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Application of SVM and ELM Methods to Predict Location and Magnitude Leakage of Pipelines on Water Distribution Network

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Abstract

In this research, the system of leakage of pipelines detection will be done by a computerized technique by using analysis of pressure monitoring as a determinant of presence of pipeline leaks in the water distribution network. The pressure data obtained from EPANET software, namely a modeling in a hydraulic system. This study uses two methods, artificial intelligence, namely Support Vector Machine (SVM) and Extreme Learning Machine (ELM) which the results can be compared in order to predict the magnitude and location of leakage. Overall, both of these methods can be used to predict the magnitude and location of leakage. The accuracy of predictions for the magnitude and location of leakage of these methods is based on the value of NRMSE. In this case the results obtained by using the method of ELM are more accurate compared than the method of SVM of the entire pipeline systems.

Keywords

Leakage of pipelines , EPANET, SVM, ELM, NRMSE.

1. Introduction

Water is an essential need in human life, thus the good management and distribution of water resource, are required. The distribution system carries the treated water from the treatment plant to the residential, office and water-consumed-industrial. To distribute the water to the costumers with sufficient quality, quantity and water pressure, it needs a decent piping system.

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But in the distribution process, loss of water due to leakage pipe occurred.
There are many methods used to detect the leakage. In outline, the leakage pipe methods are divided into two methods, acoustic method and non-acoustic method. Acoustic method is a technique using a portable device to sense sound waves that arise along the pipeline, the sound waves indicate a leakage point on the pipeline. The method is able to detect the fitting location at below the ground level. However, it has some weakness because it is distorted easily by its surrounding noises such as traffic sound. Also because, sound waves are highly dependent on pipe material used and signal strength depends on the land size and soil condition. Therefore, it is difficult to detect a signal from plastic pipe and skilled-experienced-labors are urgently needed on this method [1]. Non-acoustic method is performed by injecting tracing substances, Helium gas (He), into the pipeline. If there is a broken, or leaked pipe, the water and helium gas will come out of the pipe. The technique is a costly and high risk, because the water will be contaminated. Thus, it is uncommonly used for leakage detection.

With the development of soft computing technology, so it also develops the use of artificial intelligence methods for detection magnitude and location of pipe leaks. Because pipeline leak causes pressure changes along the pipe [2]. Therefore, it is possible to perform computerized analysis to detect patterns of change in the pressure of the leak. By using artificial intelligence makes it possible to study the changes in the pattern of pressure at every junction to predict the location and magnitude of leakage that occur in the pipe.

2. Literature Review

There have been many studies were done regarding to this matter. According Van Zyl, 2007, stated the relationship between the amount of leakage with pressure by comparing some leakage exponents [2]. Caputo and Pelaggage, 2003 stated using artificial neural networks in predicting oil pipeline leak from information from the pressure sensor [3]. Huang, G. B, et al, 2006, stated theori and Application from Extreme Learning Machines method [4]. According Mashford et all. 2009, is using the EPANET in modeling the water pipe leaks. Pressure data from EPANET used by the method of SVM to predict the magnitude and location of leakage up to 90 L/hour and the distance of prediction is 100 to 500 m [5]. A. Jalalkamali and N, Jalalkamali, 2011 stated using hybrid neural network and radial basis function in determining large of water leak in the distribution network [6]. De Silva, et al, 2011 is a continuation of previous studies by Mashford, 2009 with adding sensor instrument which has a sensitiveness toward the small leaks [7].

Therefore, in order to complete the previous studies, this research is done to compare Support Vector Machine (SVM) and Extreme Learning Machine (ELM) methods to determine the location and magnitude of pipeline leak in the water distribution system.

3. Methodology

3.1. The data retrieval

In the data process to obtain a good prediction results with high accuracy, it requires a lot of training data so that it takes the actual leak data contained in the field as training data. They can be obtained from the simulation results by using the EPANET 2.0 software [5]. It's the hydraulic system software is used by the Regional Watework Company in monitoring pipelines. The EPANET is a computerized simulation model produced by the Environmental Protection Agency of the USA that predicts the dynamic hydraulic and water quality. Leaks of various sizes can be simulated in EPANET and the resulting pressures in the network can be calculated.

In terms of data collection techniques, there are several things that must be done is to make a pipe network using EPANET 2.0 software, then enter data in the form of a large flow of water in the reservoir, the length and diameter of the pipe, the amount of elevation and demand (average water needs in each junction), and the level of roughness on each pipe in accordance with the data on Housing Parks Khayangan Makassar can be seen in figure 1.

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. The 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 [5]:

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

Where EC is the emitter coefficient, Q is the water flow to the surface, P is the fluid pressure, and P exp is the exponential pressure. Thus, the emitter is the discharge coefficient of each unit of pressure units of liters per second per meter pressure ($L.s^{-1}.m^{-1}$). For nozzles and sprinkler head P exp as 0.5. Emitter coefficient used for the simulation of leakage is ranging from 0.0005 to 0.01 at intervals of 0.0005.

The magnitude of the average pressure in the pipelines 15.815 m. From the eq(1), $Q = EC * P^{p\ exp} = 0.0005 * (15.815)^{0.5}$, thus the size of the water flow to the surface simulation ranged from 0.002 L / s to 0.4 L/s at a distance of 4 meters each. The data will be used as training data on artificial intelligence. For example, for a 78 pipe (pipe between junctions 7 and 8) with a distance of 24 meters produces 600 data leakage.

Figure 1 : Pipeline System of Khayangan Park Makassar by using EPANET 2.0

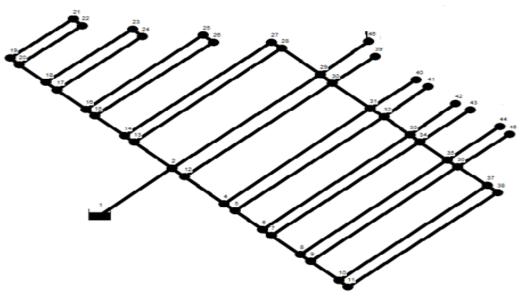

Figure 2: The position of the pipes and junctions on the pipeline network in Khayangan Park Makassar

To detect leaks that occur in different pipes, must use different models. It is caused by pressure on the crossing pattern changes when a leak is different in each pipe. The position of pipes and connections in the pipeline in the housing of Khayangan Park Makassar, Indonesia can be seen in Figure 2.

3.2. The Implementation of 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 on 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 leak. These data 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 44 junction. The flowchart of Support Vector Machine (SVM) can be seen in figure 3.

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

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 α value.
4. Determining the Super Vector, if $\alpha \neq 0$.
5. Finding out the w and b value using the determined support vector.

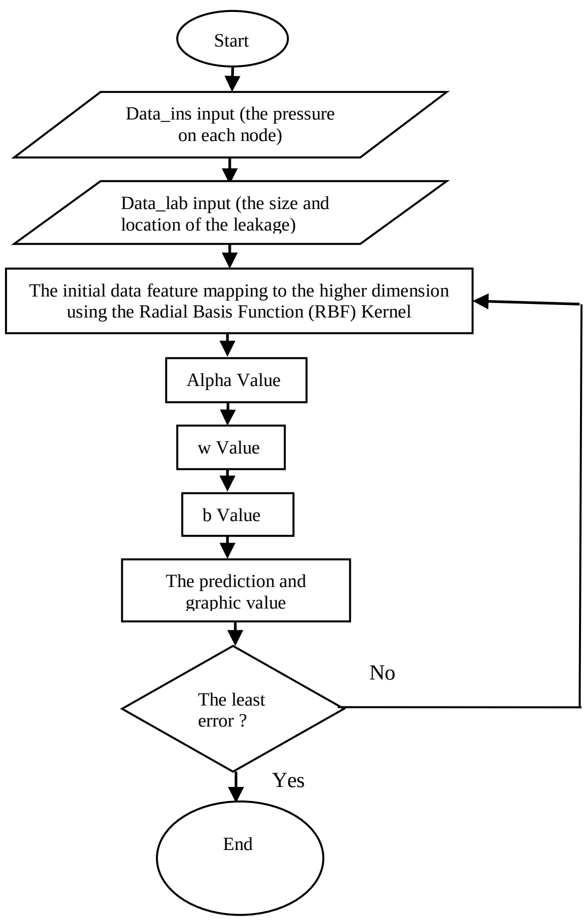

Figure 3 : The Support Vector Machine (SVM) Flow Diagram

3.3. The Implementation of Extreme Learning Machine (ELM)

There are several stages to be followed in implementing the method of ELM, Broadly speaking, these measures are divided into three phases:

1) **The division of data**
The division of data is intended to distinguish the input data is the pressure at 44 junctions and the data output (emitter coefficient and the location of leakage) on the training data and the testing data.
2) **Training ELM**
Before being used to forecast of leakage, ELM methods have to go through the training the process in advance to get the

input weight (w), biases (b) and the weighted output (ß) with the smallest NRMSE value. Flowchart ELM training can be seen in Figure 4.

3) **Testing ELM**
Once the training process, it will be obtained the input weight, biases and the output weight that will be used to the best predict pipeline leak from the testing data.

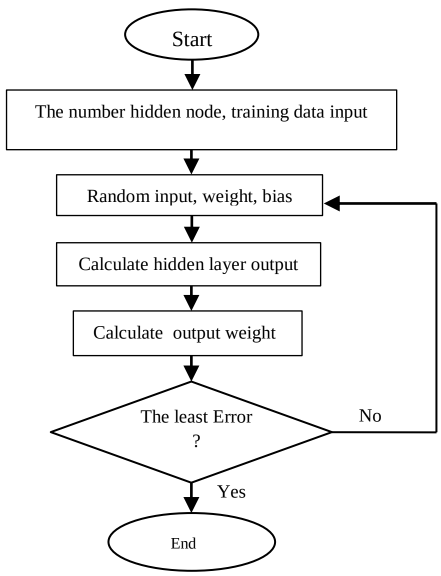

Figure 4 : The Extreme Learning Machine (ELM) Flow Diagram

4. Result

Both of these methods, both SVM and ELM analyzed using MATLAB software. After doing the training data for both methods, obtained a model for the entire pipeline on each method. Because there are 28 pipes in Housing Heaven Park Makassar, so there are 28 models of prediction for each method. After that, do the testing on every model of pipe for each method. The test data obtained also from EPANET software. Here is an example of a leak test data taken at random for 1138 pipes and pipe 78. The results of sample location and magnitude of leakage leakage predictions can be seen in Figure 5 and 6.

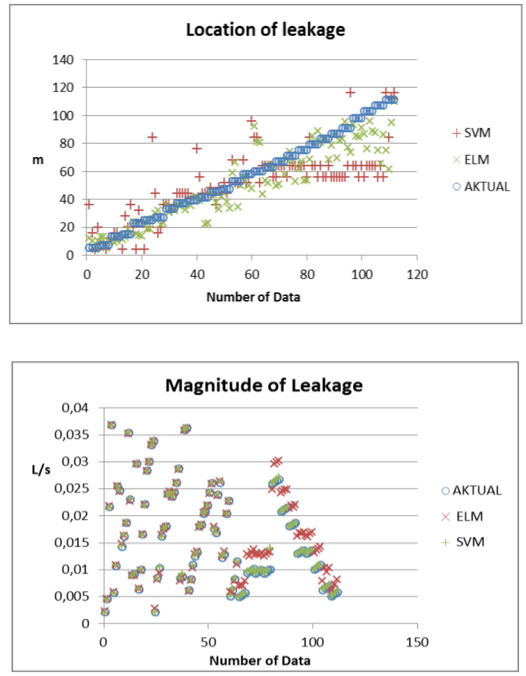

Figure 5 : Prediction of location and magnitude of leakage in pipe 1138

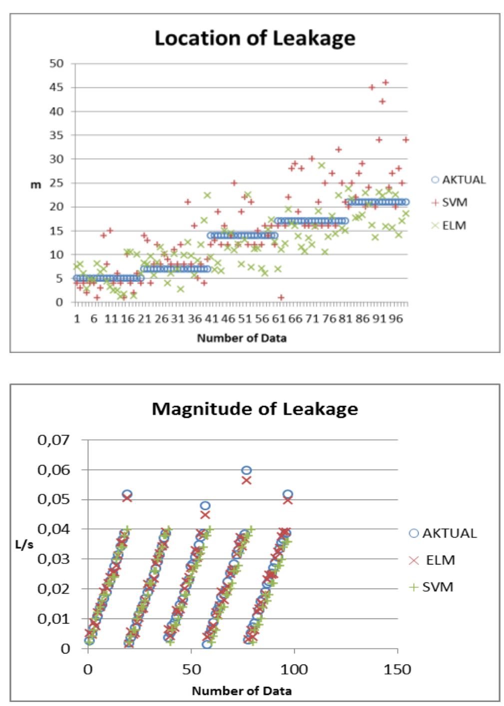

Figure 6 : Prediction of location and magnitude of leakage in pipe 78

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 NRMSE (Normalize Root Mean Square Error). The magnitude of error showed the magnitude difference between the prediction results and actual data. The lower NRMSE value, the more accurate the prediction results. To find the comparison of the performance, accuracy prediction of the Extreme Learning Machine (ELM) and Support Vector Machine can be seen from the value of the Normalize Root Mean Square Error (NRMSE). The NRMSE value can be calculated by the formula as follows:

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

Where :

N : The total of the input data
P : Actual value
A : The results of prediction value
P*max* : The maximum value of the actual data
P*min* : The minimum value of the actual data.

Example for using ELM methods to predict the location of leakage for pipe 1138, consist of the total of the input data testing 112 data, P*max* is 111 and P*min* is 5, $\sum(P\text{-}a)^2$ for 112 data is 17785, thus from eq(2), NRMSE value is 0.1188. The result average prediction from SVM and ELM methods based on NRMSE value for all pipe can be seen in Table 1.

Table 1: The Average Results Prediction Of SVM And ELM Methods Based on the NRMSE Value for all pipelines

Methods	Data test from the random data	
	Magnitude of Leakage	Location of Leakage
SVM	**0,1508**	**0,4258**
ELM	**0,1017**	**0,2063**

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. Results display of the program in the form of the leakage location and magnitude will be seen directly. The display of the prediction results on GUI can be seen in figure 7.

There are two buttons available in this application, the "input data" is used to open the excel file which is a data input pressure in 44 junction and the "prediction" to see the results of a large prediction and location of the leak. Field "Description" will display the predicted results in the map location will appear in the form of red-yellow dot flashing on the point of leakage.

Figure 7 : Layout of GUI Leak Detection System by using MATLAB

5. Conclusion and Future Work

This research compares two methods, artificial intelligence, namely SVM and ELM in processing the pressure value obtained at a number of junctions in water distribution networks. Training data were obtained from the EPANET hydraulic system modeling program. Overall, both of these methods can be used to predict the location and magnitude of leakage. Based on the NRMSE values was obtained 0.1508 and 0.4258 for SVM and 0.1017 and 0.2063 for ELM for predicting the magnitude and location of leakage from the whole pipeline. It shows that the ELM method more accurately predict than SVM method.

The accuracy of prediction for both methods is still small. This is due to insensitivity from EPANET programs in pressure data processing for a very small leakage ranging from 0.002 to 0.4 L / s. Future studies could use other artificial intelligence and programs hydraulics models which is more sensitive to small leaks.

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