Cloud-Based AGV Control System

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Abstract. With the development of artificial intelligence technology, the application of mobile robots is more and more extensive. How to solve the control problem of mobile robots in complex network environment is one of the core problems that plague the promotion and application of AGV clusters. In view of the above problems, this paper studies the control technology in the cloud big data environment, and realizes the decision, planning and control of AGV in the cloud environment. Firstly, cloud-side data sharing and cross-domain collaboration are used to realize intelligent adaptive association of heterogeneous data, then establish a collaborative hierarchical information cloud processing model, and design a new AGV sensing structure based on various devices such as laser radar and ultrasonic sensors. Finally, a set of AGV motion control methods in cloud environment is proposed. The experimental results show that the efficient coordination among network nodes in the heterogeneous AGV system in the cloud environment is stable overall and has a lower delay rate, which will greatly promote the application of AGV in various complex network environments.

Keywords: Cloud environment · AGV · Control system

1 Introduction

Automated guided transport vehicle (AGV) is a transport vehicle equipped with an automatic guiding device such as electromagnetic or optical, which can travel along a prescribed guiding path, with security protection and various transfer functions. Kiva in Amazon Smart Warehouse The handling robot is one of the typical representatives. The AGV has become one of the important transportation equipments in modern logistics systems with its unique advantages. The core of the AGV transport vehicle lies in the control and navigation system. However, for the research of the AGV navigation system, the combination of the encoder and the gyroscope is mainly used in the early stage [1, 2], but it cannot be avoided due to the inherent characteristics of the inertial navigation elements such as the gyroscope. The influence of traditional hardware defects such as zero drift and temperature drift will cause cumulative error when it is used as the core component of the navigation system. In the traditional way, the absolute position method is adopted to calibrate the AGV position. As in the literature [3, 4], GPS is used as the

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absolute position to calibrate, in addition to the multi-source data fusion calibration scheme using GPS and machine vision images [5], and the multi-source fusion scheme has become a mainstream solution for navigation systems. With the popularization and application of laser radar in the unmanned field, it is possible to integrate AGV and laser radar. The robot level uses different guiding methods, such as laser guidance, to control the robot to move autonomously on the free path or the fixed path, and the guiding and expanding of the robot becomes simple and easy.

The emergence of a variety of high-precision sensors such as laser radar has greatly increased the amount of data processing. It is difficult for ordinary computers to meet the timeliness requirements. Adding a server not only increases the cost of AGV but also compresses the space of other components. Due to the complexity of the AGV operating environment, a single LAN is difficult to meet the needs of AGV control, especially in complex environments where communication node loss, signal delay, and data loss are common.

Cloud computing is one of the hotspots of current research and application. It is based on grid computing [6], parallel computing and distributed computing. It has the characteristics of high reliability and versatility. It uses data multi-copy fault tolerance and computational node isomorphism. Interchangeable measures to ensure high reliability of services [7, 8], using cloud computing is more reliable than using local computers. Cloud computing is not targeted at specific applications. Under the support of "cloud", it can be constructed for a variety of applications. The same "cloud" can support different application operations at the same time [9, 10], which is very suitable for AGV control in complex environments. In order to solve the above phenomenon, the heterogeneous AGV control system in the specially designed cloud environment has a large amount of computation in the AGV environment, and the communication nodes are easily lost in a complex environment. Ordinary equipment is difficult to meet the current calculation requirements, so a heterogeneous AGV computing environment is designed. Simple data preprocessing is performed by running Ubuntu 14.04 industrial computer, and then the final mission planning result is given by the cloud computing environment.

2 System Logic Architecture

The common architecture is difficult to support the calculation of the AGV in operation in this design. Therefore, the cloud environment AGV system architecture for big data is designed to virtualize large-scale resources and distributed resources, and finally realize the parallel of lidar data and sensor data. deal with. The system realizes the control and management of AGV by constructing the "application layer - logic layer - cloud computing layer" three-tier architecture (Fig. 1). The application layer is mainly responsible for the collection of environmental data and the execution of AGV actions. The logic layer is mainly a module that manages the basic ROS node, and is responsible for the transmission, parsing, preprocessing, and execution of control instructions of the sensor acquisition data. The cloud computing layer is mainly responsible for the fusion analysis of multi-source data, the assignment of tasks, and the storage of location information, attribute information, and status information of the AGV.

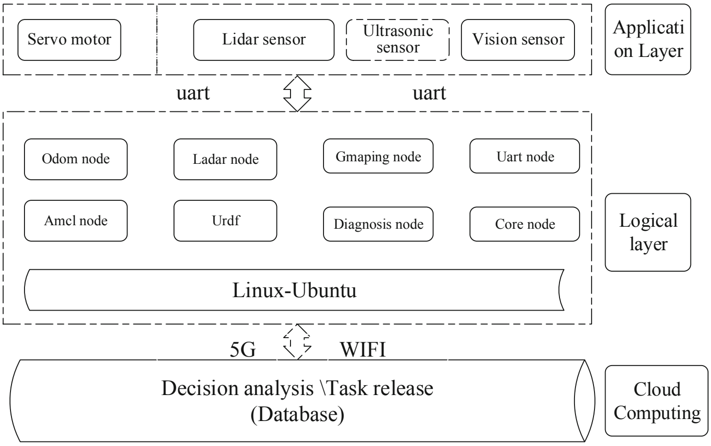

Fig. 1. Cloud environment based AGV system logical architecture

2.1 Application Layer

The application layer provides data acquisition and AGV action execution functions, including laser radar sensors, ultrasonic sensors, vision sensors, and servo motors. Laser lightning sensor is an important part of AGV environment sensing. It provides basic data for positioning navigation for AGV. Single-line laser radar is used in this system. The ultrasonic sensor is an important collision avoidance device, which can effectively avoid the collision of the AGV with the wall and other obstacles while driving, and maintain a safe distance. Vision sensors are used to identify two-dimensional codes on the ground and at specific locations to aid in precise positioning.

The servo motor is the component used in the AGV control system to convert the electrical signal into a corner or speed on the shaft to control the motion of the AGV.

2.2 Logical Layer

The logic layer is the core of AGV control and is responsible for receiving, parsing, storing, and managing sensor upload data. The core carrier of the logic layer is the industrial computer with Ubuntu14.04 installed. The basic ROS node module is run on the carrier to realize the basic functions of AGV operation, such as uploading and downloading of data, control command release, etc., wherein the Urdf node is responsible for AGV. The description of the action description; the Amcl node is responsible for the probabilistic positioning of the AGV two-dimensional motion, using the particle filter to track the attitude of the AGV to the known map; the Gmapping node creates a two-dimensional grid map from the lidar data and the pose data acquired by the AGV; Diagnostics The diagnostic node is responsible for collecting, publishing, analyzing, and viewing data.

2.3 Cloud Computing Layer

The cloud computing layer is the decision basis of the AGV control system. It is responsible for the analysis and integration of the AGV multi-source data. The data server in the cloud computing layer establishes a TCP/IP connection with the AGV through WIFI, GPRS and other communication methods, and receives the AGV environmental data and the AGV ontology. Attribute data and exception information data.

The cloud server uses the Java SE Runtime Environment, the Java SDK, and the Tomcat technology to build a data server, and uses the MINA (Multipurpose Infrastructure for Network Applications) framework to process large-scale concurrent data from the AGV cluster. The MINA framework is used to develop high performance. And highly available web applications that help users with complex tasks such as underlying I/O and thread concurrency. The MINA framework is dominated by I/O service management (IoService), I/O filter chain (IoFilterChain), and I/O processing. It consists of modules such as IoHandler and I/O session management. The I/O service management interacts directly with the operating system I/O interface to handle the actual I/O operation protocol read and write operations. Its two implementation classes IoAcceptor and IoConnector correspond to the server-side and client-side service management classes respectively; then, IoFilterChain receives the events passed by IoService, and the IoProcessor thread is responsible for handling the filters (IoFilter) contained in the call chain; finally, IoFilter Processed events are sent to the IoHandler and implement specific business logic. Sending a message to the client by calling the IoSession write method will be passed in the exact opposite order of receiving the data until the IoService finishes sending the data to the cloud server.

The Socket port listener running in the data processing server listens to the specified port dynamics at all times. When there is a data packet access, the protocol parsing program is called to parse the data in the data packet into environment location data and attribute data, and finally use the DBMS to write the data classification. In the MySQL database, the storage of AGV data is completed.

3 The Design of AGV

For humans, we get the environmental information around us through the integration of hearing, vision and touch. By combining data from multiple sensors to take advantage of the strengths of each sensor while avoiding its disadvantages, the central control computer can obtain more reliable external environmental information, make optimal decisions efficiently, and cope with more complex and diverse road conditions.. For example, ultrasonic sensors are the most indispensable sensors for robots due to their small size and low price. However, ultrasonic sensors can only be used in applications where the accuracy of environmental sensing is not high. They are generally used in combination with other sensors, such as monocular vision sensors, etc. [8]. Infrared ranging also detects the distance of an object by emitting infrared rays and receiving the reflected light back by the photodetector. It is greatly affected by the environment. The color of the object and the surrounding light can cause measurement errors, and the measurement range is very short. It is only suitable for short distance ranging. It is generally not used alone, such as the detection of obstacles combined with ultrasonic sensors [5], so in the overall structural design of the AGV, the position of each sensor should be scientific and reasonable, so that the sensors are closely matched.

The structural design of the AGV body is closely related to the construction of the operational control algorithm. The common wheeled AGV structure is mainly composed of three-wheeled AGV and four-wheeled AGV. This design is a four-wheeled AGV. The four-wheel AGV is suitable for large-sized car bodies. This type of car body has the characteristics of negative weight and stable operation. It is suitable for structured space such as large workshops. Steering ability puts higher demands.

At present, the mainstream four-wheel AGV car adopts the front wheel drive and the rear wheel slave mode. In this driving mode, the AGV can adopt the differential control method to realize the steering motion of the vehicle body. In the four-wheel AGV design, the laser radar is often placed in the center of the structure, but the laser radar is located in the middle of the vehicle body, which reduces the bearing space of the vehicle body and is not suitable for the weight bearing. Therefore, in this design, the laser radar is embedded in the head of the vehicle body, assisting the attitude correction algorithm, taking into account the AGV weight bearing problem and the motion control accuracy problem. The specific design diagram is shown below. Two-wheel drive. The lidar AGV requires high load capacity, drive performance and volume, and a limited spatial range, thus requiring a small turning radius (Fig. 2).

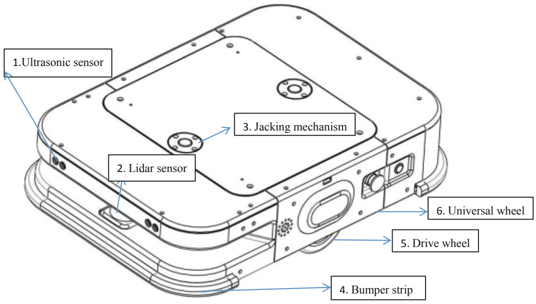

Fig. 2. AGV sensor distribution

1. It is an ultrasonic sensor used to detect nearby obstacle information and emergency obstacle avoidance, in addition to the navigation algorithm to detect obstacles of about 30 cm, cone-shaped, 15° angle cone; 2. Lidar, Fan-shaped distribution, detecting the angular range of 270°, detecting the surrounding environment and distance; 3. Lifting mechanism, scissors differential mechanism, capable of lifting 1 ton of weight; 4. Anti-collision strip, triple protection, 1 cow's force touch It can stop; 5. The driving wheel plays the role of the whole vehicle driving, adopts DC brushless servo motor, the precision can reach 2 mm; 6. The universal wheel can assist the steering of the car body under the driving of the driving wheel, and bear part of the weight.

The AGV system consists of a main control module, a power supply module, a boot module, a drive module, a safety detection module, and a communication module. The AGV uses the Advantech development board as the main control unit. The main control module issues straight, in-situ rotation and turning commands to the car based on the feedback signals of the laser radar, ultrasonic sensors and collision sensors.

The drive module coordinates the operation of the two wheel drive motors through the motor controller to realize the forward, reverse and steering of the AGV. The controller uses the PWM or DA speed regulation method to adjust the motor speed, and different speeds are required at different stages of the AGV operation. Such as starting, stopping, turning, and the transition between the stages at a smooth speed, which puts higher requirements on the performance of the drive module. After receiving the instruction, the industrial computer drive module executes the corresponding code, changes the AGV running status, and monitors. The motor running status uploads the motor running information to the main control module.

The function of the auxiliary safety module is to prevent the AGV body from colliding with obstacles. Because the single-line lidar is embedded in the AGV head, the laser radar blind zone is inevitable during the driving process of the car. The auxiliary safety module is composed of ultrasonic radar and collision sensor. When the laser radar fails to detect the blind obstacle, the ultrasonic radar assists the detection. When the obstacles are not detected at present, the collision sensors arranged on the front and rear casings of the AGV are used as the last protection means. When the collision sensor has contacted the obstacle, the system gives priority to the event and issues an emergency brake. Command and alarm.

The function of the communication module is responsible for the communication of the various functional modules within the AGV. On the other hand, it is responsible for connecting the AGV and the control background server. When multiple AGVs are running at the same time, the working paths of other AGVs are coordinated to avoid mutual interference between the AGVs.

4 AGV Motion Control

The AGV system consists of two parts: the hardware body and the control system. During the operation, the car body and the control system will affect the motion process of the AGV. In order to achieve the precise control of the AGV motion process, the AGV motion is studied on the basis of rational design of the car body. The relationship between learning and dynamics ultimately led to the construction of a kinematic algorithm that achieves precise control of AGV.

The AGV adopts the PID control method, and the PID control method is mainly applied to the system whose basic linearity and dynamic characteristics do not change with time. The controller is composed of the proportional unit P, the integral unit I and the differential unit D. Set the three parameters of Kp, Ki and Kd. The chassis PID controller is an important feedback loop component of the chassis control system. The controller compares the collected data with a reference value and then uses this difference to calculate a new input value. The purpose of this new input value is to allow the system data to be reached or maintained at the reference value. Unlike other simple control operations, the PID controller in the AGV can adjust the input value according to the historical data and the occurrence rate of the difference, which can make the system more accurate and more stable.

A PID feedback loop can keep the system stable while other control methods cause the system to have stable errors or process iterations. In a PID loop, this correction has three algorithms that eliminate the current error, the average past error, and the change in the error to predict future errors. For example, in the chassis system, if you want to control the trolley to go straight, when the speed of the two wheels of the car is given, the car starts to walk. At this time, the speed value will be fed back to the chassis control system. If there is a slip, etc., it will lead to two rounds. The speed of the car is different, the car will deviate from the original track, then the PID controller will adjust the given speed according to the speed deviation according to the error value.

There are two control modes for the chassis servo electric wheel, and the position control mode and the speed control mode are combined.

Position Control: Determine the rotation speed by the frequency of the externally input pulse, determine the angle of rotation by the number of pulses, or directly assign speed and displacement by communication. Since the position mode has strict control over speed and position, it is generally applied to positioning devices. For the ribbon navigation mode, if the displacement is specified, the AGV will follow the command to move to the relevant position and then stop.

Speed Mode: The rotation speed can be controlled by the analog input or the frequency of the pulse. The speed mode can also be positioned when the outer ring PID of the position control device is controlled, but the position signal of the motor or the position signal of the direct load must be used. Give feedback to the upper level for calculation. The position mode also supports the direct load outer loop detection position signal. At this time, the encoder at the motor shaft end only detects the motor speed, and the position signal is provided by the detection device of the final load end. This has the advantage of reducing the error in the intermediate transmission process. increasing the positioning accuracy of the entire system. For the laser autonomous navigation mode, the speed is specified for the car, and the car will drive at this speed (Fig. 3).

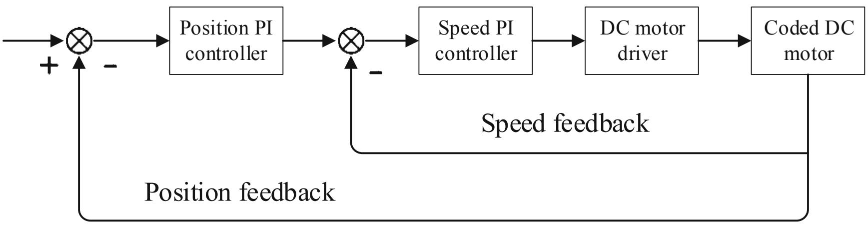

Fig. 3. PID control flow chart

AGV PID Control Algorithm Design

The PID controller consists of a proportional unit (P), an integral unit (I), and a differential unit (D). The relationship between the input e(t) and the output u(t) is:

$$\mathrm{u}(t) = kp[e(t) + 1/TI \int e(t)dt + TD * de(t)/dt$$

The upper and lower limits of the integral are 0 and t.

So its transfer function is:

$$G(s) = U(s)/E(s) = kp[1 + 1/(TI * S) + TD * s]$$

Where kp is the proportionality factor; TI is the integral time constant; TD is the differential time constant.

Two types of PID algorithms:

(1) Position control

$$\mathrm{u}(n) = K_P\left\{e(n) + \frac{T}{T_I}\sum_{0}^{n} e(i) + \frac{T_D}{T}[e(n) - e(n-1)]\right\} + u_0$$

Pseudo code of positional PID algorithm:

Algorithm: *Cloud environment Location PID*

Inputs: *SetValue, ActulaValue, PID,* E_n, E_{n1}, E_{n2}
Outputs: *Result*: *PID_Loc*

```
for i=1 to n do
  PID_En = SetValue- ActulaValue;
If
PID_En1=PID_En ;
then
PID_LocSum+=PID_En
PID_Loc=( PID_Kp*PID_ En)+(PID_Ki*PID_ LocSum)+ PID_Kd*
(PID_ En1-PID_ En2);
Return
PID_Loc
```

(2) Incremental control

$$\begin{aligned}\Delta\mathrm{u}(n) &= u(n) - u(n-1)\\ &= K_P[e(n) - e(n-1)] + K_P\frac{T}{T_I}e(n) + K_P\frac{T_D}{T}[e(n) - 2e(n-1) + e(n-2)]\end{aligned}$$

Pseudo code of incremental PID algorithm:

Algorithm: *Cloud environment Incremental PID*

Inputs: *SetValue, ActulaValue, PID,* E_n, E_{n1}, E_{n2}
Outputs: *Result*: *PID_Inc*

```
for i=1 to n do
  PID_E_n = SetValue- ActulaValue;
If
PID_En2=PID_En1 ;
PID_En1=PID_En ;
then
PID_Inc=( PID_Kp*PID_ En)-(PID_Ki*PID_ En1)+(PID_kd*PID_
En2);
Return
PID_Inc
```

5 Experiment Analysis

Experimental design: Three methods were tested in the contrast experiment. The first method is the cloud environment-based AGV control method designed in this paper; the second method is the same computing server placed on the AGV, the wired connection method; the third method is all the calculations are all on the cloud, and the AGV ontology does not do preprocessing.

Positioning analysis: The system uses a variety of distance sensors. For indoor applications, the system uses a 270° laser scanner to build a map of its environment. The laser system measures the shape, size, and distance from the laser source through the energy return mode and signal return time. In the mapping mode, the laser system describes the characteristics of the workspace by combining the scan results at multiple different locations within the work area. This produces a map of the object's position, size, and shape as a reference for runtime scanning. The laser scanner function provides accurate positional information when used in conjunction with mapping information. All three methods can achieve the centimeter-level precise positioning requirements, and can't distinguish the superiority of the method, so the response time is introduced as a new evaluation index. The positioning accuracy is the best indicator.

Corresponding time analysis: The AGV response time is defined as the time from when the system issues an instruction to when the AGV moves to the specified position. By comparison, it can be known that the method used in Method 2 is similar in time, but compared with Method 2, the AGV local space and cost are saved, and Method 1 takes much less time than Method 3. The method in this paper is more advantageous on the basis of accomplishing the same task (Fig. 4).

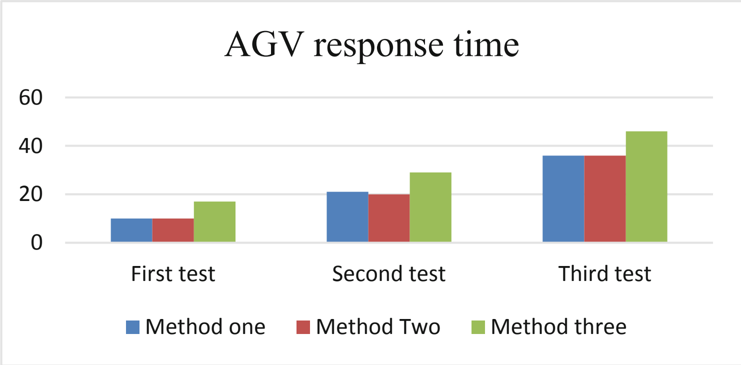

Fig. 4. AGV response time

6 Conclusion

The system is supported by cloud computing technology, combined with the characteristics of AGV control, designed and implemented a heterogeneous AGV control system in the cloud environment. The system makes full use of the high reliability and scalability of the cloud environment, builds the AGV control architecture, establishes a stable information transmission channel, unifies the service data, and solves the poor environmental adaptability of the AGV system in complex environments. In response to the delay, the AGV control system cloud platform was constructed, which has the characteristics of high integration, wide coverage and regulatory integration. The application of cloud computing optimizes the task scheduling power, which will further promote the development of collaborative control of AGV clusters, provide data support for distributed collaborative management and decision making of heterogeneous robot clusters in complex environments, and coordinate for robot clusters in the cloud environment. Aggregation mechanisms and intelligent dynamic evolution theory provide the basis for verification.

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