Navigation System Based on Learning Vector Quantization Method for Robot Inspecting Object

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ABSTRACT

One of the tasks given to the robot is to work in unpredictable environments. The physical limitation of human needs a robot to facilitate the work. In this study, the mobile robot has been designed to navigate in inspecting target or suspected objects. The Learning Vector Quantization (LVQ) method was implanted in the robot to navigate around the object. This experiment has been carried out in the arena, and the objects were rectangle, triangle, and circle shapes. The experimental results show that the robot can navigate around these objects with both the movement from the right side and the left side. The mobile robot can maintain the distance from objects ranging from 30 cm to 40 cm with the time required to surround the rectangle object and reach one rotation being 17 seconds, for the triangle object 14 seconds, and the circle object 12 seconds.

Keywords: Learning vector quantization, mobile robot, navigation system

1. INTRODUCTION

Robots are useful in helping human work such as in education, industry, medical, security, and even areas that are difficult to reach. The use of robotics is a good choice in areas that are difficult to predict, such as bomb tracking, investigation, and monitoring. Because of the physical limits of human, we require some kind of media to replace human position or job. In recent years, many objects have been found deliberately placed by strangers. The object is of concern to citizens because it is suspicious whether it contains elements of danger or not. Therefore residents feel worried about inspecting the object, so they ask for help to security officers. Meanwhile, security officers also use tools to check the suspicious object in anticipation that the object is indeed dangerous.

The development of robot technology is overgrowing and is very impacting on human life. Such as robots that are like a vehicle, food delivery robot, robot for a wheelchair, and so forth. These robots are generally equipped with a navigation system, being both manually and automatically controlled. In the field of security, manually controlled robots have been carried out for environmental monitoring [1],[2]. Whereas in robots with automatic navigation systems, target search become an example [3]. In general, the type of steering robot that is often used is the type of differential drive. This type of steering allows the robot to navigate non-holonomically in the environment. The robot can move forward, turn left or right because of changes in speed on the right and left wheels. Therefore, a good navigation system needs to be implanted with a processor-based intelligent system.

On the other hand, the use of an intelligent system is widely used in a control system, such as automation machines and even robots. The use of an intelligent system in robots that have been carried out by researchers for example is automatic navigation where the robot can determine the action of movement based on information from sensors [4],[5]. The intelligent system methods in robots that already exist use fuzzy logic [6] and artificial neural networks [4],[7]. The fuzzy logic system consists of a set of logic rules that are designed based on experience. The neuron architecture in artificial neural networks and learning algorithms is used to recognize or classify the state of the environment. The learning algorithm in neural networks has two general methods, including supervised and unsupervised. In this study, the artificial neural network method was applied based on supervised learning, and the chosen learning algorithm was Learning Vector Quantization (LVQ). The reason for selecting LVQ is because the learning process is simple, and the response is fast so that it can be programmed in a microcontroller that has a small memory. This LVQ implementation is embedded in a robot to navigate around objects.

2. METHODS

A. Mobile robot

The mobile robot is a system that can move freely using an actuator, such as wheels or legs. In this study, a mobile robot that was designed is equipped with eight proximity sensors, a microcontroller, two drivers, and two electric motors with the type of metal Gearmotor. This mobile robot has a diameter of 40 cm with an octagonal shape. Fig. 1 shows the physicality of the mobile robot and its supporting components. Based on Fig. 1, the proximity sensors are divided into three parts, including the left,

right, and front. On the left and right sides, each has three sensors, and the front has two sensors. The sensors on the left and right sides function to navigate around the object, while the front is used to avoid obstacles. These sensors are proximity sensors with analog outputs, so they need to be converted to digital values. The proximity sensors are each made provisions for detecting distances from 10 cm to 100 cm. The distance values will be a pattern drawn by the system, and the robot will activate behavior based on the stimuli of the sensors. Fig. 2 shows the architecture of behavior in the mobile robot. The behavior of the robot to navigate around the object is using the LVQ method, while the behavior of avoiding obstacles is based on logic 1 and 0.
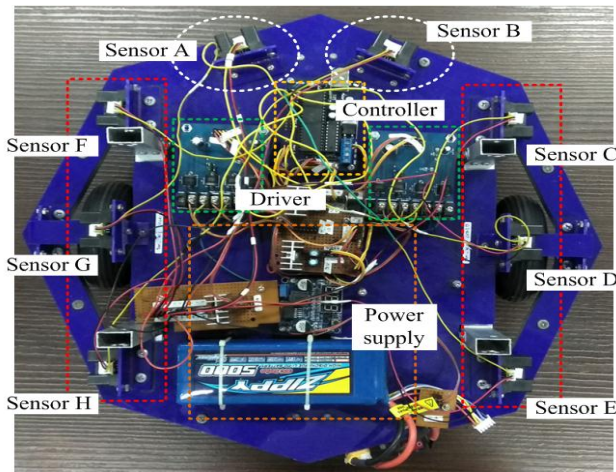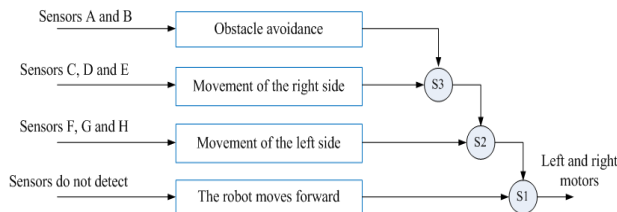

Figure 1. The mobile robot.

Figure 2. The architecture of behavior in the mobile robot.

B. *Learning vector quantization.*

Learning vector quantization (LVQ) is a supervised learning method in artificial neural networks. The LVQ method can be used for classifying data, pattern recognition, and decision making. In this study, the LVQ method consists of two-steps, namely training and implementation. The LVQ basic program for the training step was carried out in a computer where data was obtained from the values of the proximity sensors form the pattern of objects and to be classified. As for the implementation step, the LVQ program was embedded in the mobile robot, where the input was proximity sensors and output was movement actions. Fig. 3 shows the LVQ architecture applied in a mobile robot.
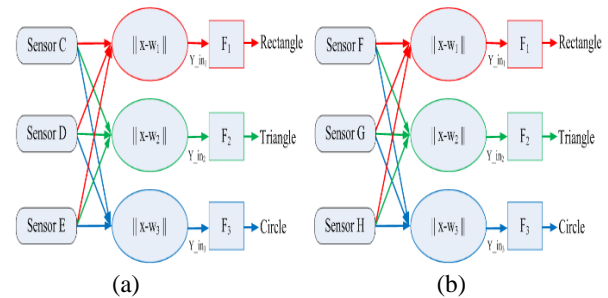

(a)   (b)

Figure 3. The architecture of LVQ in the mobile robot, (a) for the right side, and (b) left side.

$$x = \begin{cases} 1 & ; & x \le 30\,cm \\ 2 & ; & 30\,cm < x \le 40\,cm \\ 3 & ; & 40\,cm < x \le 50\,cm \\ 4 & ; & 50\,cm < x \le 60\,cm \\ 5 & ; & 60\,cm < x \le 100\,cm \end{cases}$$

(1)

Table 1. The pattern of objects obtained from the sensors on the right side.

		Sensor C. (The distance has quantized)				
		x = 1	x = 2	x = 3	x = 4	x = 5
Sensors D and E. (The distance has quantized)	y = 1	None	Triangle	Triangle	Triangle	Triangle
	y = 2	Triangle	Rectangle	Rectangle	Rectangle	Rectangle
	y = 3	Triangle	Rectangle	Circle	Circle	Rectangle
	y = 4	Triangle	Triangle	Circle	Circle	Rectangle
	y = 5	Triangle	Rectangle	Rectangle	Rectangle	None

Table 2. The pattern of objects obtained from the sensors on the left side.

		Sensor F. (The distance has quantized)				
		x = 1	x = 2	x = 3	x = 4	x = 5
Sensors G and H. (The distance has quantized)	y = 1	None	Triangle	Triangle	Triangle	Triangle
	y = 2	Triangle	Rectangle	Rectangle	Rectangle	Rectangle
	y = 3	Triangle	Rectangle	Circle	Circle	Rectangle
	y = 4	Triangle	Triangle	Circle	Circle	Rectangle
	y = 5	Triangle	Rectangle	Rectangle	Rectangle	None

Based on Fig. 3, the value of the sensors was quantized to speed up the computational process in training and implementation, and the targets were a rectangle, triangle, and circle objects. Eq. 1 shows the quantization values of the proximity sensors on the left and right sides, which was used in the training process. As for the sensors on the front, they were used to avoid obstacles. The target for the rectangle object was given the symbol class 1, the triangle object was given class 2, and the circle object was class 3. The patterns of the objects based on the right side and left side sensors, respectively, are shown in Table 1 and Table 2. Based on the pattern in Table 1 and Table 2, the distance sensors on the right or left sides were quantized to the values x = 1 to 5. For example, sensors on the right side, such as sensors C, D, and E, were used as sensors x and y. Sensor C was sensor x, and sensors D and E became sensors y. The relationship of sensors x and y was to determine the detection of objects, whether rectangular, triangle, or circle. The same method was also carried out on the left side sensors, namely sensor F as sensor x, and sensors G and H became sensors y. If sensors detect the shape of the rectangular object, the movement of the robot was set to follow the rectangle object, it also applies to the triangle and the circle objects.

The training process was carried out using the LVQ learning algorithm for pattern recognition [8],[9]. The LVQ algorithm applied to the robot are:

1. Set initial values such as weight, maximum epoch, expected minimum error (eps), and learning rate (alpha).
2. Enter input and target data.
3. Give the initial condition for epoch = 0.
4. The training process, if (epoch < Max Epoch) or (alpha > eps).
   a. epoch = epoch + 1
   b. for values of i = 1 to n:
      - Calculate the minimum distance $\|x - w_j\|$ (referred to as C_j).
      - Update weights with provisions:
        If T = C_j then :
        $$w_{j(new)} = w_{j(old)} + \alpha\left(x - w_{j(old)}\right)$$

If T $\neq$ C_j then :
$$w_{j(new)} = w_{j(old)} - \alpha\left(x - w_{j(old)}\right)$$

   c. Update alpha value:
$$\alpha = \alpha - \left(0.1 * \alpha\right)$$

The training process produced value fixed weights, these weights were used for the implementation process in real-time inside the microcontroller of the robot.
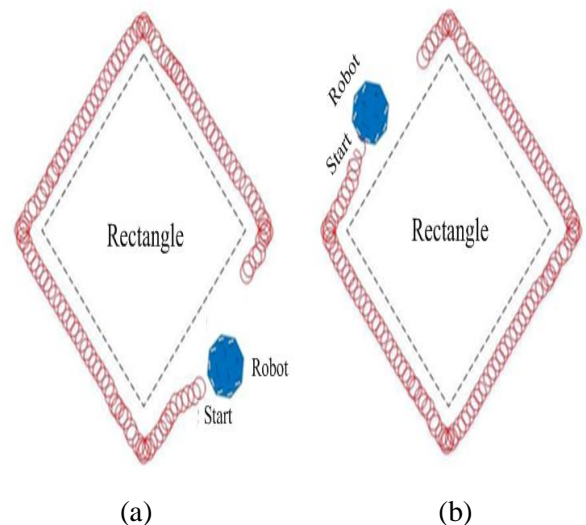

(a)   (b)

Figure 4. Navigate the mobile robot around the rectangle object, (a) the trajectory on the right, and (b) on the left.

EXPERIMENTAL RESULT

A. *The movement of the mobile robot on the rectangle object.*

The mobile robot was tested in an arena with rectangle, triangle, and circle objects placed alternately. In the first experiment, the mobile robot was on the side of a rectangle object, both from the right or left sides. The rectangle object was sized 75 cm on each side, and the angle is 90°. In this experiment, the robot run and

navigated around the object. Fig. 4 shows the trajectory of the movement of the robot from the right and left sides. In these conditions, the robot must maintain a position between the object's wall with the robot ranging from 30 cm to 40 cm. The robot navigated according to the shape of the object with the angle 90º, and the robot returned to maintain the position. When turning, there was a change in the value of the proximity sensors and affected changes in speed on the left and right motors, which in this case, set in the form of Pulse Width Modulation (PWM). The PWM value given to the motor varied from 10% (25 decimal) to 30% (76 decimal). This data was used to control the speed of the motors. The mobile robot was set to not move in the high-speed mode because it affected the sensor reading and computational.

Based on Fig. 4, the robot path is shown in navigating around the rectangle object both from the right and left sides. When the robot was running straight, the robot tried to maintain the distance so that the robot was not too close and not too far from the object. The robot passed through the corner of the object, the robot maneuvering that forms an angle of 90º to maintain the position between the robot and the object's wall. The mobile robot could do navigation on the right and left sides. The response of the robot moves around the rectangle object to the right side is shown in Fig. 5, and the response to the left side movement is shown in Fig. 6.
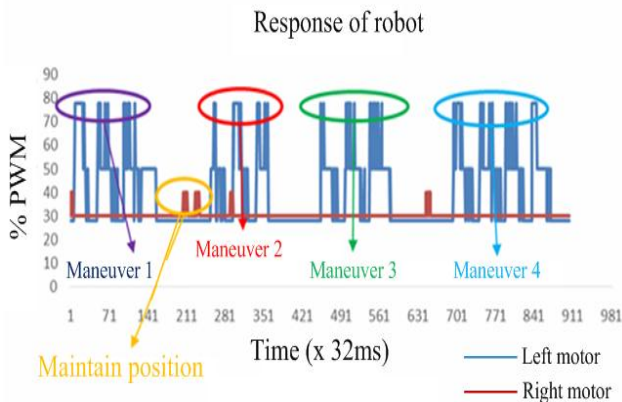

Figure 5. The response of the robot moves around the rectangle object from the right side.
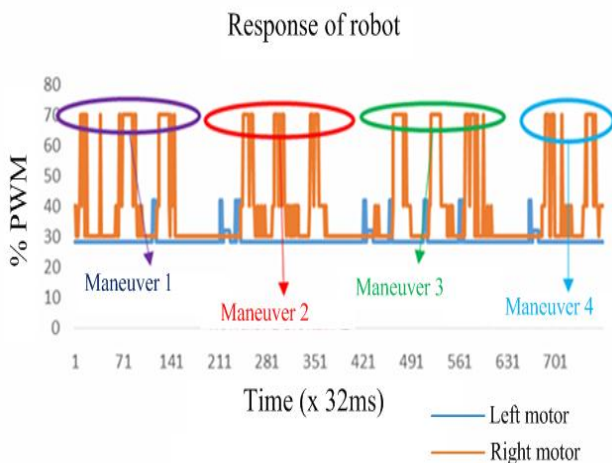

Figure 6. The response of the robot moves around the rectangle object from the left side.

Based on the responses in Fig. 5 and Fig. 6, there were significant changes in the left and right motors, depending on the side of the movement. The movement of the robot from the right side shows the change in speed on the left motor compared to the right motor (see Fig. 5). The robot tried to maneuver to the right, and the movement was always changing but still within the established pattern rules. While the robot moved from the left side (see Fig. 6), the figure shows the change in speed the right motor, this was to maneuver to the left and maintain the position of the robot with the object. Therefore the mobile robot could navigate around the rectangle object. The time obtained in reaching one round on the rectangle object, both moved from the right side, or the left side was 17 seconds.
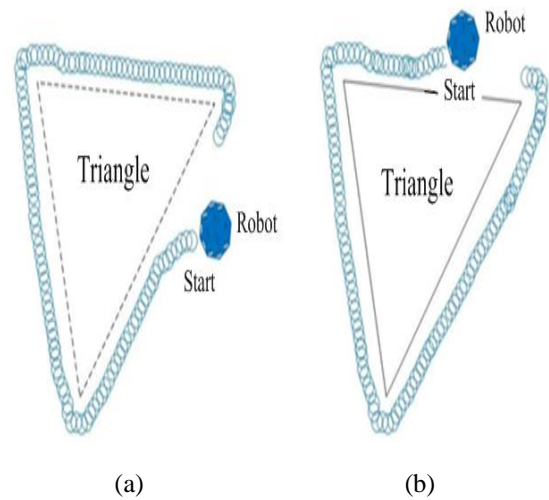

(a)   (b)

Figure 7. Navigate the mobile robot around the triangle object, (a) the trajectory on the right, and (b) on the left.

The movement of the mobile robot on the triangle object. Next, an experiment was carried out on the triangle object. The length of a triangle set at 75 cm, and the angle is 60º. The robot was placed on the right or left the side of the object. Fig. 7 shows the trajectories in the mobile robot, both the movement from the right and left sides. Based on Fig. 7, the robot run and maintained a distance of 30 cm to 40 cm, and when the robot passed through the angle 60º, the maneuver performed until the sensor read the specified ideal distance. When the robot performed this maneuver action, the robot experienced a temporary error because the robot tried to follow the pattern of an object. The maneuver action gave the difference in the speed of the two motors significantly. But the robot still navigated according to the rules of the triangle object pattern. The response of the robot moves around the triangle object to the right side is shown in Fig. 8, and the response to the left side movement is shown in Fig. 9.
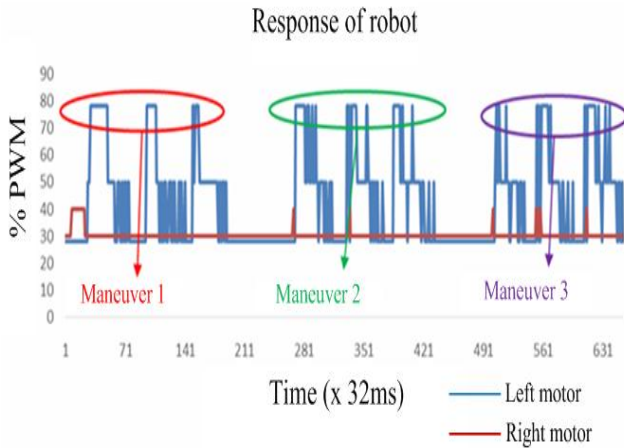
Figure 8. The response of the robot moves around the triangle object from the right side.

Based on the responses in Fig. 8 and Fig. 9, there were also significant changes in the left and right motors when viewed from the side of the movement. The movement of the robot from the right side shows a large change in speed on the left motor compared to the right motor because the robot attempted to maneuver turn right (see Fig. 8). While the robot moved from the left side (see Fig. 9), it shows the change in speed the right motor, this was to maneuver to the left and maintain the position of the robot with the object. Therefore the mobile robot could navigate around the triangle object. The time obtained in reaching one round was 14 seconds.
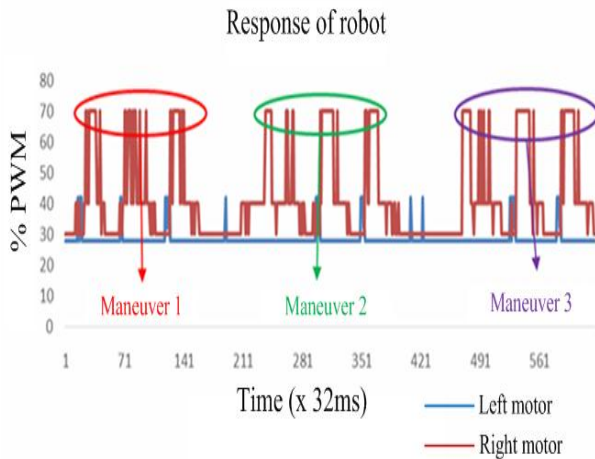

Figure 9. The response of the robot moves around the triangle object from the left side.

The movement of the mobile robot on the circle object. The mobile robot was placed near an object in the form of a tube or circle. Different from the two objects that had flat sides, this time was a circle object with a curved surface and diameter 40 cm. This experiment was also carried out from the right or left sides between the robot and the object. The navigation of the mobile robot around the circle object is shown in Fig. 10. The mobile robot moved around the circle object and maintain the distance to the wall at ± 30 cm. The response of the robot moves around the circle object to the right side is shown in Fig. 11, and the response to the left side movement is shown in

Fig. 12. Based on the responses of movement in Fig. 11 and Fig. 12, the difference between the two motors can be seen. There were several conditions where the robot required maneuver to always maintain the desired position. The time obtained in reaching one round was 12 seconds.
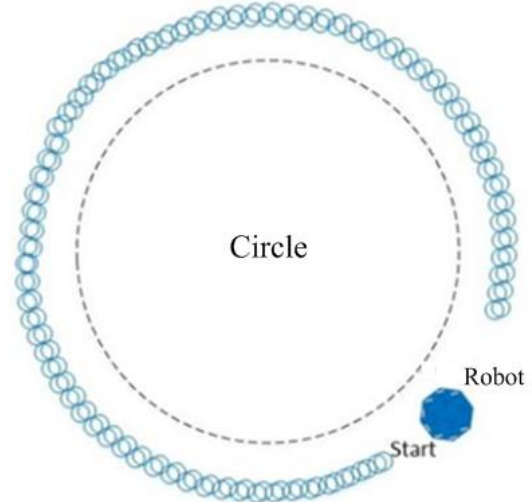

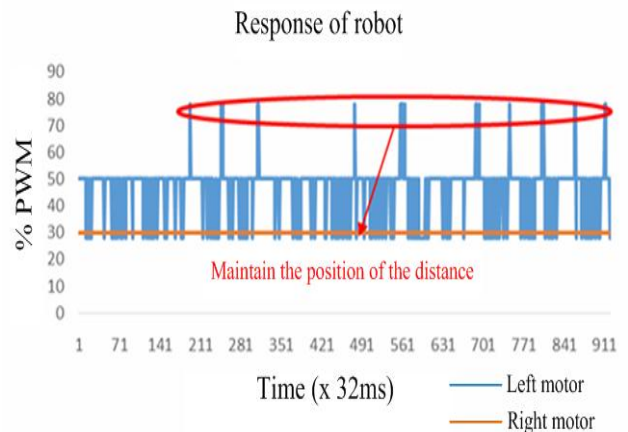**Figure 10.** Navigate the mobile robot around the circle object.

Figure 11. The response of the robot moves around the circle object from the right side.
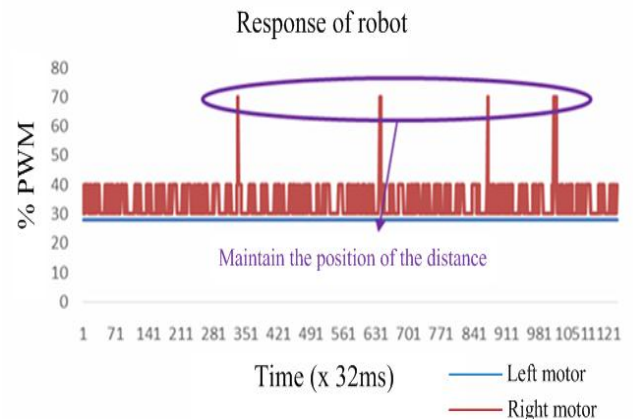

Figure 12. The response of the robot moves around the circle object from the left side.

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CONCLUSION

This study has developed a mobile robot, where the robot is octagonal, and the diameter is 40 cm. The robot is equipped with eight pieces of proximity sensors and is divided into three parts, namely the right, left, and front. The robot is also equipped with a microcontroller, driver, and motor. In this study, the robot is implemented to surround objects with rectangle, triangle, and circle shapes. The navigation system in the robot uses the LVQ method. The robot is run near objects both from the right or left sides to get the responses of movement in one rotation. In the experiment, the movement of the robot to surround the rectangle object obtained the time of 17 seconds, the triangle object 14 seconds, and the circle object 12 seconds. The experimental results show that the robot can navigate on these objects and maintain the position of the distance between the robot and the object from 30 cm to 40 cm.

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