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Application of Distributed wMPS System in AGV Automatic Navigation

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Abstract: AGV vehicles play an important role in industrial automation production, and automatic navigation is the basis for automatic operation of AGV vehicles. In order to improve the navigation accuracy of AGV vehicles, based on the workspace measuring and positioning system (wMPS), this paper proposes to use upright and top mounted transmitter stations to build precision coordinate measuring fields, and analyzes the construction process and layout optimization principle of precision measuring fields in detail, Finally, the measurement accuracy of the coordinate field is illustrated through experiments. The experimental results show that the comparison error between the precision coordinate measurement field constructed by the method proposed in this paper and the measurement results of the tracker is controlled below 0.2 mm, which can effectively ensure the measurement accuracy and realize the automatic precision navigation of AGV vehicles.

Keywords: AGV navigation; Positioning measurement system; Measuring field; Layout optimization.

1. Introduction

At present, China's industrial production fields, such as machining, parts assembly, splicing, are characterized by multiple tasks and strong repeatability. If manual operation is adopted, a large amount of labor needs to be invested, and processing technology and precision cannot be well guaranteed [1]. Therefore, manufacturing enterprises are gradually introducing new industrial technology and information technology to realize the automation of production process. However, at present, the automation of the workshop is mainly concentrated on the unit level. For example, one station uses multiple industrial robots for automatic processing, but the transportation between stations still requires manual or semi mechanical methods, which also reduces the overall generation efficiency. In addition, it needs to establish multiple stations, which also increases the cost input [2].

The emergence of AGV (Automated Guided Vehicles) has solved some of the above problems and realized highly automated production and processing. AGV car first appeared in the 1950s. It is an unmanned intelligent carrying car, belonging to a mobile robot. AGV vehicles are generally equipped with automatic guidance devices, which do not require manual operation, and do not need to lay tracks, supports and other auxiliary equipment in their work areas. They have low requirements for the site, roads and surrounding environment, and are characterized by strong flexibility, good repeatability, good safety, and can work 24 hours a day, which can effectively improve the production efficiency and reduce costs, and the task scalability is very good [3][4].

The automatic processing system realized by AGV car is mainly divided into parts processing area and AGV car moving area [5]. As shown in Figure 1, multiple processing areas can be set in the site, and each processing area can achieve different processing tasks. The processing tasks are completed by the industrial robot fixed on the AGV car. When the processing task of one area is completed, the AGV car's automatic navigation function and advance path planning are used to transport it to the next processing area, so as to complete the processing task of each area. It can be seen that in order to realize automatic processing of AGV vehicles, it is necessary to realize automatic navigation of AGV vehicles. Due to the high precision requirements of the processed parts, when the AGV car moves to a processing area, it needs to stop at the designated position. Each designated position has four holes drilled. These four holes can be connected with the four retractable supports installed on the AGV car to fix the AGV car, so that the robot will not be affected by the AGV's own shaking during the processing. In order to enable the AGV vehicle to accurately move to the designated parking position in each processing area and dock with the four holes, high-precision navigation is required for the AGV vehicle.

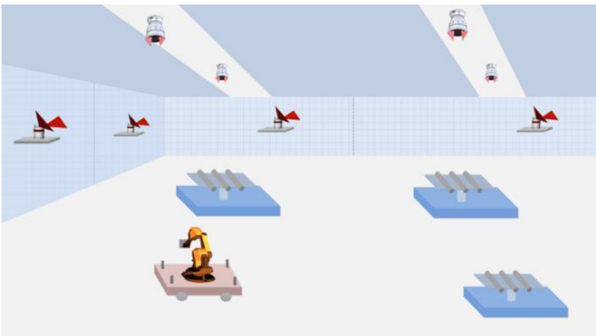

Figure 1. Schematic Diagram of AGV Automatic Processing

Schematic Diagram for Automatic Processing of AGV Traditional AGV vehicle navigation mainly includes electromagnetic navigation, inertial navigation, visual navigation and other technologies, but these technologies mainly have problems such as poor anti-interference ability, low real-time, low precision, which can't meet the requirements of high-precision dynamic navigation processing. Moreover, because of the large processing area and large navigation space, AGV vehicles need to ensure high precision in the whole process of moving in large space. the workspace measuring and positioning system (wMPS) is a new industrial distributed large-scale coordinate positioning system based on the photoelectric scanning principle, which has the advantages of high precision, good scalability and parallel real-time measurement. This paper proposes a high-precision measurement field construction method based on distributed wMPS, which can effectively ensure the accuracy of AGV vehicle navigation process.

2. wMPS Related Technologies

2.1. Measuring Principle

The wMPS is a new industrial distributed large-scale coordinate positioning system based on photoelectric scanning principle, mainly including laser transmitting stations distributed around the workspace and receivers located at various points to be measured, as shown in Figure 2.

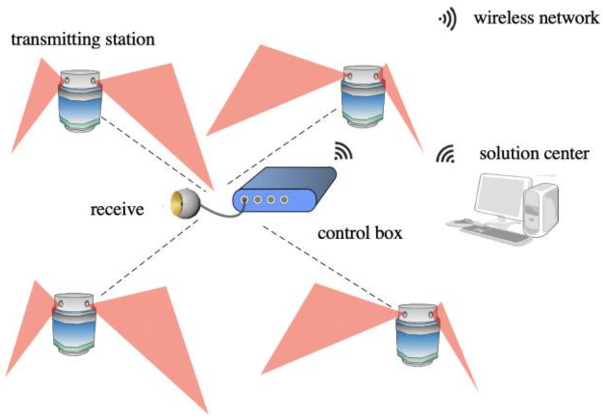

Figure 2. Composition Diagram of Measuring System

The uniform rotating turntable of the transmitting station drives two linear lasers that can emit sector laser to scan space at a uniform speed. When the photodiodes inside the receiver at the point to be measured perceive signals from different transmitting stations, the solving workstation can use the principle of forward space intersection to calculate its own spatial coordinates [6] [7]. During operation, the transmitting station turntable rotates counterclockwise at a constant speed driven by the motor. When the rotary head turns to a predetermined initial position, the transmitting station shoots an isotropic synchronous light signal into space as the starting point of timing. When the transmitting station laser plane scans the receiver, a scanning signal will be generated. According to the time difference between the two and the rotating speed of the transmitting station, the solution workstation can determine a virtual plane passing through the receiver. Similarly, After obtaining at least three such planes, the spatial coordinate P(x,y,z) of the receiver can be calculated. One equation can be determined for each plane, and the equations [7] can be solved by using multi plane constraints as follows:

$$[a_{mn}\ \ b_{mn}\ \ c_{mn}]\cdot \boldsymbol{R}_{\theta_{mn}}\cdot\left[\boldsymbol{R}_n\cdot[x\ \ y\ \ z]^T+\boldsymbol{T}_n\right]+d_{mn}=0 \qquad (1)$$

Where $a_{mn},b_{mn},c_{mn},d_{mn}$ represents the coefficient of the mth initial laser plane equation of the nth transmitting station, $m\in\{1,2\}$, $n\in\mathbf{N}^+$. $\boldsymbol{R}_{\theta_{mn}}$ Indicates the rotation of the laser plane θ Rotation matrix of. $\boldsymbol{R}_n$ 、$\boldsymbol{T}_n$ Represent the rotation matrix and translation matrix from the global measurement coordinate system to the transmission station coordinate system respectively.

2.2. Distributed wMPS System

The distributed wMPS system has the characteristics of large measurement space, high precision, good real-time and strong scalability. Therefore, using wMPS to build a large space precision coordinate measuring field can solve the problem of high-precision navigation of AGV vehicles. As shown in Figure 1, the top mounted transmission station and the upright transmission station are used to jointly build a coordinate measuring field, so that they cover the working space of the entire AGV vehicle. Omnidirectional receivers are placed at the fixed positions of the four corners of the AGV vehicle. When the AGV vehicle moves, the position coordinates of the four receivers are measured through the wMPS system, so that the position of the AGV vehicle under the constructed coordinate system can be known, so as to achieve real-time accurate navigation.

2.3. Layout Optimization

The measurement field constructed by wMPS needs to place multiple transmitting stations, and the location of the transmitting station will affect the final measurement accuracy. In order to obtain the best placement location of the transmitting station and optimize the layout, an evaluation model is required first, that is, how to evaluate the advantages and disadvantages of a layout, analyze and solve the equations (1), Finally, it can be simplified into the following linear equations model:

$$\mathbf{Ax}=\mathbf{b} \qquad (2)$$

The condition number of coefficient matrix A is A_{cond}, because matrix A is full rank,

$$N_{\text{cond}}=(A_{\text{cond}})^2 \qquad (3)$$

The smaller the condition number of A is, the smaller the relative change of solution is, and the higher the measurement accuracy is. Therefore, the optimization of layout is to find parameters to minimize the conditional expression of A. Genetic algorithm is a heuristic and adaptive global search algorithm [8]. This paper uses genetic algorithm to solve the optimal solution.

3. Building a wMPS measurement field

The establishment of the measurement field needs to take into account many factors such as the measurement site interference, complex environment, and many obstacles. The constructed measurement field needs to achieve full coverage of the entire space while ensuring the accuracy, so as to ensure that the AGV vehicle can get accurate navigation in the entire space to complete the measurement task. In order to improve the measurement accuracy of the construction, it is necessary to optimize the layout. The optimization strategy and method mainly use the relevant models and algorithms proposed in this paper. In order to better adapt to the on-site environment and needs, it is necessary to improve the construction and optimization process. The construction process of the measuring field is mainly divided into the following steps.

(1) Determine the measurement area. The size of the measurement area directly determines the number of transmission stations to be arranged. Because the establishment of the measurement field is mainly used for the navigation of AGV vehicles, the measurement area is the moving area of AGV vehicles. Considering that the AGV car needs to stop at a precise position near the processing area, the accuracy is required to be high, while the accuracy is relatively low in other moving areas, so the measurement area can be divided into multiple parts, which is helpful for the subsequent layout and layout optimization of the launch

station.

(2) Determine the station layout area. The determination of the station layout area mainly considers the coverage of the transmitting station, obstacle avoidance, measurement accuracy and other aspects. Considering the best working distance of the laser in the transmitting station, the coverage of the transmitting station is mainly a circle within 10 meters. The blind area of the transmitting station is roughly two cones with a top angle of 60 degrees, taking the Z-axis of the transmitting station as the centerline. Therefore, the greater the distance between the measuring areas in the Z-axis direction, the greater the blind area. At the same time, due to the complexity of the on-site working environment, when processing, other processes and equipment should be considered to block the signal of the transmitting station. It is necessary to ensure that each position can receive at least two transmitting station signals. Since the AGV vehicle is required to move inside the measuring area, the transmitting station cannot be placed. It can be considered to use a top mounted transmitting station and a vertical transmitting station.

(3) Determine the initial layout. After the station layout area is determined, an initial layout can be determined according to experience. The transmitting stations can be placed in batches by using the previously divided multiple measuring areas to ensure that each measuring area is covered. Considering the large measurement field, if the unified calibration computation is large and time-consuming, and the subsequent layout needs to be optimized, the optimized layout needs to be recalibrated. Therefore, external parameter calibration can be carried out for the transmission stations in different regions. Since there are fewer transmission stations in each region, calibration is more convenient.

(4) Determine the optimized layout. After the first three steps are completed, all three parameters required for layout optimization are available, and then the layout can be optimized through genetic algorithm. In the same way, the space of each measurement area divided previously is locally optimized. Because the accuracy of the processing area is required to be high, first optimize the layout of the transmitting stations around the processing area, so as to determine the positions of some transmitting stations, and then optimize the layout of other transmitting stations as a whole, so that each transmitting station can achieve high accuracy in the measurement area covered by itself. After optimization, manually adjust the launch station to the optimized position according to the software prompts, and adjust the attitude of the top mounted launch station. Finally, the external parameters of the whole measuring field need to be calibrated.

4. Experiment

In order to compare the measurement accuracy of the constructed coordinate measurement field, the following comparison experiment is designed. First, select the position to place the laser tracker, make its measurable area as large as possible, and take the global coordinate system as the tracker coordinate system. Then the coordinate system of the measurement field of the wMPS system is transferred to the global coordinate system through the method of multiple common points transformation. Then make the AGV vehicle move freely in the working area. When it moves to a position to be measured, first use the omnidirectional receiver of the wMPS system to measure and record the data, then remove the omnidirectional receiver, replace it with a laser tracker target ball, and use the laser tracker to measure and record the data at the same position, thus completing a group of measurements. Move the AGV vehicle to multiple locations for the above measurement, so that multiple groups of measurement data can be obtained, and some data can be sorted out as shown in Table 1.

Table 1. Partial data comparison of wMPS precision coordinate measuring field (mm)

Point Number		X	Y	Z	dX	dY	dZ
1	Laser Tracker	-3765.155	4956.667	818.661	-0.181	-0.118	0.059
	wMPS	-3764.974	4956.549	818.720			
2	Laser Tracker	-3731.107	6242.841	826.394	-0.167	0.121	0.08
	wMPS	-3730.94	6242.962	826.314			
3	Laser Tracker	-5218.944	6844.735	811.053	0.123	0.139	0.132
	wMPS	-5219.067	6844.874	811.185			
4	Laser Tracker	-5711.576	5784.552	796.472	0.137	0.125	0.065
	wMPS	-5711.713	5784.677	796.573			
5	Laser Tracker	-1242.292	2109.69	819.472	-0.112	0.160	-0.13
	wMPS	-1242.18	2109.85	819.602			
6	Laser Tracker	-452.60	7477.672	818.835	0.128	0.121	0.053
	wMPS	-452.728	7477.551	818.782			

From the experimental data in Table 1, it can be seen that the precision coordinate measurement field constructed by the wMPS has a high measurement accuracy, and the comparison error between the measurement results of each direction and the tracker is controlled below 0.2mm, which provides a guarantee for the automatic high-precision navigation of AGV vehicles. In addition, the good scalability of the wMPS system can ensure the high accuracy of the measurement when adding stations or measuring tasks to the AGV automatic processing system. It can be seen that the precision coordinate measurement field constructed by wMPS system has a very broad application prospect in the field of high-precision navigation.

5. Conclusion

The automatic navigation of AGV vehicle is of great significance in the industrial automation production, and the automatic navigation requires very high accuracy. In order to ensure the high-precision automatic navigation of AGV vehicle, this paper introduces the wMPS system. The wMPS measurement system has the characteristics of large range, high precision, multi task parallel, full space real-time measurement, and convenient space expansion. Therefore, the measurement field based on wMPS has high precision. In order to further improve the accuracy of the measurement field, this paper first analyzes the measurement principle of the wMPS and the solution equation, then analyzes the principle of layout optimization, and then proposes a method for constructing high-precision wMPS measurement field. Finally, the comparative analysis is carried out through experiments. The results show that the comparison error between the constructed measurement field and the measurement results of the tracker is controlled below 0.2mm, which can effectively meet the accuracy requirements of AGV vehicle automatic navigation. Considering the complexity of measurement requirements in practical applications, we can further study how to use wMPS and other measurement systems to build high-precision coordinate measurement fields to improve the accuracy of measurement fields.

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