IIT Kanpur

UNDERGRADUATE PROJECT REPORT

JAL JEEVAN MISSION: WATER LEAKAGE DETECTION USING IOT AND ML TECHNIQUES

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1 Introduction

Access to clean water is a critical issue in rural India. Furthermore, water leakage poses a major problem in modern water distribution systems, both in urban and rural settings, leading to significant economic losses. The Jal Jeevan Mission project aims to address this issue by developing an effective water leakage detection system that is cheap, accurate, and scalable. This report outlines the methodology used in the project, the literature review conducted, the test bed design, future work, and conclusion.
Multiple methods have been developed to detect water leakages. In this project report, we summarise the main methods which have been proposed and used for water leakage detection, which include water flow meters, noise loggers, custom fabricated accelerometers, etc. We also discuss the methods suggested to process the data generated by the sensors, which can be divided mainly into machine and deep learning algorithms and correlation techniques. We discuss the individual merits and demerits of the sensors as well as the methods. In this project, after studying various methods, we have used water flow meters in the testbed constructed for detection of water leakage. We discuss the main considerations behind the design of the testbed. Finally, we describe the future work which can be undertaken.

2 Literature Review

The literature review conducted in this project aimed to identify the ideal method of water leakage detection that should be deployed. The review involved reading many papers containing state-of-the-art methods of water leakage detection using various techniques such as water flow meters, noise loggers, and custom fabricated accelerometers. The individual merits and demerits of the sensors, as well as the methods they suggest to process the data generated by these sensors, were covered in the review. Broadly, sensor data is usually classified using deep learning-based algorithms, various mathematical manipulations like FFT and DWT, and correlation techniques. The feasibility of each of these sensors was discussed, ranging from the cheap flow meter to the very expensive but highly accurate smart ball.

2.1 Water Flow Meters

Water Flow meters are a low cost method to detect water leakages. Tina, Juma S. et al.[1] propose an IoT based method to detect water leakages. The paper uses Hall effect based water flow meters along with Arduino and nodeMCU to collect and transmit the data for storage. They propose a simple comparison of water flow rates between the upstream and downstream water flow sensors to detect a leakage. R F Rahmat et al.[2] apart from providing a method to detect water leakages, provide a method to localise the leak. They also use Arduino to process the data collected from the water flow meters. If the flow starts to decrease, and eventually attains a stable value, which is lesser than the normal initial flow, the system detects a leakage. The Arduino converts the initial and final flow meter readings into velocities, and then applies the basic equation of motion to calculate the distance of the leak from the sensor.

2.2 Accelerometers

Kang et al.[3] propose a novel method to detect and localise a leak using an ensemble 1D-CNN-SVM model. Piezoelectric accelerometers (PCB-393B31) were used to measure the leakage signals noninvasively. These accelerometers can measure a vibration to the acceleration level objectively. The raw data was processed to remove the high frequency components. This was fed into a 1D-CNN-SVM model. The data used is in the form of a time series. A convolutional layer was used for feature extraction using learnable kernel filters. Finally the extracted features were passed through SVM as well as 1D CNN paths, and a combination of the results of these two models was used to provide the final prediction. Okosun, F. et al.[4] also provide a method to construct custom fabricated piezoelectric sensors.

2.3 Noise Loggers

Noise loggers work by employing complex algorithms to distinguish between the sound produced by regular operations and that of the leak, thereby identifying leaks as they happen. I.A. Tijani et al.[5] proposes the use of noise loggers in a real WDN because laboratory data usually does not generalize well to actual WDNs. Acoustic signals collected were de-noised using discrete wavelet transform(DWT) to imporove Signal-to-Noise(SNR) Ratio. Zahab et al.[6] propose a novel approach for the analysis of acoustic signals collected in the city of Montreal using noise loggers.Signals are converted into usable parameters using a FFT followed by a series of transformations. Level, spread, and frequency distribution are used as inputs to ML models. The weights of these parameters are calculated using Shannon entropy algorithm. Chang et al.[7] propose an acoustic signal detection method based on CNN for real-time leak detection on water pipes which offers a classification accuracy of over 98%. A Mel-Freqeuency transformation is applied to the collected acoustic signals, after which MFCC features are extracted. The extracted MFCCs are used to train three models: CNN, KNN and SVM.

2.4 Smart Ball

The SmartBall is a spherical, free-swimming device that is smaller than the pipeline bore, allowing it to roll silently through the pipeline and detect small leaks with high responsiveness. It can be used to inspect both liquids and gas pipelines, and any pipeline size of 4-inch diameter or greater can be inspected. The device monitors many miles of pipeline during a single deployment.

Because the device travels in the fluid column and passes directly adjacent to the leak, it clearly and distinctly identifies the noise signature created by the release of pressure. The SmartBall's position is logged internally by on-board accelerometers and the ball can also be tracked by GPS synchronized surface sensors. This allows the location of any leaks to be determined within ± 1 meter. The SmartBall is fully sealed with no exposed electronic components, making it reliable in a wide range of hostile conditions, and intrinsically safe for use in flammable products.

2.5 Data Processing methods

Various data processing methods were used in the papers studied. However they can be majorly classified into two types - machine/deep learning based, and mathematical, statistical and correlation based techniques.
In [1] and [2] the authors simply compare readings of flow meters to detect leakages. Whereas, Kang et al. [3] provide an elaborate signal processing regime followed by an ensemble 1D-CNN-SVM model to extract information and predict leakages from the data.

3 Methodology

The methodology for the Jal Jeevan Mission project involves the development of an effective water leakage detection system that is cheap, accurate, and scalable. To achieve this goal, the project followed a three-step approach. The first step involved a literature review of the state-of-the-art methods for water leakage detection. The second step involved the design and construction of a test bed to collect data on the sensors' feasibility. The third step involved using the data collected to test the accuracy of leakage detection using different algorithms.

4 Testbed Design

To test the feasibility of using these sensors for large scale, cheap, and accurate water leakage detection, a pilot test bed was created, which included initial sensors of ultrasonic flow meters. The main considerations behind the design of the test bed were to collect data on the test bed and use models to test the accuracy of leakage detection. The test bed was designed to simulate a water distribution network, and the sensors were placed at various points along the network to capture data on water flow. Data collection has started, and the focus of future work will be on selecting the optimal method of leakage detection.
While choosing the sensors, water flow sensors were chosen, since they provide the cheapest and most scalable method for water leakage detection. Apart from that accelerometers are also to be added, as although they are costly, they can be used to collect time series data which can be used to train predictive models which give promising results as in the work of Kang et al.[3].

Figure 1: Test bed behind environmental science building

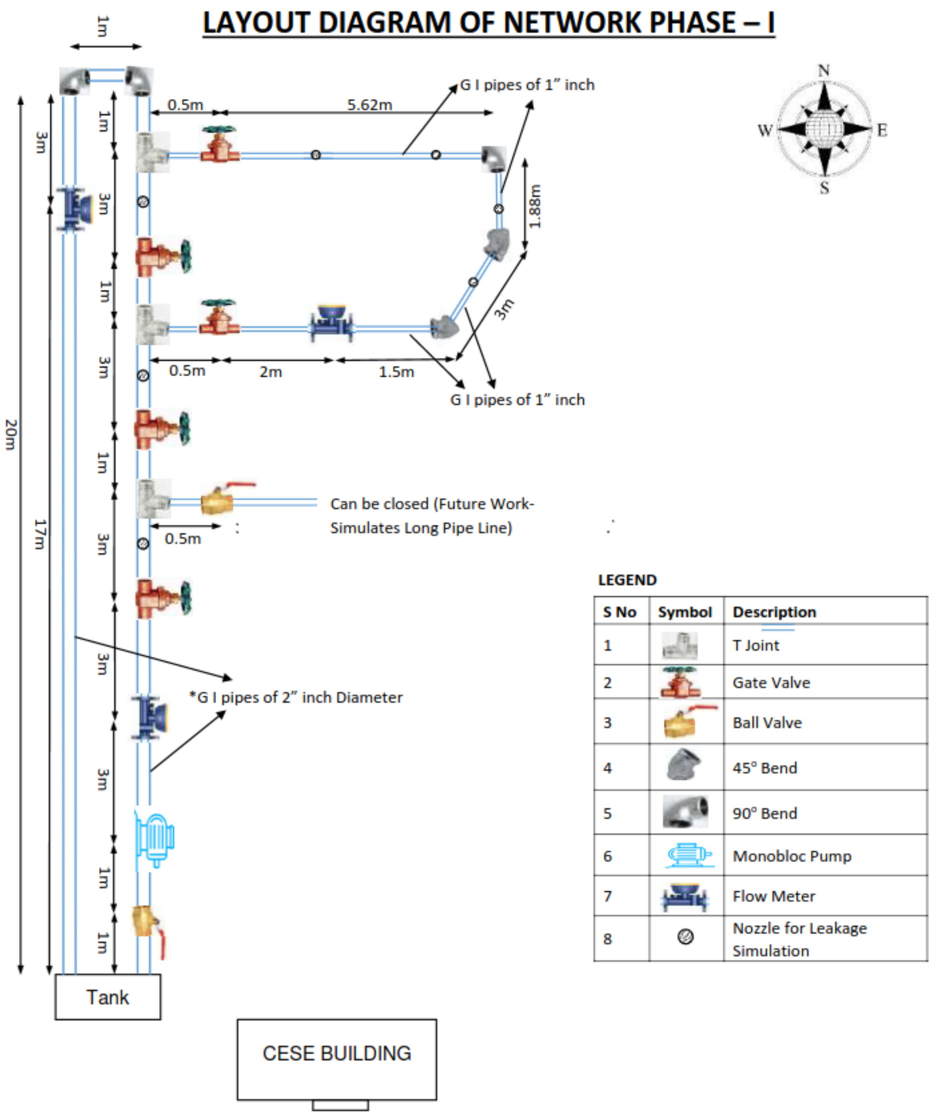
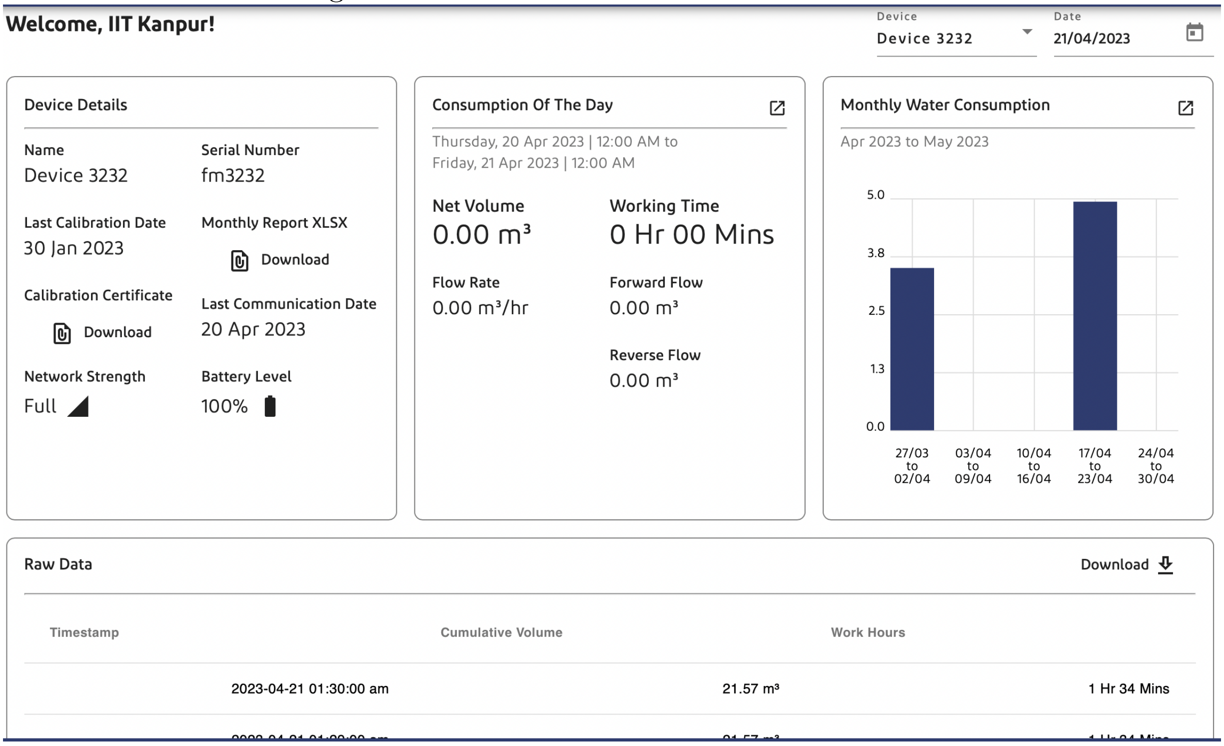


Figure 2: Dashboard for data collection



5 Future Work

The future work in this project will involve analyzing the data collected from the test bed and selecting the optimal method of leakage detection. This will involve comparing the accuracy and cost-effectiveness of different algorithms and sensors to determine the best approach for detecting water leakage.

In the initial experiments, it was observed that the high pressure of water in the pipeline of the testbed significantly affects the readings of the water flow meters. If there is a leak in a section of the pipe, it is noted that instead of the downstream flow rate decreasing, actually, the upstream flow rate increases and compensates for the leak. This is possibly due to the high pressure pump in the pipe system. The effect of this phenomenon must be considered.

Another factor which the project plans to address is how well the taps in the pipes of the testbed emulate actual leaks. This is a major factor in deciding how the models trained on the data collected from the testbed will actually behave in the actual environment, where the leaks will not be emulated using taps. Further there is also a possibility of mispredicting the user opening an actual tap as a water leakage, which must be addressed.

Once the optimal method is identified, and work is conducted to address the issues identified above, the project will move towards deploying the system to address this critical issue on a larger scale, and aim towards reducing costs through optimisations in the number and type of sensors used while maintaining the accuracy of prediction.

6 Conclusion

The Jal Jeevan Mission project aims to address the critical issue of water leakage in rural India by developing an effective water leakage detection system that is cheap, accurate, and scalable. The project followed a three-step methodology involving a literature review, test bed design, and data analysis. The literature review identified the ideal methods for water leakage detection, and the test bed was designed to collect data on the feasibility of using different sensors for large scale, cheap, and accurate water leakage detection. The focus of future work will be on selecting the optimal method of leakage detection and deploying it to address this critical issue.

References

[1] J. S. Tina, B. B. Kateule, and G. W. Luwemba, "Water leakage detection system using arduino," *European Journal of Information Technologies and Computer Science*, vol. 2, no. 1, pp. 1–4, Jan. 2022. DOI: 10.24018/compute.2022.2.1.43. [Online]. Available: https://www.ej-compute.org/index.php/compute/article/view/43.

[2] R. F. Rahmat, I. S. Satria, B. Siregar, and R. Budiarto, "Water pipeline monitoring and leak detection using flow liquid meter sensor," *IOP Conference Series: Materials Science and Engineering*, vol. 190, no. 1, p. 012 036, Apr. 2017. DOI: 10.1088/1757-899X/190/1/012036. [Online]. Available: https://dx.doi.org/10.1088/1757-899X/190/1/012036.

[3] J. Kang, Y.-J. Park, J. Lee, S.-H. Wang, and D.-S. Eom, "Novel leakage detection by ensemble cnn-svm and graph-based localization in water distribution systems," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 5, pp. 4279–4289, 2018. DOI: 10.1109/TIE.2017.2764861.

[4] F. Okosun, P. Cahill, B. Hazra, and V. Pakrashi, "Vibration-based leak detection and monitoring of water pipes using output-only piezoelectric sensors," *The European Physical Journal Special Topics*, vol. 228, no. 7, pp. 1659–1675, Aug. 2019. DOI: 10.1140/epjst/e2019-800150-6. [Online]. Available: https://doi.org/10.1140/epjst/e2019-800150-6.

[5] "Improving the leak detection efficiency in water distribution networks using noise loggers," vol. 821, pp. 1–4, Jan. 2022. DOI: https://doi.org/10.1016/j.scitotenv.2022.153530. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0048969722006222.

[6] S. El-Zahab, A. Asaad, E. Mohammed Abdelkader, and T. Zayed, "Development of a clustering-based model for enhancing acoustic leak detection," *Canadian Journal of Civil Engineering*, vol. 46, no. 4, pp. 278–286, 2019. DOI: 10.1139/cjce-2018-0229. eprint: https://doi.org/10.1139/cjce-2018-0229. [Online]. Available: https://doi.org/10.1139/cjce-2018-0229.

[7] "Chuang, wei-yi and tsai, yao-long and wang, li-hua," vol. 821, pp. 83–86, Jan. 2019. DOI: 10.1145/3319921.3319926. [Online]. Available: https://doi.org/10.1145/3319921.3319926.