# DIFFERENTIAL DRIVE AND STEERING CONTROL TECHNOLOGY OF AUTOMATIC NAVIGATION HANDLING TOOL BASED ON PLC

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**Abstract -** In order to improve the differential drive and steering control technology, the differential drive and steering control technique for automatic navigation based on power line communication (PLC) is designed. The steering of the automatic guided vehicle (AGV) is divided into steering and differential steering. Because of the different steering modes, the AGV will cause different errors when moving along the desired trajectory in the path trajectory transformation. The AGV locus consists of straight and arc line. Among them, the steering trajectory of AGV is not complex because of the lack of spin adaptation, so its trajectory transition is complicated. Taking the self-developed single wheel drive and steering AGV as the object of study, the AGV trajectory planning program and motion program are developed by using Matlab and VC++. The error of AGV in trajectory transformation is analysed theoretically, and it is proved that the error caused by acceleration of motor can be compensated. At the same time, combined with the development of AGV control card PMAC, the program of motion is discussed. In addition, visual navigation has become the main direction of navigation technology because of its large amount of information and flexibility. In order to improve the robustness and accuracy of landmark detection, the effects of image denoising, edge detection and other techniques in navigation are discussed in turn. For the identification of path trajectory, genetic algorithm is introduced to improve the accuracy and time truth of navigation. Finally, the experiment proves the feasibility of the theory, and also gives the method to reduce the error of vision navigation. It provides a good foundation for improving the accuracy of visual navigation.

**Keywords:** Single Wheel Drive / Steering AGV, Turn Error, Visual Navigation, Genetic Algorithm, PLC.

## 1. Introduction

PLC (Power Carrier Communication) is a communication technology that couples data signals to power lines and uses power lines as propagation media. With the development of DSP and digital coding technology, PLC technology will be used more widely. As an important means of communication, PLC technology can replace the special communication network through the existing power line network. It is easy to implement the lighting control automation, security monitoring, remote meter reading and so on. According to the bandwidth size, PLC technology can be divided into narrowband PLC technology (9-500kHz) and broadband PLC technology (2-34, MHz). Narrowband PLC technology is often used in situations where data transmission rate is not high, such as power grid load control, automatic meter reading system and street light control. Broadband PLC is commonly used in high-speed data transmission occasions, such as large file transceiver, voice calls, video calls and other high-speed data transmission services. As one of the greatest inventions of mankind in twentieth century, robot has made great progress after more than 50 years' development, especially mobile robot. Because of its unique advantages, it has been widely used in all walks of life. As a member of mobile robot, it has the characteristics of good flexibility, automation and high intelligence [1]. The path can be changed according to the storage and production process changes. It has realized the automation of loading and unloading of goods and materials, and has become the main logistics tool in FMS.

According to the definition of American Logistics Association, AGV refers to a vehicle equipped with an electromagnetic or optical automatic guidance device. It can travel along a prescribed path. At the same time, it also has car programming and parking selection device, security protection and various load removal functions. The AGV is an unmanned automatic transport vehicle with a contactless guidance device and an independent addressing system. It is powered by batteries, and it is an automatic material handling equipment developed in 50 and 60s. The utility model can be used for transportation of goods in docks, airports, hospitals, shops, etc., and can also be used as a movable assembly platform for assembly lines. In particular, there is an urgent need for dangerous workplaces where staff cannot operate [2].

Through theoretical analysis, the method of solving this problem for single wheel AGV is discussed. The attitude of black guiding belt is recognized by CCD camera, and the AGV motion is guided by the acquired data. Since the curvature of the black band is guided to guide the AGV, the single wheel AGV can be satisfied as long as the rudder angle is controlled. But for two-wheel differential drive AGV, the control is more complicated than single wheel drive. Therefore, the visual navigation of two wheeled AGV is mainly discussed.

## 2. Literature Review

The first AGV in the world was developed by Barrett electronics company in America in 1950s. Prior to the middle of the 80s, most of the AGV was fixed wired guidance, limiting the restructuring and layout of its production. With the rapid development of modern industry, the level of AGV technology is also increasing. AGV is equipped with on-board computers, communication devices and materials handling devices, and the overall complexity and automation are greatly improved [3]. The United States government set up the National Automatic Highway Alliance (NAHSC) in 1995 to study the feasibility of developing an automatic guided vehicle and to promote the practicability of AGV. Generally speaking, the development of mobile robots in foreign countries basically follows two lines. Some universities and research institutions in Europe follow the academic line that robots are used as a vehicle for research into artificial intelligence. Since artificial intelligence and other intelligent technologies are far from expected, this kind of research is mostly in the experimental stage.

In recent years, the research and development of automatic guided vehicle (AGV) in our country shows a thriving scene, which is mainly related to the logistics heat in recent years. Beijing Hoisting Machinery Research Institute, China Postal Science Planning Institute, CAS Shenyang Automation Institute, Dalian composite machine tool research institute and other research institutes are the earliest units involved in the development of AGV.

Some of them have been produced in small quantities. AGV, the company that produces the real scale, is the Kunming marine equipment company [4].

In addition, Shenyang SIASUN, robotic company also developed a variety of AGV. Tsinghua University has developed a THMR_V automatic guided vehicle, has realized the structured Lane under the environment of automatic tracking, quasi structured environment road tracking under complex environment, obstacle avoidance, telepresence driving and other functions. National University of Defence Technology has developed automatic guided vehicle CITAVT series. The CITAVT_ IV vision autonomous navigation vehicle also implements autonomous navigation on the highway.

## 3. Methods

### 3.1 The composition and working principle of AGV

Because of its wide range of applications, the specific purpose and working conditions of AGV vary greatly. Therefore, it also has many kinds. But functionally, a variety of AGV should have the following subsystems:

Drive / boot system: The driving system and the guidance system of AGV are inseparable, and they are related to the chassis structure adopted. The design of the chassis structure ensures that the AGV can move freely and flexibly under the control of the drive / guidance system. The commonly used is three-wheel chassis dual rear wheel differential drive / steering, three-wheel chassis single-wheel drive / steering, four-wheel dual rear wheel differential drive / steering, four-wheel drive dual-wheel drive / steering, differential drive / steering, six-wheel drive dual-wheel drive / steering. Depending on the guidance system, the AGV can automatically run along the ground lead wire or the ground reflector or even any designated route [5].

Communication system: Several AGV can form an automated guided transport system (AGVS) together. When the automatic guided vehicle system in multiple car works at the same time, in order to make the car work conflict (task conflict, route conflict), logistics automation equipment and all other car in the system are unified by the central control computer control [6]. The car needs to receive instructions from the host computer for the next step, and also needs to report its current status to the main controller, which is done through the communication system. Fixed line AGV can communicate by wires embedded on the running line, while AGV can only use wireless communication in all directions [7]. When there are many interference sources, the communication system must have higher reliability in order to ensure the normal operation of the system.

### 3.2 Main technical parameters of AGV

Rated loading capacity. It is the maximum weight that AGV can bear. Dead weight. It refers to the total weight added by the AGV and the battery.

Car body size. It refers to the size of the car body, and this size should be subject to the size of the goods and the site.

Stopping accuracy. It refers to the number of millimetres between the location of the AGV job and the location of the program.

Minimum turning radius. It refers to the distance between the instantaneous steering centre distance and the AGV longitudinal centreline when the AGV is in the form of no-load, low speed and maximum deflection.

Running speed. It refers to the maximum speed at which AGV travels at rated loads.

Cell voltage. There are two specifications for battery voltage, 24V and 48V respectively.

Work cycle. It refers to the time required for AGV to complete a cycle of work.

## 4. Results and Discussion

AGV is a wheeled autonomous mobile robot, which mainly completes the tasks of path planning, positioning and obstacle avoidance. Therefore, path planning is one of the basic steps of AGV navigation [8]. It searches for an optimal or nearly optimal collision free path from the start state to the target state according to a performance index. According to the degree of robot access to environmental information, path planning is divided into two types.

The environment information is fully aware of the global path planning and the environment information is completely unknown or partially unknown to the local path planning [9]. The global path planning that is fully aware of the environment information is applicable to static environments, and the path is off-line planning. The local path planning environment information completely or partly unknown is detected by the sensor online on the robot operation environment, information obstacle location, shape and size to complete planning. The path is planned online. This article only discusses the planning of known paths for single round AGV.

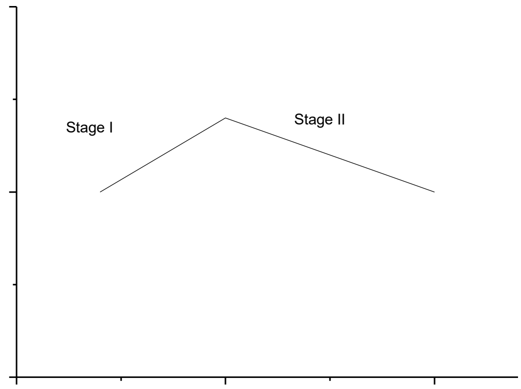
### 4.1 Trajectory analysis of single wheel drive / steering AGV

According to the structure and motion analysis of AGV, the trajectory of double wheel drive AGV can be divided into straight line, arc and spin. When the two wheels are the same in size and speed, the AGV can move forward or backward in a straight line. When the two wheels have the same speed direction, but the size is different, the AGV can move forward or backward in the arc motion [10]. When one wheel does not move, the AGV will rotate at the centre of a wheel. When the two wheels move at the same speed in the opposite direction, the AGV will spin at its centre of mass.

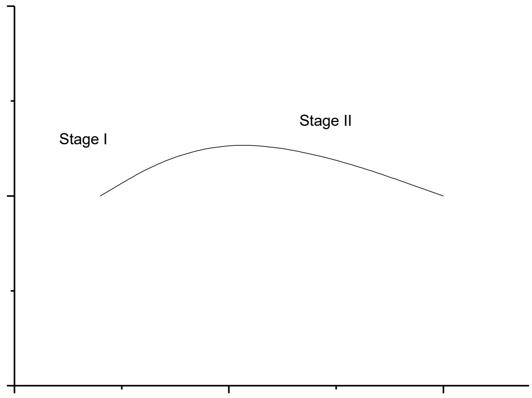
For a single wheel drive / steering AGV, since its steering is controlled by the steering motor to drive the wheel, the AGV has only two tracks of circular and straight lines, and there is no spin. However, if there is an angle between the front and rear two tracks, since there is no spin, the AGV must go through a transition arc to complete the trajectory. It is necessary to know that AGV needs to take the amount of arc ahead of time and the amount of second segments that have not gone. That is, the point between the arc and the two trajectories.

At the same time, when the AGV is taking the arc path, the steering motor needs to control the drive to rotate an angle. Obviously, the radius of the arc is different. The steering motor needs to be controlled, and the angle of rotation is different. So, it is assumed that the AGV moves from line to arc, the steering motor needs to be controlled to rotate over an angle. However, the steering motor is unable to turn the drive wheel suddenly to the desired angle.

At the same time, the steering motor itself also has acceleration and deceleration process. So, there is a lot of error here, and the law needs to be found out. The error is then reduced by compensation. This chapter deals with the two issues mentioned above.




*(a) The angle between the two paths*




*(b) The translation between the two paths*

*Figure 1: The trajectory analysis of AGV*

## 4.2 Trajectory planning of single wheel drive/ steering AGV

The flow chart of the AGV motion planning program is introduced. This program is AGV's entire PC program, and AGV can follow the planned results of the movement. The program has the function of track input and display. The parameters are written into the moving program, and the attitude parameters are feedback when the AGV is moving.

First of all, users need to design the trajectory parameters, while the trajectory is divided into straight line trajectory and arc trajectory. The parameters required for the line trajectory include five aspects. They are the running speed of the AGV, the direction of motion of the AGV (forward or backward), the distance of the AGV motion, the angle between the trajectory of the segment and the previous section, the direction of the included angle (clockwise or counter clockwise). The parameters of arc trajectory include six parameters. They are the speed of the AGV movement direction (forward or backward), the direction of rotation of the arc (clockwise or counter clockwise), arc radius, arc angle, the angle of the trajectory with a trajectory, direction angle (clockwise or counter clockwise) a total of six parameters.

## 4.3 Experimental result analysis

The AGV vision navigation experiment was completed in the laboratory. Taking black belt as its navigation road marking, its driving environment is the cement pavement in the laboratory. In the experiment, the running speed of AGV is set to 5m/min, and its trajectory is paved with straight line, arc, ladder and so on. AGV can track the trajectory, and the results are satisfactory. The parameters obtained by a trajectory with smaller curvature and a wavy trajectory are analysed.

Experimental results for the first trajectory. The trajectory of this strip consists of a straight line and a curve with smaller curvature. Figure 2 is a result of a comparison of the identified trajectory deviations and the measurement deviations

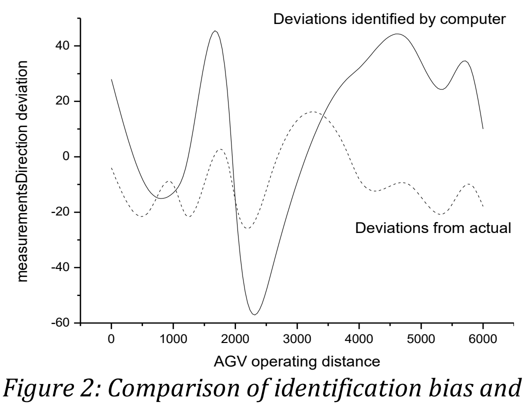



*Figure 2: Comparison of identification bias and measurement deviation*

As shown in the figure, the AGV begins at least in a straight line, and the slope of the identified trajectory is within 5S. Then, AGV moves along an arc, and the change of the slope is that the slope begins to grow from small to small at last. AGV adjusts the attitude of the AGV according to the positive and negative value that identifies the deviation. If the identified value is negative, the AGV moves in the positive direction, and vice versa. By comparison, it can be seen that the deviation of the measured AGV is basically changed according to the detected deviation direction. It shows that the correction effect of AGV is satisfactory according to the result of visual navigation.

Experimental results for the second trajectory. This trajectory is a S curve consisting of several arcs with large curvature. At the same time, the response speed of AGV is improved due to the large curvature. The trajectory deviations and measurements identified by the computer are shown in figure 3.

The result of the deviation comparison shows that there is a gap between the actual running track of AGV and the laying track. As shown in the diagram, the starting angle of the AGV is a negative value, that is, AGV has an angle at the beginning of the path. As AGV runs, the angles tend to become smaller and then change toward positive values. It shows that AGV is in an arc, and then the angle change is violent. It shows that the curvature of the second section arc is larger than that of the first section. Finally, the angle slowly returns to zero and then moves to a stop along a slightly curved arc. Because the response speed of AGV is improved, the deviation correction effect of AGV is better than that of the first experiment. Although the response speed is increased, the error is greater than the first experiment due to the large curvature and rapid curvature change. But the results of the AGV follow the guidance belt are still satisfactory.

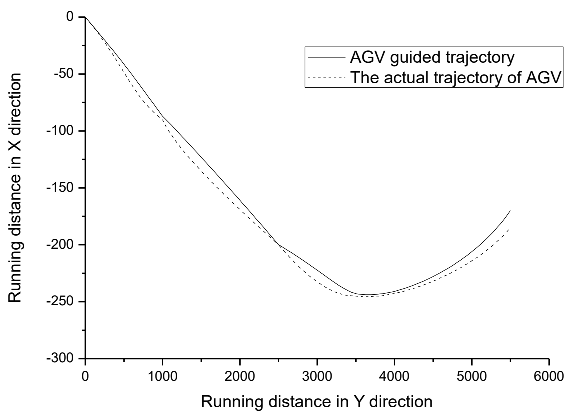



*Figure 3: Comparison of actual trajectory and following trajectory*

From the above experiments, it is shown that the volume of AGV used in the experiment is larger. For a larger trajectory, the tracking error is significantly larger than the curvature of the trajectory. Therefore, the vision navigation is suitable for small size and fast response AGV. On the other hand, the external conditions will have a certain impact on the results, so the accuracy of the image recognition needs to be improved. At the same time, the results of this experiment are satisfactory, which fully demonstrates the feasibility of AGV using visual navigation.

## 5. Conclusions

The motion path of AGV trajectory is discussed in two aspects. One is to use the path shape developed by the user on the upper computer to plan the path of the AGV. Another is to use visual navigation to direct the AGV along a fixed path. In the former method, it not only analyses the existence of the angle between the two tracks, but also analyses the theoretical solution that produces the error in turning. This not only guarantees the movement accuracy of AGV between different trajectories, but also provides a good solution and reference for the future study of using this method to formulate AGV trajectories. In the second method, through analysis of image enhancement, denoising and segmentation, genetic algorithm is used to solve the trajectory recognition. The feasibility of the theory is proved by experiment, and the actual error is given. This provides a good theoretical and practical guarantee for the recognition of other images in the future.

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## References

[1] Vogel-Heuser, B., Rösch, S., Fischer, J., Simon, T., Ulewicz, S., & Folmer, J. (2016). Fault handling in plc-based industry 4.0 automated production systems as a basis for restart and self-configuration and its evaluation. Journal of Software Engineering & Applications, 9(1), 1-43.

[2] Hu, C., Jing, H., Wang, R., Yan, F., Li, C., & Chen, N. (2015). Fault-tolerant control of electric ground vehicles with differential drive assisted steering. IFAC PapersOnLine, 48(21), 1180-1185.

[3] Xiong, Z., Zhenhuan, Y. E., Juan, H. E., Chen, L., & Linghu, J. (2015). Small agricultural machinery path intelligent tracking control based on fuzzy immune PID Robot, 37(2), 212-223.

[4] Pan, X., Zhou, Y., Gao, S., & Xu, M. (2015). Virtual endoscopy automatic navigation method based on rotation minimizing frames. Jisuanji Fuzhu Sheji Yu Tuxingxue Xuebao/Journal of Computer-Aided Design and Computer Graphics, 27(8), 1550-1555.

[5] Zhang, R., Li, Y., Yan, Y., Zhang, H., Wu, S., & Yu, T., et al. (2016). Control of a wheelchair in an indoor environment based on a brain–computer interface and automated navigation. IEEE Transactions on Neural Systems & Rehabilitation Engineering, 24(1), 128-139.

[6] G. Lin, X. Zou, Q. Zhang, & J. Xiong. (2017). Visual navigation for automatic guided vehicles based on active contour model. Nongye Jixie Xuebao/Transactions of the Chinese Society of Agricultural Machinery, 48(2), 20-26.

[7] Sun, Q., Teng, S., Du, Y., Kang, Z., Yin, C., & Chen, L. (2016). Research on calibration method for tractor automatic navigation control system, 10(1), 129-140.

[8] Bai, X. P., Hu, J. T., Gao, L., & Zhang, T. (2016). A sliding-mode variable-structure controller based on exact feedback linearization for automatic navigation system. International Journal of Agricultural & Biological Engineering, 9(5), 158-165.

[9] Cai, D. (2015). Museum navigation based on nfc localization approach and automatic guidance system. International Journal of Computer Applications, 120(3), 514-517.

[10] Luan, S., Qiu, T., Song, A., Wang, P., Li, J., & Tan, H. (2017). Automatic dependent surveillance-broadcast time delay estimation based on extended recursive maximum correntropy algorithm. Iet Radar Sonar & Navigation, 10(8), 1500-1507.