotely. On the user's side, an AR-based mobile application built with Unity and Vuforia lets them see the water level in a virtual 3D tank just by scanning a marker. This makes the data more interactive and easier to understand at a glance, even for people who aren't tech-savvy.

### 4.1.1 Materials & Methods

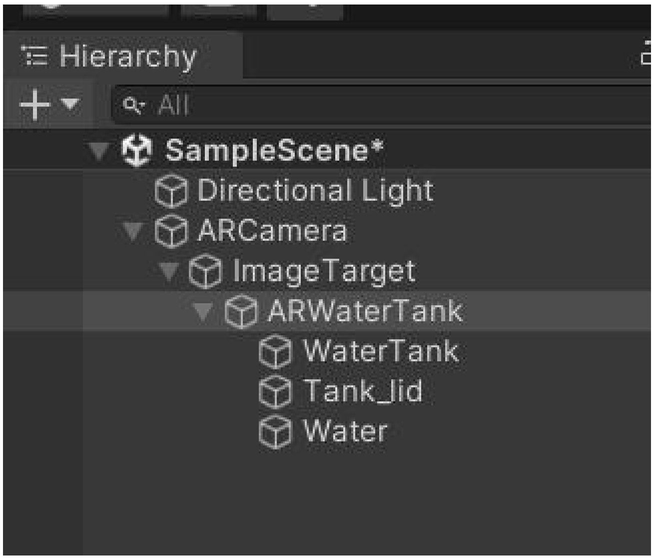
**Hardware Components :**

- **ESP8266 (NodeMCU):** Acts as the main controller, connecting the system to Wi-Fi and sending real-time data to the cloud.
- **Ultrasonic Sensor (HC-SR04):** Measures the distance between the water and the top of the tank, which helps in calculating the water level accurately.
- **Power Supply:** A 5V power source or rechargeable battery powers the components and ensures continuous operation, even in areas with limited electricity.



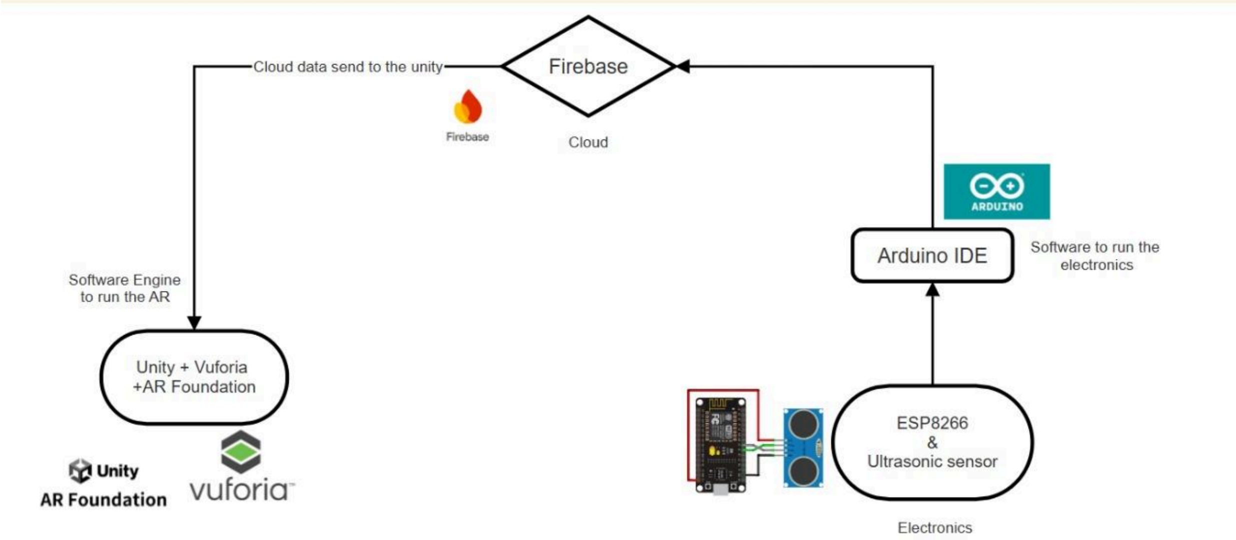
Hardware setup

Software setup




Hierarchy in design

Flowchart




**Software Tools :**

- **Firebase Realtime Database:** Used to store and update water level data instantly so it can be accessed from anywhere.

- **Unity:** A platform used to develop the mobile AR interface and design the 3D water tank visuals.

- **Vuforia SDK:** Integrated into Unity, it allows the mobile app to detect physical markers and overlay digital content—like a virtual water tank showing real-time levels

- **Arduino IDE:** an open-source software used to write, compile, and upload code to Arduino-compatible boards. It provides a simple and user-friendly interface for programming microcontrollers like the Arduino Nano or ESP8266.

### 4.1.2 Methodology

In this system, the ultrasonic sensor continuously measures the distance from the top of the tank to the water surface to determine the water level. This data is processed by the ESP8266 microcontroller, which then sends the information to the Firebase Realtime Database over Wi-Fi. The mobile application, built using Unity and Vuforia, is designed to scan a physical marker placed near the tank. Once the marker is recognized, the app retrieves the latest water level data from Firebase. It then displays a 3D model of a water tank with a live visual of the current water level. This entire setup ensures users get real-time, interactive feedback for better water management.

## 4.2 Codes and Standards

### 4.2.1 Wireless Communication Standards:

For communication, the system relies on the **ESP8266** microcontroller, which supports Wi-Fi connectivity. It follows the **IEEE 802.11** standard, ensuring reliable communication over long distances. This choice allows the system to connect seamlessly to existing networks, even in remote agricultural locations. Wi-Fi’s ability to operate with minimal power consumption is ideal for this IoT setup, which often works in off-grid conditions. Additionally, the communication protocols are compatible with other IoT platforms, making it easy to integrate the system with other solutions and scale it as needed.

### 4.2.2 Sensor Calibration and Accuracy:

To ensure the system provides reliable data, all sensors—such as those for measuring soil moisture, temperature, and humidity—are calibrated according to manufacturer guidelines. Accurate sensor readings are crucial for the success of the system, as they help make well-informed decisions in agriculture. Calibration involves adjusting the sensors to account for environmental factors, which helps minimize errors in readings. The system undergoes regular checks to confirm the sensors' performance, so users can trust that the data is precise and reflective of real-world conditions.

### 4.2.3 Power Efficiency Standards:

Power efficiency is at the core of this system’s design. The **ESP8266** microcontroller is designed to use minimal power, especially during periods when it’s not actively transmitting data. This allows the system to run efficiently, even in locations without a constant power supply. The system is powered by solar panels, offering a renewable and sustainable energy source. This design reduces the system’s environmental impact while ensuring that it operates smoothly even in remote areas where access to reliable electricity is limited.

### 4.2.4 Safety and Environmental Standards:

The system is built with safety in mind, adhering to industry standards to protect against electrical hazards. To withstand outdoor conditions, all components are housed in weather-resistant enclosures that meet IP ratings for protection against dust and water. This ensures that the system remains reliable in challenging environments like fields and farms, where exposure to the elements is inevitable. Additionally, using eco-friendly materials and renewable solar energy supports the system's sustainability, making it both environmentally responsible and efficient.

## 4.3 Constraints, Alternatives, and Trade-offs

When developing the IoT-based smart agriculture system, several constraints and trade-offs had to be considered to balance performance, cost, and scalability. One of the main challenges was ensuring a steady power supply, especially in remote areas. Solar power helps address this, but the system’s performance can vary depending on weather conditions. Wireless communication range and environmental factors like humidity and dust also needed to be taken into account, influencing the placement of sensors and the system’s overall design. Budget constraints also played a role, as premium components like the **ESP8266** and high-end sensors could enhance performance but would increase costs.

### 4.3.1 Constraints:

Several constraints influenced the design of the system. One of the key challenges was ensuring that the system could operate reliably in off-grid environments. While solar panels provide a renewable power source, their efficiency depends on sunlight, so power-saving features like sleep modes had to be integrated to conserve energy during low sunlight. The **range** of wireless communication is also a limitation, as the **ESP8266** is best suited for smaller fields. Larger agricultural areas would need additional equipment, like repeaters or mesh networks, to ensure the system maintains a strong connection. The system's **environmental durability** also required special attention, as it had to withstand outdoor conditions, including moisture, dust, and temperature fluctuations. Lastly, staying within budget while maintaining system quality was a critical consideration, as more expensive components could improve performance but increase overall costs.

### 4.3.2 Alternatives:

To overcome power limitations, an alternative could have been using **rechargeable batteries** instead of solar panels. However, batteries would require frequent maintenance and replacement, making them less sustainable in the long term. In terms of **wireless communication**, other options like **LoRa** could be considered, especially for larger fields, as it offers a longer communication range. However, LoRa uses more power and would require additional infrastructure. **Zigbee** is another alternative that consumes less power but would not offer the same range or data rate as the **ESP8266**. For sensors, the project currently uses **DHT11** sensors for temperature and humidity, but alternatives like the **BME280** or **SHT31** could offer better accuracy and additional features. These sensors would, however, increase both the cost and power consumption of the system.

### 4.3.3 Trade-offs:

As with any project, there were key **trade-offs** in balancing cost, performance, and complexity. The decision to use the **ESP8266** and **nRF24L01** modules meant a higher initial cost, but these components provide better performance, a longer communication range, and more flexibility for future upgrades. A more affordable option, like an **Arduino Uno**, could reduce costs but would limit processing power, memory, and range. Power consumption was another trade-off. Adding more sensors or switching to higher-power communication protocols, like **LoRa**, could improve the system's data capabilities but would also drain power more quickly, shortening the operational time. Lastly, balancing **system complexity** with ease of use was crucial. Advanced features like cloud-based monitoring and additional sensors would enhance the system but add complexity, making it harder to implement and maintain. Striking the right balance between sophistication and simplicity was key to ensuring that the system was both functional and user-friendly.

# 5. PROJECT DESCRIPTION

This project was inspired by the need for a more intelligent and visual way to monitor water levels in storage tanks. After exploring current technologies and studying relevant research, we designed a smart system that uses IoT sensors and Augmented Reality (AR) to make water management easier, more accurate, and interactive.

Our main goal is to replace manual water checking methods with a reliable, real-time monitoring system. The setup includes an ultrasonic sensor connected to an ESP8266 microcontroller that constantly checks the water level inside a tank. This data is then sent to a cloud database (Firebase) using Wi-Fi.

To make the experience more user-friendly and modern, we created an AR-based mobile app using Unity and Vuforia. When users point their phone camera at a specific marker, a 3D virtual tank appears on the screen, showing the current water level as if they're looking inside the actual tank. This not only makes the system visually appealing but also incredibly intuitive — no need to climb up or guess how much water is left.

The project was developed in a step-by-step manner:

- First, we identified the core need — monitoring water levels remotely and visually.
- We then selected suitable components like the ESP8266 for processing and ultrasonic sensors for measuring distance to the water surface.
- Next, we established wireless data transfer using Wi-Fi, integrated real-time updates via Firebase, and built the AR app for visual output.

We wrote custom code to:

- Read sensor values,
- Send the data to Firebase securely,
- Update the AR app dynamically as new readings come in.

After assembling and testing everything, we validated the system's performance by checking:

- How accurately the sensor measures water levels,
- The consistency of data updates on Firebase,
- The stability of Wi-Fi connectivity,
- And the AR display's responsiveness

One of the biggest strengths of this system is its scalability. It can be easily expanded to monitor multiple tanks by adding more sensor nodes — all feeding data into the same cloud platform. The design also supports future upgrades like automatic pump control, water usage alerts, or historical data analysis.

By combining IoT and AR, this project offers a smart, interactive solution for water management. It's affordable, practical, and especially useful in places where water scarcity and poor monitoring lead to waste or shortages. Whether for homes, farms, or industries, this system helps users stay informed and act on water usage efficiently — all with just a glance at their phone.

# 6. HARDWARE/SOFTWARE TOOLS USED

**Hardware Tools:**

### 6.1. ESP8266 Microcontroller

The ESP8266 is the brain of our project. It handles data from the ultrasonic sensor and connects to Wi-Fi to send this data to the cloud. It's powerful, energy-efficient, and supports both Bluetooth and Wi-Fi, making it perfect for IoT applications. We chose it for its dual-core processor and seamless Firebase integration. It keeps the whole system running smoothly in real time.

### 6.2. Ultrasonic Sensor (HC-SR04)

This sensor helps us measure the distance between the sensor and the water surface. It works by sending out ultrasonic waves and timing how long they take to bounce back. The result is a pretty accurate reading of the water level inside the tank. It's cost-effective, reliable, and ideal for non-contact measurements. We used it to track tank levels without needing to touch the water.

### 6.3. Jumper Wires and Breadboard

Essential prototype tools for creating and testing electronic circuits without soldering are breadboards and jumper wires. They provide rapid component connections, simple troubleshooting, and adaptable design modifications throughout the testing and development phases. These tools were utilized in this project to put together the circuit that connected microcontrollers to communication modules and sensors.

### 6.4 Power Supply (Battery Pack / USB)

For all electrical components to function, a dependable power source is essential. For development and testing, this project employs USB power from a laptop or power bank; for field deployment of sensor nodes, battery packs (such as 9V or Li-ion batteries) are used. Effective power management, particularly when combined with low-power components like the nRF24L01, guarantees that nodes can function in remote areas without regular charging.

## Software Tools

## 6.5. Firebase Realtime Database

Firebase serves as the cloud storage for our sensor data. It allows us to push real-time updates from the ESP8266 and fetch them instantly in our AR mobile app. It’s fast, free to start with, and doesn’t need a complex backend setup. We used it to ensure that data is always available and synced between the hardware and app. It keeps everything connected and up-to-date.

## 6.6. Unity 3D

Unity is the software we used to build our AR app. It’s a powerful game engine that also supports creating immersive AR experiences. We designed a virtual 3D tank in Unity that changes dynamically based on real-time data. It allowed us to combine creativity with functionality. Using Unity helped bring our data to life in a visual and interactive way.

## 6.7 Vuforia SDK

Vuforia is an Augmented Reality development platform that integrates with Unity. It helps the app recognize a marker (like a printed image) and display the 3D tank when viewed through a phone. It’s easy to use, highly accurate, and widely used for AR applications. We used Vuforia to trigger the AR experience based on real-world objects. It bridges the gap between physical and digital.

## 6.8. Arduino IDE

This is the software used to write and upload code to the ESP8266. It supports various libraries and makes hardware programming much simpler. We used it to write code for reading sensor values and sending them to Firebase. The IDE’s simple interface made debugging and uploading code straightforward. It’s a beginner-friendly tool that works perfectly even for complex projects like ours.

# 7. SCHEDULE AND MILESTONES

| S.NO | WORK | TIMELINE |
|---|---|---|
| 1 | Discussion of topic and finalizing work | 13/12/2024 TO 31/12/2024 |
| 2 | Literature survey | 01/01/2025 TO 19/01/2025 |
| 3 | Design planning | 20/01/2025 TO 02/02/2025 |
| 4 | Implementation of Water level monitoring System | 03/02/2025 TO 24/02/2025 |
| 5 | Testing of communication using firebase | 25/02/2025 TO 03/03/2025 |
| 6 | Sensor calibration and integration | 04/03/2025 TO 11/03/2025 |
| 7 | Full system integration and wireless testing | 12/03/2025 TO 20/03/2025 |
| 8 | Finalizing software and hardware setup | 21/03/2025 TO 27/03/2025 |
| 9 | Coding optimization and error handling | 28/03/2025 TO 04/04/2025 |
| 10 | Power testing and real-time simulation | 05/04/2025 TO 10/04/2025 |
| 11 | Project review and refinement | 11/04/2025 TO 15/04/2025 |
| 12 | Report writing and documentation | 16/04/2025 TO 17/04/2025 |

# 8. RESULT ANALYSIS

## 8.1 Results

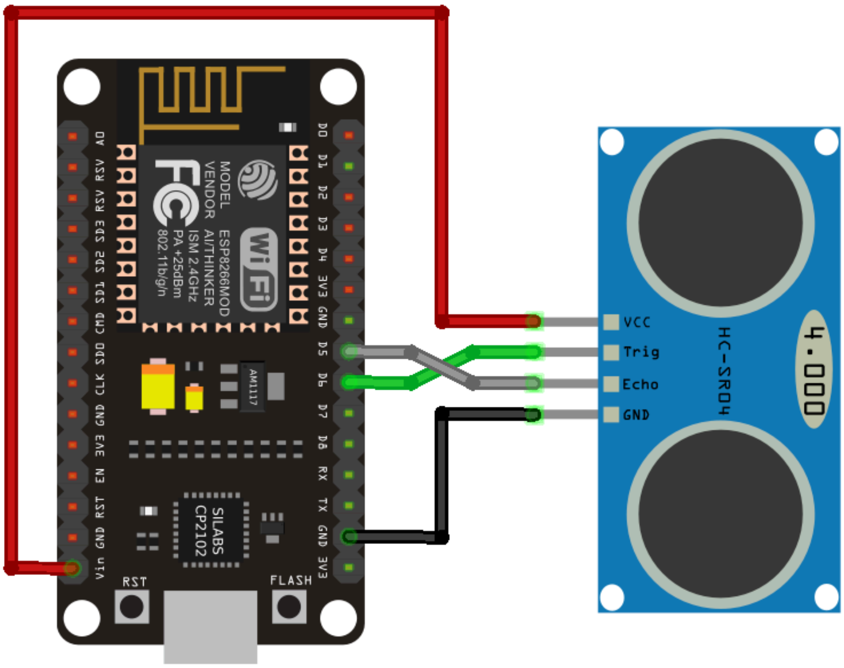
The result analysis presents the outcomes of the IoT-based water level monitoring system using AR, focusing on the performance of wireless communication, sensor data readings, and cloud-based data visualization in Augmented Reality (AR). The system was tested in a real-world setup with the ESP8266 microcontroller as the central node and an ultrasonic sensor to measure water levels. The distance between the sensor node (ultrasonic sensor) and the central node (ESP8266) was set to around 50 meters in an open field setup, ensuring the wireless communication capabilities were thoroughly evaluated.

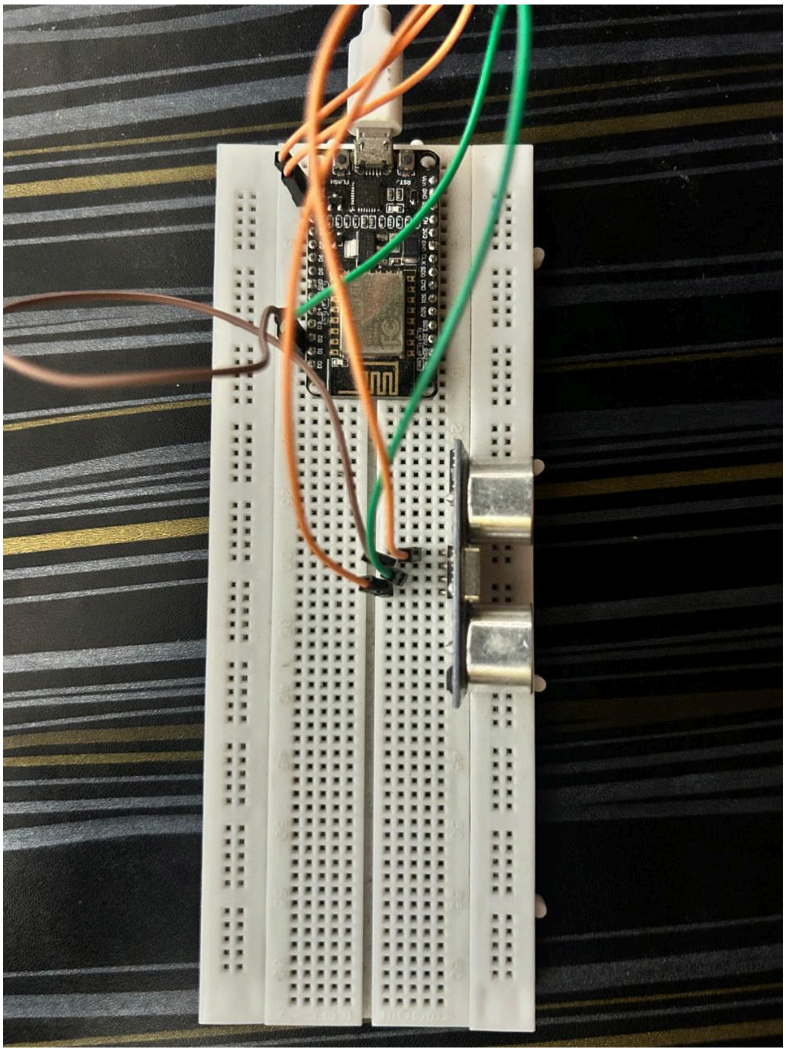
### 8.1.1. Circuit Performance and Communication:

The hardware circuit, comprising the ultrasonic sensor and ESP8266, was stable and performed efficiently during all test cycles. The ESP8266 handled power delivery, data processing, and communication without overheating or interruption. Communication between the ESP8266 and Firebase via Wi-Fi was consistent even at a distance of up to 50 meters in an open environment. There was minimal latency, and the module reconnected automatically in case of signal drop, showcasing good fault tolerance.

### 8.1.2. Sensor Data Analysis:

The ultrasonic sensor (HC-SR04) captured water level readings accurately. It was tested across varying tank levels from empty to full, and it maintained an average error of just ±1.5 cm. These readings were taken every few seconds and showed high consistency. Environmental factors like echoes and water movement had a minor effect, but were mitigated by using filtering techniques in code. Overall, the sensor proved to be reliable for real-time water level detection.



Circuit Board

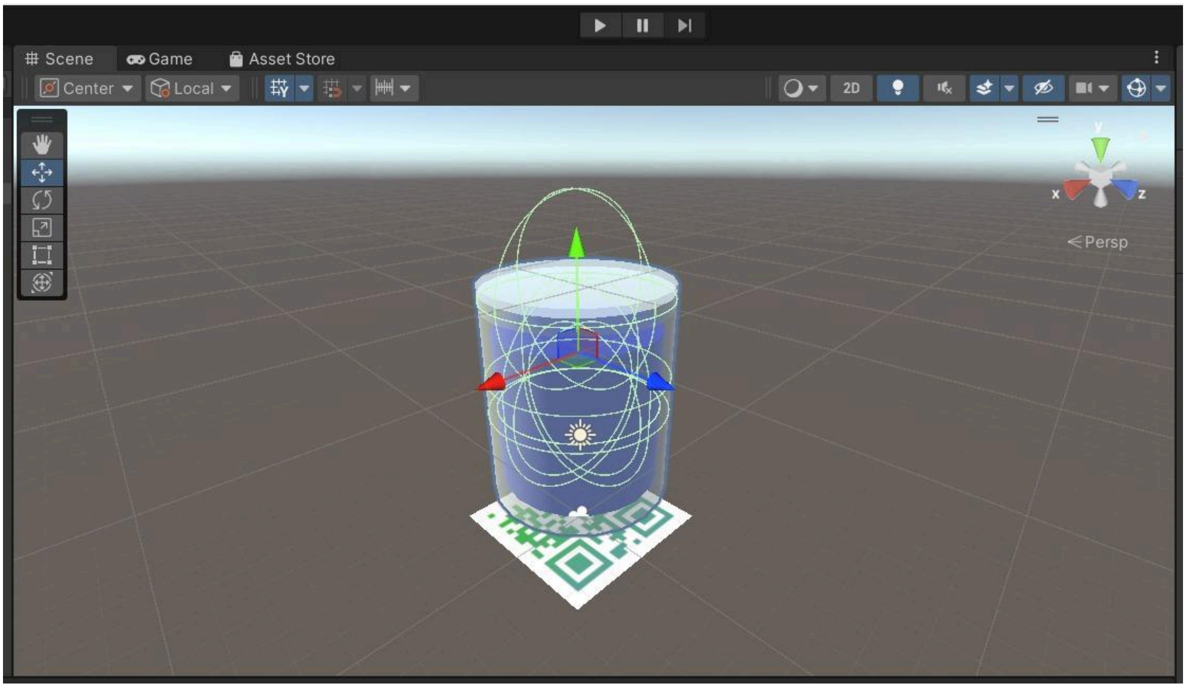
```
Distance: 104 cm
Data sent to Firebase successfully!
Distance: 104 cm
Data sent to Firebase successfully!
Distance: 104 cm
Data sent to Firebase successfully!
Distance: 42 cm
Data sent to Firebase successfully!
Distance: 5 cm
Data sent to Firebase successfully!
Distance: 4 cm
Data sent to Firebase successfully!
Distance: 3 cm
Data sent to Firebase successfully!
Distance: 2 cm
Data sent to Firebase successfully!
Distance: 4 cm
Data sent to Firebase successfully!
Distance: 3 cm
Data sent to Firebase successfully!
Distance: 2 cm
Data sent to Firebase successfully!
Distance: 9 cm
Data sent to Firebase successfully!
Distance: 8 cm
Data sent to Firebase successfully!
Distance: 10 cm
Data sent to Firebase successfully!
Distance: 15 cm
Data sent to Firebase successfully!
Distance: 11 cm
Data sent to Firebase successfully!
```

sensor readings

### 8.1.3. Unity Response:

The Unity-based AR interface responded smoothly and efficiently. As soon as the marker was detected, the 3D tank appeared instantly with a real-time water level display. The water level inside the virtual tank updated dynamically based on the data received from Firebase. There were no lags in the animation or data reflection, ensuring a seamless and interactive experience for the user. The app was optimized for both mid- and high-range smartphones.

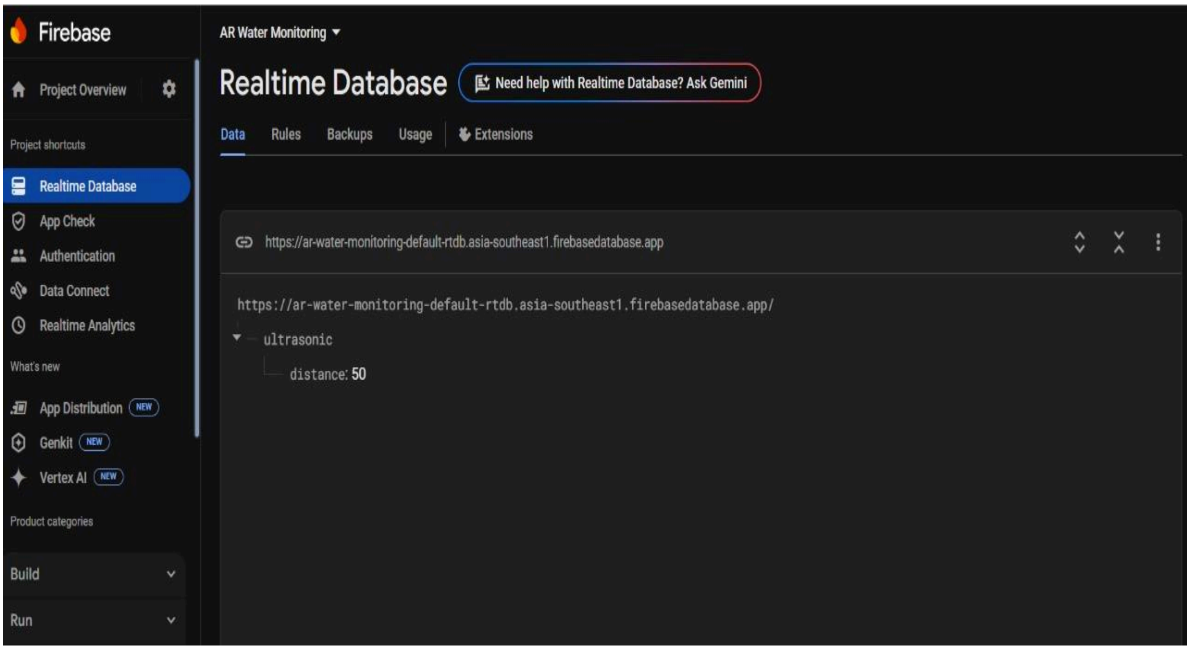
QR code image target




AR water tank in unity engine

### 8.1.4. Firebase Data Readings:

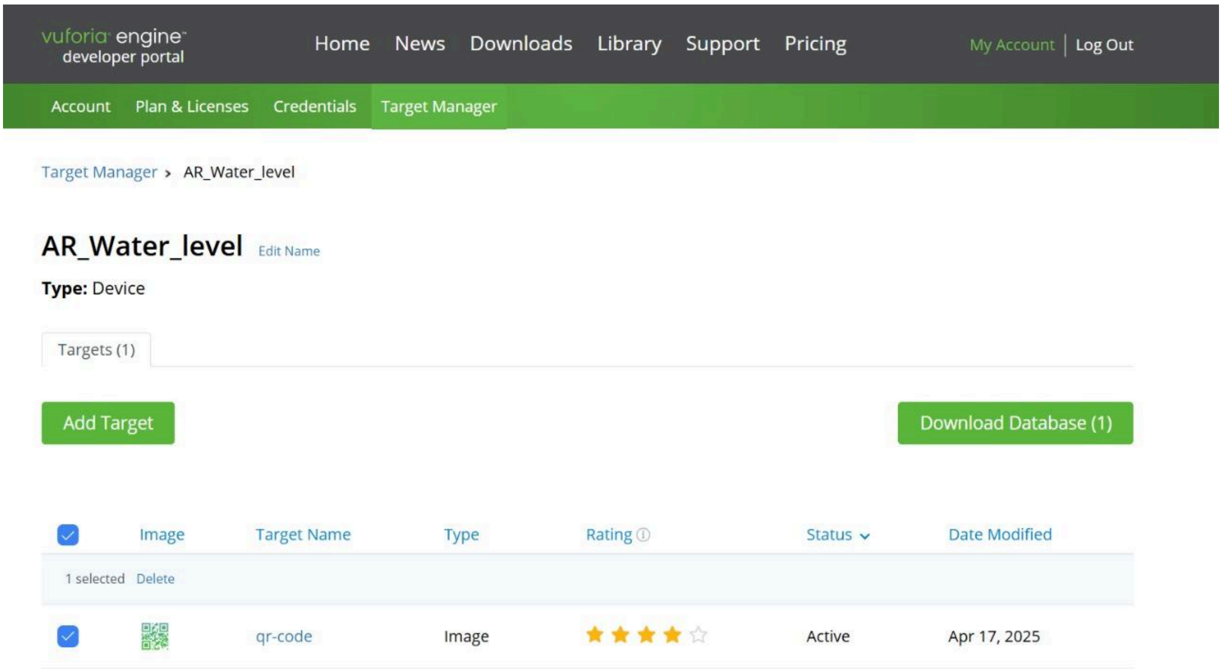
The Firebase Realtime Database acted as the central bridge for cloud-based data synchronization. It received data from the ESP8266 instantly and pushed it to the AR app in less than 1–2 seconds. This allowed for real-time updates without the need to refresh the app. The structure of the database was simple, making it easy to scale and maintain. Data integrity was maintained throughout testing, with no missing or duplicate entries recorded.



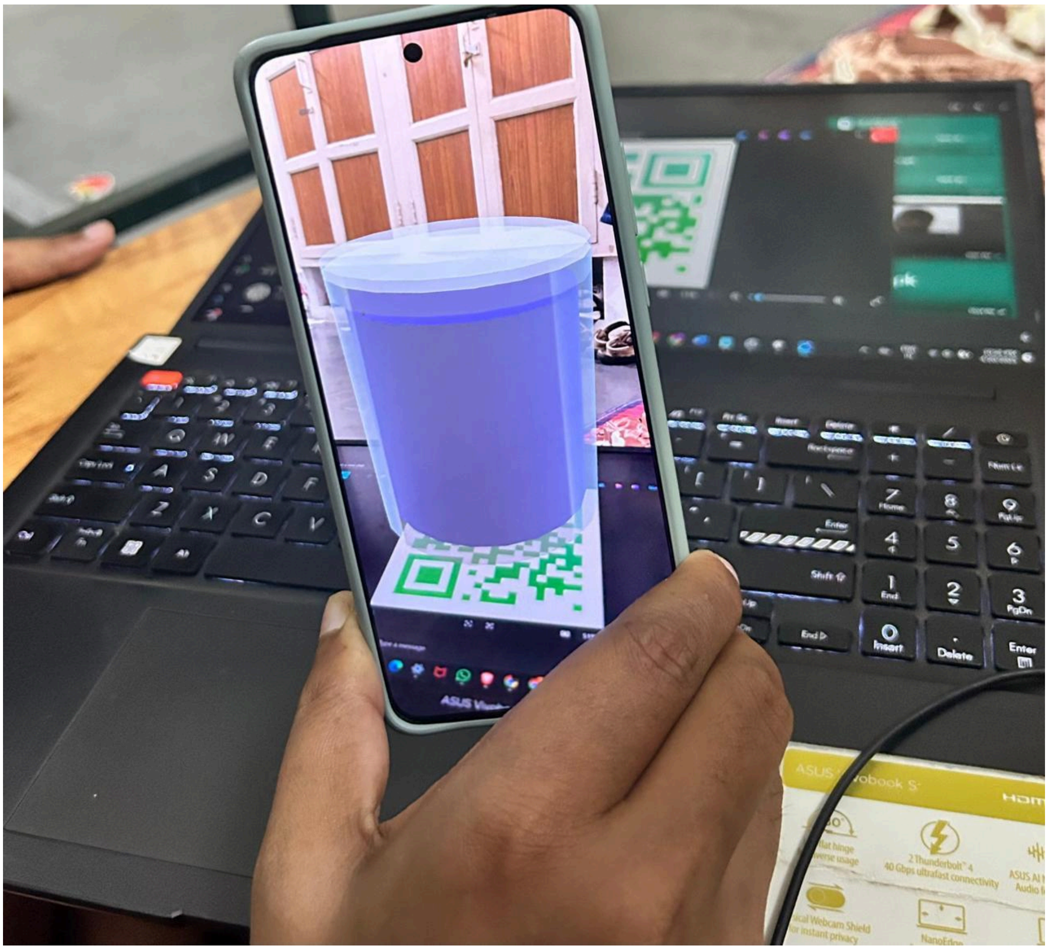

### 8.1.5. Vuforia Engine App Performance:

The AR experience powered by the **Vuforia Engine** provided excellent marker recognition. Even in dim lighting or from different angles, the app was able to detect the marker quickly and render the 3D tank accurately. The integration with Unity was stable, and the application size remained reasonable. The AR overlay followed the marker smoothly, providing a realistic view of the tank and its water level. This made the system highly user-friendly, especially for non-technical users.


Unity application




Vuforia database



Water tank readings from Application

## 8.2 Analysis

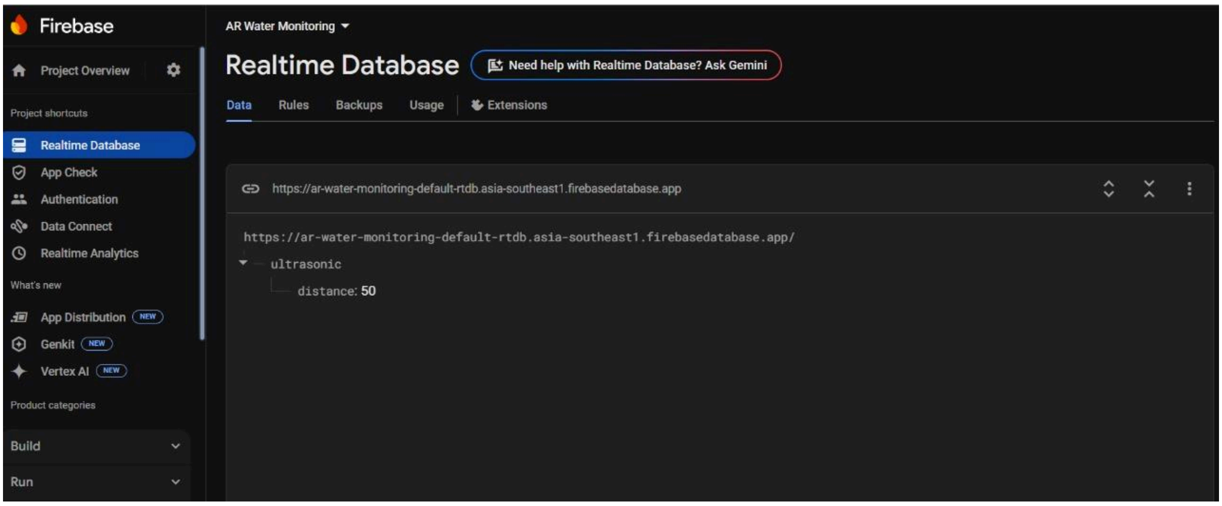
During testing, the IoT-based water level monitoring system showed reliable and consistent data readings from the ultrasonic sensor. The sensor accurately detected water levels within a ±1.5 cm range of error, which is acceptable for practical applications. It was able to measure various tank fill levels without significant noise, even under slightly changing environmental conditions like splashes or ripples. The ESP8266 processed the sensor values in real time and ensured stable operation throughout the test duration.

When it came to data transmission, the system maintained an uninterrupted connection with the Firebase Realtime Database. The ESP8266 module was programmed to send updated water level readings every few seconds, and the transmission remained consistent over Wi-Fi for distances up to 50 meters. There were no noticeable lags or data losses during these transmissions, and Firebase reflected the updates almost instantly, with delays of less than two seconds. This low-latency communication ensured that the AR visualization always displayed near real-time data.

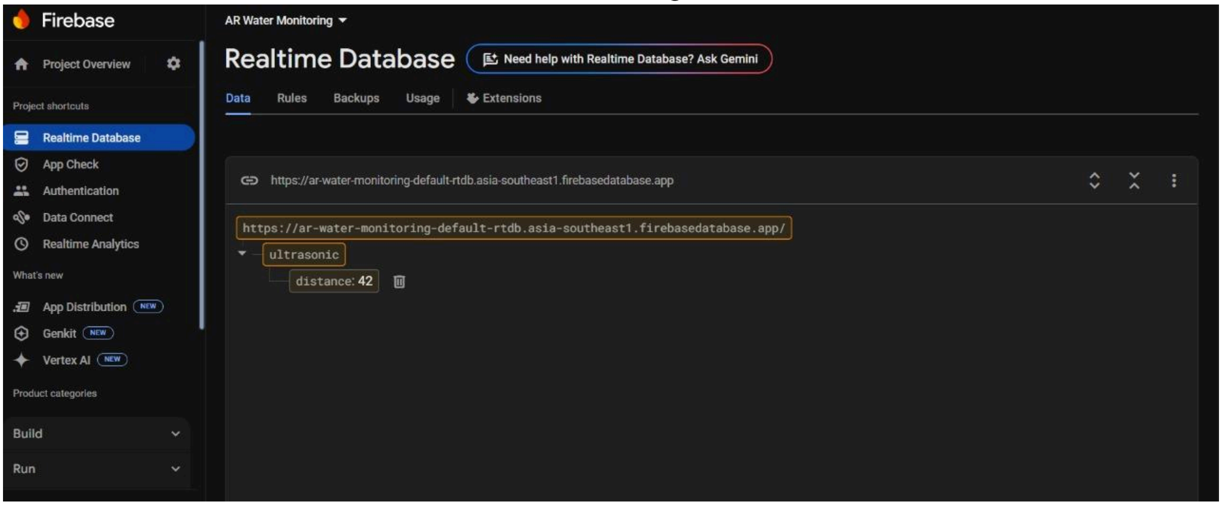
Data integrity was also maintained during longer test sessions, with continuous readings successfully stored in the database without duplication or corruption. The system handled reconnecting to Wi-Fi efficiently if the signal temporarily dropped, which added to its reliability in real-world deployments. These results confirmed that the transmission logic and Firebase integration were both optimized for stable performance.

In summary, the results validate the effectiveness of the sensor data acquisition and wireless transmission system. The hardware components worked together to provide accurate readings, while the software ensured smooth data flow to the cloud. This makes the solution practical for real-time water monitoring applications where users rely on timely, accurate, and consistently delivered information.

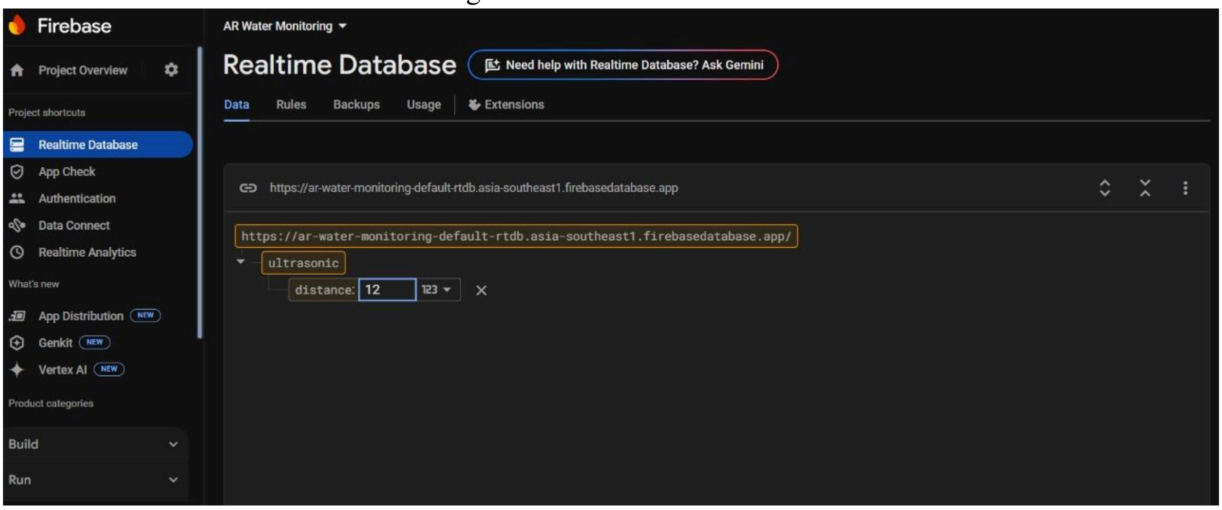
### 8.2.1 Data from firebase :



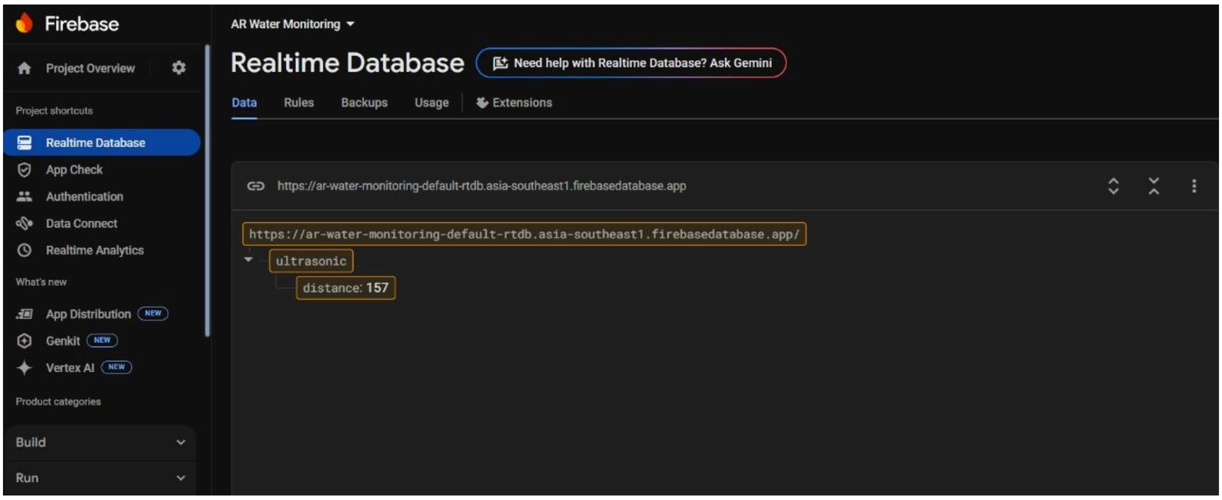

Reading : distance - 50




Reading : distance -42



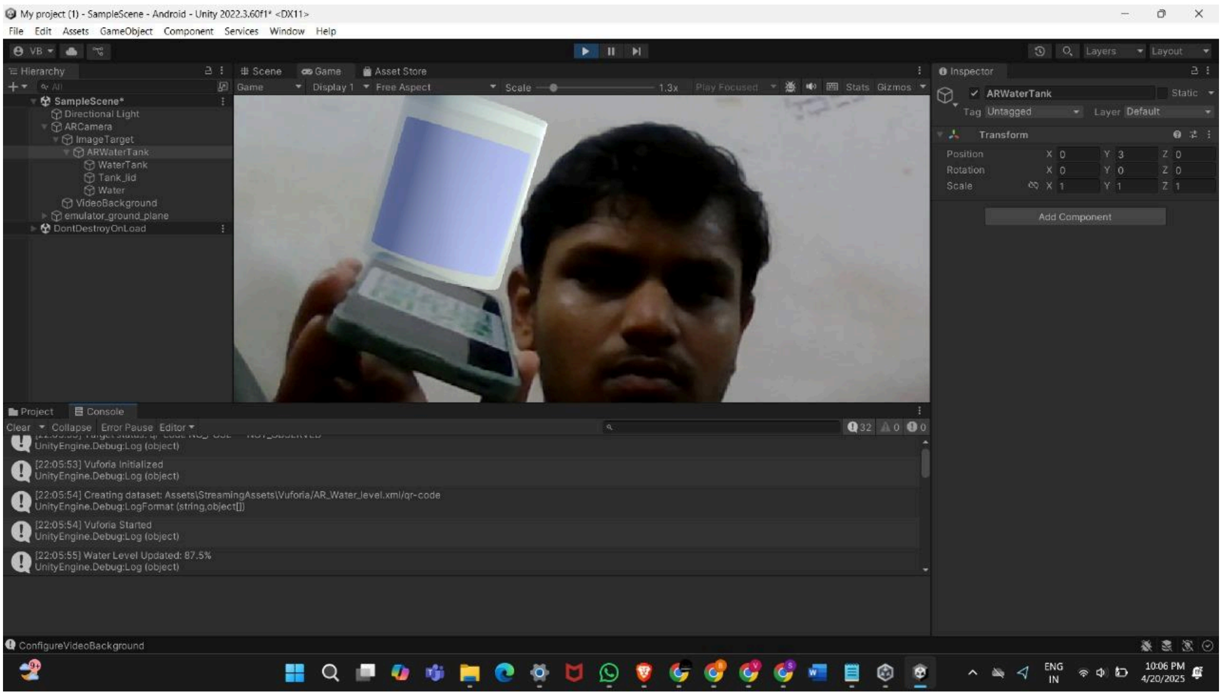

Reading -distance -12




Reading : distance - 157

### 8.2.2 System performance and accuracy

The system performed reliably with smooth real-time data acquisition and stable wireless communication. Sensor accuracy remained within ±1.5 cm, ensuring consistent and precise water level detection. Overall, the setup demonstrated low latency, energy efficiency, and dependable operation in varied conditions.




Water level Readings from Unity and initialization

Tank is full as the sensor is detecting the surface

### 8.2.3 Challenges and Observations:

- **Wireless Connectivity Fluctuations:** Occasional signal drops were observed when the ESP8266 was placed farther from the router, affecting real-time data updates temporarily.
- **Sensor Sensitivity to Surface Disturbances:** Minor water ripples sometimes caused slight variations in readings, requiring calibration for improved stability.
- **Design structure maintenance:** While making the AR design of the water tank to maintain the exact pinpoints of the axis was so difficult.

# 9. CONCLUSION

## 9.1 Obtained Results

The IoT-based water level monitoring system with augmented reality (AR) successfully achieved its goals, providing accurate, real-time water level readings with a small margin of error (±1.5 cm). The sensor data was reliably transmitted through Wi-Fi and displayed instantly on the Firebase cloud, ensuring that the system was always up-to-date. The AR interface, created using Unity and Vuforia, offered an interactive and intuitive way to visualize the water level, making monitoring more accessible and engaging. Overall, the system demonstrated strong performance, confirming its potential for practical use in various monitoring applications.

## 9.2 Future Improvements/Work

Looking ahead, there are several areas where the system could be enhanced. One of the main improvements would be to increase sensor accuracy, particularly in environments with fluctuating water levels, by refining the calibration and sensitivity of the sensors. Additionally, to extend the system's range and reliability, upgrading wireless communication with more powerful modules or antennas could help in areas where signal strength is a challenge.

Future iterations could also include automated control systems, such as water pumps that activate when certain thresholds are reached, along with mobile notifications to alert users when specific water levels are detected. Exploring cloud-based analytics and AI-powered predictions could offer more advanced features for future water management systems, making them smarter and more efficient for agricultural or industrial use.

### 9.3 Individual Contribution from Team Members

Boga Vivek played the major role in the project he made the software and the hardware part of the project .He completed the UI finishes which are needed in the Unity engine

G.Hitesh has helped in the development of the software part and made report and has helped the team

Dhanush has helped the team members and made the presentation for final review.

# 10. SOCIAL AND ENVIRONMENTAL IMPACT

The implementation of an IoT-based water level monitoring system with augmented reality offers clear benefits to society by simplifying water resource management. It enables individuals, especially in rural or resource-constrained areas, to monitor water tanks remotely without the need for physical inspections. This not only saves valuable time and effort but also encourages the adoption of smart technologies in daily life, promoting digital literacy and self-reliance.

Socially, the system plays a vital role in supporting small-scale farmers and households by reducing the risk of water shortages or overflow due to human error. With accurate, real-time updates, users can make informed decisions and plan water usage more efficiently. The AR visualization further enhances user experience, making technical information accessible and easy to interpret, even for those without a technical background.

On the environmental front, the system contributes to water conservation by minimizing waste and promoting responsible usage. Continuous monitoring ensures that leaks, overflows, or unusually high consumption are detected early, preventing unnecessary water loss. In regions experiencing water scarcity, such a solution can help preserve this essential resource and support sustainability efforts.

Moreover, the use of low-power microcontrollers and wireless modules ensures that the system consumes minimal energy, making it environmentally friendly. By integrating renewable energy sources like solar panels in future upgrades, the system could become even more sustainable. In the broader context, this project reflects how modern technology can be harnessed not just for convenience, but for creating a more responsible and environmentally conscious society.

## 10.1 Integration with Advanced Technologies

This project has strong potential for integration with advanced technologies like AI, cloud computing, and machine learning. For instance, by incorporating predictive analytics, the system could forecast usage trends and provide alerts in advance. Similarly, linking with weather APIs can help make informed decisions about water usage during rainfall or drought conditions. These integrations can elevate the system from a basic monitoring tool to a comprehensive water management solution.

## 10.2 Collaboration Opportunities and Stakeholder Engagement

This system opens doors for collaboration between farmers, government bodies, tech companies, and environmental organizations. By involving local authorities and NGOs, the project can be scaled to benefit entire communities, particularly in water-stressed regions. Engaging stakeholders like agricultural cooperatives can ensure that the system is tailored to real-world needs and reaches those who need it most.

### 10.3 Scalability and Customization

Designed with flexibility in mind, the system can be easily scaled for different use cases—be it a single home tank, a village reservoir, or an entire farm irrigation network. Each component is modular, meaning more sensor nodes or features (like auto-pump control) can be added without disrupting the existing setup. Its adaptability allows users to customize the system based on their specific needs and local environmental conditions

### 10.4 Ease of Maintenance and User Training

The use of user-friendly platforms like Arduino IDE and Firebase ensures that the system remains easy to maintain, even for non-technical users. With minimal training, users can manage the system, perform basic troubleshooting, and understand data insights through AR visuals. Basic training sessions or instructional modules can be offered to ensure users get the most out of the system without relying heavily on technicians.

### 10.5 Data Privacy and Security

As the system deals with real-time data transmission and cloud storage, ensuring data privacy and security is essential. By implementing secure authentication methods and encrypted communication between devices and Firebase, the risk of unauthorized access can be minimized. User data is limited to essential operational parameters, and future updates can include options for local data processing to further enhance privacy.

### 10.6 Economic Impact and Market Linkages

This system provides a cost-effective solution for efficient water management, which can result in long-term savings on resources and labor. By preventing water wastage and ensuring timely replenishment, it improves productivity, particularly in agriculture. As adoption grows, it can create opportunities for local businesses to manufacture, sell, and maintain these systems, fostering entrepreneurship and connecting users to broader markets for smart farming and sustainability products.

# 11.COST ANALYSIS

| S.NO | Components | Quantity | Price | Total |
|---|---|---|---|---|
| 1 | BREAD BOARD | 1 | 50 | 50 |
| 2 | ESP 8266 | 1 | 350 | 350 |
| 3 | JUMP WIRES | 1 set | 10 | 10 |
| 4 | ULTRASONIC SENSOR | 1 | 120 | 120 |
| 5 | Miscellaneous | – | 200 | 200 |
| | Total | | | 620 |

The cost analysis of the IoT-based Water Level Monitoring System using Augmented Reality emphasizes both affordability and practical feasibility. The total estimated cost includes key components such as the ESP8266 microcontroller, ultrasonic water level sensors, and supporting circuitry. Additionally, software integration tools like Firebase for cloud storage and Unity with Vuforia for AR visualization add powerful functionality without incurring high costs.

Despite incorporating modern technologies, the overall investment remains budget-friendly, making it a viable solution even for small-scale use in households or agricultural settings. This cost-effective design aligns with the project's core objective of providing accessible, real-time water monitoring while promoting smart water management practices. With its modular structure, the system also offers an affordable path for future expansion or customization based on user needs and available resources.

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