Smart Water Techniques To Detect And Reduce Water Leakage

Project submitted to

Shri Ramdeobaba College of Engineering & Management, Nagpur

in partial fulfillment of requirement for the award of

degree of

Bachelor of Engineering

In

COMPUTER SCIENCE AND ENGINEERING (ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING)

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December 2023

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CERTIFICATE

This is to certify that the project on **"Smart Water Techniques To Detect And Reduce Water Leakage "** is a bonafide work of

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submitted to the Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur in partial fulfillment of the award of a Degree of Bachelor of Engineering, in Computer Science and Engineering (Artificial Intelligence and Machine Learning). It has been carried out at the Department Computer Science and Engineering, Shri Ramdeobaba College of Engineering and Management, Nagpur during the academic year 2022-23.

Date: 17-12-23

Place: Nagpur

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DECLARATION

I, hereby declare that the project titled **"Smart Water Techniques To Detect And Reduce Water Leakage"** submitted herein,has been carried out in the Department of Computer Science and Engineeringof Shri Ramdeobaba College of Engineering & Management, Nagpur. The work is original and has not been submitted earlier as a whole or part for theaward of any degree / diploma at this or any other institution / University

Date: 17-12-23

Place: Nagpur

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is approved for the degree of Bachelor of Engineering, in Computer Science & Engineering.

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Examiner(s)

Name & signature of HOD

Date: 17-12-23

Place: Nagpur

ACKNOWLEDGEMENT

We would like to express our deep and sincere gratitude to our guide **Dr. Chitraja Rajan,** Professor of Computer Science and Engineering Department(AIML), RCOEM,for giving us the opportunity to work on this project and providing valuable guidance throughout the project. It was a great privilege and honor to work under her guidance. We are extremely grateful for the experience we had in this project with her.

We express our sincere gratitude to **Dr. Suresh Balpande,** Head of the Department of Computer Science Department (AIML), RCOEM for his guidance. Talent wins games, but teamwork and intelligence win championships. We would like to take this opportunity to express our deep gratitude to all those who extended their support and guided us to complete this project.

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ABSTRACT

The primary goal of the project is to leverage recent developments in smart water technologies to detect and reduce water leakages in large water distribution networks with the aid of neural networks. We address the problem of demand for well equipped and maintained homes
by proposing a cost effective solution to detect leakages and manage pressure, which in turn leads to significant water savings and reduced pipe breakage frequencies, especially in older infrastructure systems.

This is a research project under Department of Computer Science and Engineering. We Developed the model a regression model based on Multi-Layer Perceptron (MLP) algorithm, which is a class of feedforward Artificial Neural Networks (ANNs).

In the pursuit of optimizing the model for water leakage detection, our meticulous exploration of key hyperparameters revealed valuable insights. The choice of activation function played a pivotal role, with ReLU and Leaky ReLU, applied over 3000 and 1000 epochs with a batch size of 8, demonstrating superior accuracy at 79.6554% and a minimal Mean Absolute Error (MAE) of 0.85. Meanwhile, Sigmoid activations, despite variations in epochs and batch sizes, showcased varied performance, emphasizing the nuanced considerations in optimizing the MLP model. Leveraging these observations, we successfully developed a leak node classification system that outperformed a more complex SOM model. By integrating the MLP model with a user-friendly UI and implementing a seamless Streamlit backend, we enhanced the user experience with visualizations, a feedback mechanism, and clear instructions, deploying the system for practical use.

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Chapter 1
INTRODUCTION

1.1 Introduction

In the field of water pipeline leakage detection, diverse methods, categorized as conventional, software-based, and hardware-based, are employed. Conventional techniques rely on visual observation by personnel, while software-based methods monitor internal parameters, and hardware-based approaches use specialized equipment. This project focuses on implementing a multiple model algorithm integrated with AI techniques to enhance leak detection in the distribution system. This innovative approach combines hardware and software, aligning with the Internet of Things (IoT)(1) trend for real-time process control and improved energy efficiency. However, challenges, such as installing flow rate sensors within the pipeline, are considered in the pursuit of a comprehensive solution. The chosen strategy blends hardware and software methodologies, leveraging the multiple model algorithm and AI techniques to advance leak detection capabilities within the distribution system(3). Aligned with the IoT trend, the approach aims for real-time process control and improved energy efficiency. Nevertheless, challenges like installing flow rate sensors within the existing pipeline infrastructure are acknowledged and addressed(5). Through this multidimensional strategy, the project aims to usher in a new era of efficiency in water pipeline management.

1.2 Motivation

The motivation behind our research project on water leakage detection using neural networks stems from a critical need to address challenges in older infrastructure systems(4). Aging water distribution networks often face issues related to undetected leaks, leading to water wastage, increased maintenance costs, and potential environmental consequences. Recognizing the limitations of conventional detection methods, our team, under the Department of Computer Science and Engineering(AIML), has embarked on a quest to leverage cutting-edge technologies, particularly neural networks. The primary goal is to enhance the accuracy and efficiency of leak detection by developing and evaluating two distinct models: a classification model based on a regression model based on the Multi-Layer Perceptron algorithm.

Through extensive experimentation and evaluation, our research has yielded promising results. Both models have demonstrated the ability to accurately classify leak nodes, with the Multi-Layer Perceptron model exhibiting superior performance. Furthermore, our findings emphasize the importance of model simplicity, revealing that a straightforward Multi-Layer Perceptron model. With a commitment to improving the reliability of water distribution systems, our research embraces innovative approaches that integrate artificial intelligence techniques, paving the way for smarter, more efficient infrastructure management.

1.3 Objectives

1. Develop and Evaluate Classification and Regression Models:

- Objective: Develop two distinct models – a classification model based on Supervised Self-Organizing Maps (SOMs) and a regression model based on Multi-Layer Perceptron (MLP) algorithm.
- Rationale: These models aim to effectively classify leak nodes and predict leak values based on pressure data in water distribution systems.

2. Assess Model Performance and Comparative Analysis:

- Objective: Evaluate the performance of both models using appropriate metrics.
- Rationale: Understand how well the models can correctly classify leak nodes, compare their accuracy, and analyze the trade-offs between model complexity and performance.

3. Optimize Model Hyperparameters:

- Objective: Perform hyperparameter tuning for both models to optimize their performance.
- Rationale: Fine-tune parameters such as learning rates, iterations, and activation functions to enhance the accuracy and efficiency of the models.

4. Demonstrate the Applicability of Neural Networks in Leak Detection:

- Objective: Showcase the practical utility of neural networks in addressing water leakage issues in aging infrastructure.
- Rationale: Illustrate how the developed models can contribute to the detection and analysis of leaks in water distribution systems, emphasizing the role of neural networks in smart water technologies.

1.4 Problem Definition

This project addresses the limitations of current water pipeline leakage detection methods by integrating the multiple model algorithm with AI techniques in an IoT-driven framework. The goal is to enhance accuracy and efficiency while overcoming challenges associated with the installation of flow rate sensors inside the pipeline.

1.4.1 Front End

Developed a responsive frontend interface for the leak detection project using HTML and CSS. The interface seamlessly integrates Matplotlib charts, providing an intuitive visualization of pressure differentials for efficient leak identification. Users can input data effortlessly through a user-friendly form, initiating the backend analysis. The implementation enhances user experience by presenting accurate leak predictions in a clear and accessible manner. The HTML and CSS frontend ensures a visually appealing and interactive platform, facilitating effective decision-making for water distribution network management.

1.4.2 Back End

Streamlit is a user-friendly open-source Python library designed to simplify the development of interactive web applications, particularly in the realms of data science and machine learning. Its strength lies in its remarkable ease of use, allowing developers to create dynamic apps with minimal effort. In a Streamlit app, the structure is defined by a Python script that dictates both layout and functionality. The app updates in real-time as the script is executed, fostering a straightforward and iterative development process. Streamlit provides a range of widgets, such as sliders and buttons, facilitating user interaction, while seamless integration with data visualization libraries like Matplotlib or Plotly enables the inclusion of charts and plots. A notable feature is its reactivity, automating updates in response to changes in input without the need for explicit callback management. Furthermore, deploying Streamlit apps is hassle-free, with options to host on popular cloud services like Heroku or AWS, making it an ideal tool for quickly transforming data projects into accessible and interactive web applications.

Chapter 2 LITERATURE SURVEY

A Modern Approach for Leak Detection in Water Distribution System (2018) [5]

The paper introduces an innovative approach to water distribution system management, combining traditional modeling techniques with contemporary Machine Learning (ML) methods for effective leak detection. Emphasizing the critical importance of efficient water system operation and the challenges posed by concealed infrastructure, the proposed solution integrates real-time monitoring, dynamic modeling, and ML algorithms. The advantages lie in the synergy of traditional and modern methods, enabling real-time monitoring, enhanced data processing, and dynamic modeling. However, challenges include the potential high cost of hardware solutions and accuracy considerations in ML-based detection. The approach advocates for a model-based strategy incorporating both steady-state and transient effects, integrating unsupervised learning like k-means, and enhancing dynamic modeling for more realistic simulations. Overall, the paper addresses key issues in leak detection, offering a promising avenue for improving efficiency and accuracy in water distribution systems.

RESEARCH PAPER 2017 A Design of Automatie Water Leak Detection Device

water leakages in pipelines and water distribution systems are the major issues in many countries. In this paper, we propose an automatie water pipeline leak detection device to continuously monitor the water pipelines to reduce man power involvement. This device not only reduces human resource but also the time used to process collected information. Our device allows leak detection staff to remotely listen to leak sounds of any pipelines by focusing their attention

on the suspicious area. The leak detection staffs can easily distinguish the realleakage from the false alarm by our system design. If leakage occurred, leak detection staffs will be able to determine the severity of the leak and its precise location. Our device is more effective and practicable for government agencies to implement to deal with the problem of water leakage.

Determination and Applications of Water Age in Distribution System

The paper delves into a comprehensive exploration of water age determination and its applications within the context of the Shanghai Pudong water distribution network. By defining water age as the duration from treatment to customer delivery, the study meticulously analyzes influential factors such as water demand, system design, and operational dynamics. Employing tracer studies and mathematical models enhances the precision of water age calculations and predictions, especially in relation to crucial water quality parameters like chlorine residual. Noteworthy advantages include the holistic analysis of contributing factors, the application of tracer studies for in-depth insights, and the integration of hydraulic and water quality models. The introduction of a reliability metric to assess the correlation between water age and model accuracy contributes a practical measure for enhancing model effectiveness. However, limitations include the study's specificity to the Shanghai Pudong network and potential challenges associated with data dependency and intricate calibration processes. Despite these considerations, the paper provides valuable methodologies and insights into water age dynamics, emphasizing the need for context-specific applications and thorough model calibration.

CHAPTER 3 – TECHNICAL SPECIFICATIONS

3.1 Algorithms Used

1. Multilayer Perceptron [3]

The implemented Multilayer Perceptron (MLP) model is designed to establish correlations between pressure values and leak nodes in a water distribution system. The architecture follows a sequential model structure with three layers: input, hidden, and output. Each dense layer comprises 16 neurons, facilitating the learning process. The dataset is split into 80% for training and 20% for testing. The Nadam optimizer, a combination of Adam and Nesterov Accelerated Gradient, is employed to enhance convergence speed and robustness. Evaluation relies on the Mean Absolute Error (MAE), providing a measure of average absolute differences between predicted and actual values. The model's performance is assessed through a comprehensive set of metrics, including accuracy, precision, and recall, offering insights into its overall effectiveness in predicting and explaining leak occurrences in the water distribution network.

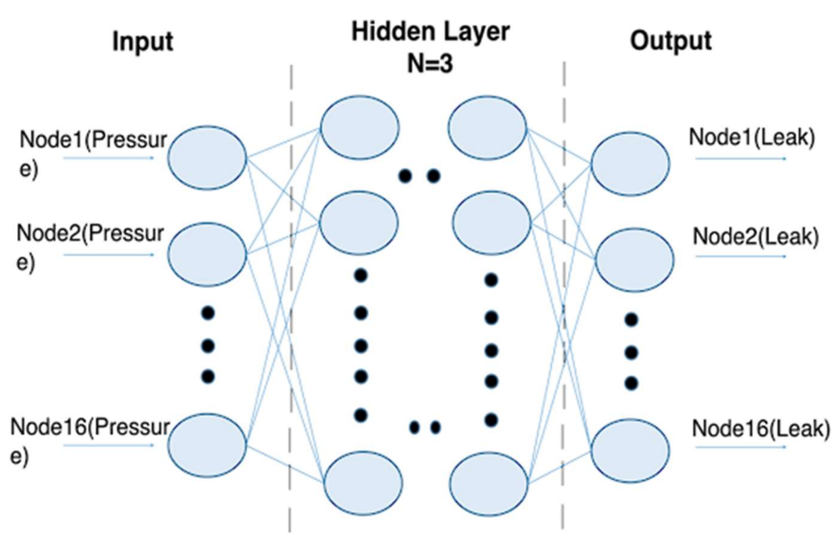


Fig. 4. Multilayer Perceptron Model

3.2 Python 3.10.4 [9]

Python is an interpreted, high-level programming language that is available freely for distribution and commercial use. It is an open-source language and is OSI-approved.

Various NLP libraries are available under Python for building NLP solutions. These are as follows:

3.2.1 Scikit-learn:[8]

Scikit-learn (Sklearn) is a versatile machine learning library in Python, providing efficient tools for various tasks. It played a crucial role in the project for data preprocessing, offering functions for handling missing values, scaling features, and encoding categorical variables. Additionally, Scikit-learn facilitated accuracy measurement through built-in metrics and the creation of confusion matrices for model evaluation.

3.2.2 Pandas:

Pandas was employed for seamlessly reading data files from CSV formats. Its powerful data manipulation capabilities were leveraged for organizing and preprocessing structured data, ensuring a smooth workflow in handling input datasets.

3.2.3 Matplotlib:

Matplotlib, a popular data visualization library, was instrumental in plotting learning and complexity curves. It provided clear visual representations of model performance, aiding in the analysis of learning patterns and the determination of optimal model complexities.

3.2.4 SuSi (Supervised Self Organising Maps) Implementation:

The SuSi library, an implementation of Supervised Self Organising Maps, brought a unique dimension to the project. It allowed for the exploration of unsupervised learning techniques with a focus on organizing and classifying data patterns.

3.2.5 Keras: [7]

Keras, a high-level neural networks API, facilitated the loading of different model layers and the tweaking of hyperparameters. It streamlined the process of building, training, and evaluating neural network models, enabling efficient experimentation with different architectures.

3.2 HTML5 and CSS3

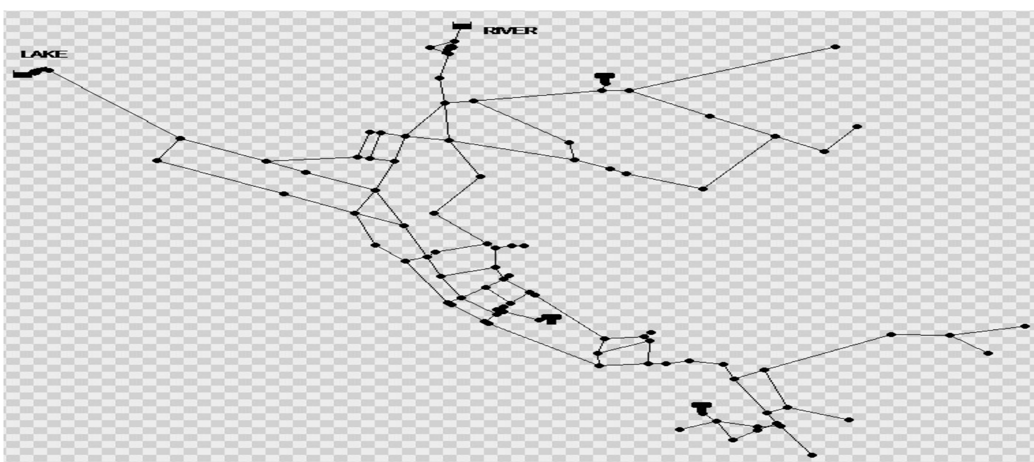
HTML and CSS are the core language components that are used for the construction of web pages. HTML describes the structure of the pages, primarily in regards to tables, text, headings, and images or graphics. It’s the standard programming language for the overall appearance of web pages. CSS, on the other hand, is the language used for describing the presentation of each page, and primarily in regards to the layout, fonts, and colors.

Chapter 5 WORKING

5.1 Acquiring dataset.

EPANET, a comprehensive hydraulic analysis software, enables simulation of water distribution networks. Simulations generate valuable data on hydraulic parameters, including pressure and flow rates. Machine learning algorithms can learn from these simulations to identify patterns indicative of leaks.

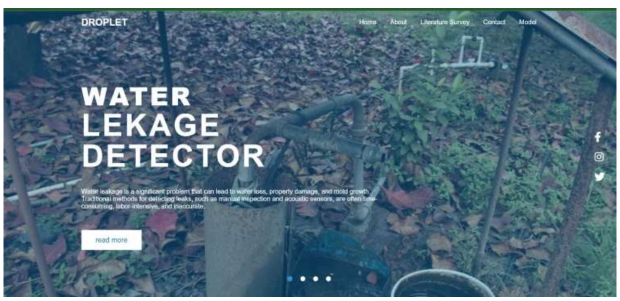
EPANET is a powerful and widely utilized software tool designed for the modeling and simulation of water distribution systems. Developed by the U.S. Environmental Protection Agency (EPA), it serves as a crucial resource for engineers, water utility professionals, and researchers in assessing and optimizing the performance of water networks. EPANET enables users to create accurate representations of complex water infrastructure, incorporating details such as pipes, pumps, tanks, and valves. The software facilitates hydraulic and water quality analysis, allowing users to simulate various scenarios, identify potential issues, and evaluate the impact of system modifications. With its user-friendly interface and robust functionalities, EPANET plays a pivotal role in enhancing the efficiency, reliability, and sustainability of water distribution systems, contributing significantly to the advancement of water management practices globally.



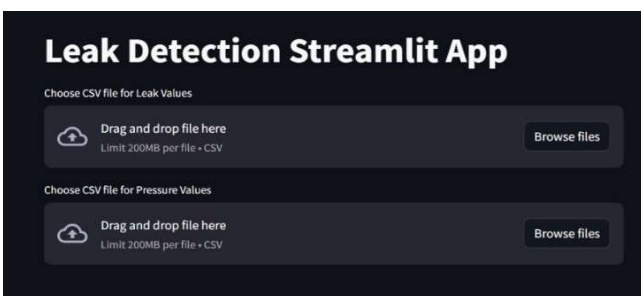
5.2 Building the web pages

Now for the front-end part, we built a home page and a form to take input from the user. [Inputs taken from user-

- Home
- Literature Survey
- Model



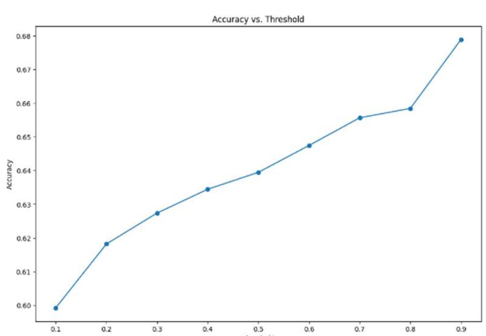
Home Page

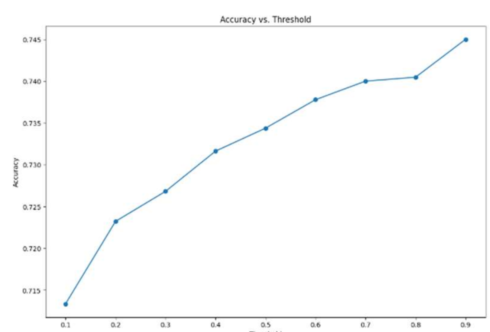


5.3 Model Outcomes

In the pursuit of optimizing the Multi-Layer Perceptron (MLP) model for water leakage detection, a meticulous exploration of key hyperparameters was conducted. The considered parameters included the choice of loss function, activation function, number of epochs, and batch size. To fine-tune the model's architecture, variations in the number of hidden layers and neurons were systematically experimented with, commencing from a single hidden layer with 32 units and progressing to three layers, each comprising 16 neurons. Overfitting became evident beyond three hidden layers or with more than 16 neurons, emphasizing the need for a balanced model structure. Activation functions were also scrutinized, with ReLU initially employed but encountering the 'dying ReLU' problem, similar to Leaky ReLU. Sigmoid activation was explored as an alternative, necessitating the standardization of pressure and leak values to a [0,1] range. However, this approach yielded lower accuracy and higher Mean Absolute Error (MAE), highlighting the nuanced considerations in optimizing the MLP model for enhanced water leakage detection performance.

The MLP regression model's varied accuracies can be represented by following graphs

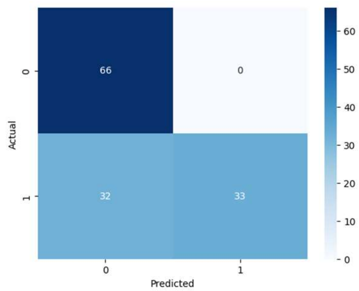


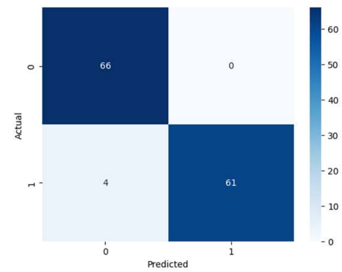


Accuracy of 65% Accuracy Of 79%

The following graph showed us that for a lesser accuracy there is a good deviation in accuracy vs threshold graph . But with good accuracy the deviation is removed .

The following is the accuracy vs confusion matrix for the model which gave us the best accuracy .





Activation Function	Epochs	Batch Size	Accuracy	MAE
ReLU	**3000**	**8**	**76.5824**	**1.15**
Leaky ReLU	**1000**	**8**	**79.6554**	**0.85**
Sigmoid	**1000**	**16**	**57.9483**	**2.14**
Sigmoid	**5000**	**8**	**69.538**	**0.98**
Sigmoid	**5000**	**32**	**65.4752**	**1.97**

CHAPTER 6 CONCLUSION

6.1 Conclusion

In conclusion, the Water Leakage Detection project addresses a critical issue in large water distribution networks. Leveraging smart water technologies and neural networks, the team proposed a cost-effective solution to detect and manage water leakages, ultimately contributing to water savings and reduced pipe breakage frequencies. The project employed a model: a regression model based on the Multi-Layer Perceptron algorithm. The results indicated the model successfully classified leak nodes, with the Multi-Layer Perceptron model. The experiments highlighted the importance of model complexity and revealed that a less complex Multi-Layer Perceptron model achieved. The hyperparameter tuning and evaluation process provided valuable insights, showcasing the potential for accurate water leakage detection using neural network approaches. Overall, the project contributes to advancements in smart water systems and underscores the effectiveness of machine learning techniques in addressing critical infrastructure challenges.

Chapter 7 REFERENCES

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