Modeling and Tracking Control of Differential-Drive Mobile Robots Using Artificial Fuzzy Neural Networks

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***Abstract*—This paper contributes to the development of mechanical modeling and motion control of autonomous mobile robots (AMRs) using artificial fuzzy neural networks. An interval type-2 fuzzy neural network (IT2FNN) algorithm is incorporated with the mechanical modeling of mobile robots to develop intelligent control schemes. The metaheuristic genetic algorithm is employed to determine the initial IT2FNN structure. Taking the mechanical modeling, genetic algorithm and IT2FNN control strategy, the two-wheeled nonholonomic mobile robots are steered to accomplish time-varying trajectory tracking tasks. Numerical simulations were conducted to illustrate the efficiency and superiority of the proposed intelligent IT2FNN control method for autonomous mobile robots.**

Keywords—autonomous mobile robots, fuzzy neural network, intelligent control, motion control.

I. Introduction

In robotics research, autonomous mobile robot is a type of robot that can understand and move through its environment independently [1-2]. They are computer-controlled machines designed to improve operational efficiency, speed, precision, and safety.

Differential-drive mobile robots are nonholonomic robotic systems with movement based on two separately driven wheels which are situated on each side of the robot body [3-4]. This study presents a type-2 artificial fuzzy neural network (FNN) computation for intelligent nonholonomic AMR control considering the mechanical modeling and uncertainty.

Mechanical modeling and motion control are fundamental issues of mobile robotics [5-6]. With the derived mathematical models of mobile robots, the motion control schemes are synthesized to steer the robots to track desired time-varying trajectories. This paper presents a genetic algorithm based IT2FNN intelligent control for differential-drive AMR robots.

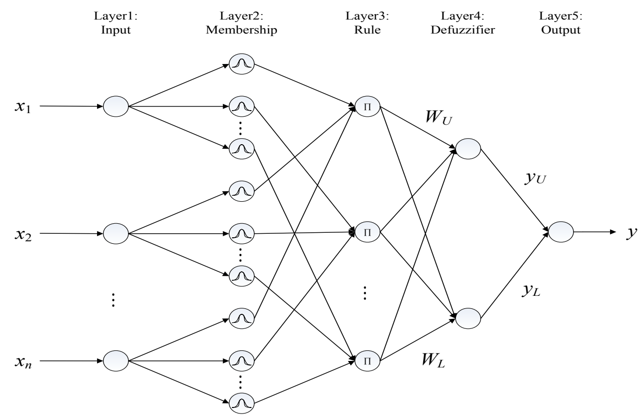

Fig. 1. Structure of the artificial IT2FNN.

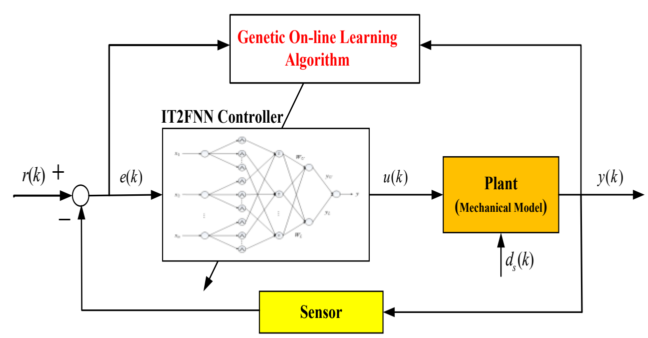

Fig. 2. Structure of the genetic IT2FNN control scheme.

II. Methods and Results

A. Artificial IT2FNN Learning Control

Fig. 1 depicts the five-layered structure of artificial IT2FNN with an input layer, three hidden layers and an output layer. Fig. 2 presents the framework of the proposed genetic IT2FNN control scheme. $r(k)$ is the desired reference, $e(k)$ is the error signal, $u(k)$ is the control output, $d_s(k)$ is the disturbance/uncertainty and $y(k)$ is the system output in discrete time k.

B. Mechanical Modeling

In the world coordinate frame, the pose of the non-holonomic AMR robot is defined by

$$q = \left[x_w \; y_w \; \theta\right]^T \tag{1}$$

where x_w, y_w and θ are the position and orientation vector of the AMR robots. The kinematic model of the differential-drive robots is formulated by

$$\dot{q} = \begin{bmatrix} \dot{x}_w \\ \dot{y}_w \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} v\cos(\theta) & 0 \\ v\sin(\theta) & 0 \\ 0 & \omega \end{bmatrix} \tag{2}$$

were v is the velocity and ω is the angular velocity of the two-wheeled AMR robots, calculated by

$$\omega = \frac{v_r - v_l}{L} \tag{3}$$

$$v = \omega R = \frac{v_r + v_l}{2} \tag{4}$$

where v_r is the velocity of right wheel, and v_l represents the velocity of left wheel. R is the curve radius and L is the distance between two wheels.

C. Genetic IT2FNN Control of Mobile Robots

As shown in Fig. 2, the robotic sensors are employed to perform the feedback control of mobile robots. The fitness function of the proposed IT2FNN with genetic algorithm is defined by the weighted integral square error:

$$F = w_f \int_0^t \left(x_e^2(\tau) + y_e^2(\tau) + \theta_e^2(\tau)\right) d\tau \tag{5}$$

where x_e and y_e are the position errors and θ_e is the error of vehicle's orientation for autonomous vehicles.

D. Simulation Results

Fig. 3 presents the simulation result of circular trajectory tracking and Fig. 4 depicts the tracking errors for the two-wheeled autonomous mobile robots. As shown in Figs. 3-4, the proposed optimal self-tuning IT2FNN motion control scheme successfully steers the vehicle to track this trajectory with satisfactory performance.

III. Conclusions

This paper contributes to the development of mechanical modeling and motion control of AMRs using artificial fuzzy neural networks. The evolutionary IT2FNN algorithm is incorporated with the mechanical modeling of mobile robots to develop intelligent control schemes. The proposed IT2FNN is applied to self-tuning online motion control of autonomous vehicles. Simulations were conducted to illustrate the efficiency of the proposed IT2FNN control method for mobile robots

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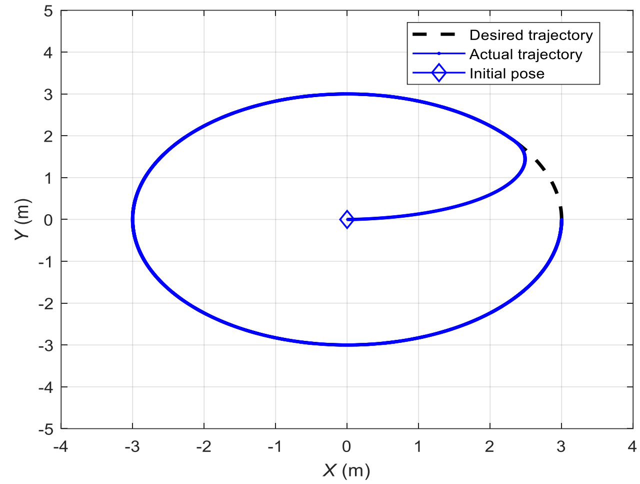

Fig. 3. Simulation result of the circular trajectory tracking.

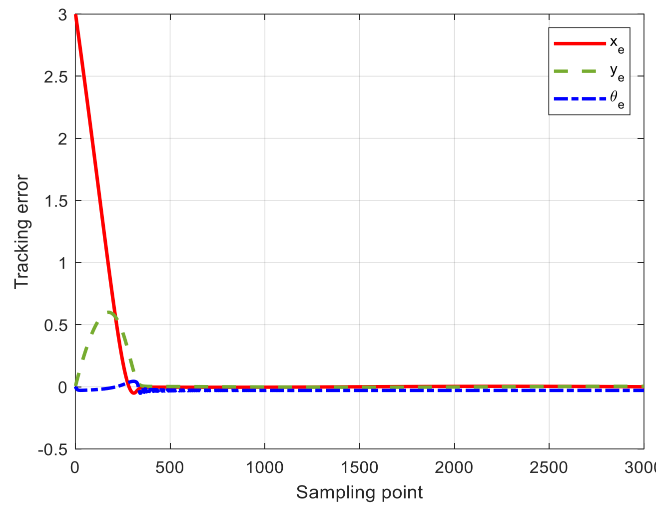

Fig. 4. Tracking errors of the circular trajectory tracking.

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