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Water Leakage Detection and Management System

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Abstract - In this era of globalization, water leakage significantly contributes to water waste and can adversely affect the environment if left unchecked. Much water is wasted due to unsupervised and poorly managed actions. The primary objective of leak detection is to locate leaks and measure their dimensions in secured products and systems. The process begins with hardware development, which is crucial for obtaining raw data by measuring water flow velocity at specific crack locations. Software-based methods use computer systems to monitor pressure and flow rate data to detect leaks continuously. This involves converting the velocity data into audio frequency signals. The gathered signals are then processed in MATLAB, a high-performance technical computing software, through four phases: segmentation, pre-processing, feature extraction, and classification, with Internet of Things (IoT) features integrated. Finally, the data is analyzed using the k Nearest Neighbour (kNN) classifier for classification.

Keywords. Water Leakage Detection, Signal Processing, Internet of Things

1. INTRODUCTION

In this era of globalization, water leakage significantly contributes to water waste and can have adverse effects on the environment if not addressed. A substantial amount of water is wasted due to unsupervised and poorly managed actions. This issue is linked to inadequate water resource allocation, ineffective usage, and insufficient water management practices. Consequently, wasteful water uses and inadequate monitoring present challenges for residential and commercial water management systems [1]-[2].

Leaks in piping systems often result from excessive pressure that exceeds the maximum rating specified by the manufacturer, causing distortions or malformations in the pipes. This can lead to ruptures when water flows through them. Factors such as the material and age of the pipes, third-party interference, or attachments may also contribute to this problem [3]

Implementing a water leakage detection and management system using modern technologies is an effective way to prevent or minimize water losses. A flow liquid sensor, which measures the amount of liquid flowing through the pipes, can be used as part of this system. The data obtained is processed using short frequency domain analysis to detect outflows based on signals generated from flow and pressure. Users are notified of leaks, and this information is upgraded and improved in a cloud-based system, allowing for analysis of cracks or leaks through IoT.

The Internet of Things (IoT) involves connecting everyday objects like smartphones, Internet TVs, sensors, and actuators to the Internet, enabling interactive and real-time communication [4]. IoT technology can also enhance smart home development by providing intelligent understanding, comfort, and convenience, thereby improving the quality of life. This creates a detailed connection between the cyber world and the physical world through sensors and smart devices [5].

This paper will utilize modern technologies to identify the size and location of cracks causing leakage by capturing short time frequency data from water flow velocity. The position of the leakage will be determined based on processed signals using MATLAB software, which will also notify the user. Additionally, time domain analysis techniques, including Fast Fourier Transform and wavelet transform, will be examined. For frequency domain analysis, techniques such as sinusoidal modeling and dimension reduction of the modeling spectrum will be investigated to enhance signal quality. This approach can serve as a guideline for future applications, providing data on crack size and position inside tanks [6].

2. FLOW CHART AND PROJECT DEVELOPMENT

The flowchart elaborates on the methodology used in processing data to design and classify input signal data generated from the velocity of water flow through three different hole sizes and the location of the water leakage. Each signal process follows specific procedures, utilizing signal processing methods with MATLAB to attain the results.

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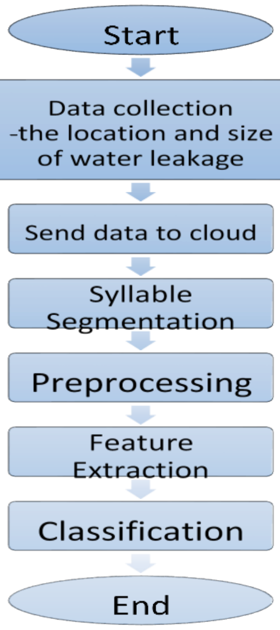

Figure 1. Flowchart for Water Leakage Detection and Management System

Figure 2 illustrates the project development, which includes both hardware and software development. In the hardware development phase, data is collected from sensors and buzzers and then stored in the cloud via an internet connection. In the software development phase, the data is processed through several steps using MATLAB software.

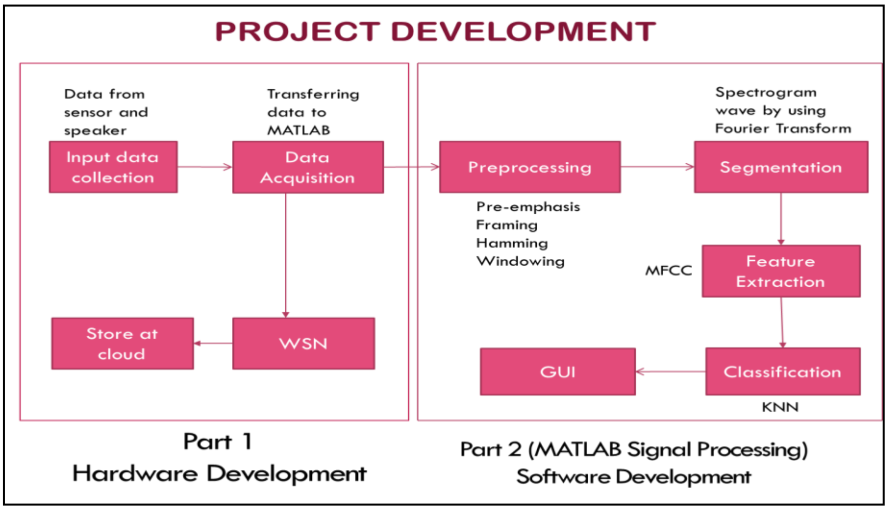

Figure 2. Project development

Project setup and configuration

At the start of this project, the Arduino Mega was used and illustrated in Figure 3. The connections between the Arduino and the three water flow sensors are shown based on the prototype to obtain readings from each sensor. Each water flow sensor is placed in a different location within the pipeline system. Three-hole sizes will be punched for each pipeline where the hole size will be varied into large, medium and small sizes as shown in Figure 4. The electronic circuit connection is illustrated in Figure 5.

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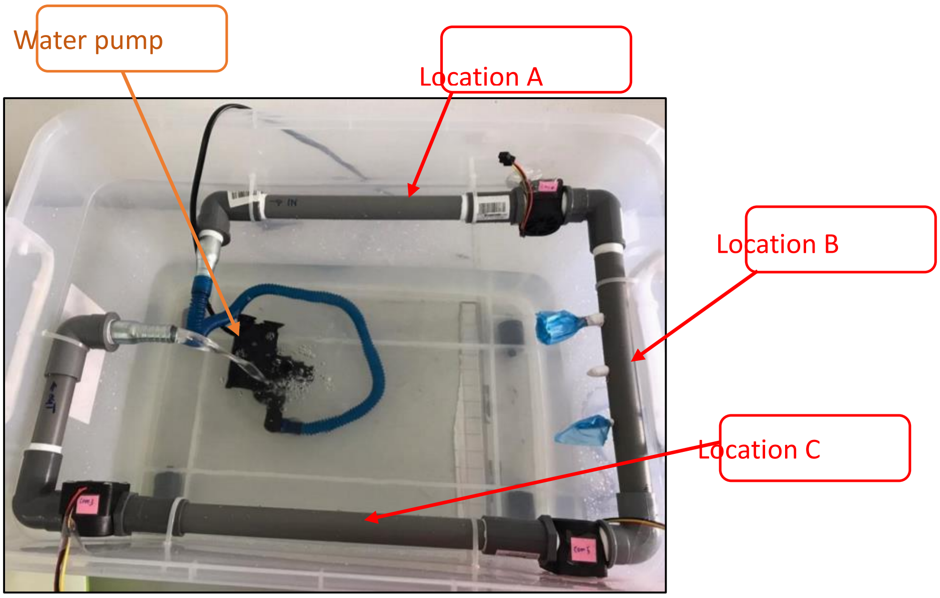

Figure 3. The location of each pipeline to detect leakage

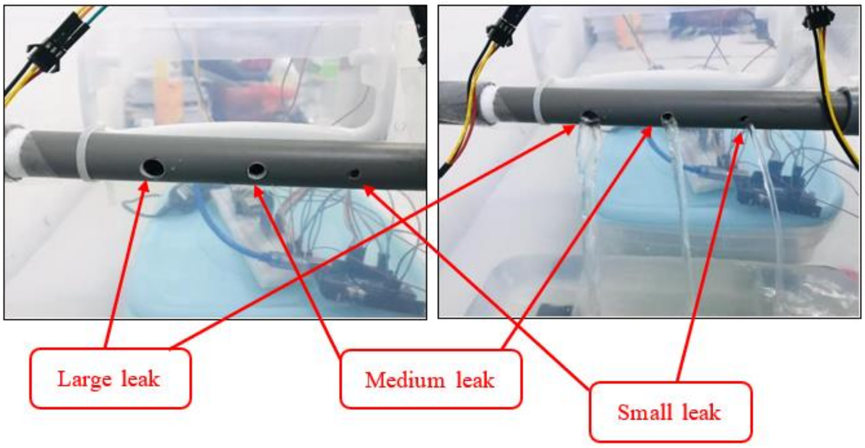

Figure 4. The three sizes of leakage for each location

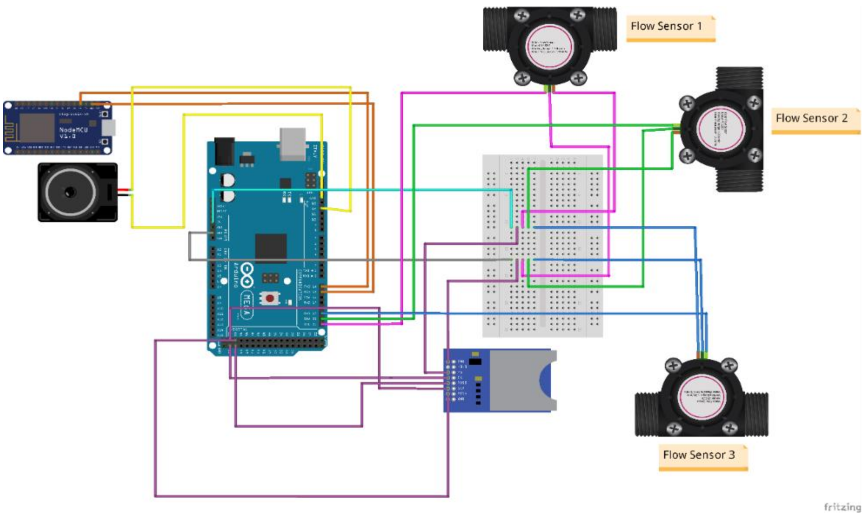

Figure 5. The design of the circuit connection

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3. DATA COLLECTION

Based on the previous work, a database recording the hourly water flow is essential for understanding the normal flow of the system and determining the sizes of water leaks. This data is gathered from the water flow measurements taken by the installed sensors. Each data point is collected based on the set water flow conditions.

Table 1 displays 10 readings obtained from the microcontroller (Serial Monitor) for each leak size when water is flowing through the pump. Each water flow measurement is recorded to accurately identify the leaks at various locations within the system. Based on the results, the water flow averages between 4000 and 4800 liters per hour with a small leakage. When the leakage is medium-sized, the water flow averages between 3000 and 3500 liters per hour. In the case of a large leakage, the water flow decreases to an average of 1000 to 2500 liters per hour.

Table 1. Ten readings were taken from each tested flow in liter/hour

No Leakage	Small Leakage	Medium Leakage	Large Leakage
62568	4080	3100	1096
56676	4080	3152	2097
63576	4072	3168	2720
61576	4404	3442	2048
60568	4800	3256	2150
62576	4072	3092	1272
63576	4072	3400	2302
61576	4604	3311	2155
60568	4064	3256	1120

Several pipe leakage scenarios were analyzed to assess the effectiveness of the sensors and systems used. Table 2 details these scenarios. In Situation A, pipes A, B, and C did not experience any leaks. Situations B, C, and D represent pipe A with small, medium, and large leaks, respectively. Situations E, F, and G examine pipe B with small, medium, and large leaks. Finally, Situations H, I, and J analyze pipe C with small, medium, and large leaks.

Table 2. Raw Data Collection obtained from Arduino

Situation	Condition of pipe	Output from Microcontroller
A	Pipe A, Pipe B and Pipe C have normal flow	13:32:19.549 -> 62854 Litre(1) 62478 Litre(2) 62422 Litre(3) 13:32:23.579 -> ALL PIPES HAVE NORMAL FLOW
B	Pipe A has small leakage	13:35:49.536 -> 4016 Litre(1) 3904 Litre(2) 4008 Litre(3) 13:35:53.575 -> PIPE B HAS SMALL LEAKAGE
C		

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	Pipe A has medium leakage	13:37:29.405 -> 3152 Litre(1) 3168 Litre(2) 3256 Litre(13:37:50.452 -> 3152 Litre(1) 3168 Litre(2) 3256 Litre(13:37:54.456 -> PIPE A HAS MEDIUM LEAKAGE
D	Pipe A has large leakage	13:39:45.401 -> 1096 Litre(1) 2296 Litre(2) 2048 Litre(3) 13:39:49.456 -> PIPE A HAS LARGE LEAKAGE
E	Pipe B has small leakage	13:50:30.787 -> 61614 Litre(1) 3899 Litre(2) 4008 Litre 13:50:34.813 -> PIPE B HAS SMALL LEAKAGE
F	Pipe B has medium leakage	13:14:48.720 -> 63606 Litre(1) 3448 Litre(2) 3320 Litre(3) 13:14:52.777 -> PIPE B HAS MEDIUM LEAKAGE
G	Pipe B has large leakage	13:12:42.466 -> 63798 Litre(1) 2792 Litre(2) 2648 Litre(13:12:46.516 -> PIPE B HAS LARGE LEAKAGE
H	Pipe C has small leakage	13:41:57.789 -> 61582 Litre(1) 61614 Litre(2) 3992 Litr 13:42:01.822 -> PIPE C HAS SMALL LEAKAGE
I	Pipe C has medium leakage	13:46:12.904 -> 61582 Litre(1) 61614 Litre(2) 3256 Litre 13:46:16.901 -> PIPE C HAS MEDIUM LEAKAGE
J	Pipe C has large leakage	13:48:23.124 -> 61582 Litre(1) 61614 Litre(2) 2225 Litr 13:48:27.171 -> PIPE C HAS LARGE LEAKAGE

Data Acquisition Result

After data collection, each situation will produce a distinct audio sound from the buzzer. To prepare for signal processing in MATLAB, each audio file must be converted to a WAV file format. The WAV file should be set to a sample rate of 16,000 Hz, mono channel, and 8 bits per sample. Each condition will have its audio file played via an SD card adapter in the microcontroller setup. The audio data will be filtered for each condition obtained from the water pipeline prototype.GoldWave software tools are used to filter out noise from the raw audio signal. Each audio condition must be filtered and converted into a .wav file, as detailed in Table 3.

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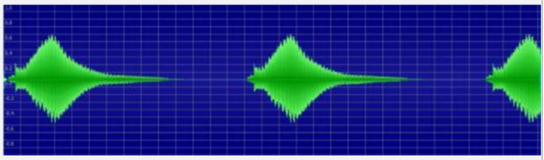
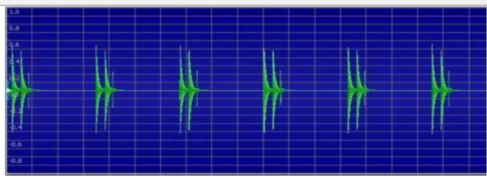
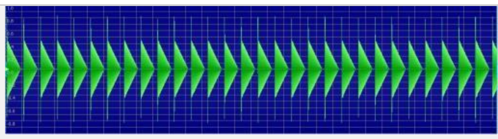
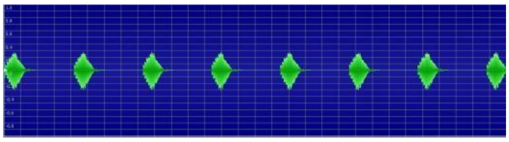
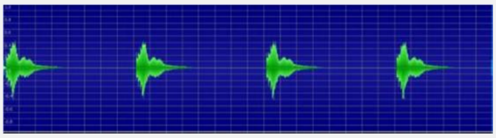
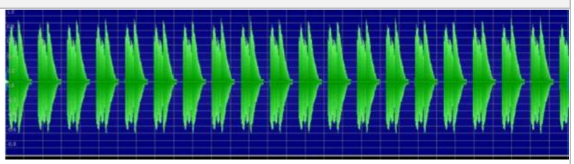
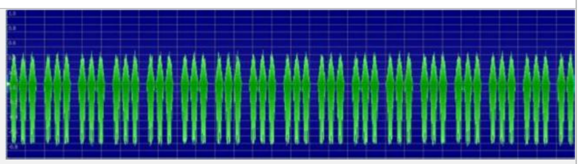
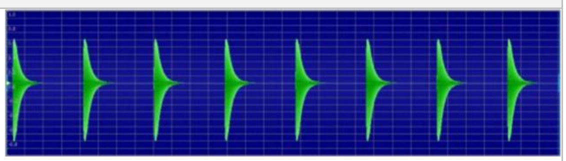
Table 3. Audios in .wav files

Situations	**Audio in wav. File (for 15seconds)**
Situation A Pipe A, Pipe B and Pipe C have normal flow	
Situation B Pipe A has small leakage	
Situation C Pipe A has medium leakage	
Situation D Pipe A has large leakage	
Situation E Pipe B has small leakage	
Situation F Pipe B has medium leakage	
Situation G Pipe B has large leakage	
Situation H Pipe C has small leakage	

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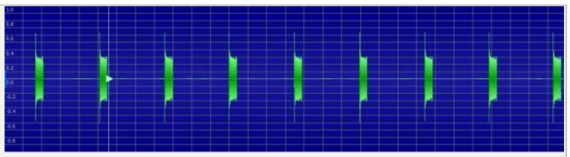
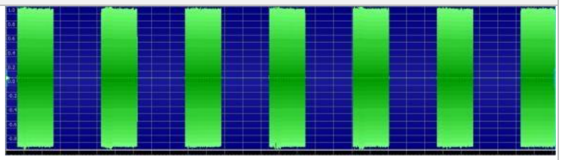
Situation I Pipe C has medium leakage	
Situation J Pipe C has large leakage	

Feature Extraction

In this process, the signals obtained from the previous steps will be converted into numerical data. Before extraction, all condition data will be combined and processed for feature extraction, resulting in the file **`collectdata_speaker.mat`**. This process will involve filtering the signal data and converting it into numerical data using Mel Frequency Cepstral Coefficients (MFCC).

Classification of KNN (K Nearest Neighbour)

For this process, the MFCC data will be classified using Artificial Intelligence (AI) with the K-nearest Neighbors (KNN) algorithm. The MFCC data will be divided into two parts: one for testing **(`resizemfcc_dattrain20`)** and one for training **(`resizemfcc_dattest10`**). This separation is essential for the classification process using KNN.

Graphic User Interface (GUI) Notification

The GUI will display the condition of the water pipeline when the push button is clicked, indicating any leakage in the water pipeline. Figure 6 shows the condition as represented in the GUI.

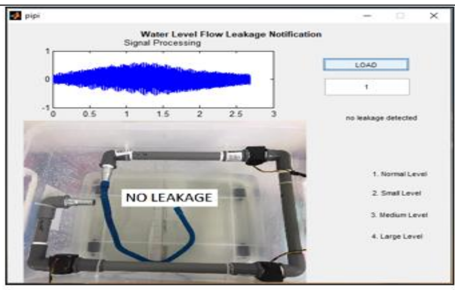
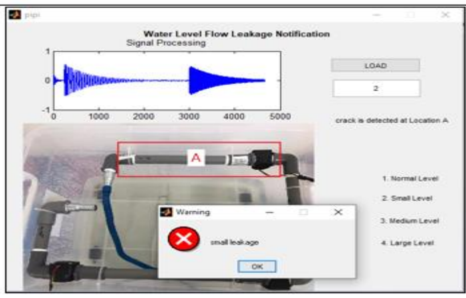
Situation	GUI Notification
A	
B	

Figure 6. The GUI interface

4. CONCLUSIONS

In conclusion, this project effectively detects the location and size of leaks in pipelines by utilizing the data rate of water flow obtained from sensors. The system operates stably by employing specific methods to determine the condition and location of the leak, which is then displayed in the GUI notification. The signal processing method

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encompasses four phases: segmentation, preprocessing, feature extraction, and classification. This software is crucial for differentiating background noise associated with each crack size and location, achieving more precise and accurate results.

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