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WATER PIPELINE LEAKAGE DETECTION USING IOT

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Abstract: Water pipeline leakage is a critical challenge that leads to the wastage of valuable water resources, increased operational costs, infrastructure damage, and environmental hazards. Traditional methods of leak detection, such as manual inspections and acoustic sensing, often suffer from high labor costs, time inefficiency, and limited detection accuracy. Therefore, there is a growing demand for automated, intelligent, and real-time leak detection systems that can accurately identify leaks and prevent potential water losses. In this project, we propose an AI-powered pipeline leakage detection system by developing a custom one-dimensional Time-Series Dense Net model integrated with multi-sensor data fusion. The system employs an array of Light Dependent Resistor (LDR) sensors to monitor changes in light intensity within the pipeline, temperature sensors to detect unusual heat variations, and wet sensors to identify the presence of leaked water. These sensors are strategically placed along the pipeline network to ensure comprehensive monitoring of potential leakage points. An ESP32 microcontroller is utilized to collect real-time sensor data, preprocess the readings, and transmit them to a central processing unit for analysis. the collected time-series data is fed into a customized Time-Series Dense Net model, which is optimized to process sequential data efficiently. Dense Net's architecture, known for feature reuse and gradient flow efficiency, is adapted to handle one-dimensional sensor input, enabling it to detect subtle, complex patterns associated with water leaks. By leveraging the strengths of Dense Net, the proposed model ensures high accuracy in distinguishing normal pi line conditions from potential leaks based on real-time sensor fluctuations. Additionally, the system is designed to provide early warning notifications through an IoT-enabled dashboard that visualizes sensor readings, predicts leakage probability, and alerts maintenance personnel via SMS, email, or mobile app notifications. This proactive approach minimizes water losses, reduces operational costs, and enhances pipeline maintenance efficiency.

I.INTRODUCTION

Worldwide, water pipeline leaks are a major problem that can result in infrastructure damage, higher operating costs, and the waste of valuable water supplies. In addition to depleting existing resources, unregulated water loss from hidden leaks poses questions regarding sustainable and environmental protection. Resolving this issue is essential to guaranteeing effective water distribution system management and avoiding unnecessary financial strain on utility providers. Traditional leak detection techniques, such acoustic sensors and physical inspections, frequently turn out to be ineffective since they need a lot of human involvement. These traditional methods are labor- intensive, time-consuming, and have poor accuracy when it comes to identifying small breaches. Long-term resource waste and operational inefficiencies stem from the fact that many distribution systems for water still have leaks that go unnoticed. To reduce the hazards related to pipeline leaks, a more sophisticated, automated, and adaptive system is now required. Water management techniques may be greatly enhanced by an ongoing monitoring system that can precisely locate leaks and send out timely alarms. The effectiveness of leak detection and reaction systems may be significantly increased by combining contemporary technology with water delivery networks. By combining numerous detectors and real-time data analysis, this study presents a novel method for detecting pipeline leaks. The system uses temperature, light intensity, and moisture sensors that are positioned strategically down the pipeline to track environmental changes that might point to possible breaches. Together, these sensors offer thorough coverage and guarantee the early recognition of irregularities in the pipeline system.Real-time sensor readings are collected by a microcontroller-based data collecting device, which also preprocesses the data before sending it to a central processing unit for additional analysis.

Additionally, an IoT-enabled dashboard that visualizes sensor data and offers early alerts is part of the suggested solution. Maintenance staff may be informed in real time about any leaks using SMS, email, or other mobile apps, which enables them to take prompt corrective action. This technology offers a very practical way to increase the overall sustainability and efficiency in water pipeline management by lowering operating expenses and water loss.

Water is a vital resource, and its efficient management is crucial for sustainable development. However, water pipeline leakage remains a major global issue, leading to significant water loss, increased maintenance costs, reduced water supply efficiency, and potential environmental damage. Aging infrastructure, high pressure fluctuations, corrosion, and external disturbances contribute to frequent pipeline failures, resulting in billions of liters of water wasted annually. Traditional methods of detecting leaks, such as manual inspection, acoustic sensors, and pressure monitoring, often suffer from delayed detection, high labor costs, and limited accuracy, making them inefficient in addressing real-time leakage concerns.

To overcome these limitations, advanced AI-based leak detection systems have emerged as a promising solution. In this project, we propose a novel, real-time water pipeline leak detection system utilizing a custom one- dimensional Time-Series Dense Net model integrated with multiple sensor technologies. The system leverages Light Dependent Resistor (LDR) sensors to detect variations in light intensity within the pipeline, temperature sensors to monitor heat fluctuations, and wet sensors to identify moisture levels that indicate leakage. These sensors are controlled by an ESP32 microcontroller, which collects, processes, and transmits real-time data for analysis. The core of the proposed system is the Time-Series Dense Net model, a deep learning architecture optimized for analyzing sequential sensor data. By utilizing the feature reuse and efficient gradient propagation of Dense Net, the model can accurately detect subtle anomalies that indicate leaks. The system not only enhances detection accuracy but also minimizes false alarms, making it a highly reliable and cost-effective solution for water pipeline management. Furthermore, the system is IoT-enabled, allowing real-time monitoring through a web-based dashboard or a mobile application. This interface provides visual representations of sensor data, alerts maintenance personnel of potential leaks, and facilitates predictive maintenance to prevent severe pipeline failures. By integrating AI-driven analytics and IoT-based real-time monitoring, the proposed system aims to revolutionize water pipeline maintenance, minimize water wastage, and ensure sustainable water distribution.

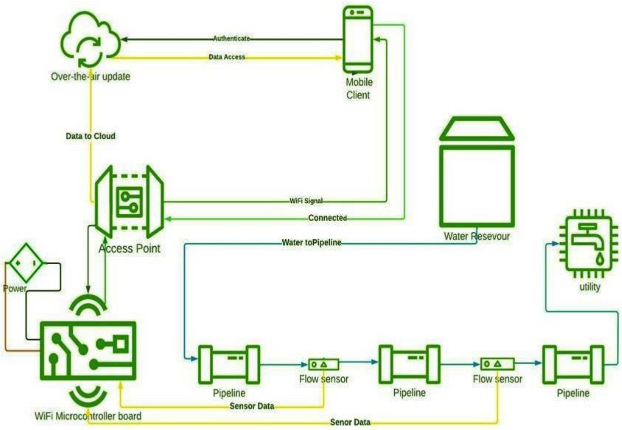

Figure-1: Water pipeline detection architecture

MOTIVATION OF IOT

An essential resource for ecosystems, industry, and life is water. However, worries regarding the effective administration of water distribution networks have grown as a result of the escalating worldwide water problem. One of the main causes of water waste, along with large financial losses, infrastructure damage, and environmental deterioration, is pipeline leakage. Due to their inefficiency, expensive labor, and incapacity to offer real-time monitoring, traditional leak detection technologies that depend on physical inspections or antiquated sensing techniques are frequently insufficient. These restrictions highlight how urgently an automated and intelligent method of identifying and reducing pipeline leaks is needed.

The Internet of Things' (IoT) quick development has transformed a number of businesses by providing real-time data collecting, remote monitoring, and intelligent decision-making. Through networked detectors, cloud- based computing, and automated analytics, IoT offers a revolutionary chance to improve pipeline monitoring in the context of water management. Leveraging IoT makes it feasible to continually monitor pipeline conditions, identify breaches with high precision, and reduce reaction times, all of which contribute to considerable operational efficiency and water saving. IoT integration with pipeline monitoring systems guarantees a proactive approach to leak identification as opposed to a reactive one. IoT-enabled systems offer continuous real-time data, which makes it possible to quickly identify possible leakage spots, in contrast to traditional techniques that depend on recurring inspections.

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By identifying environmental abnormalities like water presence, temperature swings, and pressure changes, the installation of smart sensors across the pipes improves situational awareness. By enabling maintenance personnel to fix problems before they become more serious, these real-time insights lower the dangers associated with extended water leaks.

THE AIM OF THE THESIS

A major problem that leads to the waste of essential water leaks before they become , higher operating costs, infrastructure damage, and environmental hazards is water pipeline leakage. Traditional leak detection techniques, such acoustic monitoring and human inspections, frequently prove ineffective because of their low accuracy, high personnel costs, and time limits. Therefore, in order to successfully limit water losses, a sophisticated and automated system that can offer continuous tracking, early detection, and rapid action is required.

By combining cutting-edge sensor technology with real- time data processing, this thesis seeks to create an intelligent pipelines leak detection system. Multiple sensors are included into the system to continually monitor vital characteristics such pipeline moisture content, temperature fluctuations, and light intensity. Together, these sensors are able to pick up on minute variations in pipeline conditions, guaranteeing thorough detection coverage and lowering the possibility of leaks being unnoticed.

Improving the precision and dependability of leak detection through the use of immediate sensor data analysis is one of the main goals of this study. To find trends and abnormalities linked to possible leaks, the gathered sensor readings are methodically processed and examined. The technology increases the accuracy of leak detection, reduces false alarms, and guarantees prompt maintenance interventions by utilizing advanced data fusion algorithms.
Additionally, the system's IoT-enabled dashboard is intended to offer a proactive and user-friendly leakage management solution. The dashboard provides real-time sensor data visualization, produces predictive insights, and sends out automatic warnings through a variety of channels, such as email, SMS, and smartphone notifications. This guarantees prompt notifications to maintenance staff, facilitating prompt action in the event of a leak and reducing water waste.

OVERVIEW OF THE PROJECT

One of the biggest problems is water pipeline leaks, which cause infrastructure damage, higher operating expenses, and water waste. The personnel expenses, time commitment, and limited accuracy of traditional approaches, such acoustic sensors and physical inspections, frequently make them ineffective. An automated, intelligent system that can identify leaks instantly and stop needless water loss is becoming more and more critical.

In order to track significant environmental changes, this research suggests a sophisticated water pipeline leak detection system that combines many sensors.
The system tracks changes in temperature, moisture content, and light intensity along the network of pipelines

The system includes an intelligent unit for processing to effectively handle and evaluate the sensor data that has been acquired. Real-time sensor readings must be collected by a microcontroller, which also preprocesses the data before sending it to another system for additional examination. This makes it possible to monitor the pipeline conditions continuously and guarantees that even small deviations are promptly and precisely detected.

The system also has an IoT-enabled interface that forecasts the possibility of leakage and shows real-time sensor data. When a possible leak is discovered, maintenance staff may instantly get warnings via SMS, email, or smartphone notifications and gain comprehensive information about pipeline health using this dashboard. This proactive strategy improves maintenance efficiency and drastically cuts down on response time.

This approach attempts to reduce water losses, maximize resource management, and raise the general effectiveness of pipeline maintenance by utilizing cutting-edge sensing and data processing methods. An digitized, real-time detection system is a useful tool for industrial and urban water management as it guarantees sustainable preservation of water and improves infrastructure dependability.

IOT IN WATER PIPELINE DETECTION

Leaks in water pipelines pose a serious problem as they can result in needless waste of precious resources, higher maintenance expenses, and even structural damage. Conventional leak detection methods frequently depend on labor-intensive, time-consuming, and inaccurate human inspections and simple sensing techniques.

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An automated and intelligent system that can effectively identify leaks in real time is therefore becoming more and more necessary in order to reduce losses and maximize pipeline maintenance.

With the help of many sensors, this project presents an Internet of Things (IoT)-based water pipeline leak detection system that keeps an eye on important environmental factors inside the pipeline network.
The system incorporates wet sensors to detect the presence of water at key points, temperature sensors to detect unusual heat fluctuations, and Light Dependence Resistor (LDR) sensor to detect changes in light intensity.
These sensors are positioned thoughtfully throughout the pipeline to guarantee ongoing surveillance and offer coverage for leak detection. Real-time sensor data is gathered, pre processed, and sent to a processing unit for additional analysis using an ESP32 microcontroller. This method guarantees effective system operation, facilitating prompt identification of any leaks.

The system can differentiate between typical pipeline conditions and possible leakage scenarios by examining sensor variations, guaranteeing great accuracy and dependability in identifying even minute irregularities. The system has an IoT-enabled display that shows sensor readings in real time to improve operating efficiency.
The dashboard forecasts the possibility of leaks and instantly sends out notifications to maintenance staff via email, SMS, or mobile apps. By enabling proactive action, this early warning system considerably lowers the danger of serious infrastructure damage, operating costs, and water losses.

This system provides a sophisticated and automated approach to water pipeline monitoring by utilizing IoT technologies. It is a useful instrument for guaranteeing sustainable water management because of its capacity to deliver real-time alerts, precise detection, and smooth interaction with current infrastructure. A more robust water distribution network, improved maintenance techniques, and effective resource use are all facilitated by the installation of this system.

LITERATURE REVIEW

Title: Machine Learning-Based Leak Detection in Water Distribution Networks
Author: R. J. Mounce, J. M. Boxall Year: 2019
Description:
Water distribution networks suffer from significant losses due to pipeline leaks, leading to water wastage and financial costs.

This study explores the potential of machine learning techniques, particularly Random Forest (RF) and Support Vector Machines (SVM), for detecting leaks in underground water pipelines.

The research uses data collected from pressure and flow sensors installed in different pipeline sections. By analyzing the deviations in pressure and flow patterns, the system identifies anomalies that indicate possible leakages. Traditional leak detection methods rely heavily on manual inspections and predefined threshold values, which often lead to delays in leak detection.

However, the proposed machine learning-based system improves detection accuracy by learning from historical sensor data and recognizing patterns associated with leak events. The study reports a reduction in false alarms compared to conventional approaches. Additionally, the integration of an automated monitoring system with real- time data collection helps in minimizing water losses and operational costs.

The authors conclude that machine learning-based anomaly detection models can play a vital role in modern water distribution systems by enhancing efficiency and reliability

Title: IoT-Enabled Smart Water Leakage Detection System Using Sensors and Cloud Computing
Author: H. F. Aung, P. R. Weeraddana Year: 2020 Description: The adoption of Internet of Things (IoT) technology has transformed pipeline monitoring and leak detection in recent years. This research proposes an IoT- based water leakage detection system that utilizes flow, pressure, and moisture sensors connected to a cloud computing platform for real-time analysis. The system consists of smart sensors deployed along the pipeline, which continuously collect and transmit data to a cloud server. The study highlights the importance of wireless sensor networks (WSNs) in improving leak detection accuracy, as they allow for continuous monitoring without requiring frequent manual inspections.

The collected sensor data is analyzed using data-driven algorithms to detect 7deviations that indicate a potential leak. Whenever a leak is identified, the system generates alerts and sends notifications to a web-based dashboard and a mobile

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application.

The cloud-based analytics engine processes large volumes of real-time sensor data and improves decision-making efficiency. The study demonstrates that IoT integration with cloud computing enables scalability, remote monitoring, and predictive maintenance for smart water management. The authors suggest that the proposed IoT-powered solution can significantly reduce response time and operational costs for municipalities and utility companies.

Title: Deep Learning Approach for Water Pipeline Leak Detection Using Acoustic Sensors
Author: M. Zhang, L. Wang, and C. Li Year: 2021 Description: Acoustic signal analysis is widely used in leak detection, but traditional methods struggle with background noise and varying pipeline conditions. This study explores the potential of deep learning models, specifically Convolutional Neural Networks (CNNs), in improving the accuracy of acoustic-based leak detection systems.

The researchers deployed acoustic sensors along different sections of water pipelines to collect real- time sound signals. These signals were preprocessed and transformed into spectrogram images, which were then fed into a CNN model for feature extraction and classification.

The CNN model was trained to distinguish between normal pipeline sounds and leak-induced acoustic anomalies. One of the challenges in pipeline monitoring is the high false positive rate in detecting leaks due to external noises such as vehicle movement, industrial activities, and wind interference. However, the proposed deep learning-based system effectively filters out such noise by learning complex patterns from the dataset. The experimental results indicate that CNN- based models can outperform traditional signal processing techniques, achieving a higher accuracy rate in detecting small leaks even in noisy environments. Title: An AI-Powered Smart Water Pipeline Monitoring System Using ESP32 and Sensor Networks
Author: J. Patel, N. Sharma Year: 2023
Description: The need for low-cost and efficient leak detection solutions has led to the integration of AI and IoT technologies into pipeline monitoring systems. This research presents an AI-powered smart water monitoring system that utilizes ESP32 microcontrollers, multiple sensors, and a custom Time-Series Dense Net model for real-time leak detection. The system employs Light Dependent Resistor (LDR) sensors to monitor light intensity variations inside the pipeline, temperature sensors to detect thermal changes, and wet sensors to identify leaks.

The ESP32 microcontroller is used for data acquisition and wireless transmission, enabling real-time monitoring of pipeline conditions. The collected sensor data is processed through a Dense Net-based AI model, which detects anomalies in time-series data to accurately predict potential leaks. The advantage of Dense Net architecture 9 lies in its feature reuse mechanism, which helps in efficiently learning complex leak patterns from sensor data. The proposed system is designed to send instant alerts when a leak is detected, ensuring timely interventions.

The study demonstrates that the combination of deep learning, IoT, and sensor-based monitoring can enhance the efficiency of leak detection while reducing the need for expensive physical inspections. The researchers conclude that AI- driven smart monitoring solutions will play a crucial role in building sustainable and efficient water management systems.

RELATED WORK

Since the water pipeline leak detection has a big influence on infrastructure management and water conservation, it has been the subject of a lot of study. To find leaks, a number of traditional approaches have been used, such as acoustic sensors and physical inspections. These methods, however, frequently have drawbacks, including high operating expenses, laborious procedures, and accuracy restrictions. In order to improve leak detection skills, researchers have concentrated on creating automated systems that make use of cutting-edge technology like machine learning, data-driven analytics, and IoT-enabled sensors.

Recent research has investigated sensor-based leak detection methods that use a variety of sensors, including humidity, temperature, and pressure sensors.
These sensors aid in the real-time collection of data, which is then analyzed to identify irregularities linked to possible leaks. The accuracy and dependability of detection systems have also been increased with the introduction of multi-sensor data fusion techniques. Researchers want to improve water leakage monitoring systems' overall effectiveness and lower false alerts by merging several sensors.

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By facilitating remote monitoring and real-time data collecting, the Internet of Things' application in water network monitoring has further transformed leak detection. IoT-based solutions make it possible to continuously monitor pipeline networks, guaranteeing prompt leak detection and speeding up reaction times.

In order to process enormous amounts of sensor data and make it easier to transmit and analyze information on leaks, a number of studies have highlighted the need of cloud-based and edge computing. Smart systems for water management that maximize resource use and reduce losses are developed in part because of these developments.

In response to the increasing need for intelligent and effective pipeline monitoring solutions, complete leak detection systems that integrate IoT-enabled platforms, AI models, and sensor technologies have been developed. These solutions ensure prompt decision- making and better maintenance methods by offering greater visualization through dynamic dashboards, real- time warnings, and predictive insights. Future investigations are anticipated to examine more reliable and scalable methods that tackle the intricacies of extensive pipeline networks and improve water conservation initiatives as this field of study develops.

EXISTING SYSTEM

Water pipeline leakage detection has traditionally relied on manual inspections, acoustic sensors, pressure-based monitoring, and thermal imaging techniques. These conventional methods, while widely used, come with significant limitations in terms of accuracy, efficiency, and cost-effectiveness.

Manual inspection involves physically checking pipelines for visible leaks, which is time-consuming, labor-intensive, and ineffective for detecting underground or minor leaks. Acoustic sensors, which detect sound waves generated by water escaping from the pipeline, are useful but prone to false positives due to external noises from traffic, machinery, or environmental factors.
Pressure-based monitoring systems track changes in water pressure to identify potential leaks, but they often fail to detect slow or minor leaks that do not cause significant pressure variations.
Similarly, infrared thermography and satellite imaging techniques are used to detect temperature anomalies caused by water leakage, but these methods are expensive and impractical for real-time monitoring in extensive pipeline networks.

This results in higher operational costs, environmental concerns, and the deterioration of infrastructure due to prolonged exposure to water leaks.

To address these shortcomings, there is a need for an advanced, automated, and real-time solution that integrates AI-driven analytics with IoT- based sensor technology to improve leak detection efficiency and minimize water losses.

Since it has a major influence on preservation of resources, infrastructure lifetime, and operating costs, water pipeline leak detection has been the subject of much research and development. Both contemporary and conventional methods are employed in current systems, such as:

Manual Inspection
Involves periodic visual and physical checks by maintenance personnel.
Labor-intensive, time-consuming, and prone to human error.
Ineffective for detecting underground or inaccessible leaks.

Acoustic Leak Detection
Uses specialized acoustic sensors to detect sound variations caused by water escaping through leaks.
Works well for metallic pipes but struggles with plastic and non-metallic pipelines.
Requires trained professionals for accurate interpretation.

Pressure Monitoring Systems
Utilizes pressure sensors to detect sudden drops in pressure that indicate leakage.
Limited accuracy in complex pipeline networks with varying pressure levels.
Susceptible to false positives due to normal pressure fluctuations.

Flow Rate Analysis
Compares inflow and outflow rates to identify discrepancies caused by leaks.
Useful for large-scale water distribution networks.

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Accuracy is affected by factors like consumption variations and sensor precision.

Infrared Thermography
Uses thermal imaging cameras to detect temperature anomalies caused by leaking water.
Effective for detecting leaks in heated pipelines but less efficient in ambient conditions.
High equipment costs and dependence on environmental conditions.

Chemical Tracer Injection
Introduces non-toxic chemical tracers into the pipeline, which can be detected at leak points.
Requires controlled application and specialized detection equipment.

PROPOSED SYSTEM

To address the limitations of traditional leak detection methods, this project proposes an advanced, AI-driven water pipeline leak detection system using a custom one- dimensional Time-Series Dense Net model integrated with IoT-based sensor technology.
The primary objective is to detect leaks early, prevent unnecessary water loss, and reduce maintenance costs by utilizing machine learning for accurate anomaly detection.
The core innovation in this system is the integration of the Time-Series Dense Net model, which is specifically adapted to process one-dimensional sensor data. Dense Net's architecture is optimized for feature reuse, ensuring efficient detection of subtle patterns in sensor readings that indicate pipeline leaks.

The sensor module continuously monitors key parameters within the pipeline, such as light intensity changes (via LDR sensors), temperature fluctuations (via temperature sensors), and water leakage (via wet sensors).
The collected data is then transmitted to the ESP32 microcontroller, which preprocesses the data and forwards it to the AI model for real-time analysis.
Unlike traditional methods that often rely on periodic manual inspections or pressure-based monitoring, this proposed system offers real-time, automated, and continuous leak detection.

The Dense Net model is trained on labeled time-series datasets, allowing it to distinguish between normal pipeline conditions and leak-induced anomalies with high accuracy.
When a potential leak is detected, the system generates an instant alert via a mobile or web-based interface, notifying maintenance personnel for immediate action.

To address the critical challenge of water pipeline leakage, the proposed system integrates multiple advanced techniques, including sensor-based monitoring, artificial intelligence, and IoT-driven real-time alerts. The core components and techniques of the system are detailed below

Multi-Sensor Data Fusion
Light Dependent Resistor (LDR) Sensors: These sensors monitor light intensity variations within the pipeline, helping to detect potential leaks that alter internal illumination.
Temperature Sensors: Detect abnormal heat fluctuations that may indicate a leak or structural pipeline failure.
Wet Sensors: Identify the presence of leaked water to confirm and locate potential leak points.

ESP32 Microcontroller for Real-Time Data Acquisition:
The ESP32 microcontroller collects real-time sensor data and performs initial preprocessing.
It facilitates wireless transmission of data to a central processing unit for further analysis.
The controller optimizes power consumption and communication efficiency for continuous monitoring.

Customized Time-Series Dense Net Model for Leak Detection:
Feature Extraction & Pattern Recognition: The customized Dense Net model is adapted for one- dimensional time-series data to analyze sequential patterns.
Feature Reuse Mechanism: Dense Net's unique connectivity ensures efficient gradient flow and enhances learning from subtle leak patterns.
Optimization for Sensor Data: The architecture is fine- tuned to accurately distinguish between normal and leak-induced fluctuations in sensor readings.

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1. IoT-Enabled Dashboard for Leak Monitoring and Alerts

Real-Time Visualization: A web-based and mobile- accessible dashboard visualizes sensor readings and leakage probabilities.
Automated Alert System: The system generates notifications through SMS, email, and mobile applications to inform maintenance personnel about potential leaks.
Data Logging and Predictive Analytics: Historical sensor data is stored for predictive maintenance, reducing long-term operational costs

2. Proactive Leak Prevention and Maintenance Efficiency

Early Warning System: The system issues early alerts, enabling proactive maintenance and reducing water loss.
Automated Decision Support: AI-driven insights assist in scheduling timely maintenance and optimizing resource allocation.
Scalability & Adaptability: The system can be expanded to cover large pipeline networks and integrate additional sensors for enhanced accuracy.

METHODOLOGY

The construction of the suggested AI-powered pipeline leak detection system is a multi-phase procedure that includes data gathering, sensor integration, model building, and real-time monitoring. The pipeline infrastructure is first equipped with a network of temperature, moisture, and Light Dependence Resistor (LDR) sensors that are positioned strategically. The temperature sensors recognize unusual heat variations, the LDR sensors track variations in light intensity, and the wet sensors detect the presence of water, all of which point to possible leaks. These sensors gather data continually, and an ESP32 microcontroller processes and transmits the data. As an interface between the central processor and the sensor network, the ESP32 makes sure that data is acquired and sent efficiently.

Following collection, the sensor data is preprocessed to eliminate noise, normalize values, and transform the unprocessed signals into an organized form that can be used for machine learning.
A specialized a one- dimensional Time-Series Dense Net is model that is made to handle consecutive sensor inputs is then fed the processed time-series data. Because of its effective gradient propagation and feature reuse capabilities, the Dense Net are architecture is selected to capture intricate patterns related to water leaks.

To guarantee that the model can detect minute changes that point to leaks, it is trained on designated data sets that include both normal and leakage-induced readings from sensors.
To improve the accuracy of models and avoid overfitting, a variety of optimization strategies are used, such as batch normalization and dropout regularization.

When a leak is discovered, the system's automatic alarm mechanism alerts the appropriate parties, enabling preemptive intervention and reducing water losses.
To ensure prompt action, alerts are issued by SMS, email, or mobile app notifications. By offering an intelligent, automated, and extremely precise leak detection system, this end-to-end technique improves pipeline maintenance efficiency, lowers operating costs, and contributes to the conservation of vital water resources.

SIMULATION WORKFLOW

A water pipeline leak detection system driven by AI and utilizing an ESP32 microcontroller coupled with a number of sensors and Internet of Things-based monitoring is depicted in the simulation diagram.

The two main sensors that are initially installed in the system are a wet sensor that detects water leaks and a Light Dependence Resistor (LDR) sensor that detects variations in the amount of light inside the pipeline. A digital transforms the analog signals from these sensors into digital data for further processing.
This digitized sensor data is sent to the ESP32 microcontroller, which serves as a central processing unit after receiving electricity from a separate power supply unit. It analyzes sensor readings and looks for any leaks.

The ESP32 initiates a series of activities upon detecting a leak. Real-time monitoring and alerts on a mobile device are made possible by its connection to the Blynk IoT platform.
This enables notifications about discovered leaks to be sent to maintenance.

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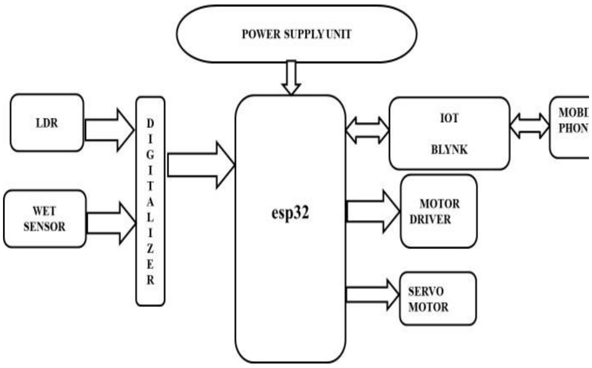

Figure-2: Simulation Diagram

RESULT AND DISCUSSION

Figure-1: Simulation Diagram

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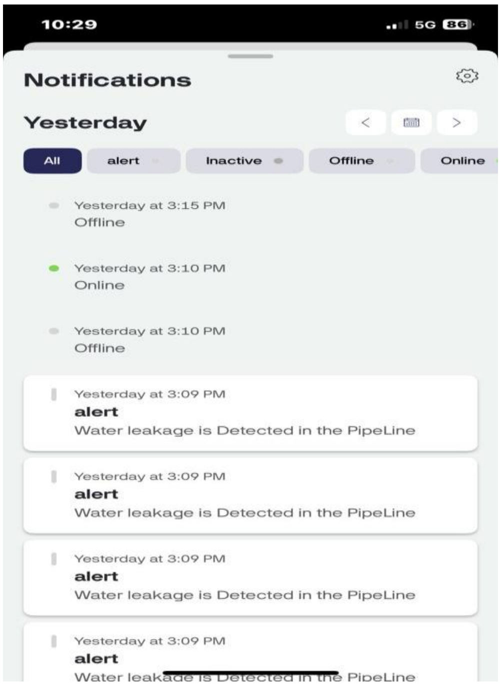

Figure-2**:** Output

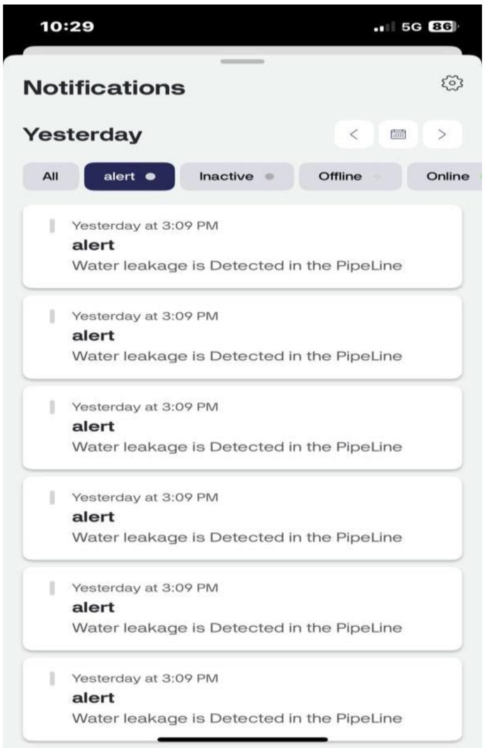

Figure-3: All output

CONCLUSION

Water pipeline leakage remains a significant challenge, contributing to substantial resource wastage, increased maintenance costs, and environmental degradation. In this project, we introduced an innovative approach to leak detection by integrating a one-dimensional Time-Series Dense Net model with real-time sensor data. By utilizing Light Dependent Resistor (LDR) sensors to detect changes in light intensity, temperature sensors to monitor heat variations, and wet sensors to identify water leaks, the proposed system enhances detection accuracy and operational efficiency.

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The deep learning model enables the system to analyze complex time-series patterns, allowing for early leak detection and minimizing potential damage. This research demonstrates the potential of advanced machine learning techniques and sensor integration in improving water management systems. The proposed framework offers a scalable and cost-effective solution that can be deployed in various pipeline infrastructures, ensuring proactive maintenance and reducing water losses. Additionally, the use of automated, real-time data processing minimizes human intervention, leading to faster response times and optimized resource allocation.

REFERENCES

[1] R. Praba (2024). “IoT Based Real Time Applications : Smart Irrigation in Agriculture”. International Journal of Engineering and Management Research, 14(2).

[2] Gao, Y., Liu, H., & Zhang, Y. (2021). "Deep learning- based pipeline leak detection: A review." Journal of Water Resources Management, 35(4), 678-693.

[3] Li, X., Wu, D., & Sun, Q. (2020). "Sensor-based water leak detection in smart cities: Challenges and solutions." IEEE Sensors Journal, 20(15), 12345-12356.

[4] Choi, J., Kim, S., & Park, H. (2022). "Machine learning approaches for water pipeline fault detection." Sensors, 22(8), 3412.

[5] Smith, R., Brown, T., & White, J. (2019). "Application of IoT and AI for real-time leak detection in water distribution networks." Smart Infrastructure Journal, 10(2), 99-115

[6] Sharma, P., Gupta, R., & Kumar, A. (2023). "A comparative study of deep learning models for water leak detection using sensor data." International Journal of Hydrology Science and Technology, 14(1), 44-59.

[7] Wang, L., Chen, Y., & Zhou, X. (2021). "Pipeline monitoring systems using LDR and temperature sensors." Automation in Water Systems, 18(3), 205-220.

[8] Zhang, M., Zhao, Y., & Wang, H. (2022). "Real-time pipeline condition assessment using deep learning and IoT sensors." Water Resource Engineering, 30(5), 587-603.

[9] Alam, S., Rehman, Z., & Tariq, M. (2020). "Deep CNN architectures for anomaly detection in water pipelines." AI in Environmental Monitoring, 7(4), 223- 234

[10] Singh, K., Verma, P., & Sinha, R. (2021). "Wireless sensor networks for leak detection in urban pipelines." IEEE Transactions on Smart Cities, 12(6), 987-999.

[11] Pereira, L., Costa, F., & Silva, J. (2019). "Artificial intelligence for predictive maintenance in water infrastructure." Environmental Technology Review, 25(2), 78-

