Optimal Mobile Robot Navigation for Obstacle Avoidance Based on ANFIS Controller

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***Abstract*—Over the past 20 years, there has been a lot of research done on the movement control issue of an automated wheeled movable robot. This paper suggests navigation and collision avoidance in a new setting by utilizing the sensor-based steering angle control method, the Adaptive Neuro-Fuzzy Inference System (ANFIS) controller has already been introduced for the safety of navigation of single and multiple movable robots in cluttered surrounding areas. The front, right, and left obstruction distances have been measured using the sharp infrared reported significant and the ultrasonic distance finder sensor. This paper proposes navigating and collision avoidance in a unique environment. It uses the sensor-based angle of steering control approach. The acute ultraviolet detected is significant, and an ultrasound distance finder sensor was utilized to determine front, right, and left jump distances. In this study, a multi-layer ANFIS controller is used, with two levels for movement and the others for hurdle avoidance. The proposed ANFIS controller must be tested using a Matlab simulation. In six separate test situations, six obstacles in the surrounding region are used in a simulation, and then the robot can reach the objective without collisions in the shortest course.**

***Keywords*—Intelligent Controller; Movable Robot; Navigation; Movable Robot.**

I. Introduction

Independent movable robot can navigate by sensing its surrounding area, perceiving the sensed information to specify its location, and designing a real-time trajectory that links between starting and target positions by avoiding hurdles and arranging its velocity and steering angle to attain the target. Suitable solutions for accomplishing local navigation, trajectory planning, speed control, and steering can be designed by utilizing control neural-fuzzy logic. The characteristics of optimal trajectory are attained by reducing the number of turnings and bypassing a small rotation radius, which in turn decreases the magnitude of braking so the minimum path lies between the start and target points is obtained Real-time navigation is simple for humans and animals while avoiding all hurdles in the surrounding area. However, it is still a challenge for mobile robots, especially in the ambiguous and uncharted surrounding areas. Many applications in different fields such as security, healthcare, military, space exploration, education, industry, weather, and mining need wheeled mobile robot systems. Furthermore, a mobile robot can execute different dangerous tasks such as defusing bombs, recognizing shipwrecks, and transporting machines. Depending on this significance, the mobile robot is considered an effective research zone. In recent years, there are many techniques such as fuzzy, particle swarm optimization, ant colony optimization is vastly utilized for path designing, and to fix issues of static and dynamic hurdles in the surrounding area for different actions [1][2].

The moveable robot can use Fuzzy Logic (FL) and Artificial Neural Networks (ANN) to reach its desired destinations. The input layer is the first layer in an ANN, while the output layer is the highest. Data is altered using concealed (middle) and output layers. Data is processed and estimated at each layer before being transformed to the next layer. The increased number of hidden layers allows for more efficient programming of ANN. The ANN operates through these layers, estimating and overwriting the result as it is practiced with incoming data. This improves the network's overall efficiency and ability to forecast future results and make proper decisions. This explains why neuron cells in the human brain imitate ANN.

Better results will be obtained by mixing two intelligent algorithms in terms of quality and quantity, the calculation of both algorithms will be available at the same time, the split of membership function and specify rules number are the main complications of a fuzzy logic system, the specification of optimal structure and the synaptic weight are the main complication of neural network. To solve these complexities, the neuro fuzzy models for mobile robots are designed, the neural network is utilized for training the robot to attain the target, and the fuzzy system is utilized to regulate the robot's velocities [3][4].

The design of a Mamdani-type Minimum Principle Based ANFIS Controller for movable robot navigation trajectory arrangement in the clutter surrounding area is illustrated in this paper. for two essential purposes, an ANFIS system is designed: first target exploring, and second hurdle avoidance in a cluttered surrounding area. A multivariable input system of ANFIS contains hurdle distance acquired from the front, left, and right sensors combination, the output is a heading angle that regulates the movable robot movement [5][6].

Simulations are carried out with moving robots in various cluttered environments, such as those with many obstacles. The robot can successfully navigate complex obstacles and reach its destination [7][8]. Our goal is to create an ANFIS controller that can train the robot securely and independently without colliding in a congested environment. The robot will need to perform tasks such as changing its heading (steering) angle. These activities are carried out by calculating or managing the variables' values, with the output variable representing a heading (steering) angle [9].

By depending on fuzzy–neural network algorithms, various successful navigation techniques are proposed in the literature. In [10], navigation optimization of the Khepera mobile robot in a dynamic surrounding area is achieved through utilizing genetic algorithm learning. With many hurdles, computer simulation is taken by (KIKS arena). Error Penalty (EP) is utilized as a measure of success in this article, the results present an EP equal to (12.58, 9.73) for a fuzzy logic controller and the suggested controller respectively. It was present that the output of the suggested adjustable controller is better than an easy fuzzy controller. In [11], another modern technique for movable robot control is presented, a neural network is utilized in this technique to select the best number of principles to decrease the calculation period in real-time applications. A measure in this work related to the CPU period expanded in the implementation of the control loop. Experimental results display the effectiveness of this controller by raising the response as matched to prior fuzzy logic controllers and execution development which is related to collision averting. In [12], a dynamic neuro-fuzzy method that contains a tiny memory for hurdle avoidance in ambiguous surrounding areas is suggested [13].

For simulation, the surrounding area is 45 m and 40 m long, while the robot is 1.5 m and 1 m wide. The results showed that this proposed technique may inspire the robot to reach the target position using the optimal trajectory while efficiently avoiding obstacles in a certain surrounding area when compared to a counterfeit fuzzy-principle-based approach. In [14], a fuzzy-neural connectivity is improved by developing a system that operates in dynamic environments. Back Propagation Artificial Neural Networks must be practiced using simulation-generated samples to maintain precise training time. In [15], another neuro-fuzzy approach was proposed for real-time moveable robot navigation.

By utilizing a neural network algorithm, the components of membership functions are regulated. This modifies the path created by the fuzzy-logic system regularly. The number of principles is decreased to 48 fuzzy principles, much less than the techniques that anticipate hundreds of principles as shown from simulation results that utilized a Robotsim version 1.0.03. ANFIS is utilized in our work as a controller for movable robot navigation and hurdle-averting in ambiguous surrounding areas. To display the effectiveness of our suggested system, the ANFIS controller is matched with an imitative fuzzy logic controller [16].

There were many studies outcomes concerning hurdle avoidance and trajectory tracking of a movable robot. In ambiguous and complicated industrial surrounding areas, the fuzzy logic system has been vastly utilized as one of the effective means. In many research results, for upgrading the activity of hurdle avoidance and trajectory designing of mobile robots a fuzzy logic system has generally been performed. For performing controllers, the fuzzy logic system has been convenient due to its efficiency of deduction and approximate reasoning under suspicion [17].

Most fuzzy logic structures include a complex principal list to achieve various control objectives. The size of the bases of the total principles increases exponentially with the number of input variables. Many strategies for hurdle avoidance and mobile robot trajectory design can be found in related articles [18]. In [19], a hierarchical action-based control architecture was proposed. The hierarchical nature of activity, which is an assumption in the ethological paradigm, reinforced this structure. He proposed a novel technique for creating a fuzzy controller to improve the ability of mobile robots to respond to changing surroundings. In [20], an easy design of a fuzzy logic system was done, and the key idea for this system was demonstrated in [21]-[28].

The invention of this work is related to: developing system computational qualification by utilizing a novel control strategy that depends on ANFIS strength to facilitate the decision-maker operation, the utilization of four ANFIS leads to minimizing the rule set of the fuzzy controller while ensuring system qualifications, enabling active navigation in the ambiguous surrounding area via a simple rule structure, enhancing the specifying of optimal trajectory and upgrading the qualifications of autonomous of robot navigation [29]-[36].

In this paper, a fuzzy logic-based control system for the trajectory tracking of an indoor mobile robot is suggested. The ultrasonic sensor is utilized for attitude and characterizing the hurdle sensing [37]. The left and right wheels' angular velocities are dominated by a fuzzy logic system. Singleton and Mamdani's method is utilized for fuzzification and reasoning. The number of control principles in the imitative fuzzy logic system is forty-nine for each wheel [38]. So, we understand the fuzzy control principles of the imitative system, and thereafter another control principle based on eight statuses of hurdles positions and three portions of the angle between the robot and the goal position is created [39]–[44].

The paper is arranged as follows: The architecture of an indoor mobile robot is demonstrated in the next section. ANFIS controller-based hurdle avoidance algorithm for an indoor mobile robot is characterized in Section 3. Simulation examples are displayed in Section 4. Matlab/Simulink as a simulation tool is utilized. Good realization acquired from several simulation results is displayed. At last, some concluding remarks are displayed.

II. RELATED WORK

Pothal and Parhi [25] introduced a study that includes an ANFIS controller to detect a trajectory without collision for a movable robot, it comprises four factors front, right, and left hurdle distances, in addition to the target angle, which are supplied to the controller. In [45], for numerous movable robots in ambiguous surrounding areas, Mohanty and Parhi suggested a hybrid navigation method by using cuckoo search and ANFIS (CSANFIS). Training of the preface part process by cuckoo search and training the outcome factors of the ANFIS controller process by the least square estimation method.

Al Mashhadany et. al. [46] presented an anti-collisions controller that prevents robot collisions depending on a Petri net model which is related to a set of collision avoidance principles [47]. The distance between the robot and the hurdles is calculated by utilizing probability distributions, this method is dependent on the collision probability density threshold to determine the region of the hurdle. By utilizing a Lagrange multiplier technique, less distance is assigned as the outline of the hurdle zone.

Mohanty et al. [48] presented a neural Q-learning strategy for avoiding collisions with an independent moveable robot in uncertain surroundings. A random neural Q-learning technique is used to process two competing goals: avoiding obstacles and achieving the target; at each action step, an action selector function selects one goal. Zhang et al. [30] demonstrated a hurdle avoidance learning stage using a learning approach. Robots in various states are trained to avoid obstacles based on their experiences. The training set contains a large data set from which task restrictions can be inferred using the Gaussian mixture model. Gaussian mixture regression generates a smooth and unobstructed trajectory, and a proper control policy.

Mohanty et. al. [49] introduced an upgraded technique of dynamic window for hurdle avoidance of movable robots. An appropriate connection between the size of the robot and the surrounding areas in the existence of several hurdles is generated by using this technique. By utilizing a laser range finder, the sensing and prediction characteristics are developed [50]. The technique attempts to disband the local minima issue and achieve the perfect navigation trajectory. Empirical verification of the potential field affected by two-wheeled movable robot navigation among hurdles was introduced by Patle et. al. [51]. The study's purpose is to confirm the online hurdle discovery abilities based on a laser scanner with consideration of the no-holonomic limitations of movement [52]-[60].

To change the distance between the moving robot and the hurdles. Al Mashhadany et al. [61] developed a hybrid position actual-force controller [62]. A deep learning technique is proposed that uses multi-layer feed-forward neural networks to combine hybrid location and actual force. The assumptions of the moveable robot dynamics and hurdles are taken into account when regulating the spacing between the robot and the obstacles. To get the best and most optimal trajectory, the robot must move along a suitable trajectory calculated by estimating the minimal distance between the robot and the obstacle or the robot and the destination [63]-[70].

Most of the previous work used costly sensors, hardware, and calculations. An ANFIS-based hurdle avoidance navigation algorithm introduces in this paper utilizes the least number of ordinary ultrasonic sensors to detect a shortened trajectory without collision toward a goal position. To obtain a real-time reaction for a movable robot with normal hardware, the total number of parameters is maintained as least as possible [71]-[77].

III. Proposed Architecture of Mobile Robot

Robot autonomous movement represents one serious point of robot intelligence grade. Advanced navigation technology must supply the best services for humans, so to overcome the complicated changes in surrounding areas, design efficient autonomous navigation to ensure that mobile robots accomplish tasks.

A kinematics paradigm of a movable robot utilized in this paper is displayed in Fig. 1. Two driving wheels on the same axis, Target position is known, hurdle positions are not known Accelerations of left and right wheels are and, respectively. We suggest that the connection between the wheels and the land is absolutely teetering and non-skidding.

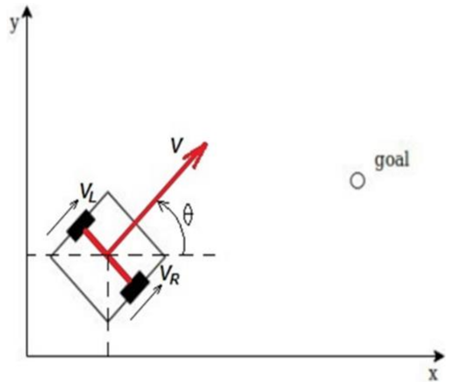

Fig. 1. Suggested movable robot model [23]

The equations of the left and right wheels of velocity and acceleration can be expressed as:

$$V_L = r\omega_L, \;\; V_R = r\omega_R \tag{1}$$

Where $\boldsymbol{r}$ represents the radius of the wheel. $\boldsymbol{V}$ represents the linear velocity of the movable robot. V_L and V_R, represent linear velocities for the left and right wheels respectively. The relation between ω_L, ω_R that represent angular velocities for left and right wheels, V_L and V_R can be represented as:

$$V = \frac{V_R+V_L}{2} = r\frac{\omega_R+\omega_L}{2} \tag{2}$$

$$\omega = \frac{V_R-V_L}{2} = r\frac{\omega_R-\omega_L}{2} \tag{3}$$

A dynamic paradigm for the mobile robot can be summarized as:

$$x' = V\,cos\theta \,.\, y' = V\,sin\theta \,.\, \theta' = \omega. \tag{4}$$

$$\begin{bmatrix} x' \\ y' \\ \theta' \end{bmatrix} = \begin{bmatrix} cos\theta & 0 \\ sin\theta & 0 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} V \\ \omega \end{bmatrix} \tag{5}$$

Where x and y represent position coordinates, θ represents orientation angle.

The inputs for the suggested fuzzy logic system contain distances that lie between hurdles and sensors, and angle lies between the robot and target. On the left, right, and front parts of the robot, sensors are positioned. The angle lies between the robot's direction and goal position. The output variables are related to the left and right wheel velocities.

IV. Design of ANFIS Cotroller

As we educate, fuzzy systems offer a great number of troubles related to designing and fulfilling membership functions and principles. ANFIS is our trial to process a set of such cases. ANFIS is a combined arrangement of Takagi–Sugeno fuzzy inference system (FIS) and artificial neural network (ANN). From the dataset, the ANFIS understands the principles and regulates the membership functions. A multi-layer ANFIS controller is utilized in our suggested method. Two of these layers are devoted to movement action and the other two layers are devoted to hurdle avoidance action. Figure (2) illustrates this architecture. The main characteristics of the ANFIS controller are easy to execute, rapid and precise learning, robust generalization capability, superior illustration skills via fuzzy basis, and a simple combination of linguistic and numeric learning for problem fixing. Neural fuzzy systems are recognized by utilizing neural networks to supply fuzzy systems with a form of automatic adaption method, but without changing their operation. One type of this process uses neural networks to formulate membership functions and mapping between fuzzy sets that are used as fuzzy basis.

Fig. 2 displays the common structure of a hybrid neuro-fuzzy method as declared previously. This system presents two actions movement to the target (MTT action) and hurdle avoidance. There is only one output can be obtained from the Sugeno model so four independent Sugeno models are designed. Left and right wheel velocities are controlled by two of these models through MTT action and left and right velocities through hurdle avoidance action are controlled by the other two models. The inputs to MTT action are the heading angle between the robot and target (Angle) and distance between the robot and target (Distance), the inputs to hurdle avoidance action are left, right, and front distances to the hurdle (LD, FD, RD) respectively.

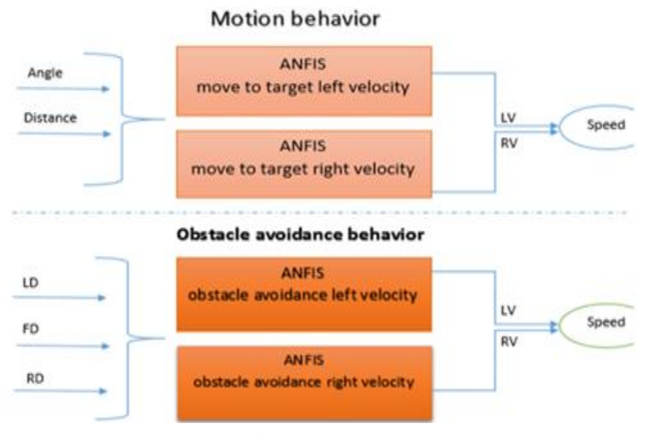

Fig. 2. The general structure of the suggested method [33]

The optimization of the fuzzy logic controller can be achieved by utilizing the Adaptive Neural Fuzzy Inference System (ANFIS). Depending on an Artificial Neural Network (ANN), this optimization is constructed which links with the Fuzzy Inference System. The principle of the FIS is fundamentally based on the practice of the evolver, it will develop the system widely but it can be improved by utilizing the ANN. The ANN is the scope system that could be utilized in the FIS practice. ANN utilizes the FIS data for the education operation. The membership function will be estimated to suit the best arrangement. ANFIS contains five layers as displayed in Fig. 3, the training process depends on this structure.

- Layer 1: Estimate the proper rate for the parameter of the membership function.

$$O_{Mn}^{1} = \mu_{Mn}(x) \tag{6}$$

$$O_{Nn}^{1} = \mu_{Nn}(y) \tag{7}$$

$$O_{On}^{1} = \mu_{On}(z) \tag{8}$$

Where μ_{Mn}, μ_{Nn}, μ_{On} represent input membership functions that can be triangular, trapezoidal, guassian, generalized bell-shaped and other shape functions. In this paper, the following generalized bell-shaped member function is utilized: -

$$\mu_{Mn}(x;a,b,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \tag{9}$$

The similar generalized bell-shaped membership equation will be written for μ_{Nn} and μ_{On}, where a, b and c are the premise parameters of the generalized member ship function, called the half width, slop control, and center respectively.

- Layer 2: Estimate the value's firing intensity. It is related to the rule satisfaction stage of the previous part and the shape of the output function of the rule.

$$O_n^2 = W_n = \mu_{Mn}(x)\cdot\mu_{Nn}(y)\cdot\mu_{On}(z) \tag{10}$$

Where W_n represents a firing strength of the truth value, of the n^{th} rule and $n = 1, 2, 3 \dots 8$ is the number of Sugeno-type fuzzy rule.

- Layer 3: Estimate for equalizing the firing intensity.

$$O_n^3 = \overline{W_n} = \frac{W_n}{\sum_{n=1}^{8} W_n} \tag{11}$$

- Layer 4: Propose the outcome principles of the FIS.

$$O_n^4 = \overline{W_n}\cdot f_n = \overline{W_n}\,(p_n\cdot x + q_n\cdot y + r_n\cdot z + s_n)$$

- Layer 5: Collect all inputs to demonstrate the total output.

$$O_n^5 = \sum_{n=1}^{8}\overline{W_n}\cdot f_n = \sum_{n=1}^{8}[(\overline{W_n}\cdot p_n)\cdot x + (\overline{W_n}\cdot q_n)\cdot y + (\overline{W_n}\cdot r_n)\cdot z + (\overline{W_n}\cdot s_n)]$$

Fig. 3 depicts a perfect ANFIS structure, with a circle indicating a fixed node and a square indicating an adaptable node. In the buried layers, nodes serve as membership function functions (MFs) and rules. This disables the common feedforward multilayered network reduction, which is difficult for the supervisor to detect or change. To keep things simple, we'll assume the calculated FIS has two inputs and one output. A first-order Sugeno fuzzy architecture has a standard rule set that includes two fuzzy "If-Then".

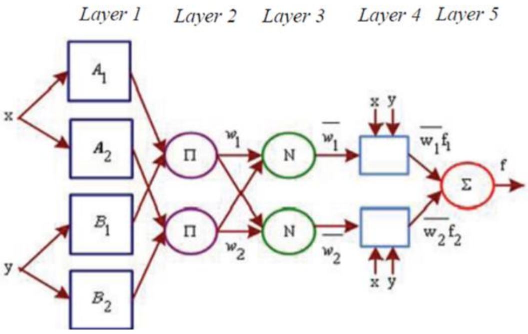

Fig. 3. Structure of ANFIS controller [37]

- Rule 1: If x is A_1 and y is B_1, then $f_1 = p_1\, x + q_1\, y + r_1$
- Rule 2: If x is A_2 and y is B_2, then $f_2 = p_2\, x + q_2\, y + r_2$
- x and y represent crisp inputs, and A_i and B_i are the linguistic labels the node function supports.
- The proposed ANFIS controller architecture is verified through mean squared error (M.S.E) method: -

$$M.S.E\ (\%) = \left[\sum_1^k \left(\frac{SA_a - SA_p}{k}\right)^2\right] \times 100 \qquad (12)$$

- Where SA_a represents the actual steering angle, SA_p represents the predicted steering angle, k represents the number of observations.

Fig. 4 illustrates flow chart of mobile robot navigation based on ANFIS controller.

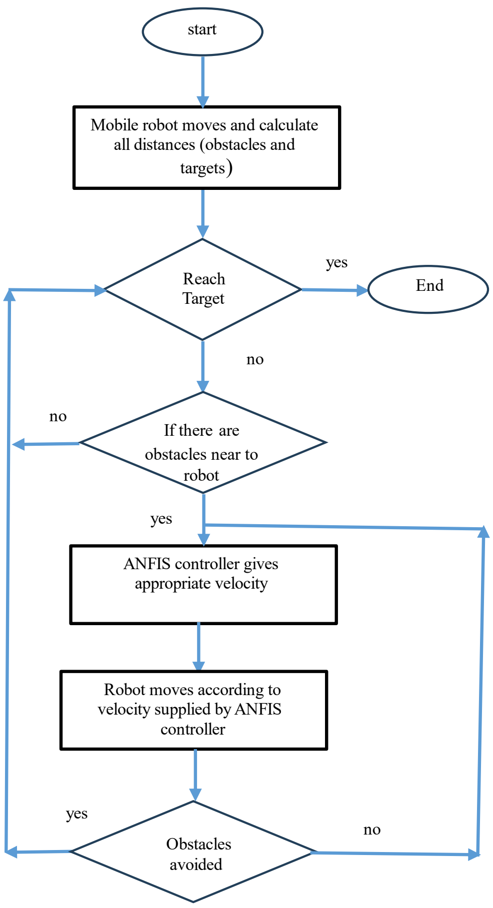

Fig. 4. Architecture of mobile robot navigation based on ANFIS controller

Rules that used are illustrated in Table I and Table II below.

TABLE I. SET OF RULES FOR THE HURDLE AVOIDANCE

No. of Rule	1st Left Sensor	2nd Right Sensor	Right Motor Speed	Left Motor Speed
01	very closed	very closed	slowly	slowly
02	very closed	closed	slowly	speedy
03	very closed	mediated	slowly	speedy
04	very closed	afar	slowly	speedy
05	very closed	very afar	slowly	speedy
06	closed	very closed	speedy	slowly
07	closed	closed	slowly	slowly
08	closed	mediated	slowly	speedy
09	closed	afar	slowly	speedy
10	closed	very afar	slowly	Speedy
11	mediated	very closed	speedy	slowly
12	mediated	closed	speedy	slowly
13	mediated	mediated	slowly	slowly
14	mediated	afar	slowly	speedy
15	mediated	very afar	slowly	Speedy
16	afar	very closed	speedy	slowly
17	afar	closed	speedy	slowly
18	afar	mediated	speedy	slowly
19	afar	afar	speedy	speedy
20	afar	very afar	slowly	speedy
21	very afar	very closed	speedy	slowly
22	very afar	closed	speedy	slowly
23	very afar	mediated	speedy	slowly
24	very afar	afar	speedy	slowly
25	very afar	very afar	speedy	speedy

TABLE II. SET OF RULES FOR THE TARGET TRACKING

No. of Rule	The Position Error	The Heading Error	Right Motor Speed	Left Motor Speed
01	big	negative big	mediated	speedy
02	big	Negative little	slowly	mediated
03	big	zero	speedy	speedy
04	big	positive little	mediated	slowly
05	big	positive big	speedy	mediated
06	mediated	negative big	mediated	speedy
07	mediated	Negative little	slowly	mediated
08	mediated	zero	speedy	speedy
09	mediated	positive little	mediated	slowly
10	mediated	positive big	speedy	mediated
11	little	negative big	slowly	speedy
12	little	Negative little	slowly	speedy
13	little	zero	slowly	slowly
14	little	positive little	speedy	slowly
15	little	positive big	speedy	slowly

V. SIMULATION OUTCOMES

The simulation surrounding areas such as in Fig. 5. It contains six hurdles and is the same surrounding area as displayed in the figure below. The robot starts from (20, 5) and the target lies at (5, 25). Thereafter the robot walked via the bold trajectory and line trajectory by the suggested ANFIS system. Fig. 5 to Fig. 9 illustrate the x-axis and y-axis of robot trajectories in different starting and target positions, and different arrangement of hurdles.

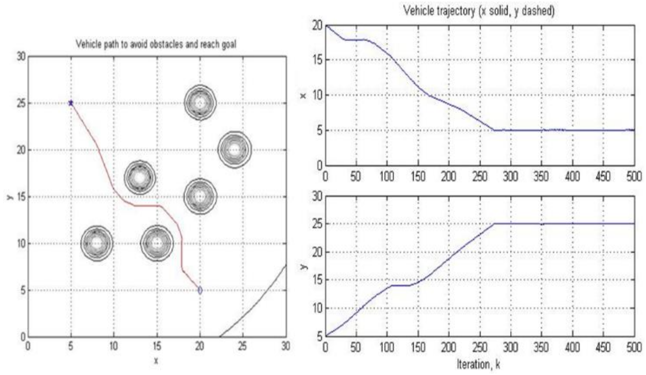

Fig. 5. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (20, 5) and the target point (5, 25)

The robot starts from (20, 5) and the target lies at (10, 25), thereafter the robot walked via the bold trajectory and line trajectory by the suggested ANFIS system. Fig. 6 illustrates the x-axis and y-axis of the robot trajectory.

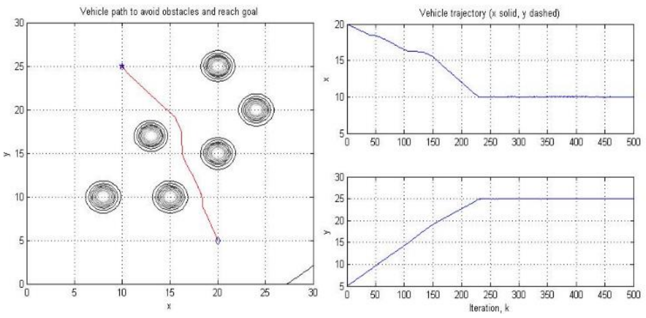

Fig. 6. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (20, 5) and the target position (10, 25)

The robot's starting location and its objective are (20, 5) as well as the target position, respectively (15, 25). The robot then followed the suggested ANFIS system's bold trajectory paths. Fig. 7 displays the robot path's x- and y-axes.

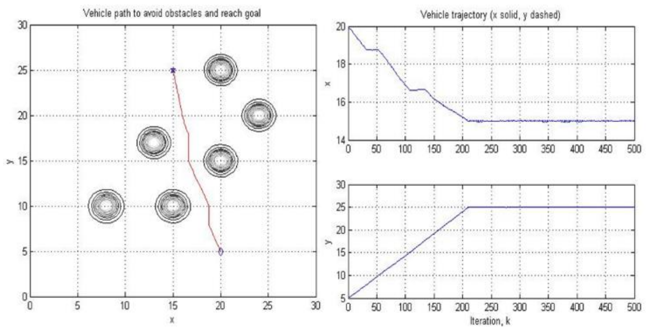

Fig. 7. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (20, 5) and the target position (15, 25)

The robot's starting location and its objective are (10, 5) as well as the goal point, respectively (15, 25). The robot then followed the suggested ANFIS system's bold and line trajectories. Fig. 8 displays the x- and y-axes of the robot's route.

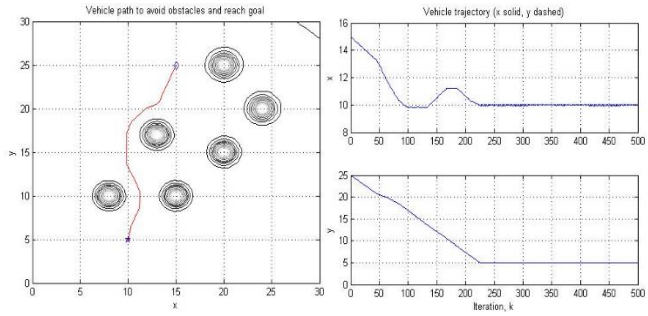

Fig. 8. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (10, 5) and the target position (15, 25)

The robot's starting location and its objective are (15, 25) as well as the goal point, respectively (10, 5). The robot then followed suggested ANFIS system's bold trajectory path. Fig. 9 displays the robot path's x-and y-axes.

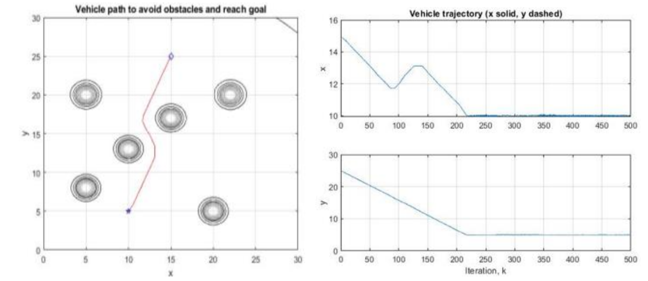

Fig. 9. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (15, 25) and the target position (10, 5)

The robot's starting location and objective are (25, 5), and the target position is (5, 25). The robot then followed the suggested ANFIS system's bold trajectory paths. Fig. 10 displays the robot path's x- and y-axes.

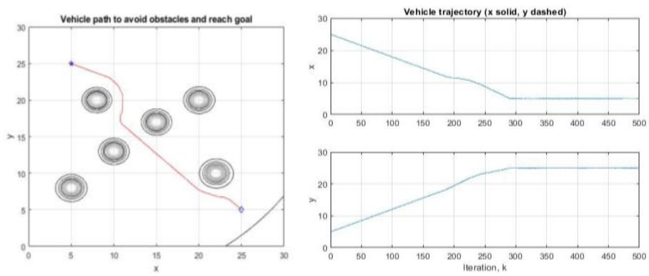

Fig. 10. Simulation of optimal hurdle avoidance based on an intelligent controller with the starting point (25, 5) and the target position (5, 25)

Some hurdles could be successfully avoided by the moving robot. Since the suggested system has fewer control principles, computations run more quickly. We examined a mobile robot's hurdle avoidance system using an ANFIS controller and detailed the design process for an ANFIS-based hurdle detection system for a movable robot.

VI. CONCLUSIONS

In this article, we have discussed the use of the ANFIS centralized controller in the present research for the navigation and hurdle avoidance of numerous mobile robots in cluttered surrounding areas. Three inputs and one output make up the ANFIS processor. The controller gets inputs from various sensors (hurdle distances) and outputs the proper Steering Angle (SA) command signals. The suggested ANFIS controller is in charge of ensuring that the movable robots autonomously reach their destinations using the best and most efficient routes. For the guidance of multiple movable robots, the eight principles and various actions, such as avoiding hurdles, robot inter-collision avoidance, and goal-seeking behavior, have been used, which is lower than the other imitative methods, forty-eight principles created by Montaner et al. and fifty-four rules created by Zhang et al. Additionally, numerous simulations have been used to confirm the ANFIS network controller's efficacy and efficiency.

Using an ANFIS controller, this technique successfully locates a collision-free route across the hurdles under a variety of scenarios. When a robot detects an obstacle in its surroundings, the Feedforward function block determines the robot's steering angle. Furthermore, based on the angle between the robot and the objective, the robot's navigation orientation is maintained towards the goal point. The simulation results showed that the robot applies the suggested strategy to find a virtually optimal guided route between the start and goal places. Furthermore, these results showed that the suggested method's route is around 20% shorter than the other approaches' pathways.

Future research may combine this ANFIS controller with other nature-inspired algorithms to solve problems involving numerous evolving hurdles and interactive goal trajectory planning in dynamic surrounding areas. In situations like walls in the surrounding areas, we can also concentrate on movable robots in the presence of distant hurdles. To overcome such far-reaching hurdles, the number of items inside the ANFIS If-Then constraints will be raised.

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