Fuzzy Controller Designed by GA for Two-wheeled Mobile Robots

Ching-Chang Wong, Hoi-Yi Wang, Shih-An Li, and Chi-Tai Cheng

Abstract

A GA-based fuzzy controller design method is proposed for a two-wheeled mobile robot to independently control two velocities of its left-wheeled motor and right-wheeled motor so that the controlled robot can move fast and efficiently to the desired position. First, the kinematics model of the considered two-wheeled robot is described and a 4-input-and-2-output motion fuzzy control structure with two 2-input-and-1-output fuzzy systems is proposed. Then a GA-based method is proposed, where a ratio coefficient coding method and a variable fitness function in the genetic algorithm are proposed to choose the input and output membership functions of these two fuzzy systems so that the selected controller has a good performance in the robot's motion. From the control results of the proposed method in the 3D Robot Soccer Simulator of FIRA, we can see that the proposed motion control method for two-wheeled mobile robots is feasible and effective.

Keywords: Mobile Robot, Fuzzy Control, Genetic Algorithms, Fitness Function.

1. Introduction

In the two-wheeled mobile robot control, many motion control design methods [1-6] are proposed for two-wheeled robots so that they can move efficiently in a two-dimensional space. One motion control problem of two-wheeled mobile robots is how to independently control the left-wheeled motor and right-wheeled motor. In this paper, a GA-method fuzzy controller designed method is proposed to determine the velocities of the left-wheeled motor and right-wheeled motor. Genetic algorithm is one kind of evolutionary computation technique to obtain an optimal solution [7]. Fuzzy system can be applied in many fields. Fuzzy controller has been proven to be a good tool for real time industrial processes, where they are difficult to obtain a mathematical model for the system. GA-based fuzzy control design approaches have been proposed in several different ways. Three categories to design fuzzy controllers by using GA are distinguished [8]. In the first category of GA-based methods, only the membership functions are considered to determine an optimal fuzzy system. In [9], they proposed a fuzzy controller whose fuzzy membership functions were altered on-line using a GA with fixed fuzzy rules. In the second category of GA-based methods, only the fuzzy rules are considered to determine an optimal fuzzy rule base. The methods proposed in [10-14] are included in the second category. Chen and Wong [10] proposed a method to design a self-generating rule-mapping fuzzy controller and the inverted pendulum control problem is considered to illustrate the efficiency of the proposed method. Feng and Wong [11] proposed an on-line rule tuning method of fuzzy control system. The on-line rule tuning grey prediction fuzzy control system structure is constructed so that the rise time and the overshoot of the controlled system can be maintained simultaneously. Ishibuchi et al. [12] first generated fuzzy rules using a supervised classification method and then used a GA to select an optimal set of fuzzy rules to describe the fuzzy control operation. Chaing et al. [13] introduced a self-learning fuzzy controller where a GA was used to find the output weights of the fuzzy controller. In the third category of GA-based methods, they determine fuzzy rules and fuzzy membership functions simultaneously. The methods proposed in [8], [15], and [16] are included in the third category. In [8], they used equally-spaced triangular fuzzy membership functions with fixed centers and tuned the support of each membership function along with tuning the fuzzy rule base. In [15], the chromosome has a rule component and a membership function component. In [16], symmetric triangular fuzzy membership functions are considered.

In this paper, a fuzzy controller designed by a GA-based method is proposed for the motion control of a two-wheeled mobile robot. First, a fuzzy control system structure is proposed to determine two velocities of its left-wheeled motor and right-wheeled motor. Then, a GA-based method is proposed to choose the input and output membership functions of fuzzy systems. Finally, the 3D robot soccer simulator of FIRA [17] is used to test the proposed GA-based fuzzy logic controller and compare its results with the other methods.

The rest of this paper is organized as follows: In Sec-

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tion 2, the kinematics model of the considered two-wheeled mobile robot is described and a motion fuzzy control structure is proposed. The motion fuzzy controller with four input variables: d (the distance between the robot and the destination), Δd (the change quantity of motion distance), α (the rotation angle of robot), and $\Delta\alpha$(the change quantity of rotation angle) are proposed to determine two velocities of U_L and U_R to independently control the left-wheeled motor and right-wheeled motor, respectively. In the motion fuzzy control structure, two 2-input-and-1-output fuzzy systems: distance fuzzy controller and angle fuzzy controller are proposed to reduce the design complexity. In Section 3, a GA-based fuzzy controller is described, where a membership function ratio coefficient coding method and a variable fitness function is proposed to select the input and output membership functions of fuzzy systems. In Section 4, some simulation results are discussed, where three motion control methods are compared: (1) the parameter motion control method; (2) the experience-based motion fuzzy control method; (3) the GA-based motion fuzzy control method. Finally, some conclusions are made in Section 5.

2. Motion Fuzzy Controller Design

A two-wheeled mobile robot is considered and its structure is described in Figure 1, where X-Y is the global coordinates and x_m-y_m is the local coordinates which is fixed to the robot with its center p as the origin. As shown in Figure 1, its body is of symmetric shape and the center of mass is at the geometric center p of the body. R is the radius of the wheel and L is the displacement from the center of robot to the center of wheel. The set (x_o, y_o) represents the position of the geometric center p in the world X-Y coordinates, and the angle θ indicates the orientation of the robot. The angle θ is taken counterclockwise from the X-axis to the x_m-axis. These two fixed wheels are controlled independently by two motors, and the passive wheel prevents the robot from tipping over as it moves on a plane. In this paper, the motion of passive wheels is ignored in dynamics of the mobile robot.

According to the schematic of the two-wheeled mobile robot described by Figure 1, its kinetic equation can be described by

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ \omega \end{bmatrix} \tag{1}$$

where $\dot{x}$ and $\dot{y}$ denote the velocity of the robot in the direction of X-axis and Y-axis, respectively. v denotes the linear velocity of the robot in the head direction of the robot (the x_m-axis) and $\dot{\theta} = \omega$ denotes the rotational angle velocity of the robot. The value of $\dot{\theta}$ is positive when the robot rotate counterclockwise and the value of $\dot{\theta}$ is negative if the robot rotate clockwise. The robot's motion is controlled by its velocity v and angular velocity w, which are function of time.

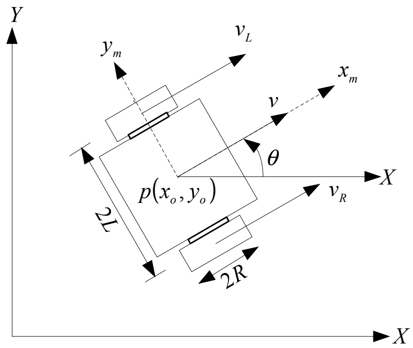


Figure 1. Schematic diagram of a two-wheeled robot for the motion control.

Two wheels are fixed in the considered mobile robot and each wheel is controlled independently by each motor, so the forward velocity of the robot and the wheel angular velocity are described by

$$\begin{bmatrix} v \\ \omega \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} \\ \frac{-1}{2\mathrm{L}} & \frac{1}{2\mathrm{L}} \end{bmatrix} \begin{bmatrix} v_\mathrm{L} \\ v_\mathrm{R} \end{bmatrix} \tag{2}$$

where L is the displacement from the center of robot to the center of wheel. $v_\mathrm{L}=R\omega_L$ and $v_\mathrm{L}=R\omega_R$ are the linear velocities of the left-wheel and right-wheel, respectively. R is the radius of the wheel and ω_L and ω_R are angle velocities of the left-wheel and right-wheel, respectively. Based on equations (1) and (2), we can obtain the following equation:

$$\begin{bmatrix} v_L \\ v_R \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & L \\ -\cos\theta & -\sin\theta & L \end{bmatrix} \begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} \tag{3}$$

In this paper, a fuzzy control structure is proposed to control the two-wheeled robot so that it can move to any desired position effectively. The robot has two degrees of freedom in its relative position and orientation, so the robot posture can be represented by the vector (x, y, θ). Two postures of the robot are described in Figure 2, where $p(x_o, y_o, \theta)$ and $p_d(x_d, y_d, \theta_d)$ denote the current posture and the desired (target) posture of the robot, respectively. θ_d is the angle of robot at the desired position. d is the distance between the current position (x_o, y_o) and the desired position (x_d, y_d) of the robot, θ is the angle between the x-axis and the head direction of the robot, φ is the angle between the X-axis and the direction of the current position of the robot toward the desired position of the robot, and α is the angle between the head direction of the robot and the direction of the current position of the robot toward the desired position of the robot. The following equations are considered so that $\alpha \in [-180,180]$ in this proposed structure.

$$d = \sqrt{(x_d - x_o)^2 + (y_d - y_o)^2} \tag{4}$$

$$\varphi = \begin{cases} \tan^{-1}\dfrac{y_d - y_o}{x_d - x_o} & , \ if \quad y_d - y \geq 0 \ and \ x_d - x_o > 0 \\ 180 - \tan^{-1}\dfrac{y_d - y_o}{x_d - x_o} & , \ if \quad y_d - y \geq 0 \ and \ x_d - x_o < 0 \\ 180 + \tan^{-1}\dfrac{y_d - y_o}{x_d - x_o} & , \ if \quad y_d - y \leq 0 \ and \ x_d - x_o > 0 \\ 360 - \tan^{-1}\dfrac{y_d - y_o}{x_d - x_o} & , \ if \quad y_d - y \leq 0 \ and \ x_d - x_o < 0 \end{cases} \tag{5}$$

$$\alpha = \begin{cases} \varphi - \theta & , \ if \quad \varphi - 180 < \theta < 180 \\ (\varphi - \theta) - 360 \ , & if \quad -180 < \theta < \varphi - 180 \end{cases} \tag{6}$$

Two wheels are fixed in the considered mobile robot and each wheel is controlled independently by each motor, so the mobile path of the controlled robot is determined by the velocities and the directions of these two motors. In this paper, the design object is to determine the velocities U_L and U_R of the left-wheeled motor and right-wheeled motor so that the robot can effectively move from the current position (x_o, y_o) to the desired position (x_d, y_d). The control system block diagram can be described in Figure 3, where a 4-input-and-2-output fuzzy controller with four input variables: d (the distance between the robot and the destination), Δd (the change quantity of motion distance), α (the rotation angle of robot), and $\Delta\alpha$ (the change quantity of rotation angle) are considered to determine two velocities U_L and U_R to control the left-wheeled motor and right-wheeled motor, respectively. The values d and α can be respectively determined by Equation (4) and (6), then the values $\Delta\alpha$ and Δd can be calculated by

$$\Delta\alpha(t) = \alpha(t) - \alpha(t-1) \tag{7}$$

$$\Delta d(t) = d(t) - d(t-1) \tag{8}$$

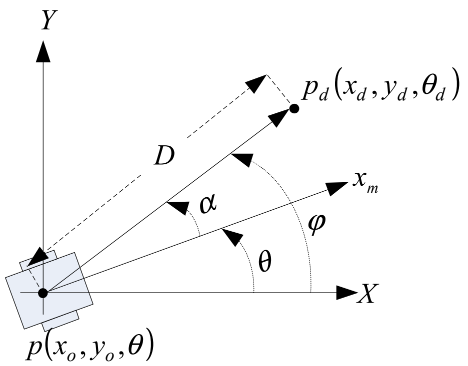


Figure 2. Description of the current posture $p(x_o, y_o, \theta)$ and the desired posture $p_d(x_d, y_d, \theta_d)$ of the robot.

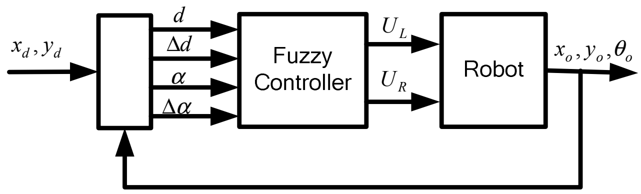


Figure 3. Control system block diagram of the two-wheeled mobile robot.

In order to reduce the design complexity, the motion fuzzy control structure is decomposed into two structures: distance fuzzy system and angle fuzzy system, which are two-input-and-one-output fuzzy systems. As shown in Figure 4, U_L and U_R can be obtained by

$$U_L = U_d + U_a \tag{9}$$

and

$$U_R = U_d - U_a \tag{10}$$

where U_d and U_a are determined by distance fuzzy system and angle fuzzy system, respectively. They are described as follows:

In the distance fuzzy controller, d and Δd are used to be the input variables and U_d is the output variable of this fuzzy system. In the angle fuzzy controller, α and $\Delta\alpha$ are used to be the input variables and U_a is the output variable of this fuzzy system. The proposed fuzzy rule bases for these two fuzzy systems are described in Table 1 and Table 2, respectively.

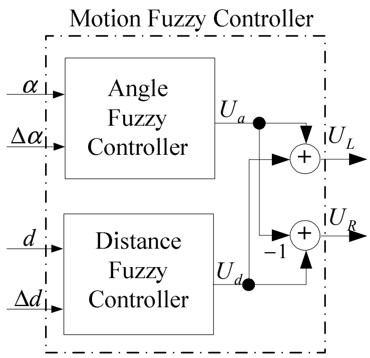


Figure 4. System block of the motion fuzzy

Table 1. Fuzzy rule base of distance fuzzy system.

U_d		d						
		NB	NM	NS	ZO	PS	PM	PB
Δd	PB	ZO	PS	PM	PB	PB	PB	PB
	PM	NS	ZO	PS	PM	PB	PB	PB
	PS	NM	NS	ZO	PS	PM	PB	PB
	ZO	NB	NM	NS	ZO	PS	PM	PB
	NS	NB	NB	NM	NS	ZO	PS	PM
	NM	NB	NB	NB	NM	NS	ZO	PS
	NB	NB	NB	NB	NB	NM	NS	ZO

Table 2. Fuzzy rule base of angle fuzzy system.

U_a		α						
		NB	NM	NS	ZO	PS	PM	PB
$\Delta\alpha$	PB	ZO	PS	PM	PB	PB	PB	PB
	PM	NS	ZO	PS	PM	PB	PB	PB
	PS	NM	NS	ZO	PS	PM	PB	PB
	ZO	NB	NM	NS	ZO	PS	PM	PB
	NS	NB	NB	NM	NS	ZO	PS	PM
	NM	NB	NB	NB	NM	NS	ZO	PS
	NB	NB	NB	NB	NB	NM	NS	ZO

The proposed fuzzy rules of these two fuzzy systems can be described as follows:

R_{U_d} (j_1,j_2): IF d is A_{j_1} AND $\Delta\alpha$ is B_{j_2}, THEN

$$U_d \text{ is } C_{j_3} \quad j_1, j_2, j_3 \in \{-3,-2,-1,0,1,2,3\} \tag{11}$$

R_{U_a} (j_1,j_2): IF α is E_{j_1} AND $\Delta\alpha$ is F_{j_2}, THEN

$$U_a \text{ is } G_{j_3} \quad j_1, j_2, j_3 \in \{-3,-2,-1,0, 1, 2, 3\} \tag{12}$$

$A_{j_1} \in T(d)$, $B_{j_2} \in T(\Delta d)$, $C_{j_3} \in T(U_d)$, $E_{j_1} \in T(\alpha)$, $F_{j_2} \in T(\Delta\alpha)$, and $G_{j_3} \in T(U_a)$. The following term sets are used to describe the fuzzy sets of each input and output fuzzy variables:

$$T(d) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{A_{-3}, A_{-2}, A_{-1}, A_0, A_1, A_2, A_3\} \tag{13}$$

$$T(\Delta d) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{B_{-3}, B_{-2}, B_{-1}, B_0, B_1, B_2, B_3\} \tag{14}$$

$$T(U_d) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{C_{-3}, C_{-2}, C_{-1}, C_0, C_1, C_2, C_3\} \tag{15}$$

$$T(\alpha) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{D_{-3}, D_{-2}, D_{-1}, D_0, D_1, D_2, D_3\} \tag{16}$$

$$T(\Delta\alpha) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{E_{-3}, E_{-2}, E_{-1}, E_0, E_1, E_2, E_3\} \tag{17}$$

$$T(U_a) = \{NB, NM, NS, ZO, PS, PM, PB\} = \{F_{-3}, F_{-2}, F_{-1}, F_0, F_1, F_2, F_3\} \tag{18}$$

where seven linguistic terms (Negative Big (NB), Negative Middle (NM), Negative Small (NS), Zero (ZO), Positive Small (PS), Positive Middle (PM), and Positive Big (PB)) are considered to describe the input and output variables of the distance fuzzy controller and the angle fuzzy controller. As shown in Figure 5 and Figure 6, the triangle membership functions and the singleton membership functions are used to describe the fuzzy sets of input variables and the output variables, respectively. Based on the weighted average method, the final outputs of the distance fuzzy system and angle fuzzy system can be respectively described by:

$$U_d = \frac{\sum_{j_1=-3}^{3}\sum_{j_2=-3}^{3}\min(\mu_{A_{j_1}}(d), \mu_{B_{j_2}}(\Delta d)) \cdot c(C_{j_3})}{\sum_{j_1=-3}^{3}\sum_{j_2=-3}^{3}\min(\mu_{A_{j_1}}(d), \mu_{B_{j_2}}(\Delta d))} \tag{19}$$

And

$$U_a = \frac{\sum_{j_1=-3}^{3}\sum_{j_2=-3}^{3}\min(\mu_{E_{j_1}}(\alpha), \mu_{F_{j_2}}(\Delta\alpha)) \cdot c(G_{j_3})}{\sum_{j_1=-3}^{3}\sum_{j_2=-3}^{3}\min(\mu_{E_{j_1}}(\alpha), \mu_{F_{j_2}}(\Delta\alpha))} \tag{20}$$

Therefore, U_d and U_a are determined by equations (19) and (20) based on the data d, Δd, α, and $\Delta\alpha$ obtained by equations (4) ~ (8). The left-wheel velocity U_L and the right-wheel velocity U_R can be obtained by equations (9) and (10). The next posture $(x(k+1), y(k+1), \theta(k+1))$ of the mobile robot can be determined by the 3D robot soccer simulator of FIRA.

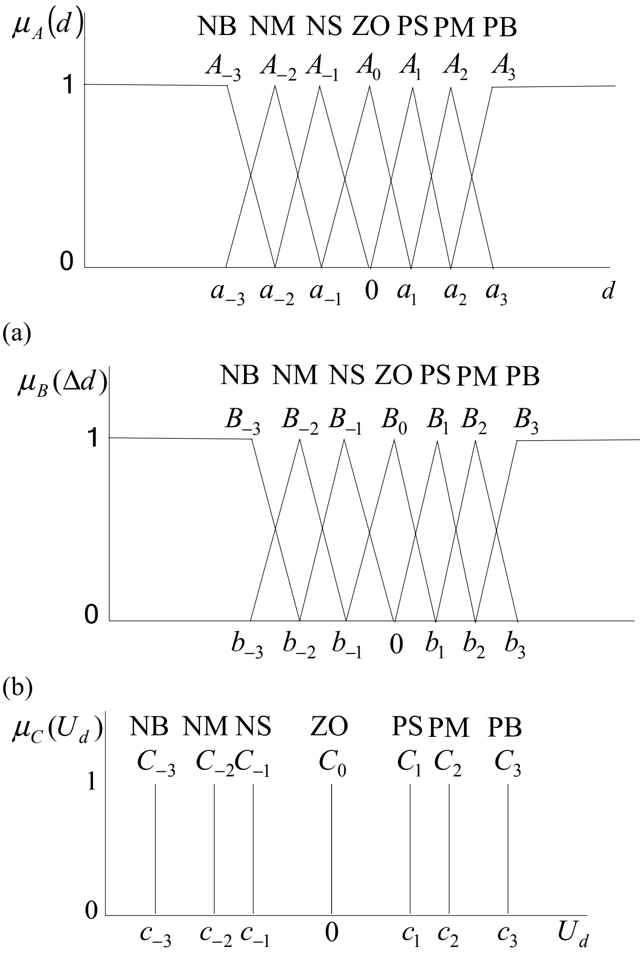


Figure 5. Membership functions: (a) the antecedent fuzzy sets for d, (b) the antecedent fuzzy sets for Δd, and (c) the consequent fuzzy sets for U_d.

3. Genetic Algorithm

How to appropriately code and design a fitness function is an important key point for genetic algorithms to effectively search a good result. In this paper, a ratio coefficient coding method and a variable fitness function are proposed so that input/output membership functions of the motion fuzzy controller can be effectively selected by the proposed GA-based method in the real application. They are described as follows:

3.1. Ratio Coding Method

Consider a fuzzy system with two input variables x_1 and x_2, and output variable y. If there are $2n$+1 linguistic terms and membership functions have the symmetric properties, the ceter values of each membership functions can be described as follows:

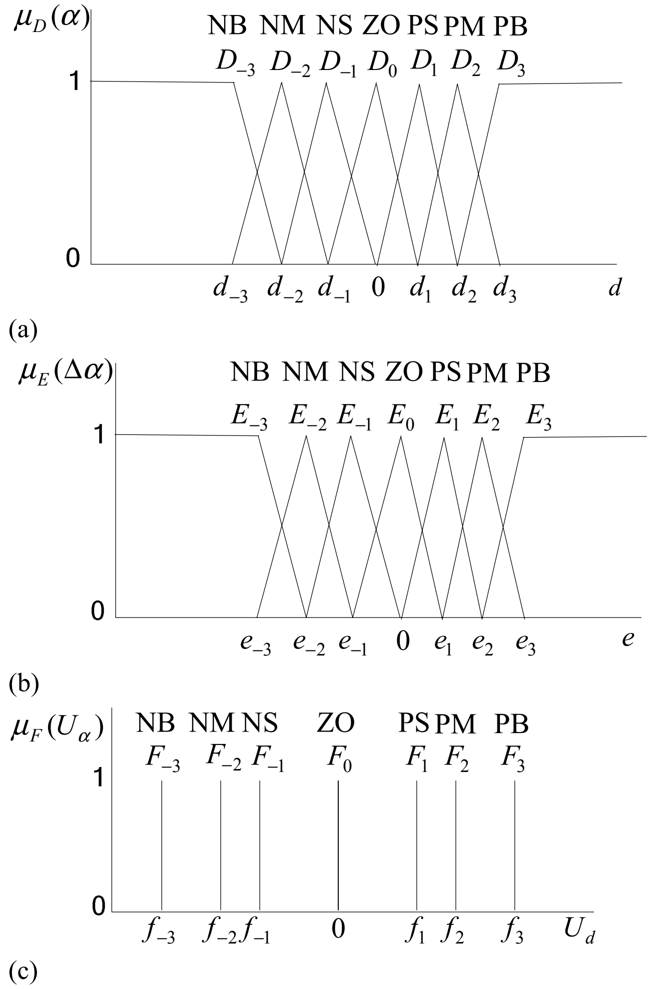


Figure 6. Membership functions: (a) the antecedent fuzzy sets for α, (b) the antecedent fuzzy sets for $\Delta\alpha$, and (c) the consequent fuzzy sets for U_a.

$$a_{j_1} = \begin{cases} -a_{j_1} & if \quad -n \le j_1 < 0 \\ 0 & if \quad j_1 = 0 \\ a_{j_1} & if \quad 0 < j_1 \le n \end{cases} \tag{21}$$

$$b_{j_2} = \begin{cases} -b_{j_2} & if \quad -n \le j_2 < 0 \\ 0 & if \quad j_2 = 0 \\ b_{j_2} & if \quad 0 < j_2 \le n \end{cases} \tag{22}$$

$$c_{j_3} = \begin{cases} -c_{j_3} & if \quad -n \le j_3 < 0 \\ 0 & if \quad j_3 = 0 \\ c_{j_3} & if \quad 0 < j_3 \le n \end{cases} \tag{23}$$

That is, only n values are needed to determine all the membership functions for each variable. In this paper, the following ratio coefficient coding method is proposed to determine the values of a_{j_1}, b_{j_2}, and c_{j_3} so that all the membership functions of these three variables x_1, x_2, and y are determined.

$$a_{j_1} = x_1^{\max} \prod_{p=j_1}^{n} k_{1p} \quad 1 \le j_1 \le n \tag{24}$$

$$b_{j_2} = x_2^{\max} \prod_{p=j_2}^{n} k_{2p} \quad 1 \le j_2 \le n \tag{25}$$

$$c_{j_3} = y^{\max} \prod_{p=j_3}^{n} k_{3p} \quad 1 \le j_3 \le n \tag{26}$$

where $x_i \in \left[-x_i^{\max}, x_i^{\max}\right]$, $y \in \left[-y^{\max}, y^{\max}\right]$. k_{ij} is described by

$$k_{ij} = \frac{w_{ij}+1}{2^3+1}, \quad i \in \{1,2,3\} \; j \in \{1,2,...,n\} \tag{27}$$

where $w_{ij} \in \{0,1,2,3,4,5,6,7\}$. In the proposed GA-based method, each w_{ij} is considered as a gene and used to determine a ratio coefficient k_{ij}.

In the proposed motion fuzzy control structure described by Section 2, seven linguistic items (n=3) are considered for the input and output variables as described in Figures 5 and 6. Three ratio coefficients are needed to decide all the membership functions for each variable. Each chromosome represents a fuzzy system and each fuzzy system has three linguistic variables, thus each chromosome can be described by

$$\text{chro} = w_{11}w_{12}w_{13}w_{21}w_{22}w_{23}w_{31}w_{32}w_{33} \tag{28}$$

where each gene w_{ij} is coded by

$$(w_{ij})_2 \in \{000,001,010,011,100,101,110,111\} \tag{29}$$

That is, each gene is coded by three bits and the bit length of the considered chromosome is 27 bits.

3.2 Variable Fitness Function

In the proposed GA-based method, a variable fitness function is proposed as follows:

$$f_i = F(chro_i) = \exp\left(-\left(\frac{Tr(chro_i)}{\delta_1^g}\right)^2\right)\cdot\exp\left(-\left(\frac{IAE(chro_i)}{\delta_2^g}\right)^2\right)$$

i=1,2,…,N; g=1,2,…,G (30)

where N is the population size, G is the maximum number of generation, f_i is the fitness function value of the i-th chromosome $chro_i$ in the g-th generation, $Tr(chro_i)$ and $IAE(chro_i)$ denote the rise time and the integral absolute error of the i-th chromosome $chro_i$, respectively. δ_1^g and δ_2^g are variables which are determined by

$$\delta_1^g = \mathrm{T}r(chro^{g-1}) \quad (31)$$

and

$$\delta_2^g = IAE(chro^{g-1}) \quad (32)$$

where $chro^{g-1}$ is the chromosome with the best fitness value in the (g-1)-th generation.

4. Simulation Results

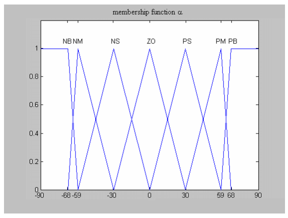
In this section, three motion control methods are compared: (i) the parameter control method: This control method is based on the parameter control principle; (ii) the experience-based fuzzy control method: The membership functions of two fuzzy systems in the proposed structure are design by the trial-and-error method; (iii) the GA-based fuzzy control method: The membership functions of two fuzzy systems in the proposed structure are design by the proposed GA-based method. Membership functions of α, $\Delta\alpha$, U_α, d, Δd, and U_d determined by the proposed GA-based method are described in Figure 7. They are simulated in the 3D robot soccer simulator of FIRA. One control trajectory of robot by the proposed GA-based fuzzy control method is shown in Figure 8, where the initial posture of the robot is $p(x_o, y_o, \theta)$=(55, 60, 180) and the desired position is (0, 0). Its time responses of d, α, U_d, U_α, U_L, and U_R are shown in Figure 9. The control results are analysis by the MATLAB. In the angle control, the control results are shown in Figure 10 and Table 3. In the distance control, the control results are shown in Figure 11 and Table 4. We can see that the proposed method has better performance than the other two methods in the rise time and the integral absolute error.

Table 3. Performance Comparison of three methods in the angle control.

Angle control	*Tr*	*IAE*
Parameter control method	13	140
Experience-based angle fuzzy control method	7	125
GA-based angle fuzzy control method	6	111

Table 4. Control results of three methods in the distance control.

Distance control	*Tr*	*IAE*
Parameter control method	21	210
Experience-based distance fuzzy control method	18	185
GA-based distance fuzzy control method	17	173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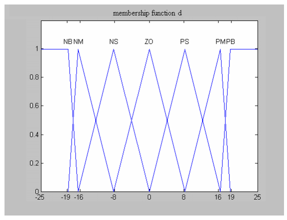
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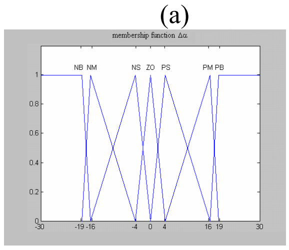
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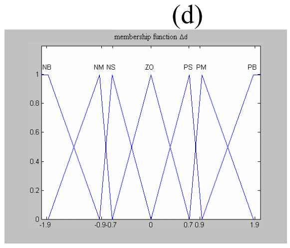
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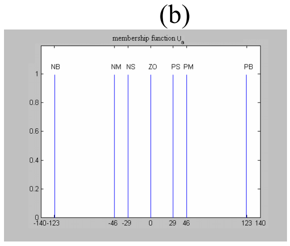
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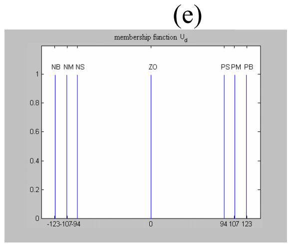
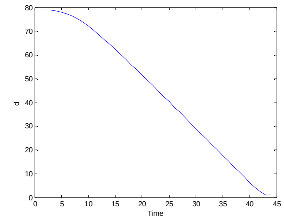
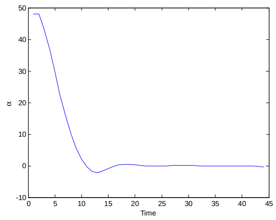

(f)

Figure 7. Membership functions of (a)α, (b)$\Delta\alpha$, (c)U_α, (d)d, (e)Δd, and (f)U_d determined by the proposed GA-based method.

Figure 8. Robot trajectory simulated in FIRA 3D robot soccer simulator.



(a)



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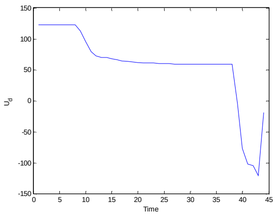
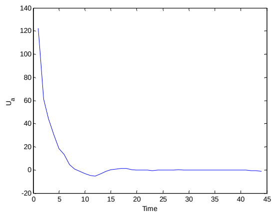
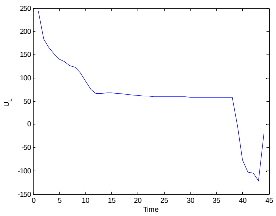


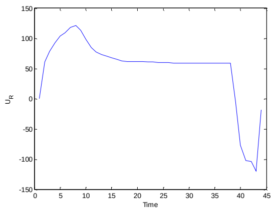
(c)



(d)

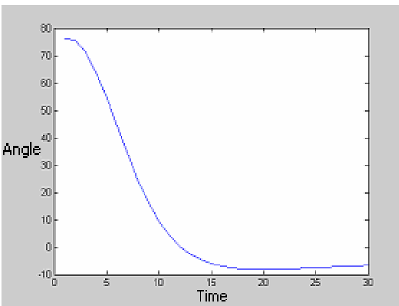


(e)

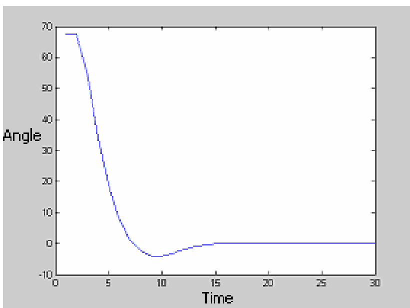


(f)

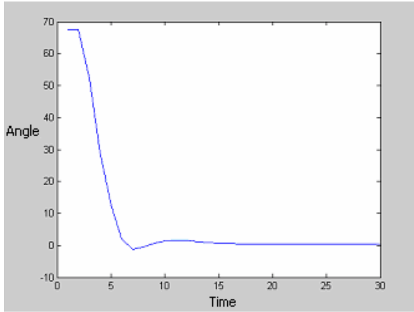
Figure 9. Time responses of (a) d, (b) α, (c) U_d, (d) U_α, (e) U_L, and (f) U_R, where 0.0167 sec/clock.



(a)

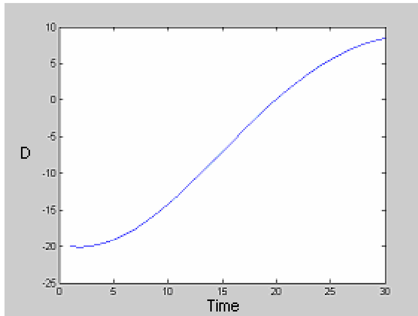


(b)

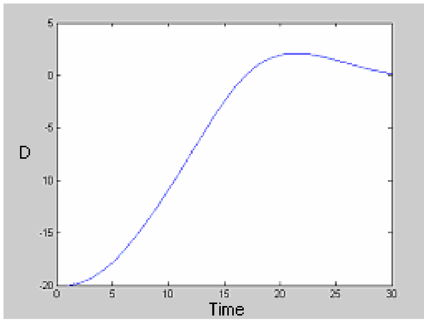


(c)

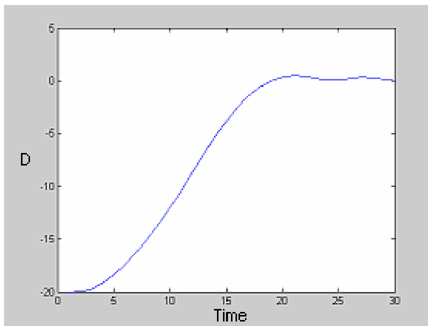
Figure 10. Control results of three methods: (a) the parameter control method, (b) the experience-based angle fuzzy control method, (c) the GA-based angle fuzzy control method.



(a)



(b)



(c)

Figure 11. Control results of three methods: (a) the parameter control method, (b) the experience-based distance fuzzy control method, (c) the GA-based distance fuzzy control method.

5. Conclusions

The control object in the two-wheeled mobile robot is to control the left-wheeled motor and right-wheeled motor of the robot so that it can move effectively in a two-dimensional space. In this paper, a GA-based motion fuzzy control method is proposed. Three control methods are simulated in the 3D robot soccer simulator of FIRA and the control results are analysis by the MATLAB. In the comparison, we can see that the proposed GA-based motion fuzzy control method has the better performance than the other two methods. The proposed method has been implemented in an object oriented programming method so that the implemented controller has the characteristics of high modularity and portability. In the practical application, the proposed method has been successfully applied in the FIRA robot soccer tournament: MiroSot. In the actual tournament, the proposed control method also has a good performance.

6. Acknowledgment

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7. References

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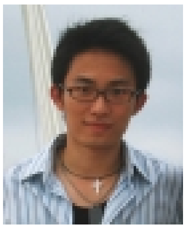

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