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A Leakage Detection System on the Water Pipe Network through Support Vector Machine Method

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Abstract— **Clean Water is the primary and basic need for human. Thus, the provision of it has to be assured by preserving the quality, quantity, and also the pressure. However, in fact, there are many leakage cases in the distribution process which become the world's problem. One of the causes of the leakage, technically, is the leakage on the pipes. The leaky pipe changed the pressure on each junction / node in water pipe network. The pattern of the pressure changes, then, is able to be analyzed computationally to detect the location and the size of the leakage. In this research, there is a detector of the leakage that will be used computerized through Support Vector Machine (SVM) method. As the research material, there is Water Pipe Network System in Taman Khayangan Resident Makassar which was made by using EPANET 2.0 software. The data of the Pipe Network System is obtained from the Data of Drinking Water Local Company (PDAM) of Makassar. The output of this Leakage Detection System is in the form of model which detects the size and the location of the leakage on the pipe. The results of the simulation showed that the SVM method is relatively accurate in predicting by resulting the RMSE average of 0.06785 for the leakage size and RMSE = 0.1382 for the leakage location.**

Keywords--- ***Leakage of pipelines, Support Vector machine (SVM), EPANET 2.0, Root Mean Square Error (RMSE).***

I. INTRODUCTION

Water is the primary need in human life. Thus, it needs a good management and distribution. By using a distribution system, it will bring processed water in processing installation to the settlements, offices, and industries which consume the water. To distribute water to the consumers with a sufficient quality, quantity, and pressure, it needs a good piping system. However, in its distribution process, sometimes there is some water lost problem caused by the pipe leakage.

One of the disadvantages in water processing and distribution system is the pipe leakage problem. Generally, the pipe leakage is categorized into 2 categories, i.e. technical and non-technical leakage. A technical leakage is a pipe leakage, especially for the leakage happened underground. Whereas, the non-technical leakage is in the form of missed registering, illegal consumption / connection on water pipes, etc.

PDAM is a company which provides a clean water service for all civilians in Makassar. However, its service is still low and experiencing the pipe leakages. All this time, in order to solve the technical leakage, PDAM conducted 2 stages to detect the leakages, i.e. step test analysis method and sounding method. Step test method is a method applied as the scoping stage of the network to restrict the area of water flow to predict the location or the size of the leakages. The step test method is needed to determine the network monitoring priority to the leakages. The implementation of step test method is one of the most effective ways to identify water leakages on the distribution network. The next stage conducted to determine the location of the leakages is absolutely conducted by using sounding technique. Sounding technique is a technique which uses a portable tool which detects the sound wave emerged throughout the pipe indicated the leakage on the pipe. However, both methods are proven to be less effective in solving the leakages. It was caused by the lack of experienced manpower and limited detection tools.

The effect of the pipe leakage is the change of the pressure on each junction node in the water pipe. The pattern of the changes can be analyzed computationally. The development of the computerization technology enables the detection process to be no longer conducted manually by using the tools but using the computer.

One of the ways in analyzing the pressure change pattern is by using the artificial intelligence method to identify the pattern based on the data of the water pressure measuring results. The pattern identify technique can be used to solve this problem is Support Vector Machine (SVM), that is a learning machine method which works over the Structural Risk Minimization (SRM) principle in order to find the best hyperplane which separates 2 class of input space and can process the data in a high dimension.

II. METHODOLOGY

The purpose of the research is to predict the location and the size of the leakage on the pipe channel in its junction based on the data of the pressure changes when the leakage happens using Support Virtual Machine (SVM) method. Generally, the schema of the research is shown in figure 1.

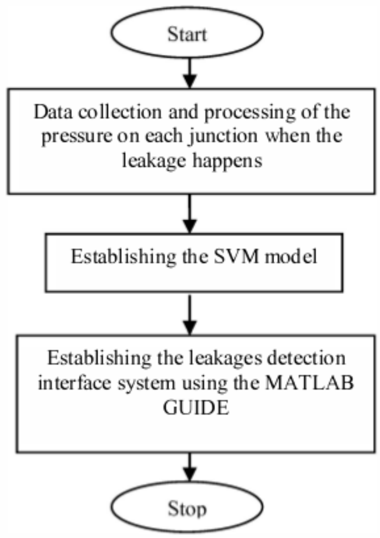

Figure 1. General Stages of the Research

A. Type of the Data

The data used in this research is the data of the pressure changes on each junction inside the pipe network in Taman Khayangan Resident Makassar when the leakage happens. This pressure data, later, used to predict the location and the size of the leakage happens in the pipe network by applying the Support Vector Machine method.

In the data processing, the data is processed by using the Support Vector Machine (SVM) to obtain the good prediction results with a high accuracy. It needs many training data, so it needs the data of the pipe leakage which will be hard to be obtained by using the actual data available on the field. So that, the Training data can be obtained from the simulation results using the pipe network software, EPANET 2.0, which is a software of hydraulic system used by PDAM in monitoring the pipe network. The Pipe Network System in Taman Khayangan Resident Makassar by using the EPANET 2.0 Software can see in figure 2.

B. Data Taking Technique

In Data Taking Technique, the first step to do is establishing the pipe network using EPANET 2.0 software by arranging the input data from PDAM of Makassar in the form of the magnitude of water debit on the reservoir as the primary source of the water flow in the pipe network, length and diameter. The magnitude of the elevation and demand (the average needs of water on each junction), and the roughness level on each pipe based on the field data in Taman Khayangan Resident Makassar [2].

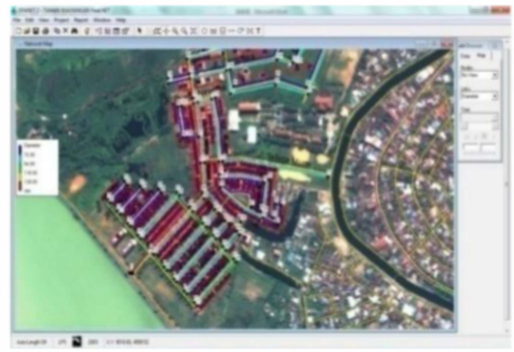

Figure 2. The Pipe Network System in Taman Khayangan Resident Makassar by using the EPANET 2.0 Software.

After establishing the pipe network using EPANET 2.0 software, the next step is creating the leakage simulation by changing the emitter coefficient on the junction which will be set as the leakage point. Emitter is a tool associated to the junction which is the model of the flow passing the nozzle of orifice released to the open air. The function of the emitter on EPANET is as the following [1]:

$$EC = Q / P^{P\ exp} \quad (1)$$

Where *EC* is the emitter coefficient, *Q* is the water debit, *P* is the fluid pressure, and *P exp* is the pressure exponent. So that, the emitter coefficient is the debit of each pressure unit of liter unit per second per meter of the pressure ($L\ s^{-1}\ m^{-1}$). For the head nozzle and the sprinkler of *P exp* as same as 0,5. The emitter coefficient used for the leakage simulation training is starting from 0.0005 up to 0.01 with the interval of 0.0005. The magnitude of the average pressure in the pipe network is 15.81486172 m. Thus, for 0.0005 of the emitter coefficient will result the leakage of 0.007 L/s. So that, the size of the simulated leakage is ranging from 0.007 L/s up to 0.14 L/s. For example, the second pipe leakage simulation (pipe 7-8) is set to be 25 sets of leakage case in the junction and 100 sets of leakage case in the pipe. Both of the leakage pipes is made in each leakage spot which has a distant of 4 meters each and the emitter coefficient of 0.0005 – 0.001. Therefore, overall, there are 19.320 data for the size and the location of varied leakages. To detect the leakages happened on the different pipe, it should use the different model. It caused by the pattern of the pressure changes on the junction when the different leakages happen on each pipe. The position of the pipes and junctions on in the pipe network in Taman Khayangan Resident, Makassar can see in figure 3. After taking the data, the SVM system is arranged using the Matlab R2008a application.

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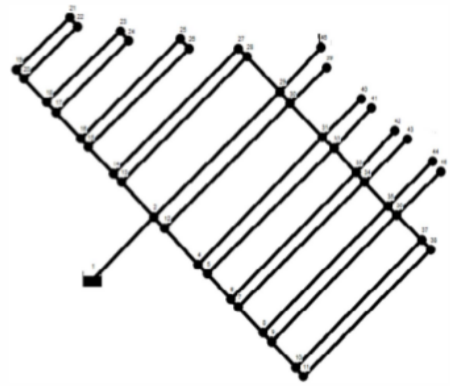

Figure 3. The position of the pipes and junctions on in the pipe network in Taman Khayangan Resident, Makassar.

C. The Training Process of using Support Vector Machine (SVM)

The purpose of the training in Support Vector Machine (SVM) method is to make the system able to identify the data pattern of the junction 1 to 44 in each leakage size and location. The training data used is the input data in the form of the pressure from the junction 1 to 44 which are symbolized by the ins data. Whereas, the lab data is used for the size and the location of the leakage. This input data, then, will be processed by the kernel of the Radial Basis Function (RBF). The purpose of the kernel determination is to ease the SVM learning process and to determine the support vector. The prediction process of the location and the size of the leakage in the pipe junction and in the pipe channel in the system are using an input variable, i.e. the pressure data in each junction. The flowchart of Support Vector Machine (SVM) can see figure 4.

The steps in the Support Vector Machine training process are as follow:

1. Containing the data of each variable input from the pipe pressure data as the training data, where the input data is the data of each junction and the target data is the size and the position of the leakage.
2. Calculating the kernel matrix using the Radial Basis Function (RBF) kernel to generate the *K* value.
3. Finding out the optimal a value.

III. THE RESULT

The results of the size and location of the leakage prediction of the training data as the test data on the pipe 11-38 (the pipes between junction 11-38) and pipe 7-8 (the pipes between junction 7 and 8) can be shown respectively in figure 5 to 8.

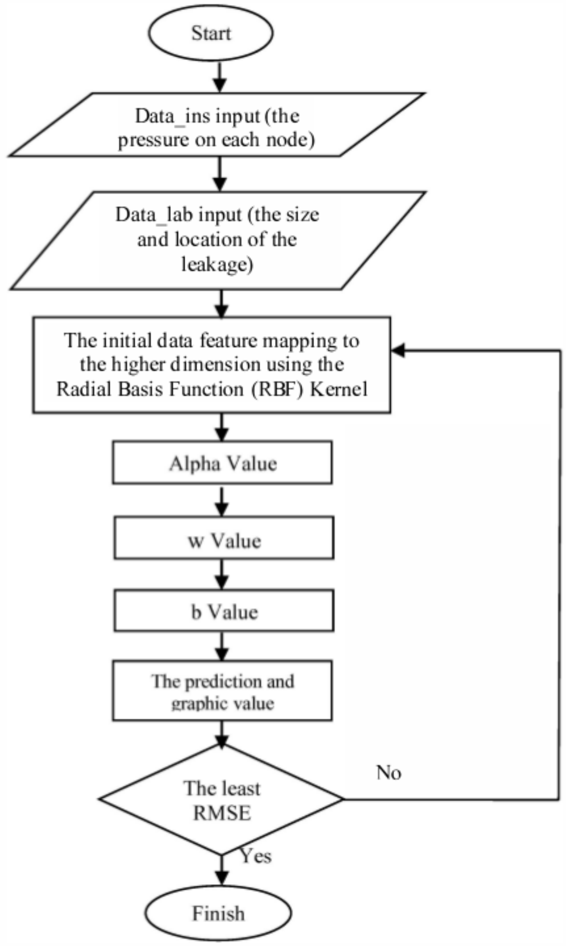

Figure 4. The Support Vector Machine (SVM) Flow Diagram.

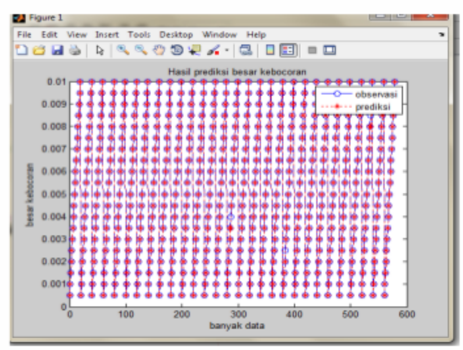

Figure 5. The graphic of the prediction results of the leakage size with the training data as the test data on the pipe 11-38.

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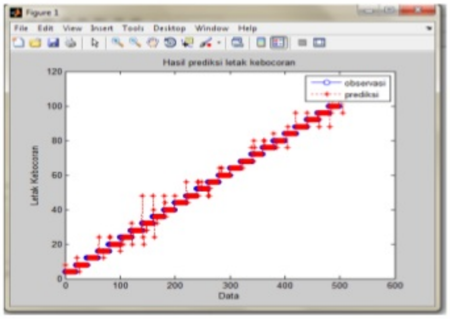

Figure 6. the graphic of the prediction results of the leakage location with the training data as the test data on the pipe 11-38.

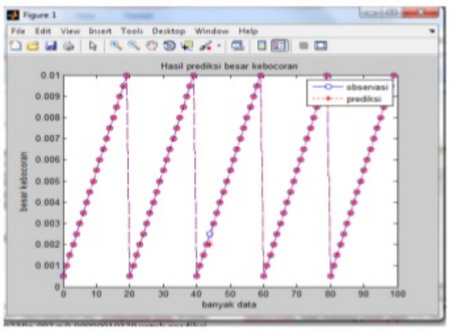

Figure 7. The graphic of the prediction results of the leakage size with the training data as the test data on the pipe 7-8.

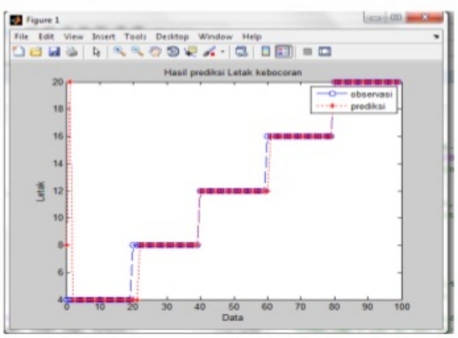

Figure 8. the graphic of the prediction results of the leakage location with the training data as the test data on the pipe 7-8.

Meanwhile, the prediction results of the size and location of the leakage with the test data outside the training data on the pipe 11-38 and pipe 7-8 can be shown respectively in figure 9 to 12.

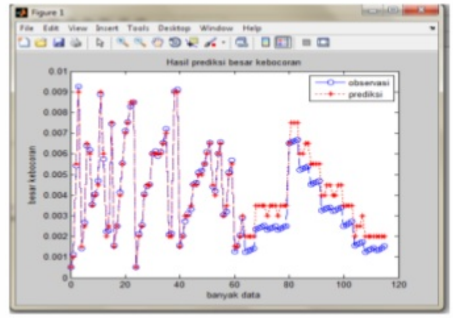

Figure 9. The graphic of the prediction results of the leakage size of the test data outside the training data on the pipe 11-38.

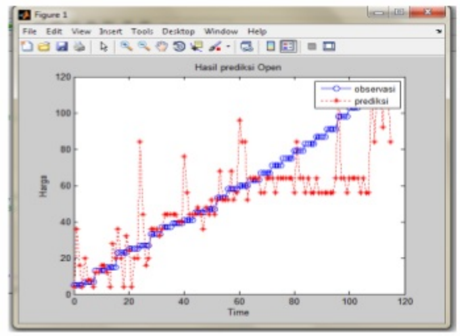

Figure 10. The graphic of the prediction results of the leakage location of the test data outside the training data on the pipe 11-38.

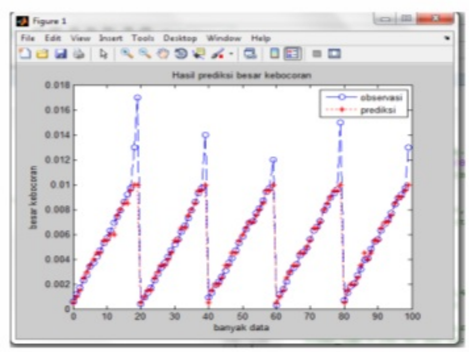

Figure 11. The graphic of the prediction results of the leakage size of the test data outside the training data on the pipe 7-8.

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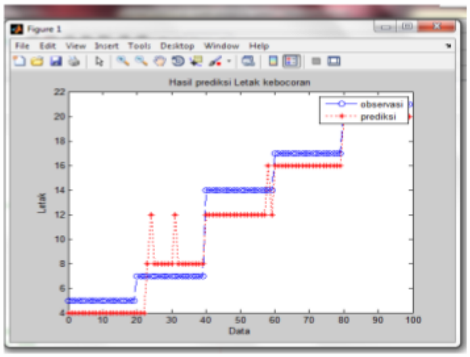

Figure 12. The graphic of the prediction results of the leakage location of the test data outside the training data on the pipe 7-8.

Validation is the process conducted to see the model reliability in conducting the prediction. The magnitude of error of the prediction results from the established model can be calculated by using the RMSE (Root Mean Square Error) calculation. The magnitude of error showed the difference magnitude between the prediction results and actual data. The lower RMSE value, the more accurate the prediction results. To find the comparison of the performance accuracy of the Support Vector Machine (SVM) method prediction can be seen on the Root Mean Square Error (RMSE) value. The RMSE value can be calculated by using SVM with the formulation as follows:

$$RMSE = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{n}(P-a)^2}}{Pmax - Pmin} \quad (2)$$

Where :

N : The total of the input data
P : Observation value
a : Observation results value
$Pmax$: The maximum value of the observation data
$Pmin$: The minimum value of the observation data

TABLE I. THE PREDICTION RESULTS OF SUPPORT VIRTUAL MACHINES METHOD BASED ON THE RMSE VALUE.

The Pipe Models	The test data from the training Data		The test data from the outside training Data	
	Size of Leakage	Location of Leakage	Size of Leakage	Location of Leakage
Pipe 1138	1.0739e-007	0.0269	0.0709	0.1812
Pipe 78	0.0000005	0.0320	0.0648	0.0952

Figure 13. The display of the prediction results on GUI

By using the GUI interface, the use of this system will ease the user in detecting the leakage. By using the available buttons, the input of the pressure data that will be tested can be conducted easily and the results display of the program that will be conducted in the form of the leakage location and size will be seen directly. The display of the prediction results on GUI can see in figure 13.

IV. CONCLUSION

The detection of the leakage location using Support Virtual Machine method obtained the average RMSE = 0.06785 for the leakage size and RMSE = 0.1382 for the leakage location. These RMSE values showed that the created RMSE values can detect the leakage location and size on the pipe network relatively accurate.

The average of the accuracy of the leakage size and location prediction is 85.68% for the leakage size and 76,14% for the leakage location.

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