Intelligent Tracking Control for AGV Navigation in Industry Environment Based on Adaptive Fuzzy-Neural Approach

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***Abstract*—This study proposes an intelligent control strategy for automatic guided vehicle (AGV) trajectory tracking control for application in manufacturing facilities Based on the fuzzy-neural network (FNN) method combined with the newly proposed error algorithm in the design of the Loss function, virtual models with the working environment and the AGV platform can be used to learn controller's parameters in advance from the simulation environment. Finally, the real-time trajectory tracking task of navigation is evaluated to verify the effectiveness of the proposed control strategy integrated with a reflector-assisted localization algorithm.**

Keywords—Automated guided vehicles, SLAM, path tracking, navigation maneuver, fuzzy neural networks.

I. INTRODUCTION

With the ever-changing nature of technology, copious categories of robots play important roles in our daily life, especially mobile robots are increasingly vital. The primary purpose of mobile robots is to carry bulky goods. As long as there is a requirement of carrying, there is a possibility of the mobile robots' application. Automatic guided vehicles (AGV) can solve some problems, including the shortage of manpower, saving costs, and increasing productivity. Advances in software and hardware engineering are bringing mechanical devices into contaminated areas where humans can never survive, inspecting the situation in the plants and continuously monitoring the radiation level of each location on the map to ensure that the operators will not be injured by radiation [1, 2]. This study focuses on intelligent tracking control design for autonomous navigation and presents a robust localization algorithm that enhances the positioning accuracy of AGV for manufacturing applications.

II. MATERIALS AND METHODS

A. System Descriptions

In Fig. 1, our AGV is built on a four-wheel drive basis. The main space configuration is composed of a touch panel, battery indicator, buttons, and IPC on the upper level, and eight motors, two laser sensors, and battery load on the lower level. The touch panel is used to display system information from IPC that is used to run the algorithms, the eight motors are used to control the movement and direction of the four wheels, and the laser sensors are installed on the opposite corners of AGV to detect the environment and position the navigation.

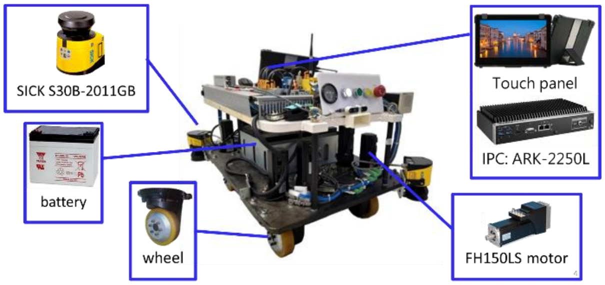
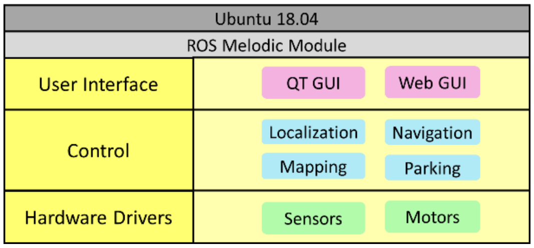


Fig. 1. Physical layout of our AGV platform.



Ubuntu 18.04	
ROS Melodic Module	
User Interface	QT GUI Web GUI
Control	Localization Navigation Mapping Parking
Hardware Drivers	Sensors Motors

Fig. 2. The software architecture diagram for the AGV navigation system.

There are three major levels in the complete program architecture of the navigation system, as shown in Fig. 2, namely the human-machine interface level, the algorithm control level, and the hardware driver level. At the human-machine interface level (User Interface), the operation of basic functions is mainly operated by users through QT GUI and Web GUI. In the control layer, there is mostly algorithm computation, mainly for the developer to contact the level, such as Localization, Navigation, Mapping, and Parking. At the Hardware level, information is retrieved from hardware or transmitted to hardware for actions, mainly operated by hardware manufacturers.

B. Tracking Control Design

In order to improve the performance of the traditionally designed controller and to avoid the trouble of constantly adjusting the controller parameters according to the changes of the environment and vehicle body, the study proposes an FNN-based controller, which can self-adjust the parameters according

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to the environment and vehicle body to adapt by the interference of different environments and still maintain the tracking performance. The overall scheme of the proposed tracking controller is shown in Fig. 3. Block (1) denotes the motion model of AGV, while block (2) is core controller and its input is $\bar{e} = [\bar{x}\ \bar{y}\ \bar{\varphi}]$, which is error of path points and AGV's position, and its output is $u_f = [v\ \omega]^T$ for the speed and . The position and attitude of AGV is $p = [x\ y\ \theta]$ and a path point is $p^* = [x^*\ y^*]$; $\bar{x}$ and $\bar{y}$ are the Dimensional plane difference between AGV and the path point; $\bar{\varphi}$ is the angle error of AGV. Block (3) is the learning equation method for updating the weights of the FNN. By employing similar approach in [3], the designed internal structure the FNN structure utilized in the tracking controller. Layer I is the input $[\bar{x}\ \bar{y}\ \bar{\varphi}]$, Layer II is the step of fuzzifying the input, which corresponds to the fuzzy membership function, also called fuzzy set, different fuzzy sets also correspond to different fuzzy rules of Layer III, and finally output is Layer VI.

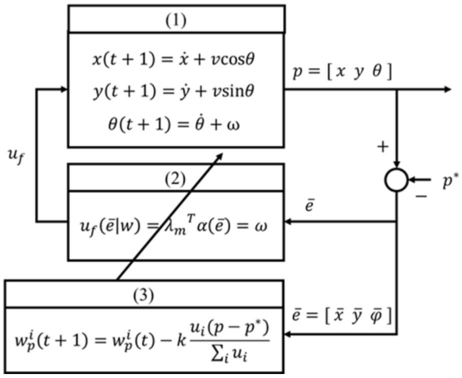

Fig. 3. Path tracking controller architecture for our AGV.

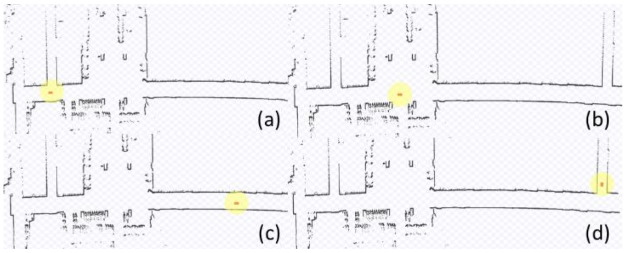

Fig. 4. Fuzzy neural network follower controller training in ROS Stage using the automobile factory corridor map.

III. EXPERIMENTAL RESULTS

The test site is an actual automobile factory with a corridor of nearly 90 meters, which have a serious corridor effect. To obtain the proper control parameters for the proposed tracking controller, the corresponding 2D map of the automobile factory is built into the simulation tool ROS Stage, as shown in Fig. 4. Through the off-line simulation, the training of FNN can achieve the self-adjusting control according to specified navigation task.

With the trained FNN-based controller, several tests under different speeds and path types are established for the path-tracking performance of AGV. The snapshot of experiment is shown in Fig. 5. To further examine the navigation performance for our approach, the following performance evaluation metrics are adopted [4]: (i) Completion time (CT), which is the total time it takes to calculate the task from the starting point to the end location; (ii) Path length (PL), which is the total distance travelled by the calculation task from the starting point to the end position; (iii) Distance error (DE), which is a measure of the accuracy of reaching the end position. In Table I, the comparison for the tracking performance of AGV with the reflector-assisted localization is illustrated. In Task 1, the AGV executes the path tracking in the corridor navigation. Without the reflectors in the "feature-less" environment, the AMCL easily degrades due to the similar scenes so that larger DE is caused to about 0.22 m while the traveled PL only reaches about 52 m. With the reflector-assisted localization in Task 2, even for the longer traveled PL, DE can be corrected to the level of about 0.05 m.

Fig. 5. The experiment conducted in an actual automobile factory with a corridor.

TABLE I. THE COMPARISON FOR TASK 1 AND TASK 2

		(Unit: meter)
Task 1	PL	DE
Average of 5 routs	52.5014476	0.226264
Task 2		
Average of 5 routs	83.1323	0.049445

IV. CONCLUSIONS

This study proposes an intelligent tracking control strategy for AGV with the improved localization method by means of reflective column-assisted positioning. Further, through the experiments in the task of path tracking and navigation, the testing results depict the proposed tracking controller with the reflector-assisted localization can termed as a promising way for the industry-level AGV to deliver parts across large-scale manufacturing workspace.

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