Design of AGV Automatic Navigation System Based on Baidu Static Map

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Abstract: In order to solve the problem of "the last kilometer" of heavy load logistics, an AGV automatic navigation system based on Baidu static map for path planning was developed. The upper computer program was designed to collect Baidu static map images as the base map of the electronic map. Path planning was conducted on the base map to generate trajectory data in byte form, which was sent to the data register area of PLC through Modbus RTU protocol. According to the data transmitted by the upper computer and sensor fusion technology, the PLC program realizes AGV positioning and automatic cruise. Replacing hardware with software to expand AGV functions is a low-cost and highly reliable alternative to current unmanned driving technology, which has certain innovation and practicability.

1. Introduction
The realization of unmanned automatic navigation system with a large load (up to 500Kg) on a small scale (20-1000m range) still has great technical difficulties. Due to not only the difficulty in eliminating the white noise caused by various interferences from geographical data sources but also the complexity of the actual road condition environment, the current unmanned automatic navigation system can only be used on two occasions. One is that it can realize the specific path cruise planned in advance and pre-installed with corresponding sensor components, and therefore its application is limited to specific areas. The other is that it can realize real-time control logic and image signal processing, respectively either with the aid of GPS positioning and machine vision or sensor network or with the aid of ARM+DSP/FPGA, but this scheme has a high cost, and thus it cannot realize user self-planning automatic cruise at a low cost. This work aims to achieve a low cost and small-scale AGV vehicle unmanned automatic navigation in a wide area to solve the problem of the last kilometer of logistics.

2. Research status at home and abroad
Automated Guided Vehicle (AGV) refers to a carrier vehicle equipped with an electromagnetic or optical guidance device, capable of following a specified guidance path, with the functions such as safety protection and various load transfers. In industrial application, unmanned AGV cars USE rechargeable devices as the power source. The development trend of AGV is more intelligent and more independent.

In the article AGV vehicle path planning and design based on GPS, Xuan Wang studied the
planning and design of AGV vehicle path using GPS as the main positioning and navigation technology. This software, in which the electronic map is made according to the actual geographical coordinates, is an excellent solution for the establishment and path planning of GPS navigation electronic map. Its disadvantage is that without using the general map, its map design and setting up needs a large workload, thus affecting its further promotion in practice.

Baidu has developed an automatic tour guide vehicle using Baidu map API+GPS positioning + machine vision. However, its operation cost is very high and it can only achieve automatic cruise in a specific automatic path, thus making it difficult to popularize the application.

In the above papers or works, the sensor networks such as GPS/ CNSS /Wifi/zigbee + machine vision are proposed to realize the AGV automatic navigation technology in a local area, but none of them can achieve the AGV car’s automatic navigation of the customized path planning in a small-scale environment under the condition of a wide area. With the increasing maturity of Baidu maps, Google maps and Autonavi maps, it has become possible to use open interface electronic maps to realize path planning and navigation. With the development of network technology and industrial control technology, the mode of realizing AGV motion control with industrial control computers is being increasingly replaced by the mode of AGV motion control with PLC as the main controller. The upper computer can realize small scale map capturing through the network with Baidu static maps, realize the path planning, generate trajectory information, and transmit track data to PLC through the Modbus RTU protocol. After that, PLC achieves the main movement according to the trajectory data, uses the auxiliary sensors to achieve compensation movement and thus achieves more accurate automatic cruise, which is a feasible technical solution.

3. The design purpose, structure composition and basic ideas of the work

3.1 Design purpose of the work
The AGV car can achieve automatic cruise in a wide area and a small scale environment based on electronic maps.

3.2 Structure composition of the work
This work is made up of the upper computer program, an AGV car and so on. The upper computer program is developed using VB, is run in a PC and transfers data to PLC through the serial port. PLC adopts XC3-32 of Xinjie Company and has two high speed pulse outputs. In addition to PLC, two sets of stepper motor and stepper driver, one brushless DC motor, 4 infrared sensors, two fiber optic sensors, some photoelectric sensors, three DC power supplies, operation buttons, one touch screen, four batteries and charging ports are needed to constitute the electrical control system. The frame, chassis and walking device of the AGV car plus the vehicle load form the mechanical body, as is shown in the figure below:

![Figure 1. Physical drawing of the work](image-url)
3.3 Basic ideas of the invention
This work USES Baidu static maps as the base map. The AGV car user plans the walking path on the base map, and the program automatically collects the path coordinates to form the track data file. The program collects the equipment parameters of the AGV car, combines with the track data file, generates both the pulse data and pulse direction data of the two stepper motors controlling the AGV car, converts them into the data required by Modbus RTU communication, and transmits the data through the serial port to the corresponding data area of PLC in order that PLC can control the stepper motor. Due to interference signals in the geographical coordinates of Baidu Map, displacement error caused by the out-of-step stepping motor and displacement error caused by both the time-varying ground friction in the walking path area and the changes in the ground slope, the system is equipped with path compensation function to achieve reliable positioning and cruise. To reduce cost, the components such as induction coils and a magnetic stripe should be abandoned, black asphalt should be sprayed into black ribbons as road marks near the turning point or the midpoint of the road and three optical fiber sensors should be installed on the front, the left and the right of the car bottom of the AGV car for detection. In this way, path deviation signals can be acquired at a lower cost within the scope of the small scale. The AGV car drive consists of not only two stepper motors as the main drive but also a brushless DC motor as the auxiliary drive. Path compensation can be divided into two types: compensation along the path tangent and compensation along the path normal. As for the former, the stepper motors replace pulse to make the AGV stop after it moves to the specified position. As for the latter, a brushless motor drives the compensation wheel to enable the AGV car to run to the middle of the path.

Through VB programming, this work can achieve the functions such as static map image acquisition, user-defined trajectory and generation and transmission of pulse information data to PLC. PLC controls the motion, path compensation and safety protection through pulse information data.

3.4 Main technical indicators
(1) It can achieve user-defined trajectory planning and friendly human-machine interface.
(2) It can realize the automatic navigation within a distance of 50-2000 meters, and the accuracy of positioning and cruise can reach the accuracy of meters.
(3) It can realize the safety protection function in the complex environment.

3.5 Program flow chart of the upper computer
This upper computer program can realize the functions of map trajectory design, AGV operation parameters setting, data generation and transmission and so on. Its program flow chart is as follows:
Figure 2. Upper computer program flow chart

3.6 PLC program flow chart
The PLC program USES the pulse information data transmitted from the upper computer to control two stepper motors and USES one brushless DC motor to realize the track movement based on Baidu static map navigation. According to the infrared sensor and fiber optic sensor on the AGV car, the path compensation function and safety protection function are realized. The specific flow chart is as follows:
4. Introduction to the key and difficult points of the software

4.1 Description of upper computer program development

The upper computer program consists of 2 forms, 1 dialogue box and 1 module. Form1 used Baidu static map to search the map of the walking area of the AGV, and took the screenshots of GetDC, BitBlt, PrintWindow and other API functions as the base map of the track planning. Dialogue 1 mainly sets AGV related parameters; In Form2, the functions of trajectory planning, data conversion and pulse transmission are completed, which is the most difficult part of this work.

Here's a quick explanation.
(1) Trajectory planning: the user selects the starting point, the middle point and the end point with the mouse on the base map. There is only one starting point and only one end point, and the middle point can be divided into several points. While drawing the trajectory, the program records the relevant coordinate points and converts them into linear information. Each linear information has length, Angle and Angle sine data.

(2) Data conversion: this information consists of the start signal + segment information + end signal. Each segment information includes segment number, pulse number of the left motor, direction of the left motor, pulse number of the right motor and direction of the right motor. According to the measured value of pulse unit described later, the segment information is converted into the pulse quantity to be sent by the left and right stepper motors. If the inclination is not 0, the two pulse quantities are different and the pulse direction is opposite, as is shown below:

\[
\begin{align*}
Zuobianmaichong &= CLng(xingchengmaichongbi * 100 * (length\_shuju + 0.5 * 0.001 * AGV\_width * \sin\_angle\_shuju)) \\
Youbianmaichong &= CLng(xingchengmaichongbi * 100 * (length\_shuju-0.5 * 0.001 * AGV\_width * \sin\_angle\_shuju)) \\
Zuobianfangxiang &= 1 \\
Youbianfangxiang &= 0
\end{align*}
\]

Among them, xingchengmaichongbi (stroke pulse ratio) and AGV_width are the center distance between the two driving wheels of the AGV car, both of which are filled in after being measured by the user.

Because of the need to control the AGV car to do both straight movement and turning movement, not only should the pulse direction on both sides be opposite, but pulse number and pulse frequency of the left and right motors should meet this requirement (the absolute value of the pulse number of the left motor/the pulse frequency of the left motor=the absolute value of the pulse number of the right motor/the pulse frequency of the right motor). The calculation of the number of the pulses per side should be correct, and only in this way can correct direction conversion be achieved. Similar codes can be used to achieve:

\[
\begin{align*}
Zuomaichongpinlv &= Pulse\_Pinlv\_base \\
Zuomaichongshu &= sign * zuobianmaichong \\
Youmaichongshu &= -1 * sign * youbianmaichong \\
Youmaichongpinlv &= CLng(zuomaichongpinlv * youbianmaichong/zuobianmaichong) \\
Maichongmsg\_xinjeleft (2 * I) &= zuomaichongpinlv \\
Maichongmsg\_xinjeleft (2 * I + 1) &= zuomaichongshu \\
Maichongmsg\_xinjeright (2 * I) &= youmaichongpinlv \\
Maichongmsg\_xinjeright (2 * I + 1) &= youmaichongshu
\end{align*}
\]

Here the sign is a forward trip (1)/reverse return trip (-1). In this way, the left and right pulse information of multiple segments can be generated respectively, and each segment is composed of pulse frequency and pulse number.

Since the pulse information data at this time is a decimal number, which needs to be converted into a hexadecimal number, and in order to realize RTU transmission, the high and low byte positions of each word need to be reversed, the program needs to organize and process the data, which is also the work needed for data conversion. This design USES the process "Private Sub to generate data _Click()" to do this.

(3) Modbus RTU transmission: sending data to Xinjie PLC via the upper computer must follow the requirements of Modbus RTU communication to achieve reliable data transmission, which is another technical difficulty of this work.\[6,7\] The code is as follows:

If comk3.portopen = True Then
    Redim bisend (8 + Pulse\_Date\_Byte\_Num) 
    Bisend (0) = "&h" + Hex(Val(1)) 'address code
    Bisend (1) = "&h" + CStr(10) 'function code write register
    Bisend (2) = "&h" + Hex(0) 'starting address high
Bisend (3) = "&h" + Hex(0) 'starting address low
Bisend (4) = "&h" + Hex(0) 'register
Bisend (5) = "&h" + Hex$(Pulse_Date_Byte_Num / 2) '
Bisend (6) = "&h" + Hex$(Pulse_Date_Byte_Num) 'bytes
Open "\f\g\plc_pulse_msg_byte_left.txt" For Input As #4
For I = 1 To Pulse_Date_Byte_Num
    The Line Input # 4, modbus_byte
    Bisend (6 + I) = "&h" + CStr(Trim(modbus_byte))
Next
The Close
CRC = CRC16(bisend, 7 + Pulse_Date_Byte_Num, btLoCRC, btHiCRC)
Bisend (7 + Pulse_Date_Byte_Num) = "&h" + Hex(btLoCRC) 'CRC high
Bisend (8 + Pulse_Date_Byte_Num) = "&h" + Hex(btHiCRC) 'CRC low
ComK3. The Output = bisend
The Else
    MsgBox "serial port not open"
End the If

Modbus RTU transmission data format must be "address code + function code + start address high
+ start address low + register number high + register number low + byte number transmitted + valid
data +CRC high +CRC low", using CRC check function. This design USES the process of "transmit
data to PLC_Click()" to send data in the order of "open serial port -> send left pulse information to
PLC register -> close serial port -> delay 1 second -> open serial
port -> send right pulse information to PLC register -> close serial port".

The upper computer program is rather complex and its other functions will not be introduced.

4.2 Illustration of PLC program development
The PLC program USES the pulse information transmitted from the upper computer to control the
forward and backward motion of the stepper motor. The motion control program can be realized by
using the ladder diagram as follows:

![Figure 4. Screenshot of the ladder diagram](image)

In addition, PLC USES a variety of sensors to achieve the functions such as self-positioning, path
compensation and safety protection. The principle of path normal compensation is the same as that of
self-positioning. First, two parallel asphalt ribbons with 1.2 times the width of AGV and 1.5 times the
length of the car are arranged at the starting and ending points of AGV car planning as the pick-up area
and the drop-off area respectively. Optical fiber sensors are used to detect asphalt ribbons. Tracing
and location are done by referring to the instruction of the stepper motor back to the origin (such as DZRN
instruction or origin regression instruction with Dog point). The AGV moves forward, decelerates
when it encounters the first ribbon (with a descending edge signal), and stops when it encounters the
second ribbon (with a rising edge signal); when the AGV starts to move, the system starts to time 10s. If the timing time arrives and no signal is found, it means the direction is wrong. The car automatically converts direction to look for the ribbon, and the system times 20s. If the signal has not been found (which is mostly caused by the fading or breakage of the ribbon), the AGV will stop and issue an alarm signal to remind the staff to handle the fault; if the position is successfully located, the AGV will wait for a period of time (the length of time is determined by the AGV's work task) and then execute the motion control instructions of S0 step when the time comes.

Asphalt ribbons are used on both sides of the road as signs. The distance between the two ribbons can be flexibly set according to the size of the AGV and the actual needs. The walking area is between the ribbons. Fiber optic sensors on both sides of the AGV car are used to identify the ribbon. Once the rising edge signal is detected, the return motor in the middle of the AGV chassis starts and the AGV moves to the center line. The return motor is an ordinary DC motor, and the length of its movement time depends on the distance between the ribbons and the speed of the return motor, which needs to be adjusted according to the actual situation.

The strategies of the security function are as follows: Infrared ranging sensors are used to detect the obstacles (people) around the AGV. If the distance is less than 0.5 meter (safety distance), the AGV will wait for 5 seconds; if the signal disappears after 5 seconds, the car continues to move forward; if the signal still exists, the motor will be suspended and the AGV warning light will flash. The return motor will move in the normal direction for 1s to detect the change in distance. If the signal is smaller, it means the normal direction is wrong, it needs to move in the reverse direction until the output data of the infrared ranging sensor reaches a safe distance. Then the car moves on. The sensor needs to be used in conjunction with the PLC analog module.

4.3 System parameter calibration

(1) Stepper motor pulse calibration

Because the stepper motor can change the pulse equivalent by subdividing the circuit, the pulse during the movement can be reduced and the control accuracy can be improved. This AGV car uses two identical stepping devices, but the pulse equivalent can be adjusted by the user according to the actual situation, so the pulse equivalent needs to be measured. Through several experiments, the displacement data cluster of the AGV car corresponding to a certain number of pulses can be measured and the pulse equivalent of the stepper motor can be calculated by means of averaging technology.

(2) Secondary calibration of Baidu static map data

The error which is brought by Baidu map should be reduced as much as possible. According to the regulations of the State Bureau of Surveying and Mapping, map data needs to use gcj02 coordinate system for encryption and interference signal should be added; on this basis, Baidu has used bd09ll coordinate system to add the white noise again, and therefore the map data has a large deviation. The static map provided by Baidu has a maximum level of 18 and an accuracy of 50 meters, which cannot meet the requirements of small-scale cruise. For this reason, we need to carry on the second calibration to Baidu map, to eliminate the interference signal in it as far as possible. Due to both the error in the static map data of Baidu and the operation error caused by a variety of other factors when the car is running, it is necessary to carry out the secondary calibration of the static map of Baidu. The fixed-length path is tested and the ratio between the stepper motor pulse and the map data of Baidu is adjusted to make them match. This is also achieved through multiple trials.

5. Instructions for the use of the software

When designing the path of this work, Baidu static map can be opened through the browser to set the website and to select the area of interest. After selecting the appropriate area, the edit box below the static map automatically generates the address information of the map to be collected. After entering this information into the browser address box, we click "Open browser" button again, and the system will automatically generate the required static map. Click the "Capture image" button to select the map that requires path planning. By default, the program selects an area of 800×600 pixels as the planning...
map, and the program automatically enters the path planning interface. In the program planning interface, the user can select the starting point, middle point and end point of the trajectory, and the program can automatically generate the trajectory, and complete the collection and processing of trajectory information.

![Trajectory information generation and display](image)

The program can set related equipment parameters based on different AGV cars. The selection of relevant parameters requires multiple experiments, recording the experimental results and averaging them to ensure the accuracy of the calculated pulse number, as is shown in the figure:

![AGV parameter setting dialog box](image)

After collecting trajectory data and AGV parameters, the program automatically generates data files, and converts them into pulse information (pulse frequency + pulse number) suitable for using PLSR instructions with XC type PLC, communicates with Modbus RTU, and sends the information to the PLC data storage area twice for PLC to control the motion of the two stepper motors. As can be seen from the following figure, there is data in the data register with the head address of D0 and D200, which is the pulse information data written to PLC by Modbus RTU.
Figure 7. Pulse information in PLC monitoring mode

After the pulse information data is transmitted to the PLC data register, the PLC performs self-positioning according to the AGV sensor and ACTS according to the transmitted pulse information. In the process of action, the program will detect the information of both the fiber optic sensor and infrared ranging sensor, and carry out path compensation and safety protection.

6. Innovation points and application fields of the design

6.1 Innovation points
(1) Baidu static map is adopted to realize user-defined path planning;
(2) Path compensation is adopted to reduce vehicle walking error at a small scale and to realize unmanned automatic cruise.

6.2 Application fields
AGV vehicle technology in the industrial environment has been relatively mature, but in the field of social service automation, the AGV automatic cruise technology is still in the immature stage due to the complexity of the environment and the requirement of the low cost of system operation in small-scale blocks (including the roads within blocks). At present, China is in the era of sharing economy. Shared bikes have solved the bottleneck of the last kilometer of people flow, but the bottleneck of the last kilometer of logistics has yet to be solved. In this sense, the work has a certain value of innovation and promotion. At present, the possible application fields of this work include the following aspects:
(1) it can be used as an automatic guide car for tourist attractions;
(2) it can be used for refuse transfer between the community refuse collection point and the transfer station;
(3) after the safety protection function of the work is completed, it can be used as a block logistics transfer device in a small scale environment to solve the "last kilometer" problem of large logistics.

7. Conclusion
The design and manufacture of AGV cars in industrial environments are mature, but the application of AGV cars in the field of social service automation is still in the early stage due to the complexity of the environment. This work focus is not to design a new kind of AGV car, but rather through the technical renovation to the existing AGV car chassis and control part, to achieve path tangential compensation (mediation function) by adding a brushless DC motor to drive compensating sheaves, and to achieve the detection of tangential error and normal error of the path planning by adding two fiber optic sensors. The AGV car is tested and the relevant parameters are obtained. We can compile and debug the upper computer program, collect the static map image of Baidu as the base map of the electronic map, make path planning on the base map, generate the track data in byte form, and send the data to the data register area of PLC through Modbus RTU protocol for the PLC program to control...
the AGV car movement.

The main work of this work lies in equipment transformation as well as equipment running parameter measurement, and the technical difficulties of the work lies in the programming and debugging of the upper computer. This work provides a technical reference for the application of AGV vehicles in the field of social service automation.

The market prospect is broad, and has certain innovation and some promotion value.

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