Journal of Cybernetics and Informatics

published by

Slovak Society for
Cybernetics and Informatics

Volume 12, 2011

http://www.sski.sk/casopis/index.php (home page)

ISSN: 1336-4774

Journal of Cybernetics and Informatics 12 (2011)
http://www.sski.sk/casopis/index.php

BEHAVIORS FUSION FOR A MOBILE ROBOT USING FUZZY BEHAVIORS WEIGHTS TUNED BY REAL CODED GENETIC ALGORITHM

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Abstract

Coordination between different behaviors, such as goal reaching, obstacle avoidance, reaching the collision–free space, and wall following, all of these represent a big problem in navigation of the mobile robots in unknown or partially known environments. In this paper a solution of this problem is presented using switched gains, these gains are inferred from a fuzzy fusion system (FFS). These gains are weighted and tuned by a real coded Genetic Algorithm (RCGA) based on a fitness function that ensures a safe and short path to the object. The proposed technique assures a safe and efficient navigation.

Key word: mobile robot-navigation-behaviors fusion-switched gains- fuzzy fusion system-Real Coded Genetic Algorithm.

1 INTRODUCTION

One of the most important challenges in robot navigation is how the mobile robot moves and coordinates between different behaviors with safe and efficient motion. Many mobile robot designs use the so called "behavioral decomposition" to achieve autonomous operation in unknown environment. A common problem between all behavior based designs is how to combine these different behaviors. Many literatures handled this problem such as that are mentioned in [1-3] with different degree of safe and success. Here in this paper a switched gains fuzzy fusion system is presented as a coordinator by weighting the different behaviors according to the local and global informations. In this work the proposed method takes into consideration that each behavior may vary from situation to another one, so the switched weights are inferred from the environmental information. A problem remaining in many literatures, as the weight for each behavior is constant, but actually the desirability of each behavior may vary from situation to another which means that the weights of behaviors are subjected to environmental informations, so we focus on the environmental informations for inference the weights for a better behavior fusion. In this Work, we propose a safe and efficient behavior fusion method. Fuzzy fusion system (FFS) is used to weight the Behaviors using both local and global environmental informations. One of important point how the robot switches smoothly from behavior to another, for example if it avoids an obstacle and it faces to a desired goal, so we propose a smooth switching gains or switching function to give the priority to the behavior under process according to the received data. So it is necessary to tune the weighting factors using optimization techniques such as the genetic algorithm (GA) or artificial neural network (ANN) to achieve the navigation requirements, safe, smooth, and traceable paths.

This paper is organized as follows: in section 1, introduction to challenges in robot navigation, literature survey and the scope of this paper are introduced. In section 2, the architecture of the proposed behavior fusion system is explained. In section 3, the fuzzy obstacle avoidance system is presented, in section 4 the behaviors fusion module is introduced, a real coded genetic algorithm is introduced in section 5, simulation results are presented with discussion in section 6. In section 7, conclusion and recommendations are discussed.

2 ARCHITECTURE OF THE PROPOSED BEHAVIOR FUSION SYSTEM

The architecture of the proposed behavior fusion system is depicted in Fig. 1. It consists of four main modules: goal reaching module (behavior1) an obstacle avoidance module (behavior2), and any other behavior (behavior3) and the coordinator module or behaviors weighting module (supervisor module). A fuzzy system is introduced to construct the goal reaching behavior and this is called attractive fuzzy controller (behavior 1), which attracts the robot to the goal, as in [1]. Also a fuzzy logic is introduced for obstacle avoidance behavior (behavior 2). Also a fuzzy fusion system (FFS) is introduced as a coordinator and behavior weighting system in the third module (behavior 3). The function of the goal reaching fuzzy logic represents an attraction vector to the main goal in case there is no any obstacle in the path of goal reaching. The attractive fuzzy logic algorithm generates an attractive vector to the goal point according to the distance between the robot and the goal point (D_g), and the difference angle between the goal point and the robot steering angle (θ_e), which are considered the inputs to the first fuzzy controller for path planning, that generates the linear velocities for the right and left wheels, and accordingly, the linear and angular velocity of the robot, which control the velocity and steering to the goal object. In Fig. 2, the posture of the mobile robot is shown, the current robot postures are, (x_k , y_k, θ_k). Where (θ_k), specifies the angle of the robot with respect to the horizontal axis. The (x_k , y_k), specifies robot location by Cartesian coordinates. The goal location at (x_g , y_g), and (θ_g) is the goal angle, (θ_e) is the difference between goal angle and robot heading angle. (D_g) is the distance between the robot and the goal point. Equations (1-3) show the calculations of the goal angle, difference between the goal angle and the robot heading angle, and the distance between the robot and the goal point.

$$dx = x_g - x_k \ , \ dy = y_g - y_k \tag{1}$$

$$\theta_g = \tan^{-1}\left(\frac{dy}{dx}\right), \ \theta_e = \theta_g - \theta_k \tag{2}$$

$$D_g = \sqrt{dx^2 + dy^2} \tag{3}$$

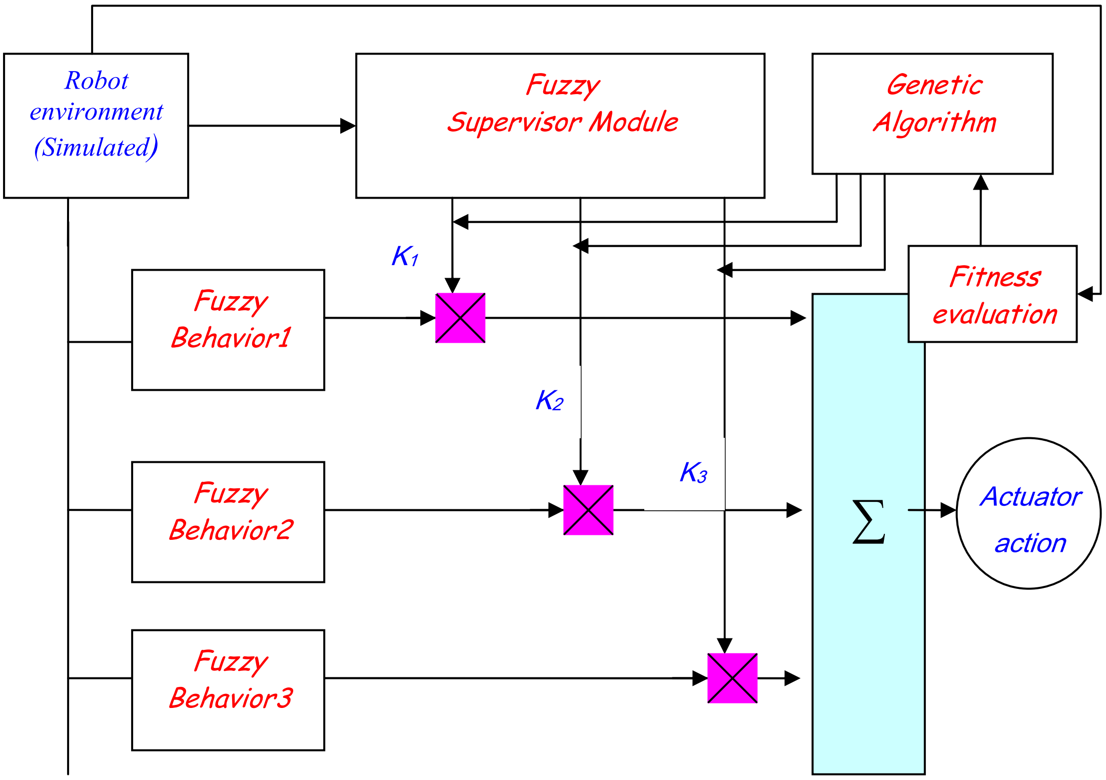


Figure 1: Proposed Behaviors fusion system (FFS) with GA weights tuner.

The fuzzy membership functions of the inputs to the attractive fuzzy logic controller are shown in Fig. 3. The output of attractive (behavior 1) fuzzy logic is the left and right wheel linear velocities; the membership functions of the output are shown in Fig. 4a, b.

3 FUZZY LOGIC FOR OBSTACLE AVOIDANCE

The function of repulsive fuzzy controller is to determine the suitable action for avoiding the obstacle encountered, and canceling it if it is not on the path of goal reaching. The safety area of motion of the robot along the goal reaching path must be safe with respect to the adjacent obstacles. The inputs of the fuzzy in this module are: the distance between the robot and the obstacle according to ultrasonic readings, Dobs, and the difference angle between the obstacle location and the robot heading angle ($\theta_{e(obs)}$). This information is supplied from the ultrasonic sensors according to its configuration (sensors data fusion). The output of this module is the steering angle (the left and right linear velocities of the robot' wheels).

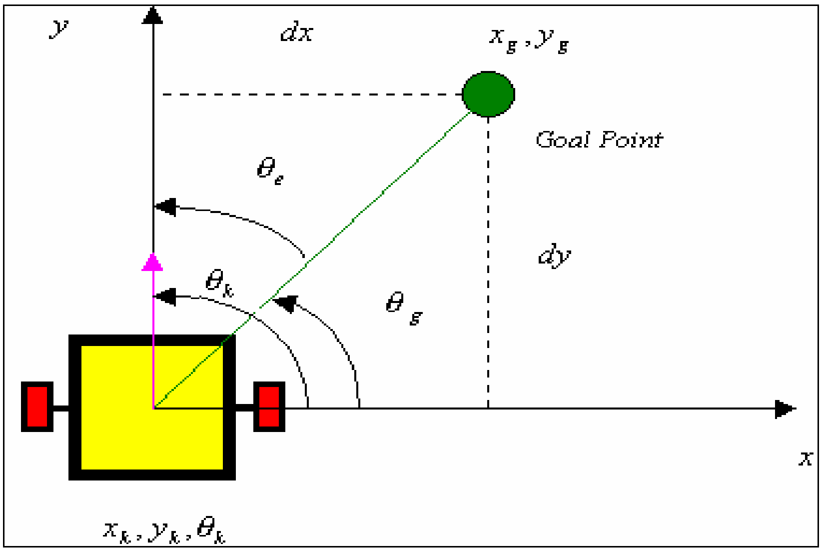
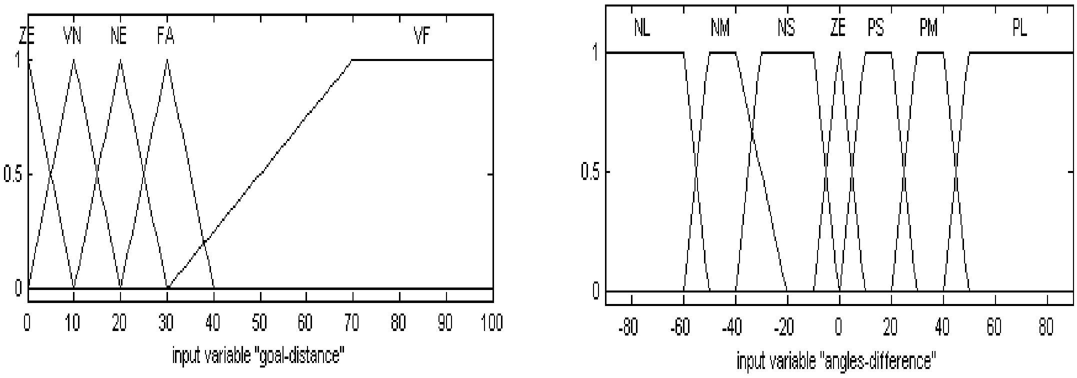
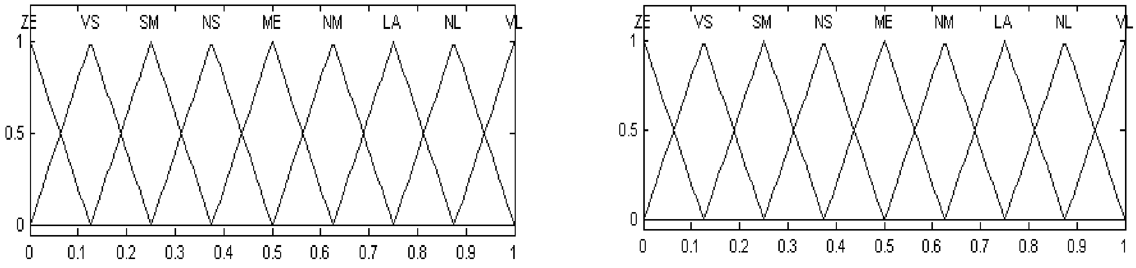


Figure 2: Robot and the goal postures



(3-a) (3-b)

Figure 3a, b: Membership functions of inputs to the attractive fuzzy logic controller, (D_g,θ_e).



(4-a) (4-b)

Figure 4a, b: Membership functions of the outputs of the attractive fuzzy controller.

4 BEHAVIORS FUSION MODULE

In this fuzzy fusion module (fuzzy supervisor module) weighting factors are inferred from fuzzy fusion system according to the environmental informations from local and global sensors. Theses weighting factors are introduced to reference linear and angular velocities generated from the first, and second behavior modules (goal reaching module and obstacle avoidance module) . So the new reference linear and angular velocities are introduced as in equation 4, and 5 respectively. The fuzzy switching gains, kobs(v), and kobs(w) are inferred by FFS (fuzzy supervisory module). The inferred reference linear and angular velocities become as follows:

$$V_{fusion} = k_{obs(v)} V_{obsAB}{}^{*} + (1 - k_{obs(v)}) V_{GRB}{}^{*} \tag{4}$$

$$\omega_{fusion} = k_{obs(\omega)} \omega_{obsAB}{}^{*} + (1 - k_{obs(\omega)}) \omega_{GRB}{}^{*} \tag{5}$$

Where:

V_{fusion}: is the inferred (fused) reference linear velocity from fuzzy fusion system tuned by real coded genetic algorithm.

ω_{fusion}: is the inferred (fused) reference angular velocity from fuzzy fusion system tuned by real coded genetic algorithm.
$K_{obs\ (v)}$: is the inferred weighted gain for the linear velocity in existence of an obstacle (equal to zero if there is no any obstacle).
$K_{obs\ (w)}$: is the inferred weighted gain for the angular velocity in existence of an obstacle.

$V_{\mathrm{obsAB}}{}^{*}$: is the inferred reference linear velocity from the second fuzzy controller for obstacle avoidance (obstacle avoidance behavior 2).

$\omega_{\mathrm{obsAB}}{}^{*}$: is the inferred reference angular velocity from the second fuzzy controller for obstacle avoidance (obstacle avoidance behavior 2).

$V_{\mathrm{GRB}}{}^{*}$: is the inferred reference linear velocity from the attractive fuzzy controller for goal reaching behavior (behavior 1).

$\omega_{\mathrm{GRB}}{}^{*}$: is the inferred reference angular velocity from the attractive fuzzy controller for goal reaching behavior (behavior 1).

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Here $K_{\mathrm{obs}(v)}$, and $k_{obs(w)}$ are fuzzy variables, which are generated according to the distance and angle of the obstacles. If there is no any obstacle on the goal reaching path, then, $K_{\mathrm{obs}(v)}$, and $k_{obs(w)}$ are zeros. So the robot follows the path that leads to the goal only. So $V_{\mathrm{fusion}} = V_{\mathrm{GRB}}{}^{*}$, which is the reference linear velocity according to the attraction force to target or goal location, also $\omega_{\mathrm{fusion}} = \omega_{\mathrm{GRB}}{}^{*}$, which is the reference angular velocity according to the attraction force to target or goal location (behavior1). The fuzzy gains are tuned using the real Coded genetic algorithm (RCGA) [8]. The fitness (target) function, which verifies a safe and efficient paths is a function of the following: the distance between the robot and the target, distance from obstacle (safe distance), the error of the perpendicular distance to the straight line tied the robot and the target (to achieve short path). The real coded genetic algorithm is presented in the following section.

5 Genetic Algorithm

Genetic algorithm tuning for the weighting factors processes as follows:

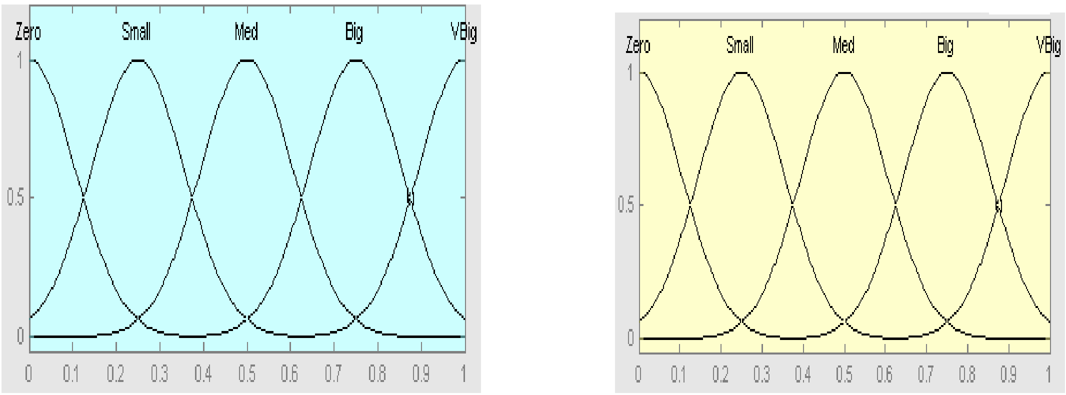
Initialize a population of $K_{obs\ (v)}$, $k_{obs\ (w)}$ having a size of 'm'. i.e. $K_{obs\ (v)}$, $k_{obs\ (w)}$ for n = 1 to n = m. Define a period of time equals 'ts', an objective function such The fitness function is a function of the following: the distance between the robot and the target, distance from obstacle (safe distance), the error of the perpendicular distance to the straight line tied the robot and the target (to achieve short path).
a constant R Є]0,1[

1- Set n = 1 and apply $K_{obs\ (v)}$, $k_{obs\ (w)}$ to the navigation system for a period of 'ts'
2- At the end of 'ts' catch the value of error and hold it as error (n) or abs (error) depending on the selected objective function. Then increment 'n' by one and apply $K_{obs\ (v)}$, $k_{obs\ (w)}$ to the navigation system for a period of 'ts'.
3- Repeat step '3' until 'n' reaches m.
4- Search for the minimum value of the objective function for n = 1 to n = m and catch the corresponding values of $K_{obs(v)}[n]$, $k_{obs(w)}[n]$. For example if the objective function is minimum when n = k then catch $K_{obs(v)}[k]$, $k_{obs\ (w)}[k]$ and use them in the next generation. This is the reproduction stage.
5- Apply the crossover operation to the rest of $K_{obs\ (v)}$, and $k_{obs\ (w)}$ Again if the objective function is minimum when n = k, then apply the following formula to calculate the crossover individuals (new modified $K_{obs\ (v)}[n]$, $k_{obs\ (w)}[n]$ that will be used in the next generation for n = 1 to n = m and n ≠ k) .

$$K_{obs\ (v)}(n)mod = R * K_{obs\ (v)}(k) + (1-R) * K_{obs\ (v)}(n) \tag{6}$$

$$K_{obs\ (\omega)}(n)mod = R * K_{obs\ (\omega)}(k) + (1-R) * K_{obs\ (\omega)}(n) \tag{7}$$

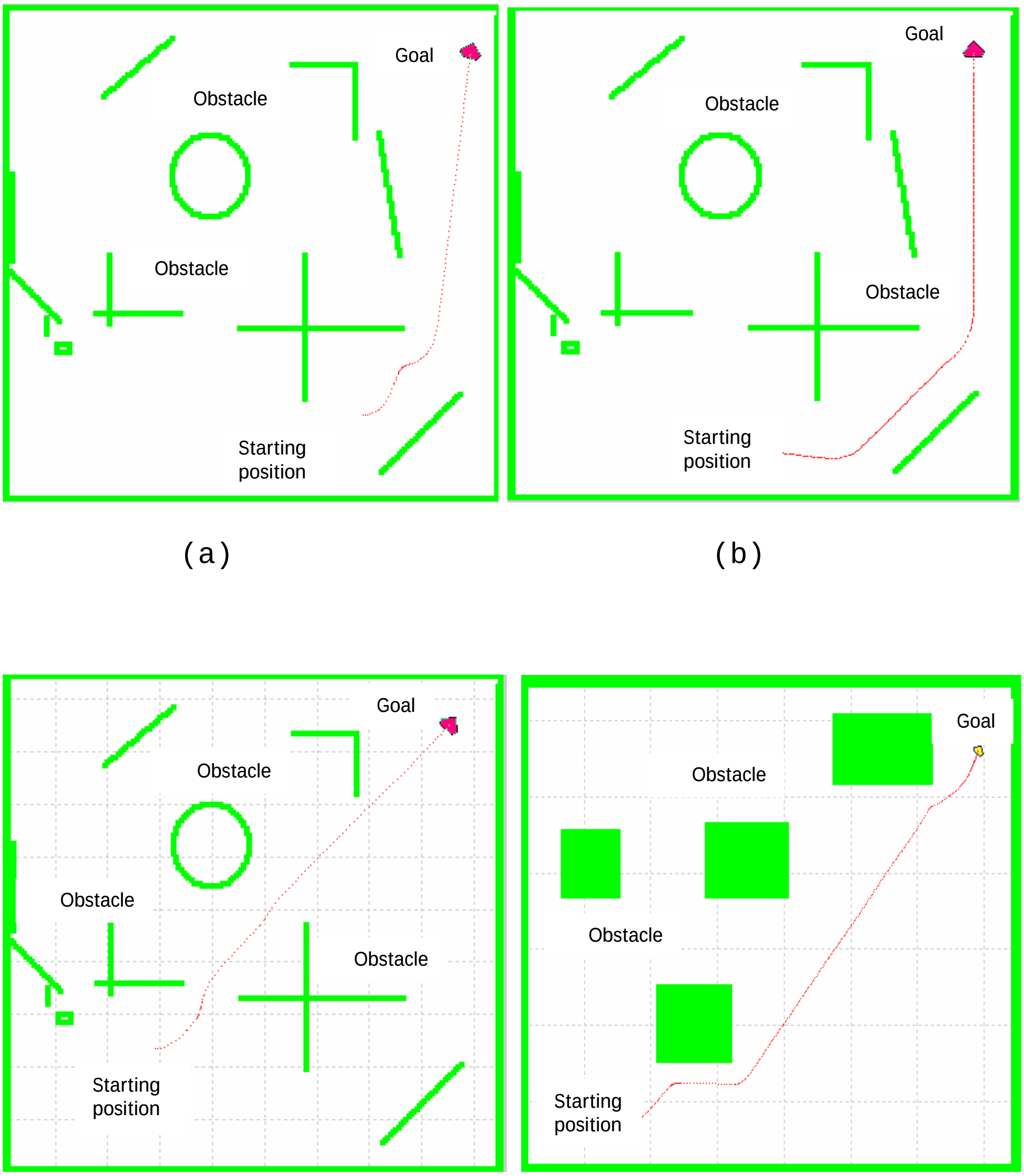
7- Check meeting the conversion criterion then if it is not met repeat steps 2-6 otherwise stop genetic algorithm and maintain the final results of the fittest values of $K_{obs\ (v)}$, $k_{obs\ (\omega)}$ and apply them continuously to the system.



(a) (b)

Figure 5a, b: Membership functions of the outputs of the third module (fuzzy fusion weights), $K_{obs}\ (v)$, and $K_{obs}\ (\omega)$.

6 SIMULATION RESULTS



(a) (b)

(c) (d)

Figure 6a, d: Simulation Resutls using the Proposed Fuzzy Fusion System (FFS) Tuned by Real Coded Genetic Algorithm(RCGA)

As shown in Fig. (6. a-d) the proposed behavior fusion system is verified by simulation results which proofed that the proposed system is safe and efficient in robot navigation in unknown and partially known environments. But the proposed technique depends on gains optimization and sensors configurations, for more safe and efficient paths, sensors configurations must be optimized.

7 CONCLUSION

A behaviors fusion system is presented with a simulation results using a fuzzy switched gains weighted by fuzzy supervisory system, these gains are tuned using the real coded genetic algorithm. A simulation results are presented using **Simrobot** toolbox under **MATLAB**. the proposed technique was efficient and safe for mobile robot navigation in unknown or partially known environments. More study is recommended for sensors configurations, and its effect on the proposed technique.

ACKNOWLEDGMENT

Special thanks to Dr. Essam Abd El Gaid for his guidance and help throughout the execution of Real Coded Genetic Algorithm.

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