Research on Vehicle Control System of Construction Machinery Based on Machine Vision

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Abstract. With the continuous development of construction machinery technology, great breakthroughs have been made in the application of electronic information technology. The control and operation system of construction machinery vehicles refers to the system that applies and receives certain instructions and makes the construction machinery produce specified actions according to the requirements of operators through its power transmission device. Compared with the previous construction machinery, the developing construction machinery has made good achievements in high efficiency, intensification, cost saving and environmental protection. The traditional speed measuring method cannot meet the requirement of measuring accuracy of actual walking speed of construction machinery, and cannot accurately reflect the actual walking speed and instantaneous motion state of construction machinery. This paper analyzes a kind of construction machinery vehicle using machine vision. It obtains important information through image processing, adopts intelligent control technology based on machine vision as an important control means of power drive, and can judge and control driving according to road conditions, thus improving the accuracy and stability of industrial autonomous transportation.

Keywords: Construction machinery vehicle; intelligent control; machine vision

1. Introduction
With the continuous research and development of technology, some achievements have been made in the formation of construction machinery level in China. At the same time, in the application of intelligent network technology, the intelligent characteristics of construction machinery and equipment can be effectively reflected [1]. In the whole system, each control unit can practice the mutual communication between them, so that the engineering application can promote the effective implementation of fine chemical engineering on the basis of information knowledge. In recent years, the field of construction machinery has become stronger, and the major domestic manufacturers have put forward higher requirements for some key electrical components [2]. The quality and working performance of these products determine the life and stability of the electrical system of the whole vehicle to a great extent. The control and operation system of construction machinery refers to a system that applies and receives certain instructions and makes the construction machinery produce
specified actions according to the requirements of operators through its power transmission device [3]. Construction machinery has low operation speed, high slip rate, high measurement accuracy and complex and changeable working environment [4]. Therefore, the traditional speed measurement method can not meet the requirements of the measurement accuracy of the actual walking speed of construction machinery, and can not accurately reflect the actual walking speed of construction machinery and its instantaneous motion state [5]. For construction machinery, control and manipulation mainly include engine manipulation, speed adjustment and direction switching, steering manipulation, braking manipulation and operation device manipulation, etc. There are mainly mechanical manipulation, pneumatic manipulation, manual hydraulic manipulation, hydraulic power-assisted manipulation and fly-by-wire manipulation [6].

Intelligent vehicles are widely used in military field survey, bomb disposal site, auxiliary operations and other military fields. Through the intelligent network technology, some construction machinery and equipment have intelligent characteristics, and can realize mutual communication among the control units of the system, which promotes the research and development of intelligent variable operation construction machinery supporting the application of "fine engineering operation" based on information and knowledge [7]. Electronic technology controls the engine, hydraulic system and electrical system in an all-round way, and machines are being endowed with various senses and wisdom [8]. With the development and technical progress of agricultural machinery, construction machinery and other industries in China, the mature controllers and sensors have been widely used in many construction vehicles [9]. Compared with the previous construction machinery, the developing construction machinery has made good achievements in high efficiency, intensification, cost saving and environmental protection [10]. At present, the application of construction machinery and equipment in our country mostly adopts the foreign advanced level, and then it is technically reformed by certain means [11]. Considering the arrangement of mechanical structure and control mechanism, wheel pressure of walking device, strength and rigidity of frame, and coordinated operation with matching machinery, it is often necessary to adopt multi-axis drive and multi-mode steering [12]. This paper analyzes a kind of construction machinery vehicle using machine vision, which can obtain important information through image processing, adopts intelligent control technology as an important control means of power drive, and can judge and control the driving by itself according to road conditions, thus improving the accuracy and stability of industrial autonomous transportation.

2. Image preprocessing of machine vision

In the intelligent driving control system, the sensing system is very important, which can collect the environment in front of or around the vehicle and provide a lot of important information for accurately controlling the driving behavior of the vehicle. In order to obtain the road curvature, a curved lane recognition algorithm based on edge point curvature voting of the region of interest is proposed. The left and right straight lane lines of the current lane are recognized in the near-field of view, and the direction and position information of the straight lane are taken as the initial parameters of subsequent curve fitting. Fieldbus technology makes a single distributed field device connect into a network control system that communicates with each other and operates cooperatively through bus, realizing distributed and open communication, which is the best way to realize the control and operation system of large intelligent vehicles and construction machinery [13]. Fieldbus, as a technology of industrial control network system, has a complete set of protocol standards and is closely related to other engineering applications. In order to reduce the influence of edge points of non-lane lines and extract lane lines accurately, the midpoint of lane lines is extracted according to the width range of lane lines. In the stage of image preprocessing, noise pollution may occur in the process of image acquisition or transmission, so it is necessary to use image filtering algorithm to purify, and then detect the road edge information, which is useful and useless for image segmentation, extract the road edge information, and further fit the road alignment and fill the lost edge information.

Due to the complex operation tasks undertaken by large construction machinery, its subsystems are numerous and scattered, so it will become very difficult to integrate motion and transmit information
among subsystems by adopting the traditional mechanical integration mode of rod system and gear train. In order to improve the real-time performance of the algorithm, the ROI is divided into the ROI for initial frame detection and the ROI for tracking after lane recognition is successful. When the lane line is not detected in the previous frame picture, the initial preprocessing is needed to divide the region of interest. At this time, the lane line should be processed according to its extreme position in coordinates. When preprocessing is used to divide the region of interest, it is necessary to divide it according to the position of the picture where the vanishing point is located after the lane line is successfully detected in the previous picture. Because there will be interference in the process of image acquisition and transmission, and noise pollution in the image, which leads to the degradation of image quality and hinders the normal recognition of road edges and objects, filtering is adopted to improve image quality and remove noise interference information.

For filtering, we can improve the stability of image acquisition by strengthening the stability of hardware and adding hardware filtering circuits, and we can also use software filtering methods to filter out interference information. On the basis of midpoint extraction in lane line, the vanishing point position of midpoint voting in lane line is detected. Fig. 1 shows the structure of agent node of servo system.

![Figure 1](image)

**Figure 1** The structure of the intelligent body node of the servo system

When no lane line is detected in the previous frame picture, the initial preprocessing region of interest is divided according to the extreme position of the left and right lane lines in pixel coordinates when the vehicle runs on the lane. When the lane line detection in the previous frame is successful, the preprocessing region of interest is divided according to the vanishing point position. When the object moves in front of the camera or the camera moves in the environment, the target image is changing. The surface movement of the image gray scale mode is called optical flow, and the optical flow at each point on the image forms an optical flow field. It is an important method to analyze moving objects in image sequences, which can not only reflect the relationship between the temporal change of image gray and the structure and movement of objects in the scene, but also reflect the movement between adjacent frames. The technology of construction machinery and equipment is relatively complex, and its automation degree and functional requirements are relatively high. As a large-scale equipment, it is necessary to automatically control the whole program through advanced technologies such as artificial intelligence, sensor technology and bus control technology. If there is noise interference, the road information and obstacles in the image in the perception system will be blurred, and the recognition of objects will be misjudged or unrecognizable in the process of processing. Therefore, getting a clean and pollution-free image is the basic of post-processing, and this link is indispensable.

3. **Overall architecture of intelligent control system**

3.1. **Control system structure**

According to the requirements of the control system from the control and controlled signals in different construction machinery and equipment, the existing sensors or actuators in the market are properly selected, or the sensors or actuators are developed and manufactured according to the
requirements of the field environment to meet the requirements of signal acquisition at the bottom of the system. Construction machinery and equipment are large-scale equipment with complex technology, many functions and high degree of automation. Advanced technologies such as bus control technology, sensor technology and artificial intelligence should be comprehensively applied in automatic control. The main idea of lane keeping auxiliary control by using artificial potential field method is to construct potential field function which can represent the danger degree of vehicles in different positions of lanes, and correct vehicles to a state with lower danger degree under the action of this potential field force. The magnitude of the potential force on the vehicle is determined by the gradient of the potential function, and the derivative function of the potential function should be continuous in order to ensure the smoothness of the control force [14].

After the vanishing point is detected, the direction angle of the midpoint of the lane line voted for the vanishing point is counted and classified. In the vanishing point detection stage, when the edge points vote for the candidate vanishing points effectively, the candidate vanishing points record the direction angle value of the edge points and accumulate statistics on the number of middle points in the current direction angle lane line. Fig. 2 is the framework of vehicle motion detection and tracking system using dense disparity variance technology.

![Figure 2 The framework of the vehicle motion detection and tracking system using dense parallax variance technology](image)

There are many components of intelligent control system, including man-machine conversation layer, control layer, signal acquisition execution layer and sensors. According to the task of the engineering system, it is divided, and its main content is to collect and control signals with the help of general controller. With the help of general monitor, the realization of man-machine conversation function can be promoted, which is used as man-machine interface to contact application system and operator. When the vehicle speed is higher, the lateral acceleration of the vehicle corresponding to the same steering wheel angle is larger. In order to ensure the lateral stability of the vehicle, the maximum steering angle allowed by the vehicle at this time should be reduced. Based on multiple lines extracted from vanishing points, the lines satisfying the single-lane model are screened and extracted [15]. For the first frame straight line detection, firstly, the direction and angle of the detected straight lines are sorted, and the straight line with the smallest absolute value of angle is found out, and then the straight line matching with the single lane width is searched. At the same time, avoid lane detection errors in the first frame caused by straight lines such as lane identifiers.
3.2. Two degree of freedom model of vehicle

Under the condition of vehicle parameter change, model uncertainty and external lateral wind disturbance, the output torque of steering motor is controlled by designing a \( \mu \) integrated controller, so that the vehicle can track the desired yaw rate command stably. In practical application, the planning of vehicle driving path and the analysis of road alignment are basically based on the center line of the road, while the road edge information is obtained after edge detection in the road image, and there is no center line of the road in the image, so the center line of the road needs to be artificially fitted and created. For different construction machinery and equipment, according to the controlled signals in the control system and the control requirements for the control system, the application of the executive layer and sensors can effectively meet the signal acquisition requirements at the bottom of the system. Vehicle vision system can effectively identify lane lines, traffic signs and traffic lights, and can also detect obstacles in driving lanes and adjacent lanes. Fig. 3 shows a hierarchical system architecture.

![Figure 3 Hierarchical system architecture](image)

Suppose the longitudinal displacement of the car at time \( k \) is \( x_k \), the lateral displacement is \( y_k \), and the yaw angle is \( \gamma_k \). As shown in Figure 1, the displacement of each point is \( x_{k-3},...,x_{k+1} \), and the instantaneous velocity is \( v_{k-3},...,v_{k+1} \), then:

\[
\begin{align*}
\frac{v_{k-2} + v_{k-3}}{2} &= x_{k-1} - x_{k-3}, \\
\frac{v_{k-1} + v_{k-2}}{2} &= x_k - x_{k-2}, \\
\frac{v_{k} + v_{k-1}}{2} &= x_{k+1} - x_{k-1}.
\end{align*}
\]  

(1)

From \( v_k-v_{k-1}=v_{k-1}-v_{k-2} \), we have:

\[
x_{k+1} = x_{k-3} + 2x_k - 2x_{k-2}
\]  

(2)

If the longitudinal displacement of the car at \( k-3,..., k \) is known, the predicted value of the longitudinal displacement at \( k+1 \) can be obtained:

\[
\hat{x}_{k+1} = x_{k-3} + 2x_k - 2x_{k-2}
\]  

(3)

The interface layer between the system and the controlled object is the signal acquisition and execution layer, which is composed of distributed special controllers and has relatively independent
functions. Different from the auxiliary intervention time of lane keeping control, the lane departure prevention system calculates the position deviation and heading deviation of the vehicle relative to the lane, and predicts the distance or time when the vehicle crosses the lane line. When the variable is lower than the set threshold, the system will not only give a warning, but also help the driver to correct the direction of the vehicle and make the vehicle return to the lane. According to the characteristics of the sample type, some features are extracted from the original features in the road image to describe the corresponding sample type, which is the feature extraction of road elements [16]. Make different speed responses in different road conditions, fit the control decisions according to the horizontal system data, and build a longitudinal intelligent control system to accurately control the vehicle's running speed, so that the vehicle can accelerate, decelerate and move at a constant speed in a suitable position. The traditional control algorithm has some shortcomings in the application of artificial intelligence. In a servo system, the parameters are always changing. To achieve good control effect, the adaptive algorithm should be adopted.

4. Conclusions
The applied technologies of intelligent control system of construction machinery are comprehensive, and the applied technologies are based on embedded controller, including control technology, information technology and electronic technology. In this way, it is very easy to realize the purpose of whole machine control, whole machine monitoring, accurate operation and fault diagnosis. Under different road adhesion coefficients, in order to use the coordination of differential braking and active steering to assist the vehicle in lane departure control, and to take into account the problems of vehicle driving safety and driver's driving freedom, the model predictive control algorithm is used to add reasonable constraints to design differential braking control and active steering and differential braking coordination controller. The magnitude of the potential force on the vehicle is determined by the gradient of the potential function. In order to ensure the smoothness of the control force, the derivative function of the potential function should be continuous. Make different speed responses under different road conditions, fit the control decisions according to the horizontal system data, and build a longitudinal intelligent control system to accurately control the vehicle's running speed, so that the vehicle can accelerate, decelerate and move at a constant speed at a suitable position. In the aspect of motion control system, we should focus on the energy saving and high efficiency of vehicles, and adopt more effective intelligent control algorithms. In the planning and decision-making system, more efficient and deep-learning planning and decision-making algorithms should be adopted.

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