Implementation of Artificial Neural Networks for Localization System on Rescue Robot

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***Abstract*— Localization system is one of the most important parts in mobile robot especially in rescue robot. Because the rescue robot is used to search, help and guide disaster victims through the safest path to the evacuation point. So a good localization system will determine the robot's success in order to find a safe path when it comes to branching. This localization system usually consists of sensor systems and pattern recognition algorithms. The catastrophic conditions cause the camera sensor, RFID, or odometers readings to be less than the optimum due to the lighting factor and the number of obstacles from the ruins. Under these conditions the ultrasonic rangefinder and compass sensors are good enough to use because it have a bit of interference. The use of these sensors as localization systems produces a difficult data patterns to identify. To ease the identification or pattern recognition problem, so this research is proposed a back propagation neural network algorithm. The neural network is used to process the input of a robot (distance to the wall), and the direction of the robot to produce the predicted robot position in the room. The neural network consists of two hidden layers that have 10 input variables and 6 output variables. In this study the robot is tested in a labyrinth with 6 branches. From the obtained test results, the neural network is able to identify the robot position with an accuracy of 80.62%.**

Keywords*— *Localization System, Back Propagation Neural Network, Rescue Robot

I. Introduction

Rescue robot is a robot that used to search, help and guide disaster victims to a safe evacuation point. In performing its duties, the robot must know its actual position within a certain time range. This affects the robot's success in taking the right path when it comes to a lane branch. In some studies, this system is called a robot localization system [1].

The robot localization system has been developed in several ways including artificial landmark [2], RFID [3], dead reckoning [4, 5], and several other ways. The use of artificial landmarks is less optimum, if the room is dark. In addition to the disastrous conditions, the use of artificial landmark will be damaged. Damage may also occur on RFID devices when implanted in a disaster-stricken building. Dead reckoning is quite precise to use but has a deficiency in case of skid on the robot wheel then the calculation results will experience an error. In almost case on the location of the disaster there are many ruins or other obstacles, so the slip on the robot wheel cannot be avoided.

To overcome this problem, an ultrasonic rangefinder and compass sensor can be used in localization system. The distance between the robot and the walls in the room and the direction of the robot will form a pattern that can be used as a positioning reference [6]. The produced pattern is difficult to recognize, so a pattern recognition method is needed. One method of pattern recognition that can be used is artificial neural networks [7, 8].

Based on the reason, in this research robot localization system will use an artificial neural network, with the concept of rocker-bogie robot. Before it being tested with the actual conditions, it is necessary to test the robot with a simple condition in a maze with a size of 3m x 3m.

II. Localization System of Rescue Robot

A. Rescue Robot

The rescue robot in this study is a rescue robot that has been developed since 2017 [9]. This robot has a rocker-bogie mechanical system that allows crashing an obstacle. This robot consists of three wheels on the side that each of them is attached to a rocker and bogie. The left and right side rockers are connected by a differential rod. The rescue robot and the rocker-bogie mechanism are shown in Fig 1.

The processing unit that used by this robot is STM32F4 microcontroller. To recognize the environment, the robot is equipped with ultrasonic rangefinder sensor, CMPS11 compass sensor, and Gas Sensor. 16x2 LCD is used to display sensor data readings and ANN algorithm results. The robot also has a L298 motor driver to set the motor direction and speed on each wheels independently. Hardware on rescue robot is shown in Fig 2.

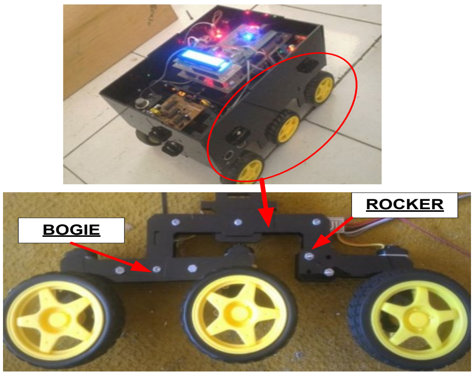

Fig 1. Rescue robot with rocker-bogie mechanism

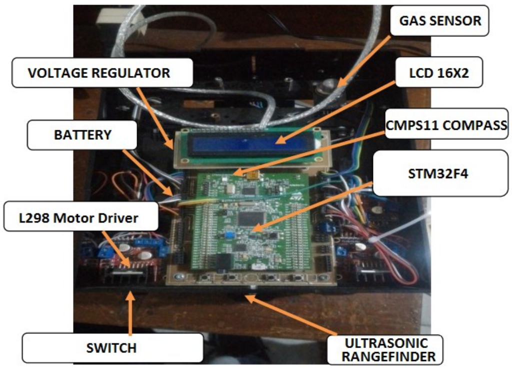

Fig 2. The rescue robot instrumentation

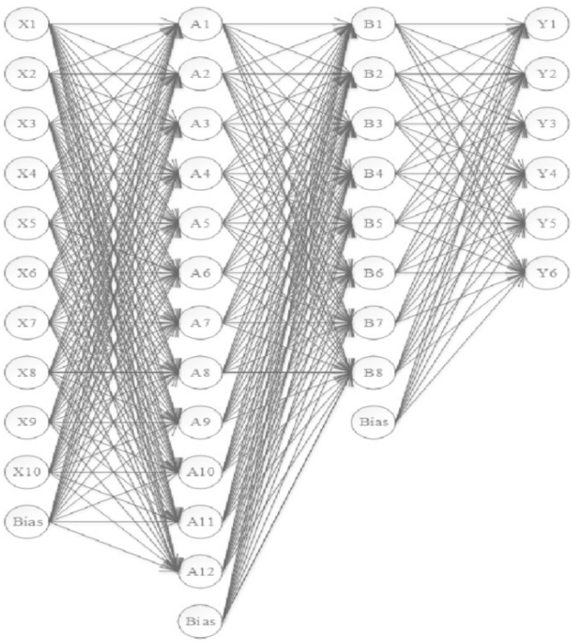

Fig 3. Neural network structure

B. Artificial Neural Networks Training on Computer

Back propagation neural network (BP-NN) is a computational system where the models have several similarities to the principle of human neural system [9]. Human nerves consist of several parts like soma, dendrites, and axon. In order to make this network is able to learn, it must be trained with some training data according to its topology. This network has 10 input variables (X1 to X10) and 6 output variables (Y1 to Y6), the used topology in this research is shown in Fig.3.

Computation begins by initializing the initial weight value with a small random value. The output value is obtained from the forward propagation. This process is done by entering the input layer to the output layer. Each node in the network provides an output that obtained from equation (1) for the first layer and equation (2) for another layer.

$$y_1 = f\left(w^1..x\right) \quad (1)$$

$$y_n = f\left(w^n.y_{n-1}\right) \quad (2)$$

$f(v_q)$ is a binary sigmoid activation function to transform an input into the desired output. This function transforms an input value to a normalized value of 0 to 1. The binary sigmoid activation function is shown in (3).

$$f\left(v_q\right) = \frac{1}{1 + e^{-\alpha vq}} \quad (3)$$

Forward propagation on the last layer will produce a predicted output. The difference of predicted output with the target on each node will make an error value that shown in (4). After error on each node is obtained, the next step is calculated mean square error (MSE) (5). Small MSE shows the neural network is capable to produce predicted output that closer to the target.

$$error_n = d_{nj} - y_{nj} \quad (4)$$

$$mse = \frac{1}{n}\sum\left(error_n\right)^2 \quad (5)$$

When the value of MSE is still greater than the tolerance, it means the system needs back propagation process. The process will update the value of initialized weights. The appropriate weights will make a small error. Weight changes are performed by using equation (6).

$$w_{ji}\left(k+1\right) = w_{ji}\left(k\right) + \mu\left(\left(d_{qj} - y_{2j}\right).g\left(v_j\right)\right).y_2 \quad (6)$$

Where:
- $w_{j,i}(k+1)$ = new weight
- $w_{j,i}(k)$ = old weight
- μ = learning rate
- $d_{q,j}$ = target

$g(v_j)$ is the first derivative of the used activation function. If the used activation function is a binary sigmoid (3) then the value $g(v_j)$ is:

$$g(v_j) = \alpha . y_n (1 - y_n) \qquad (7)$$

This algorithm is a process of learning and it was made by using computers. The results of the program can be seen in Figure 4. In addition to determine the learning data and the topology, the input programs of the system are: accuracy, learning rate, gradient activation function, and momentum update. The learning process is done when MSE is smaller than target or accuracy level.

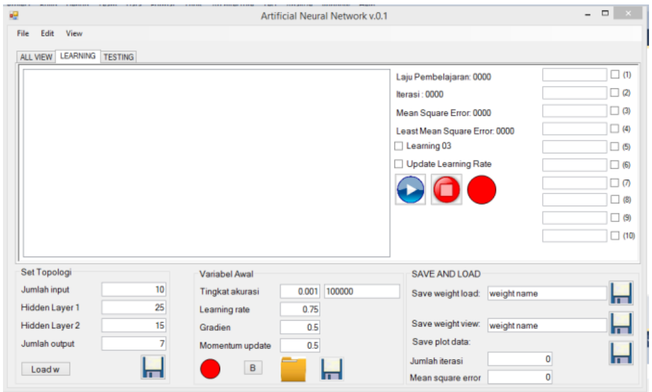

Fig 4. Display of ANN Learning Program

Data learning is arranged according to the format that shown in TABLE 1. Learning data is obtained by reading the distance between the robot and maze walls. The observed distance is the distance on the front, left, right, and rear side that corresponding to the placement of the ultrasonic sensor. The compass sensor will read the direction o the robot. The collection of learning data is done at points 1 to 6 and the position can be seen in Figure 5.

TABLE I. NEURAL NETWORK DATA TRAINING FORMAT

Front Distance (m)	Rear Distance (m)	Right Distance (m)	Left Distance (m)	Front + Rear (m)	Right + Left (m)	DIRECT-ION				POSITION					
						N	W	E	S	1	2	3	4	5	6
1,1	0,1	1,0	0,8	1,3	1,8	1	0	0	0	0	1	0	0	0	0
1,1	0,1	0,8	1,0	1,3	1,8	1	0	0	0	0	1	0	0	0	0
• • •															
1,1	0,1	0,8	1,0	1,3	1,8	1	0	0	0	0	1	0	0	0	0

Note : N=North, W=West, E=East, and S=South

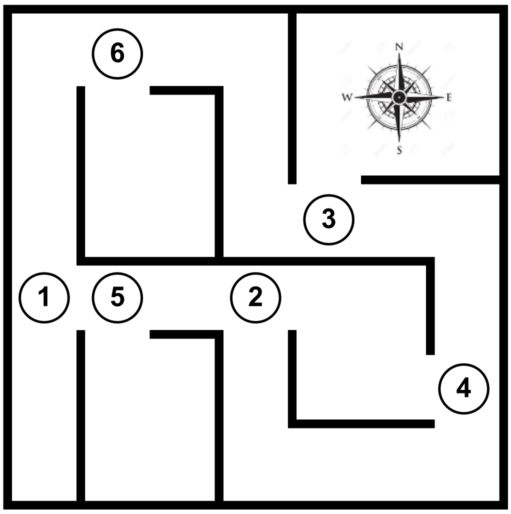

Fig 5. Test point position in the maze

In this study, the total amount of learning data is equal to 48 data. Learning process will continue until the MSE is less than 0.02. Observation of MSE is done every 100 times iteration and the obtained MSE from each iteration is shown in Figure 6. After the learning is finished then the weight is stored in the form of text file. The weight is then inserted into the robot microcontroller program.

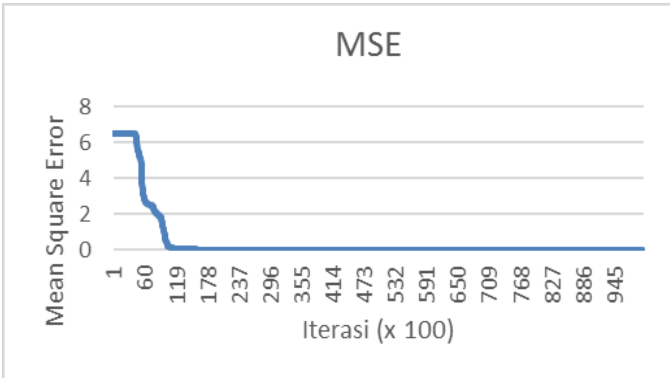

Fig 6. MSE performance

C. *Artificial Neural Networks programming on Robot*

After the learning process is completed, the obtained weights are stored in a text file. The weight value is inserted into the robot. Robot programming is done by using keil uvision because the used microcontroller is STM32F4. The weights are run by the feed forward process to determine the position of the robot in the maze. The program execution results are displayed in 16x2 LCD which shows the robot position. The display example is shown in Fig 7. The number "1" indicates the robot is in position 1.

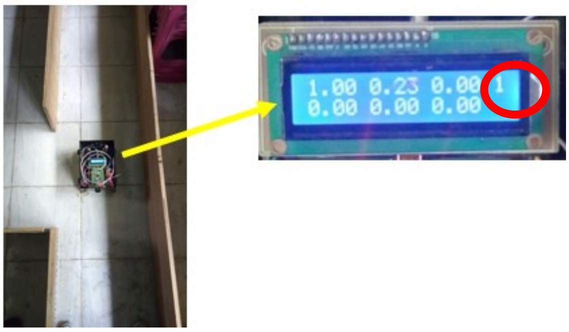

Fig 7. Results of applied artificial intelligence on the robot

III. Result and Discussion

Testing at points 1 and 2 is performed 10 times in each direction, so at point 1 is tested 40 times. From testing at point 1 the robot has successful to recognize the position correctly as much as 28 times. While at point 2 the robot can recognize as many as 34 times. Most of the errors in point 1 occur when the robot direction is in the south. This is happening due to the pattern reads that have the same pattern at another point. The test results at point 1 are shown in Fig.8.

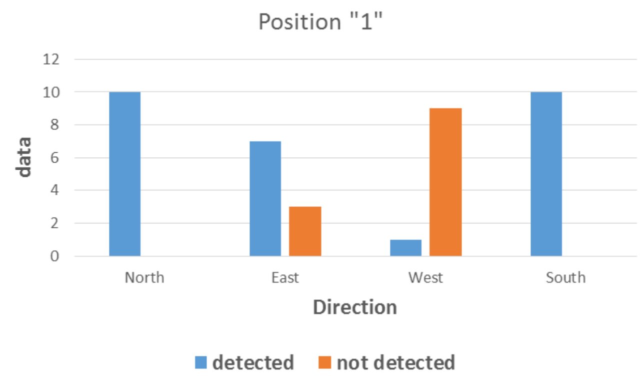

Fig 8. Test results at point 1

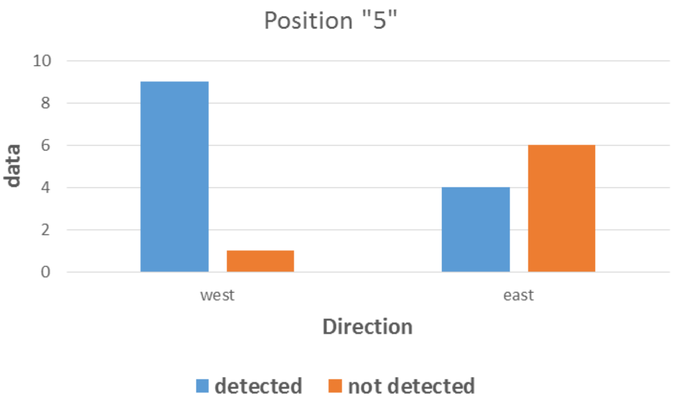

Fig 9. Test results at point 5

The tests at points 3 to 6 are performed only in the possible direction. For example at point 6 the robot only allows moving from east to west or vice versa, so the testing in another direction is not done. Testing is done 10 times or it means there are 20 times testing at each point. The best results are found in room 4, the robot can recognize the position without error. While at positions 3, 5, and 6 the robot is able to recognize the position of 17, 13, and 17 times respectively.

According to Fig.9, the test at point 5 has detected 7 errors. 6 of them are occurring when the robot position at west. This is quite similar with the testing at point 1 that experienced a fault detection when the robot at west. This error is happening due to the similar pattern reads when the robot is at point 1 and 5. This error may be solved by adding training data at both of these points. The results of the whole examination can be seen in TABLE 2.

TABLE II. OVERALL RESULT FOR POSITION RECOGNITION

Id	Working Point	Number of Testing	Number of Successful Testing	Percentage of Successful Testing (%)
1	Point 1	40	28	70
2	Point 2	40	34	85
3	Point 3	20	17	85
4	Point 4	20	20	100
5	Point 5	20	13	65
6	Point 6	20	17	85
Total		160	129	**80.62**

IV. Conclusion

Artificial neural network has been successfully implemented in rescue robot as a localization system to recognize their position in a maze. Based on the experimental results, the rescue robot can recognize the position with an accuracy of 80.62%. By adding the number of sensors and algorithm improvement will probably improve the results in future research.

Acknowledgement

The authors would like to thank all ITATS Electrical Engineering colleagues who have assisted this research. The authors also thank to the robotics laboratory that has provided the testing facilities.

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