Research on Improved Deviation Coupling AGV Multi-motor Coordinated Drive Control Based on PSO-Fuzzy

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Abstract: AGV is a rapidly developing emerging product that can automatically move along the specified path to complete certain tasks. In this paper, the multi-motor drive control technology of AGV has been studied in-depth, and an improved deviation coupling control method has been proposed, as a result, the original fixed compensation coefficient has been changed adjustable in real time as per the motor's state. An intelligent control algorithm combining particle swarm optimization (PSO) and fuzzy control has been applied for the compensation coefficient. Through modeling simulation, it has been verified that when the drive system of AGV was unstable, the control algorithm can adjust the output of each motor in real time to improve the system stability.

1. Introduction

AGV (automatic guided vehicle) needs not manpower for specific operation, but through the computer control, it can be driven accurately on the planned route and arrive at the designated destination, at the same time realizes the loading and unloading, grabbing, stacking, etc. according to engineering requirements. [1] In recent years, AGV various technologies have been greatly developed, such as path planning, multi-AGV dispatching, etc., especially with the development of 5G technology, not only AGV has received wider applications but its research has become more important.

In this paper, the study is mainly on the four-wheel drive technology with each wheel corresponding to a single driving motor to make the AGV flexible, zero-radius turning, more accurate moving and stopping and loading, but which requires a high control precision, in the case of unbalanced loading, less rotating speed and bad wheel contacting the ground due to unsmoothness, etc. that lead to its slipping and off tracking, the intelligent algorithm is needed to coordinate the drive control of each motor to keep the AGV in stable operation.

2. Design of improved deviation coupling control structure

2.1 The Basic Structure of Improved Deviation Coupling Control Mode

For multi-motor control, parallel control, master-slave control and deviation coupling control exist currently, etc.[2] [3] The deviation coupling control, among them, is that when one motor changes, other motors will adjust with it better in overall systematic coordination and anti-disturbance so as for the AGV multi-motor control. The compensation is based on the calculation of the coordinated error of motor i with other motors first, all the coordinated error is summed and then multiplied by a certain compensation coefficient. The compensation signal y_i of motor i can be expressed as:

$$y_i = \left(\sum_{j=1}^{4} (\frac{n_i}{K_i} - \frac{n_j}{K_j}) \right) \times p_i, \ 1 \leq ji \leq 4 (j \neq i) \tag{1}$$

In the form, n_i, n_j is the actual output rotating speed of the motor i, j, p_i is the compensation coefficient, K_i, K_j is the coefficient of rotating speed of the motor i, j.

When the speed compensation value is calculated, input signals n_i' of each motor can be expressed as:

$$n_i' = n_i^* - n_i - y_i \qquad (2)$$

In the form, n_i^* is the speed given by the system, n_i is the actual output rotating speed of the motor.

But in the form above, the compensation for each motor is the same, however, the disturbance to the moving multi-motor-driven AGV is different on each motor. For the problem, it is expected to design a compensation coefficient controller, as shown in figure 1, n_i^* is the speed given by the system, n_1, n_2, n_3, n_4 is the actual output rotating speed of four motor, by analyzing the deviation of four motors to compensate for each in different degrees, that is, the more seriously deviated the motor is, the higher it is compensated with the greater coefficient, so as for both its quicker catching up with the required speed and a better multi-motor system overall coordination performance.
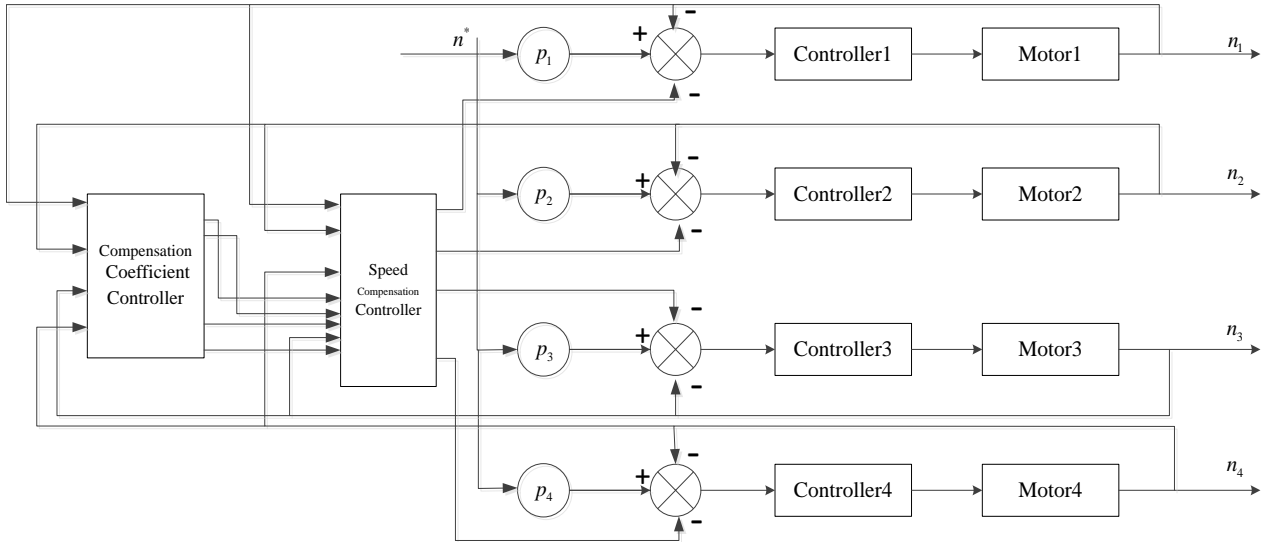

Figure 1. Improved deviation coupling control structure.

2.2 Structure of Compensation Coefficient Controller

The structure of the compensation coefficient controller is shown in figure 2 with three main parts:
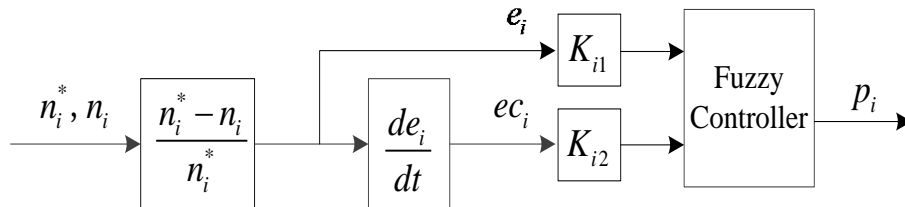

Figure 2. Compensation coefficient controller structure.

First, calculate the relative error and error change rate of each motor in the multi-motor system. Assume n_i^* is the expected value, or the given value, to be achieved at a certain moment of motor i, the degree that the motor deviates from its target speed is defined as the relative error e_i, or the ratio of the difference of the given speed n_i^* and the actual speed n_i to n_i^*. The expression of e_i is:

$$e_i = \frac{n_i^* - n_i}{n_i^*} \tag{3}$$

Its error change rate ec_i is:

$$ec_i = \frac{de_i}{dt} \tag{4}$$

Second, the relative error e_i and its change rate ec_i are multiplied by the corresponding coefficient K_{i1}, K_{i2}.

Third, through fuzzy control to deduce the compensation coefficient of each motor p_i.

3. Design of Intelligent algorithm for improved deviation Coupling Control

3.1 Particle Swarm Optimization Design

Particle swarm optimization algorithm has advantages, such as strong robustness, high control precision, fast response speed and strong searching for the optimum, etc. [4], that is why to integrate it into the coordination controller to improve overall optimization performance.

Particle swarm optimization algorithm evenly distributes particles in the given searching-for-optimal-space in the randomly initialized swarm, and updates own speed according to the pbest and gbest. Assume the flight speed at moment t and its position in the searching space of No. i particle is:

$$v_i(t) = [v_{t1}(t), v_{t1}(t), \cdots, v_{im}(t)]^T \tag{5}$$

$$x_i(t) = [x_{t1}(t), x_{t1}(t), \cdots, x_{im}(t)]^T \tag{6}$$

Fly in the searching space as per the update mode of form (7) and (8), the optimal solution can be found.

$$v_{i+1}(t+1) = \omega v_i(t) + c_1 r_1 (pbest_i(t) - x_i(t)) + c_2 r_2 (gbest - x_i(t)) \tag{7}$$

$$x_{i+1}(t+1) = x_i(t) + v_{i+1}(t+1) \tag{8}$$

In the form, ω is the inertia weight coefficient that determines the influence degree of the last speed of a particle on its current speed; c_1, c_2 are the learning factors of the algorithm that influence "self-learning" and "social learning" capabilities of the particle; r_1 and r_2 are the random numbers between [0, 1].

Values of the coefficient of relative errors K_{11}, K_{21}, K_{31} and K_{41} as well as the coefficient of relative error change rate K_{12}, K_{22}, K_{32} and K_{42} of the four motors are optimized within 0-2 through particle swarm optimization, then e_i and ec_i are multiplied by the corresponding coefficients and input into the fuzzy controller.

3.2 Design of Fuzzy Controller

Fuzzy control needs not to set up the precise mathematical model of the controlled object with strong robustness, nor suitable for nonlinear and time-varying control. The design of the fuzzy controller includes the following:

First, determine of the input, output variables and respective quantitative levels of the fuzzy controller. The relative error e_i and its change rate ec_i were multiplied by the coefficient of particle swarm optimization as the input of the fuzzy controller, the compensation coefficient p_i

was the input of the fuzzy controller. The domain of e_i was [-3, 3], the domain of ec_i was [-30, 30] and the domain of p_i was [0, 2], the 3 basic domains were all quantized to 7 levels.

Table 1. Fuzzy rules table.

e_i	ec_i						
	NB	NM	NS	Z	PS	PM	PB
NB	K7	K6	K5	K4	K3	K2	K1
NM	K6	K5	K4	K3	K2	K1	K2
NS	K5	K4	K3	K2	K1	K2	K3
Z	K4	K3	K2	K1	K2	K3	K4
PS	K3	K2	K1	K2	K3	K4	K5
PM	K2	K1	K2	K3	K4	K5	K6
PB	K1	K2	K3	K4	K5	K6	K7

Second, define to the fuzzy sub collection of input and output variables. The fuzzy sub collection of error e_i and error change rate ec_i were defined as {NB, NM, NS, Z, PS, PM, PB}, corresponding to negative large, negative medium, negative small, zero, positive small, positive median and positive large respectively, and the fuzzy sub collection of the compensation coefficient of p_i was defined as {K1, K2, K3, K4, K5, K6, K7} in the sequence from small to large of triangular membership function.

Third, determination of Fuzzy rules. In the calculation of the compensation coefficient of each motor, the higher the relative error and higher the change rate, the larger the compensation coefficient was, and on the contrary, the smaller the compensation coefficient of the motor was. Based on above, set up the following fuzzy rule control as table 1, and design FIS. In mat lab fuzzy control toolbox.
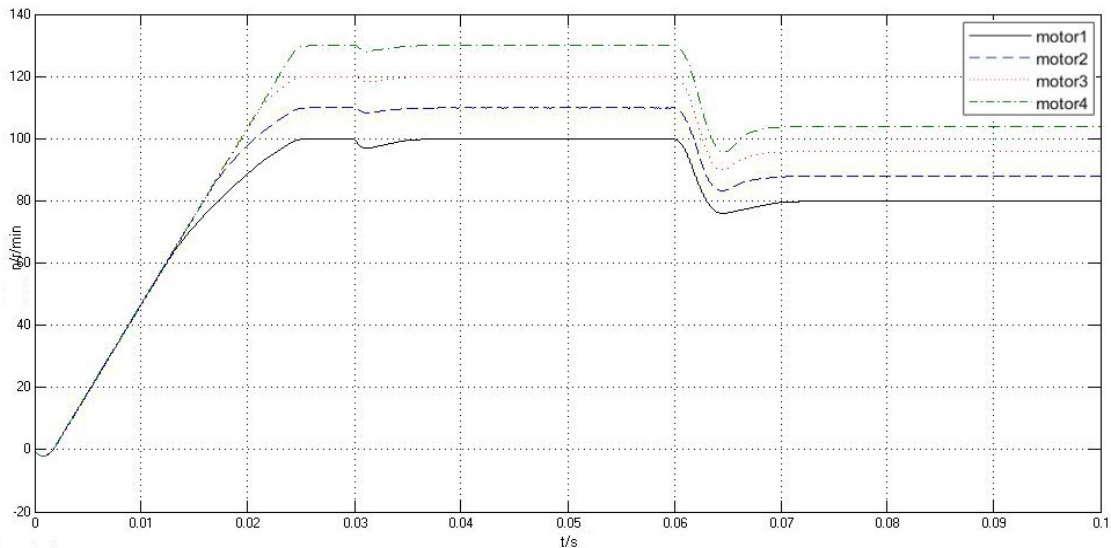
4. Modeling And Simulation

Figure 3. Simulated waveform of basic deviation coupling control mode.

For comparison, modeling and simulation of the basic deviation coupling control in Matlab/Simulink were carried out. The initial load of the 4 motors was assumed as 15N·m, and each motor was under close-cycle control of vector $i_d = 0$ with different initial given speeds. Because specific kinematic issues were not concerned in the paper, the speed was given in proportion as 100r/min, 110r/min, 120r/min and 130r/min respectively, and at 0.03s, the load of motor 1 was suddenly increased to 30N·m with loads of other motors kept unchanged, and at 0.06s, the rotating speed of the 4 motors was given to 80r/min, 88r/min, 96r/min and 104r/min respectively with 0.1s

of the stimulation lasting. Results are shown in figure 3, that the system was stable soon after operation; when the load of a motor changed, other motors changed along with it and quickly returned to the given speed; the change started at 0.060s and the system became stable at 0.072s.
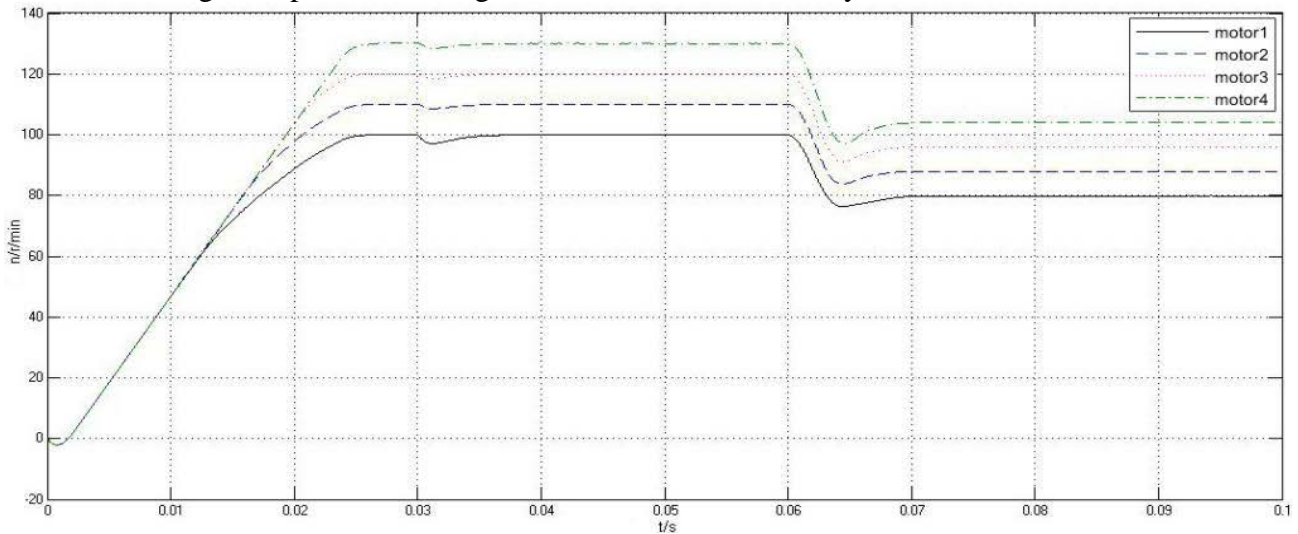

Figure 4. Simulated waveform of improved deviation coupling control mode.

According to analysis and design above, in the constructed model of improved deviation coupled multi-motor coordinated drive control system, the compensation coefficient controller adopted the combination of the particle swarm optimization algorithm and the fuzzy control. In particle swarm optimization, $c_1=1.5$, $c_2=1.5$, evolutionary algebra was 30, the population quantity was 30 and the stimulating time was 0.1 sec, shown as figure 4, that the time to the steady state in the first and second time did not change obviously, the speed of each motor returned stably at 0.070s with 16.7% of the adjusting time reduced compared with the basic deviation coupling control and the systematic anti-disturbance was improved.

5. Conclusion

Modeling and simulation show that, after improved deviation coupling control of the combination of particle swarm optimization and fuzzy control has been applied, when a motor in the multi-motor drive system fluctuates, the system can control all motors correspondingly in time for its prompt stable recovery with shorter response compared with the basic deviation coupling control, which can be applied in multi-motor driven AGV to improve its stability and coordination and makes it more competitive on the market.

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