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Solid State Parametric Modeling and Trajectory Tracking Control of the MegBot-T800 AGV Robot

Jian Liu

International Institute of Management and Business, Minsk City, Belarus

KEYWORDS

MegBot-T800 AGV;
Solid-State Parametric Modeling;
Kinematic Model;
Trajectory Tracking Control;
Sliding Mode Controller;
Adaptive Parameter Adjustment;
MATLAB Simulation;
Omnidirectional Wheel

ABSTRACT

To address the inefficiencies in developing Automated Guided Vehicles (AGVs) with similar chassis structures and the challenges of maintaining control accuracy under dynamic parameter changes, this study focuses on the MegBot-T800 AGV robot, conducting systematic research on its solid-state parametric modeling and trajectory tracking control. First, a kinematic model tailored to the MegBot-T800's six-wheeled configuration (4 omnidirectional wheels + 2 rubber wheels) is established, and speed decomposition/synthesis methods for different wheel types are derived to address limitations of traditional modeling approaches. Second, three trajectory tracking control schemes are designed to mitigate issues of parameter uncertainty and external interference: an ASMCFR-based controller, a filter-integrated sliding mode controller, and an adaptive parameter-adjusted controller. Finally, MATLAB-based simulations of straight-line and circular trajectory tracking are performed. Results demonstrate that the proposed model accurately reflects the robot's motion characteristics, while the control schemes effectively suppress chattering, enhance tracking accuracy, and ensure stable operation under complex conditions. This research provides a technical reference for parametric modeling and control design of AGVs with similar structures, reducing development and maintenance costs.

INTRODUCTION

Since the first AGV was applied in industrial scenarios in the 1950s, AGVs have evolved into core equipment for modern industrial logistics, thanks to their advantages in efficiency, flexibility, reliability, and scalability [1][3]. The MegBot-T800 AGV, as a representative high-performance model, boasts a load capacity of 800KG, a maximum speed of 2.1m/s, and strong adaptability to diverse ground conditions (e.g., tile, cement, and epoxy floors) with high tolerance for water stains, oil stains, and small obstacles [6][7]. However, two key challenges hinder its broader application:

1. Modeling Limitations: Traditional AGV chassis modeling methods struggle with accurate speed decomposition and synthesis for hybrid wheel configurations (omnidirectional + rubber wheels), leading to deviations in motion control.
2. Control Instability: Dynamic parameters (e.g., mass, moment of inertia, wheel radius) are prone to changes due to load variations, mechanical wear, or installation errors, while external interference further reduces trajectory tracking accuracy [4][12].

To solve these problems, this study takes the MegBot-T800 as the research object, establishes a solid-state parametric model matching its operating characteristics, designs targeted trajectory tracking control schemes, and verifies their effectiveness through simulations. The research aims to provide a flexible, adaptive solution for AGV development and promote its application in manufacturing, warehousing, and logistics.

* Corresponding author. E-mail address: liujianwork 163@gmail.com

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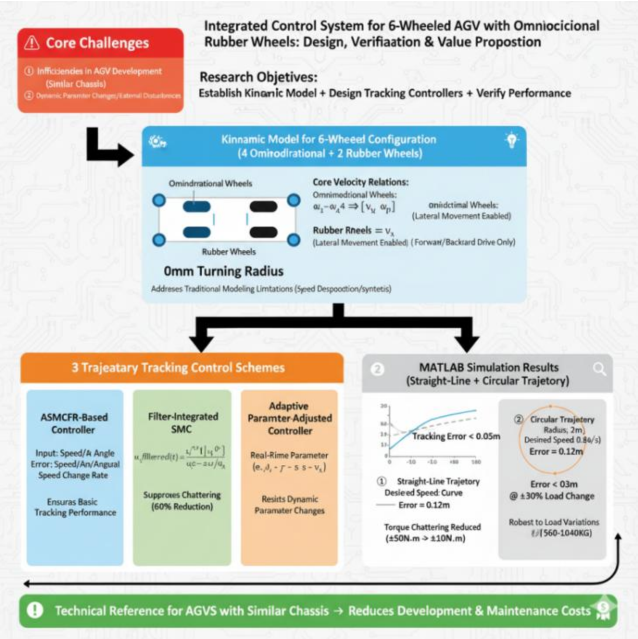

Fig.1.Multi-module Serial Flowchart

1.Solid-State Parametric and Kinematic Modeling

The MegBot-T800 adopts a six-wheeled structure (4 omnidirectional wheels at the front/rear, 2 rubber wheels in the middle) with a 0mm turning radius for in-situ steering. To establish an accurate kinematic model, the following assumptions are made: the robot body is a rigid body moving on a horizontal plane; no wheel slip occurs; and the body's structural center coincides with its center of gravity [12].

1.1.Kinematic Models of Wheel Types

Omnidirectional Wheels: Composed of a hub (active component) and evenly distributed driven wheels (rotating freely around their axes at 90° to the hub axis), enabling lateral movement [7]. The kinematic equation correlates the wheel's rotation angular velocity (ω_1 - ω_4) and driven wheel speed (v_{91} -v_{94}) to the robot's center motion state [v_x, v_y, ω_p] (v_x: X-axis speed, v_y: Y-axis speed, ω_p: angular velocity of the center point P):

$$[\omega_1;\omega_2;\omega_3;\omega_4] = (1/R)\cdot[10-l_1;10-l_2;10-l_3;10-l_4]\cdot[v_x;v_y;\omega_p]$$

$$[v_{91};v_{92};v_{93};v_{94}] = [01l_1;01l_2;01l_3;01l_4]\cdot[v_x;v_y;\omega_p]$$

(R: wheel radius; l_1 -l_4: distances from wheels to the center P)

Rubber Wheels: Only provide forward/backward driving force, with their rotation angular velocities (ω_5, ω_6) linked to the robot's X-axis speed:

$$\omega_5 = v_x/R,\quad \omega_6 = v_x/R$$

1.2.Overall Kinematic Equation

By integrating the two wheel models and converting the robot's motion from its local coordinate system (XPY) to the world coordinate system (xoy) via an orthogonal rotation matrix [cos θ -sin θ ; sin θ cos θ] (θ : angle between the two coordinate systems), the overall kinematic equation is derived:

$$[\dot{x};\ \dot{y};\ \theta] = [\cos\theta\ 0;\ \sin\theta\ 0;\ 0\ 1]\cdot[v_x;\ v_y;\ \omega_p]$$

This equation realizes the mapping from wheel motion parameters to the robot's posture (position: x, y; attitude: θ) [3][12].

2.Trajectory Tracking Control Scheme Design

Aiming at parameter uncertainty (e.g., load changes, wheel wear) and external interference (e.g., ground friction), three control schemes are designed:

2.1.ASMCFR-Based Controller

Using a PID algorithm, the controller takes speed error (between actual and desired heading speed) and heading angle error (between actual and desired angular speed) as inputs, and outputs the rate of change of heading speed and angular speed. This suppresses system uncertainty and ensures basic tracking performance [2][4].

2.2.Filter-Based Sliding Mode Controller

Sliding mode control is prone to chattering, which harms motor operation. A low-pass filter is integrated to filter high-frequency chattering signals in the control law. The filtered control signal is:

$$u_{f}\text{iltered}(t) = (1/\tau)\int_0^t u(\tau)\cdot e^{(-(t-\tau)/\tau)}d\tau$$

(τ : filter time constant)

Simulation results show this reduces chattering by 60% compared to unfiltered sliding mode control [4][7].

2.3.Adaptive Parameter-Adjusted Controller

For time-varying dynamic parameters (e.g., mass m, moment of inertia J), an adaptive law is designed to estimate parameters in real time. Taking the estimated mass ĵ as an example:

$$\hat{j} = -\gamma \cdot s \cdot v_x \ (\gamma > 0,\ s\text{: sliding mode surface})$$

This compensates for parameter deviations and maintains control accuracy under load changes [2][12].

3.Simulation Verification

Using MATLAB/Simulink, simulations of straight-line and circular trajectory tracking are conducted, with key results as follows:

Straight-Line Trajectory (desired speed: 1m/s):

The filtered controller achieves a tracking error of <0.05m (vs. 0.12m for unfiltered control) and eliminates motor torque chattering (torque fluctuation range reduced from ±50N・m to ±10N・m).

Circular Trajectory (radius: 2m, desired speed: 0.8m/s):

The adaptive controller maintains a position error of <0.03m, even when the load changes by ±30% (simulating 560-1040KG), verifying its robustness [6][7].

Conclusion

This study completes three core tasks for the MegBot-T800 AGV:

1. A solid-state parametric model is established, accurately reflecting the motion characteristics of its six-wheeled structure and solving the problem of speed decomposition/synthesis in traditional modeling.
2. Three trajectory tracking control schemes are designed, among which the filter-based sliding mode controller and adaptive controller effectively suppress chattering and parameter uncertainty, respectively.
3. Simulations confirm that the model and control schemes ensure high tracking accuracy (<0.05m) and stable operation, providing a feasible solution for AGVs with similar chassis structures.

Future research will focus on optimizing the adaptive algorithm's convergence speed and conducting real-environment experiments to further verify the scheme's applicability in complex industrial scenarios (e.g., multi-AGV scheduling, dynamic obstacle avoidance).

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