Water Leakage and Contamination detection using Goal Programming and Hypergraph

1. Shuhul Bhat, IT dept, MIT, Pune
2. Ankit Kumar, IT dept, MIT, Pune
3. Yash Lahane, IT dept, MIT, Pune
4. Prof. Priti Chakurkar, IT dept, MIT, Pune

Abstract

Most important and need of the hour issue is water conservation and water pollution. As the whole world is suffering from its population growth and worst water pollution problem due to its industrial growth. Due to this mankind is suffering a lot and most of the developing countries like India and China are unable to provide clean and healthy drinking water to its most of the citizens living in rural areas. Many methodologies are exist to provide the solution for the water leakage and water contamination level detection process, but most of them are relying on the electronic sensors and other electronic gadgets. So proposed methodology put forwards a simple and effective methodology of detection of water leakage based on the hyper graph formation for water distribution network by measuring the water collected levels at the check points using goal programming technique. And again Fuzzy logic is used to detect the water contamination level using its velocity at different checkpoints of the water distribution network.

Keywords: *Water Distribution network, Fuzzy Classification, Goal Programming, Hyper graph.*

I. INTRODUCTION

Water is avital part of our daily life. Turning on the faucet and expecting water to flow out freely is a comparatively new convenience that is essential to our modern lifestyle. However, most people have no idea of what actually goes into making this a reality. The method by which water goes from source to tap is an extensive process involving several components and numerous potential trouble spots. The main part of water supply systems includes source development supply, water treatment, pumping, transmission & storage, distribution pipe network and user, etc. The water supply system in a community provides potable water to customers by first treating raw water using various unit processes, pumping and transmitting treated water to the community, storing the water, and finally distributing the water to the customer. Each of these components is necessary for the efficient realization of the end result, which is to supply potable water at adequate pressure and flow at the demand locations. However, each 2 step in the water distribution system is subject to problems and water losses, which could affect the overall reliability of the system in accomplishing its goal. The water distribution system includes pumping, transmission and storage, and the distribution pipe network, as well as all other appurtenances, such as valves, hydrants, and service connections. These appurtenances are necessary to supply potable water to customers within the confines of the municipality.

The purpose of a municipal water distribution system is to supply potable water to a community to meet domestic, industrial, commercial, and fire flow demands. Under normal circumstances, the system is required to supply customers with an adequate flow of good quality water under sufficient pressure. Deficient conditions occur in a system when one or extra of the flow, pressure, or quality requirements are not met. There are numerous possible reasons for deficient conditions in a water distribution system. A water distribution system comprises several different components including water mains, storage tanks, valves, pump stations, hydrants, meters, and service connections. Failure in any one of these devices may lead to deficient conditions in some portion of the network. Water mains are the backbone of the entire system and therefore have the greatest outcome on the overall 3 efficiencies of the network.

Closed channel water distribution systems generally operate under pressure. The water in the system follows the way of least resistance, especially if that path leads out of the system. The pipe network of a water supply system is outlined to deliver water to specific withdrawal points with sufficient flow and pressure. These releases of water from the network at designated withdrawal locations are necessary to provide service to customers and to provide for municipal uses. Normal demands for domestic and commercial purposes are usually metered to keep track of the amount of water used. Although certain locations are specified for water to leave the system, water may also leave at unwanted points. The first step in understanding losses is to identify certain terms used in the water industry. The American Water Works Association (AWWA) has recognized three major categories of "losses" in a water supply system. These categories are accounted for loss, real loss and unaccounted for losses.

In accounted for loss system Water leaving the treatment plant and entering the distribution system (called water produced) is a valuable commodity for practicality and water authorities. Their goal is to maximize the monetary return on the water produced and distributed. Money is returned to utilities by billing consumers according to how much water they use based on meter readings. Water meters are used to monitor the amount of water that a billable and non-billable customer uses. Non-billable customers include municipal users and the fire station. All water that is metered, whether it is sold or unsold, can be recognized and quantified by the utility. Accounted-for losses occur at metered locations within the water distribution system. All metered water leaving the pipe network is termed accounted-for losses.

The ultimate goal of a water utility should be to know the quantity of water gathered at the source and be able to track its use throughout the water supply system. Unfortunately, a large percentage of water entering the water supply system is neither metered nor put to beneficial use. Water that falls into this category is called "real losses." Real losses cannot be tracked by a utility.The third type of loss in a water supply system is termed "unaccounted-for losses." Unaccounted-for losses are losses from the system that are put to beneficial use. However, these beneficial uses are either not metered or are under-registered due to meter errors. The largest source of unaccounted-for losses is municipal use. Recently there has been a large push for municipalities to meter all uses even if they are not billable. However, the initial investment deters government agencies from implementing this suggestion. In the most simple of terms, lost water is lost revenue. When water is lost due to leakage several consequences are incurred on utilities or agricultural users. Leakage in a pipe network causes the cost of pumping, treating, and distributing water to be unnecessarily higher than it should be. In the treatment process, energy and chemicals are used to treat the necessary amount of water. However, when there is a leakage in the system, more of the resources are being used than are necessary at a significant cost. The extra water that must be produced not only increases costs, but there is no return on this extra investment since leakage flows do not produce revenue. The utility will shift the cost to the consumer by dividing the total cost among the paying customers because no utility can be run at a loss.

Leaks or breaks in water mains pose significant problems for utilities. Pipe failures contribute to notable losses of drinkable water that, in turn, translate into lost revenue. Significant water losses in a system may cause premature development of new water sources at a significant cost. In addition, water leaks may result in increased groundwater levels, damage to adjacent property, and possible contamination of the water supply. Municipal utilities recognize these problems; however, time and money often preclude them from completely solving the problem of leakage in the system. To handle the problems associated with leaks in pipe networks this paper presents a mathematical formulation for analyzing water distribution systems under deficient operational conditions. This formulation is intended to determine the magnitude of flow being lost from the pipe network due to leakage. In addition, this paper will present methods by which leakage flows can be allocated among pipes to determine which pipes have the most urgent need for rehabilitation or replacement.

This research paper dedicates section 2 for analysis of past work as literature survey, section 3 deeply elaborates the proposed technique and whereas section 4 evaluates the performance of the system and finally section 5 concludes the paper with traces of future enhancement.

II. LITERATURE SURVEY

This section of the literature survey eventually reveals some facts based on thoughtful analysis of many authors work as follows.

N.Sherksi [1] proposed a different technique to analyze the various effects of leakage on different WDS such as pipe volume, water demand flow, pressure, and flow. This experiment results helpful the efforts of WDS leak detection and the water loose mitigation. Nowadays there is stress and the pressure regarding water resources is only because of the reduction in water supply and the increase in the water demand. Leakage reduction is an essential part of the management of water demand.

S. Kashid[2] presented the survey of WDS (Water Distribution System) associated problems in the water distribution system. They review of intelligent metering systems and leakage detection systems. As water is one of the most precious and limited natural resources, it is need of time to have a new cost-effective and efficient system to overcome problems in the water distribution system. They proposed an intelligent water distribution system using a DSP processor to speed up the operations.

B. Shakmak [3] proposed the use of low and high-resolution cameras to test the detection of water leakage using a small scale simulator. It has been found that when leakage occurs, a specific thermal profile will be generated that could be easily detected by both types of cameras (particularly late afternoon or early evening). The cameras are able to visualize the leak despite the leak itself is not being evident on the surface by visual inspection. The difference in the temperature generated on the surface has clearly been detected by both, the high-resolution thermal camera (Flir A310f) and the low-resolution thermal camera (IRISYS). However, the resulted images from both cameras have needed additional processing to confirm the leakage and its location. The low-resolution camera is found as successful as the high-resolution camera in detecting and locating the leakage. As the cost of producing water leakage detection system using thermal cameras is an important factor, in the design of a low-cost water leakage detection system. The produced systems could be mobile or use fixed cameras, depending on the importance of the inspected point. One other important outcome of the findings is that the high-resolution camera could be used to detect leakage in large areas from high altitudes since the pixel density of the images will still be effective as evident from a test conducted using the low-resolution infrared camera.

Elias Farah [4] presented feedback on the use of the AMR system. Water resources are limited around the world and there is a very high standard of the water management system is required around the world in many countries. In the recent advance technology intelligent water meter technology has improved the quantitative monitoring in water supply and distribution. Clear consumption patterns provided by AMR (Automated Meter Reading) can help customers to track and control their water usage and improve active leakage targeting and leak detection capability. The result of these experiments gives feedback about the use of the AMR system to detect leakage in a large-scale.

S.-C. Hsia[5] presents a highly accurate non-contact arrow sensor for a smart water metering. Oversampling techniques enable average detection accuracy exceeding 95%. They also employ a GSM/GPRS system to develop a highly efficient system capable of verifying and locating leakage. This system has a number of benefits: (i) an embedded low-cost digital meter uses non-contact arrow sensors; (ii) low-power metering system, in which power supplied is required onlywhen reading the meters; (iii) the hybrid meter is fully compatible with current mechanical meters and the installation is easy; (iv) automatic leakage detection system can solve existing water leakage problems. These advantages make the proposed smart metering system idealfor real-world applications.

Zhu Leiji[6] proposed a method of monitoring urban fire water supply system status based on hydraulic pressure mean value for the problem that the fire water supply system can't play its practical effect due to improper pressure when the fire actually occurs. This method collects water pressure data from the front-end hydraulic pressure monitoring equipment deployed at each node of the water network, uses the sliding filter method to weaken the fluctuation of the hydraulic data, and makes water network status judgment according to the deep characteristic between the water pressure average and its state transition. At the same time, the judgment results of state transition can be transferred in the form of events, triggering GPRS network upload cloud server. Test results show that this method can effectively monitor the status of the fire water supply system.

The water is one most significant resource for the human being and its existence. Due to migration of the people from the rural to urban areas the population is rapidly growing in the cities. To match the water requirements in this M. M. Srihari[7] proposed the novel approach based on IoT i.e. Internet of Things. There is a different type of sensor is used to measure water flow through a pipe the sensor is water flow sensor, pH Sensor, water control valve, and microcontroller. Thus the distribution water and the management of water flow through the pipe.

Water is one of the basic needs of human life. In today life the water is supplied to us by various via such as water tankers or by the water which is stored in dams for future usage. The water is passed by the many stages to through pipes from the dam or from the water which stored for us to reach our home. Thus the uncontrolled water flow is a major cause of consumption of water. A. Manoharan [8] proposed the methodology work mainly in the villages as Smart Village Projects. This system continuously monitors the quality of water also the level of the water from all the tanks where the water is stored all this observed under the one roof. Thus the distribution system saves the water.

Water is one of the important substances in the smart buildings where their monitor key system and units are observed quality or consumption of water. Water is one of the most discussed and commodity as it is one most important substances. J.Fikejz [9] proposed the methodology deals with a smart water meter for monitoring water the consumption and the for the leakage detection. There is a hardware part consists of mini-computer and pulse water meter this software evaluates the water consumption patterns. The water meter further increases with a backup battery and is, therefore, able to use its own power source for a certain period of time in the event of a power outage.

L.MA [10] proposed the fault hierarchical diagnosis method based on two-stage neural network for the leakage fault positioning and diagnosis of water steam circulation system of the boiler-turbine unit. The method first locates the fault subsystem and then diagnosis the fault type and severity. Then the intelligent fault diagnosis zoom technology was employed to realize real-time diagnosis of the leakage faults with different severity degrees under variable loads. By taking the water-steam circulation system of a 600MW supercritical power unit as object studied, detailed fault diagnosis tests are carried out on the full-scope simulator of the given unit, and the validity of the method is verified.

Water is one of the rich resource and most used and consumed resource today's life and so there is a need to take the contamination of controlling resource and checking the wastage of its. As the use of the water in the households and in industries is growing as the population growth constant high. There is some recycling and water treatment plants use for the conventional use of the water as the growing needs of the water. P.Gaonkar[11] presented the challenges of the water management system and automation water management system they should come with the better approach of the water management system.

Kazeem B. Adedeji, YskandarHamam, BolanleTolulope ABE and Adnan M. Abu-Mahfouz [12] presented the survey of the important aspects of the water management system leakage detection in pipelines. There is plenty amount of water is wasted whenever the leak is detected in the pipelines. Detecting the leak and taking the measures on it is one of the challenging parts in the leak detection system. It is crystal clear from this survey that the current leakage detection methods have different accuracies, cost of deployment and applicable environments. Nevertheless, combining several leakage detection methods to form a hybrid system is a common practice and is recommended. It is understood from the review presented that the existing methods are to some extent, able to detect burst type leakages.

Water is a very basic need of human life. There as to be a proper distribution system and the good management system. By distribution system the processing settlements, offices, and industries which consume the water. To distribute sufficient water to the customers need the good pipeline system which can handle the basic things such as quality, quantity, and pressure if anything fails of this may cause the leakage and there be the loss if water. A. EjahUmraeniSalam,MuhTola, Mary Selintung and Farouk Maricar [13] proposed a detector of the leakage that will be used computerized through Support Vector Machine (SVM) method. The output of this Leakage Detection System is in the form of a model which detects the size and the location of the leakage on the pipe.

III PROPOSED METHDOLOGY

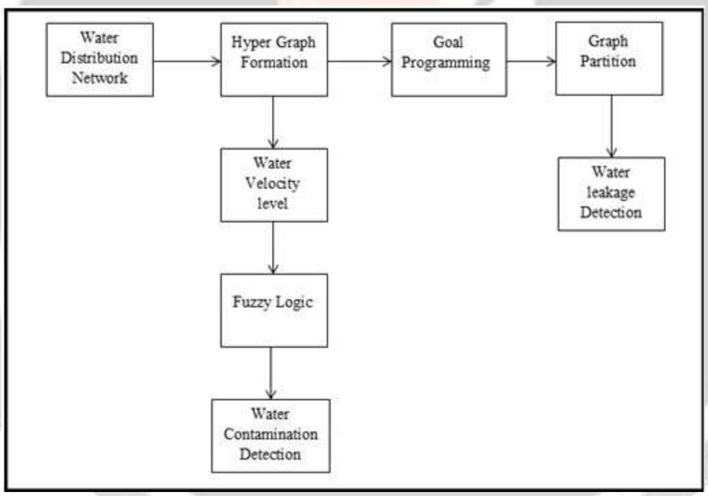

Figure 1: Proposed Methodology System Overview

The Proposed methodology of water leakage detection and water contamination level measurement is depicted in the figure 1. And the steps involved in this process are explained with the below mentioned steps.

Step 1: Goal programming - This is the initial step of the proposed model where the whole process of water leakage and water contamination detection is simulated in Java Applet and Goal programming. The simulation consists of one overhead tank of 1000 Liter and 5 small tanks of 200 Liters. Here a goal is set to fill the all the 5 tanks if all the 5 taps were Opened.

Simultaneously system is designed to have the 5 random leakage points. These leakage points are randomly assigned using the random number generation technique. As the leakage is increasing the flow to the tanks are also decreased. Based on this the leakage is estimated.

To generate the leakage points 5 pair of possible points is set to generate the random number between them. The goal set to generate the leakage is purely based on the random number generation. So where the leakage can be generated that cannot be pre decided in the designed simulation environment. For each of the leakage points all the taps that are correlated with that point is going to receive less amount of water flow. And this can be clearly seen in the developed simulation environment.

For each of the randomly applied leakage points a flow of 7 milliseconds is going to differ. Based on this, filling time of the tank varies that eventfully leads to leakage detection.

Hyper graph generation - Here this step involves the detection of leakage point correlated taps. In the simulated environment the tap1 is depends on the leakage point 1 and point 2. Tap 2 depend on point2. Tap 3 is depend on point 3, Tap 4 is depend on point 3 and point 4. And the Tap 5 is depends on point 3,4, and 5 respectively. Based on this protocol a hyper graph is created as shown in figure 2 and algorithm 1.

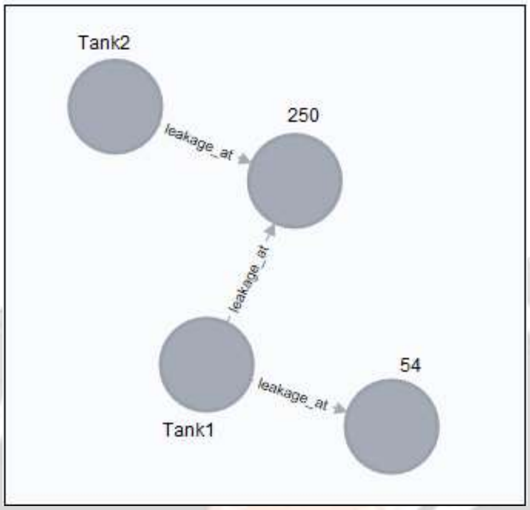

Figure 2: Hyper graph for Leakage Point Detection

Algorithm 1: Graph Formation

// Input: Tank Set T= $\{T_1,T_2,T_3,T_4,T_5\}$
Leakage Points $L_P = \{ P_1,P_2,P_3,P_4,P_5\}$
// Output: G_{SET} (Graph Object)
Function: graphFormation(T, L_P)
Step 0: Start
Step 1: $G_{SET} = \emptyset$
Step 2: ***for*** i=0 Size of T
Step 3: ***for*** j=0 Size of L_P
Step 4: **IF** $T_i \in L_{Pj}$, **THEN**
Step 5: Create Node and Edge $T_{emp}=T_i \rightarrow L_{Pj}$
Step 6: $G_{SET=} G_{SET+} T_{emp}$
Step 7: **End *for***
Step 8: **End *for***
Step 9: return G_{SET}
Step 10: Stop

Step 3: Fuzzy Classification for Water Contamination Level Estimation - The proposed model is developed to simulate to add the contamination in water randomly based on the random number generation model. So Proposed model measures the amount of the added contamination and the effect of the flow into the pipes. Then this is given to fuzzy classification to estimate the level of the contamination based on the fuzzy crisp values like VERY LOW, LOW, MEDIUM, HIGH and VERY HIGH. This process is depicted more clearly using the algorithm 2.

Algorithm 2 : FUZZY CLASSIFICATION

// Input : Contamination Level C_L , Max Level M_L
// Output : Probability String P_S
Function : fuzzyClassification(C_L , M_L)
Step 0: Start

Step 1: C_{SET}= Ø [Fuzzy Crisp Set]
Step 2: DIST= (M_L - 0) / 5
Step 3: ***for*** j=1 TO 5
Step 4: R1= 0
Step 5: R2= R1+DIST
Step 6: T_{SET}=Ø
Step 7: $T_{SET [0]}$= R1 , $T_{SET [1]}$= R2
Step 8: ADD T_{SET} TO C_{SET}
Step 9: R1= R2
Step 10: **End *for***
Step 11: ***for*** i=0 to Size of C_{SET}
Step 12: T_{SET} = C_{SETi}
Step 13: $T_{SET [0]}$= R1 , $T_{SET [1]}$= R2
Step 14: **IF** C_L >=R1 AND C_L <= R2
Step 15: $P_{S=}$ C_{SETi} .Value in String
Step 16: **End *for***
Step 17: return P_S
Step 18: Stop

IV RESULT AND DISCUSSIONS

The proposed methodology of water leakage detection and contamination level estimation is deployed in windows operating system based laptop. The laptop has equipped with processor of Intel Pentium Core i5 and Primary memory of 6GB. To deploy the model proposed system uses the Java Programming language and Netbeans 8.0 as the IDE and neo4j as the advanced graph database.

To measure the effectiveness of the proposed model Mean Reciprocal ratio (MRR) is used. The MRR is used to measure the ranks given to a system by the user.

The RR is called as the Reciprocal Rank, the values of the ranks are given from best to worst outcomes. These ranks are assigning like 1,1/2,1/3,1/4,1/5,0,0 respectively from best to worst. This MRR can be measured using the below equation 1.

$$MRR = \frac{\sum_{i=1}^{N} 1/Rank_i}{N}$$

The mean reciprocal rank (MRR) is the average score over all assigned ranks.

Where,

N - Number of Trails
i- Trail number
Rank - Rank provided by the user

Experiment NO	No of Lekage Points	MRR
1	1	0.88
2	2	0.77
3	3	0.78
4	4	0.89
5	5	0.84

Table 1: MRR Reading

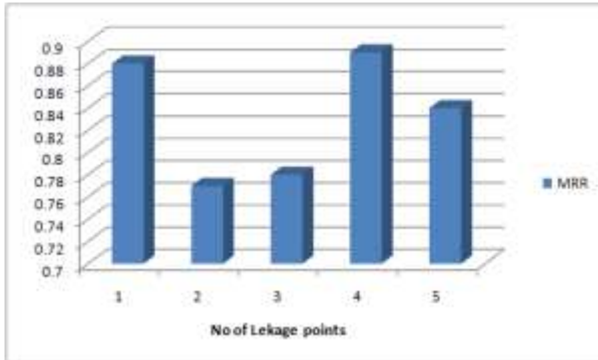

Figure 3: MRR Performance

The proposed model conducts the five experiments, each of the experiment contains the 5 trials. Then for each trails ranks are being given and they are summed up and get the average based on the equation of MRR. The tabulated result can be shown in table 2 and the figure 2 indicates the plot for the same. The proposed model yields the average MRR of 0.83 that is actually a good result in the first trail of the deployment in simulated environment.

V CONCLUSION AND FUTURESCOPE

Water leakage and contamination detection process need much more effort as it involves the many hardware instruments and the work is tedious too. So as an effort to provide an alternate approach for water leakage and contamination detection proposed system designs a simulated environment of Water distribution network using the Applets of Java. In the designed system, it contains one overhead tank of 1000 Liter capacity and 5 tanks of 200 liters. The leakage and contamination are added into the system randomly using random function. The Leakage points are identified using the goal programming and hyper graph formation techniques. Where hyper graph yields the relation between the correlated taps and leakage points. The contamination is evaluated using the fuzzy classification process to estimate the level of the contamination in the water.

In the future this system can be improved using the deployment of the same model in real time with the proper water distribution network.

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