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Path Planning and Motion Control for Vehicle Chassis Inspection Robots

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Abstract. Intelligent vehicle motion control in general scenarios is now a hot research topic. Trajectory tracking and stability control is the main parts of it. The final goal is to control the car accurate and smooth to follow target trajectoriesunder various conditions. This paper focus on the problem that separately designed lateral and longitudinal trajectory tracking control, and stability control without considering time-varying vehicle speed, their performance get worse understrong coupling conditions. From the coupling model perspective, we design lateral-longitudinal coupling trajectory tracking control strategy and stability contr-ol strategy. In the smart car bottom check system, machine vision, deep learning and position sensor work together is key. The smart car bottom check system need both hardware and software parts for it to work good. Hardware have check robots. It also have HD dot cameras and position sensors. Software have image process module and fault find algorithm for problem solving.

Keywords: Vehicle motion control, trajectory tracking, stability control, multi-objective coordination, path planning

1. Introduction

As society develop fast, every industry is becoming smart. From making things to serving people, companies use AI to work better, spend less money, and give personal service. Chinese cars is also walking to the world center. To keep cars safe, workers always check car bottom by hand. They go into the pit and look with eyes and touch to find problems [1]. This old way make workers very tired, so they work slower as time go on. It also miss some problems, work slow, and the check quality is not good. To find car bottom problems well and removehidden dangers in time, AI technology break through give new way to solve old checking problems. Smart visual inspection for car bottom is now becoming atrend.

2. RRT-Connect algorithm

RRT-Connect algorithm have good search feature, and it search faster thanoriginal RRT. This algorithm add double random tree expansion on RRT basis, the growing process is shown in Figure 1, and the algorithm principle is as follows [2].

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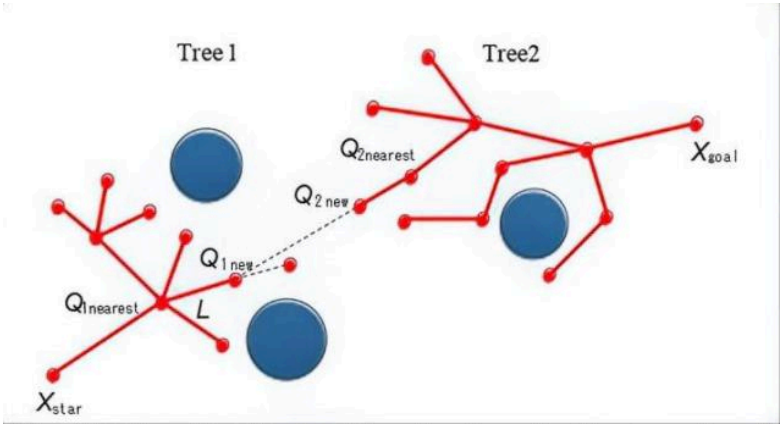


Figure 1. Schematic diagram of the RTT-Connect algorithm

If another tree expand along new node Qnew and meet non-feasible area, it need resample search points until collision-free condition is meet, this avoid algorithm fall into local optimal solution. The second tree grow steps is similar tothe first tree. Loop execute two trees expansion steps until reach set max loop times then break [3]. When shortest distance between two trees is within certain threshold, it think connection is success, finally connect two trees, and connect startpoint to goal point path through node parent-child relationship.

The sampling rule of new node Qnew is shown in equation(1):

$$\begin{cases} Q_{new}=\begin{cases} Q_{nearextx}+S\cos\theta \\ Q_{nearexty}+S\sin\theta \end{cases} \\ \theta=\arctan\dfrac{Q_{randy}-Q_{nearexty}}{Q_{randx}-Q_{nearextx}} \end{cases} \tag{1}$$

If it is outside the threshold range, use mutation sampling strategy, otherwise, use random sampling. Build bias function to guide double random tree grow purposeful, improve algorithm search efficiency.

The bias function is shown in equation (2):

$$Q_{1rand}=\begin{cases} X_{goal,p<p_1,\text{and } d>\sigma} \\ rand,p<p_1 \end{cases} \tag{2}$$

3. Vertical and horizontal coupling stability control strategy

In automotive industry control, many vehicle dynamic characteristics is generally hard to describe with exact math models. Many model-based control strategies must think about the effect of vehicle model simplification when designing controllers [4]. To further achieve desired control goals, uncertainties in vehicle system parameters and external disturbance factors also need to be considered incontroller design.

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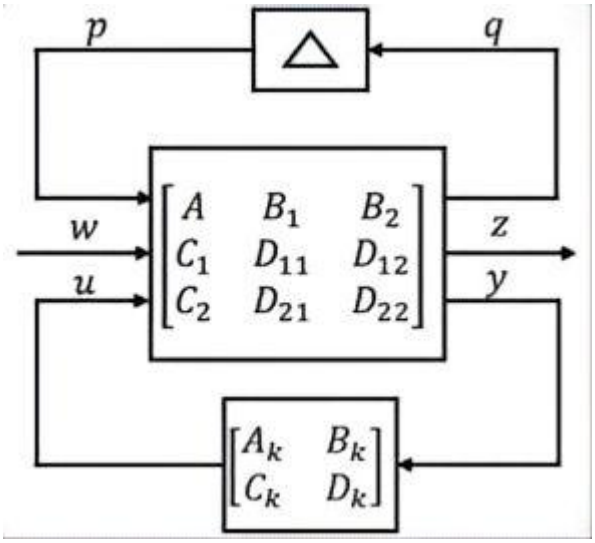


Figure 2. The simplified structure diagram of H∞ output feedback control

The state space description of the controlled plant is:

$$\begin{cases} \dot{x}=Ax+B_1w+B_2u \\ y=C_2x+D_{21}w+D_{22}u \\ z=C_1x+D_{11}w+D_{12}u \end{cases} \tag{3}$$

When the stability controller is active, the lateral force output by the controller can be achieved through active front wheel steering technology. From themotion coordination strategy mentioned earlier, it can be seen that at this time the vehicle's front wheel angle is mainly given by the trajectory tracking controller. Therefore, in order to provide additional lateral force to meet the vehicle's stability requirements, it is necessary to correct the front wheel angle provided by the trajectory tracking, and the correction formula is as follows:

$$\sigma_f^*=\sigma_f+\left(\frac{v_{hy}+l_f\omega}{v_{hk}}-\frac{F_{uy}}{C_f}\right)K_{ESC} \tag{4}$$

4. Improvement of information delay in multi-objective collaborative processes

When using stream sockets, server and client need do different things. Onserver side, first create and bind socket, then listen on the bound port, and accept client connection [5]. On client side, after server create and bind socket, client can connect to the network address and port that server socket bind to. After connection is build, client can exchange data with server. When data exchange finish, client can close socket to disconnect with server. Socket address families is divided into following types, as shown in Table 1.

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Table 1. Socket address family

Cluster Name	ID
The socket address structure of the IPv4 Internet Protocol	AF_INET
The socket address structure of the IPv6 Internet Protocol	AF_INET6
The local socket address structure used for inter-process communication on the same machine	AF_UNIX/AF_LOCAL

The performance of the method proposed in Chapter 4 in the test environment is measured by average transfer time and data integrity rate. Both indicators serve as evaluation criteria for data transfer methods. If the average transfer time of methods is similar, the method with higher data integrity rate is considered to perform better.

Let the total relay times be N_{relay}, the time when data is sent from client A be T_{start}, the time when data is received by client B be T_{stop}, and the average relay time T_{aver} is shown in equation 5.

$$T_{aver} = \frac{T_{stop} - T_{start}}{N_{realy}} \tag{5}$$

The way to measure whether relay is success is whether data format can be parsed correct. If it cannot be parsed correct, the program will throw exception. According to this, count the times of data parse failure to get data integrity rate.

5. Position adjustment of the inspection robot and instrument readings

To get high-quality instrument images and improve inspection robot reading accuracy, after the inspection robot arrive at target point, it locate instrument by measuring distance between itself and instrument, then do close-range navigation. After that, it use instrument contour features and adjust its position accordingto control strategy of different instruments, arrive at front of instrument,and finish secondary positioning [6, 7]. When camera shoot rectangle from front, the projected pattern is a rectangle. When camera shoot rectangle from side, the projected pattern is a trapezoid. As shown in Figure 3, the image shoot rectangle from front is a rectangle. The image shoot rectangle from left side is a trapezoid w-ith longer left side and shorter right side.

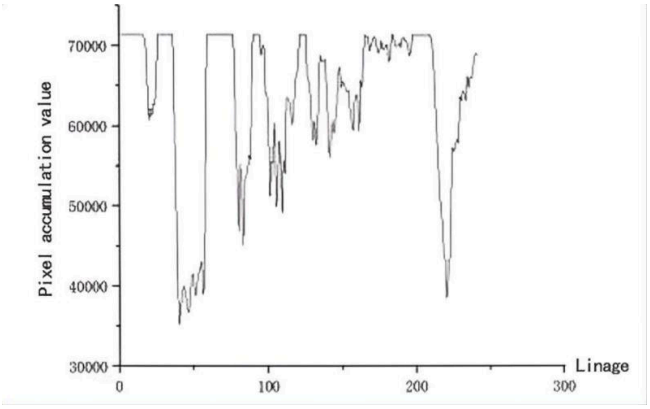


Figure 3. The cumulative curve plot of each pixel row along the Y-axis

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Inspection robot position adjustment: the width of rectangle in area can be calculated through coordinate axis, as shown in equation:

$$\begin{cases} L_{left}=\sqrt{(x_3-x_1)^2+(y_3-y_1)^2} \\ L_{right}=\sqrt{(x_4-x_2)^2+(y_4-y_2)^2} \end{cases} \tag{6}$$

By compare the size relation of L_{left} and L_{right}, we can judge the relative position between inspection robot and instrument, and guide robot move directionally to adjust position. When the difference between L_{left} and L_{right} is smaller than threshold δ, we think robot arrive at suitable position and can do follow-up work. If L_{left} minus L_{right} is bigger than δ, robot is at left side of instrument, at this time robot should move to its right side. If L_{left} minus L_{right} is smaller than minus δ, robot is now at right side of instrument, at this time robot should move to its left side.

Loss function can be used to do back propagation for network, and update network parameters according to the optimizer used. Finally get the character with maximum probability corresponding to pixel area. The CTC loss function is:

$$O=In(\prod_{(x,y)\in s}p(l|x))=(\prod_{(x,y)\in s}Inp(l|x) \tag{7}$$

The total probability of finally mapping to label text is:

$$p(l|x)=\sum_{\pi\in B^{-1}(l)}p(\pi|x) \tag{8}$$

6. Conclusion

In industrial environments, instrument inspection is a necessary work in production operations. To use inspection robot finish automatic meter reading, need complete map building of inspection environment and robot self-positioning. Then combine path planning method and robot's visual perception of instrument, make robot reach front of instrument and do reading work. The promotion value of this system not only show in technical parameters, but also show in labor cost. This operation mode change let company put limited technical force on fault diagnosis and handling. At the same time, Smart visual inspection technology shows new ideas and useful value in car bottom check area. It copy how people check things, use computer vision and deep learning together, and change hand work to automatic work. Future research should focus on making different technologies work together better. We can try put infrared heat imaging and millimeter wave radar into current visual system to build a multi-mode sensing network.

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