Design of the Multi-Car Collaboration System

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Abstract

With the development of the computer and electronic technology, it is an irresistible trend to make the multiple intelligent agents cooperate with each other to complete a specific complex task. Due to the high cost of real vehicles, most of the researches are based on simulation softwares. In our project, a few real small smart cars are used, and the design of multi-car cooperation system is completed. A system platform of the small smart cars is established, which can simulate the behavior such as positioning, formation and so on. In the experiment field, a global camera is used to achieve global synchronical positioning. The simulation results show that the multiple smart cars can get collaborating.

Keywords: Multi agent; Simultaneous localization; Robot formation;

1. Introduction

For multi agent cooperative system, some universities and research institutions in developed countries have studied the related aspects of multi-agent collaboration system. For example, the European Regional intelligent transportation CyberCars-2 project, the Collective Robotics experimental system was developed by the research team in Alberta university of Canada, the research team which led by Professor T.Fukuda in Nagoya University of Japan develop the CEBOT (Cellular Robotic System). In recent years, Shanghai Institute of Technology has designed some special robots[1,2,3]. They have developed some useful control algorithms[4,5,6], and going to establish the collaboration system based on them[7,8,9]. Because of the cost of the above research, this paper designed a low-cost platform to facilitate the research. The main contents of this paper are the overall design of the car hardware, the software design of the car and the design of the car formation algorithm. Firstly, according to the structure, function and characteristic of the real intelligent vehicle, the intelligent vehicle which can imitate the real vehicle is designed. Secondly, the software system is designed to realize the control function of the intelligent vehicle. Finally, aiming at the problem of cooperative control of multi intelligent vehicles in the experimental environment, this paper designs a control algorithm of formation control based on the travel mode.

2. Integrated design of multi vehicle cooperative system

The integrated scheme of multi vehicle cooperative system is shown in Fig.1. The whole system includes a PC machine, a global camera and three independent design of the car. The car to get the location information as shown in Figure 2 and Figure 3, PC machine running global positioning algorithm, real-time access to three cars by the global
camera position, so as to establish the corresponding coordinate positioning, and every car smart car range. The decision-making process of each intelligent vehicle is shown in Figure 4. Position data is transmitted to each car via a host. Three car can read the location of the other car information, and through the car's own processor to make decisions, and then send the results to the car around the motor, real-time control of the car's work.

3. The hardware design of control system

The hardware system structure of the intelligent car is shown in Figure 5, there are three main function modules. Respectively is the motor drive module, speed sensor module and communication module. Smart car by driving the processor module to send PWM[1] to the motor wave to realize the motor control; speed sensor is used in integrated photoelectric encoder on the motor, the encoder interface will speed by the speed of the data passed to the small processor; wireless communication module can realize communication workshop installation trolley car.

4. The design of software system

As shown in Figure 6, on the basis of the software system for the realization of intelligent vehicle control functions, the system will be divided into 3 groups. The first time, should be in the detection of measuring magnetic sensor and speed sensor; second, software project management system should also be in this piece of the signal as the navigation and rate control; third, the software system should also be in the management of the implementation of communication signal block management and control command analysis project.

The software should not only ensure timeliness, but also to complete a wealth of difficult projects. Several levels
of software architecture for intelligent vehicle control system is shown in Figure 7.

5. The Formation control algorithm of multi vehicle cooperation

Our approach relies on two key ideas\(^{10,11,12}\). The first is the use of dynamical systems as a paradigm for understanding information exchange between vehicles, and the design of a dynamical system which enables the vehicles to achieve consensus on the formation center. The second is the use of feed-forward compensation to render the sensed and transmitted information timely.

5.1 The equation of state for the control system of a single vehicle is expressed as:

\[
\dot{x} = Ax + Bu
\]

A single control system (one agent) becomes multiple agents:

\[
\dot{x}_i = Ax_i + Bu_i \tag{2}
\]

Where, \(x_i \in \mathbb{R}^n\), \(u_i \in \mathbb{R}^n\) are the vehicle states and controls, and \(i\) is the index for the vehicles in the flock. Each vehicle receives the following measurements:

\[
y_j = C_j x_j \quad z_j = C_j (x_j - x_i) \quad j \in J_i \tag{3}
\]

Where the set \(J_i = \{1, N\} \setminus \{i\}\) represents the set of vehicles which vehicle can sense. Thus, \(y_i \in \mathbb{R}^k\) represents internal state measurements, and \(z_{ij} \in \mathbb{R}^k\) represents external state measurements relative to other vehicles. We assume that \(J_i = \emptyset\), meaning each vehicle can sense at least one other vehicle. Note that a single vehicle cannot drive all the \(z_{ij} \in \mathbb{R}^k\) terms to zero simultaneously; the errors must be synthesized into a single signal. For simplicity, and without loss of generality, we assume that all relative state measurements are weighted equally to form one error measurement

\[
Z_i = \frac{1}{|J_i|} \sum_{j \in J_i} z_{ij} \tag{4}
\]

Where \(|J_i|\) is the cardinality of the set \(J_i\). The choice of weighting does not impact the results, as long as the weights for a given vehicle sum to one. We also define a decentralized control law \(K\) which maps \(y_i\) to \(z_i\) and has internal states \(u_i\), represented in state-space form by

\[
\dot{y}_i = K_1 y_i + K_2 z_i \quad u_i = K_3 y_i + K_4 z_i \tag{5}
\]

This is 2nd system for \(x_i\). It is based on the observations of the other agents and is used to determine the input to agent \(i\).

Dynamic model design of intelligent vehicle:

\[
\dot{x}_i = A_{veh} x_i + B_{veh} u_i \quad i = 1, \ldots, N \tag{6}
\]

State variable of N vehicle:

\[
\dot{x}_i = \begin{bmatrix} x_i \\ x_a_i \\ x_p_i \end{bmatrix}, \quad x_a = a_{21} x_p + a_{22} x_v + u_i \tag{7}
\]

For the information from other agents, we set \(j_i\), set of agents that can be observed by agent \(i\).

\[
\dot{z}_i = \sum_{j \in J_i} (x_i - h_j)(x_j - h_j) \tag{8}
\]

5.1. Feedback Equation

By using feedforward compensation, the sensing and transmission of information are obtained in a timely manner, and the feedback equations are as follows:

\[
\hat{x} = Ax + BFL(x - h) \quad \hat{x} = I_N \otimes A_{veh} x + L_N \otimes B_{veh} F_{veh}(x - h) \tag{9}
\]

Dimensions

\[
\hat{x} : 2N \times 2, \quad F_{veh} : 2 \times 1, \quad B_{veh} : 2 \times 1, \quad L_N : 2N \times 2
\]

5.6. Experiment simulation

Problem:

- Get three agents to move into a triangular formation
- Each agent starts with a certain position and velocity.

**Assumptions:**
- Same dynamics for each agent
- The internal system of each agent is decoupled from the others
- Each agent can observe the positions of the other two and then adjust its own velocity accordingly
- No agent can directly change the velocity of another

**Simulation result**
Simulation results are shown in Figure 8

![Fig.8 Three cars brought together a little](image)

The red line represents the moving track of the trolley, and the green represents the track of the trolley. The blue represents the track of the car. The initial location of the three vehicles (5,0), (2,2), (0,3), the convergence point is (0,0). This experiment through the global real-time camera reads three car position, so as to establish the corresponding coordinate positioning, and every car intelligent vehicle location and location information will be sent to the car, the car intelligent formation algorithm makes the three mutual cooperation, from the initial position of the respective converge at a point.

**7. Conclusion**

This experiment through the global real-time camera reads three car position, so as to establish the corresponding coordinate positioning, and every car intelligent vehicle location and location information will be sent to the car, the car intelligent formation algorithm makes the three mutual cooperation, from the initial position of the respective converge at a point.

Multi-Agent Systems: multiple agents working together to achieve a common goal. Multi Agent Systems are often a more natural model for problems, such as Autonomous highway driving, Swarm robotics and so on.

**Reference**

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