IGPS-based AGV Navigation System for Indoor Environment with Mecanum Wheel

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Abstract: In the process of product processing and assembly, it is often necessary to move products between different processing stations. However, the frequent movement of large-scale products in the processing process not only reduces the processing efficiency of products, but also reduces the safety of products. In this paper, an Omnidirectional mobile platform based on IGPS navigation and Mecanum wheel is proposed to carry processing equipment and realize products. Through iGPS navigation, the movement equipment can improve the utilization rate and working efficiency of the equipment. This paper discusses the measurement principle of iGPS, the working principle of omni-directional mobile platform, system composition and path solution method. The system can be widely used in large-scale equipment and products for high-precision moving and positioning, and has a good application prospect.

1. Introduction

In the past 40 to 50 years, the industry and automation industry have developed rapidly, and the logistics and manufacturing industries have also changed dramatically. The continuous breakthrough of AGV technology reduces production and manufacturing costs and improves overall work efficiency[1]. With the development of navigation technology, sensor technology, network communication technology and computer simulation technology, the high-end manufacturing industry is rapidly transforming and upgrading. As an omnidirectional intelligent mobile platform, AGV provides an effective solution for lean distribution and intelligent logistics of intelligent factories. AGV is mainly divided into magnetic navigation, inertial navigation, laser navigation, visual navigation, sensor based data navigation, GPS navigation, IGPS navigation, photoelectric encoder navigation, radio frequency identification navigation, etc[2].

At present, many researchers have done a lot of research on AGV guidance technology. Zhu Congmin[4], Zhong Jubin[5], He Zhen[6], et al. constructed the AGV navigation control system by using multiple sensor fusion methods, but the positioning accuracy still do not meet the positioning accuracy of auxiliary assembly . Zhang Xiaoxia[3] proposed a GPS / DR integrated navigation positioning algorithm, which realized the outdoor AGV navigation, but GPs is not used indoors and the positioning accuracy of this method is not high enough to meet the room Accuracy requirements for internal navigation. This paper presents an AGV precise navigation and positioning method based on the combination of IGPS and Mecanum wheel. The system has the characteristics of strong adaptability, high automation and high positioning accuracy[7][8].

2. IGPS Composition and Working Principle

The IGPS system is mainly composed of three parts: Transmitter, Receiver and Measurement control network.

In order to effectively manage and transmit control signals, calibration data, resource data and measurement data, the measurement data is divided into two layers: system layer data and task layer data. System level data is shared by the whole system, including resource information such as base station parameters, control network parameters and receiver parameters. Task level data is used for local tasks, including measurement results and 3D modeling data. Hierarchical management ensures the consistency of public data and the independence of task data.

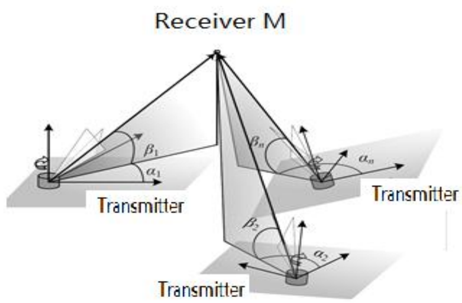

Figure 1: Schematic diagram of iGPS.

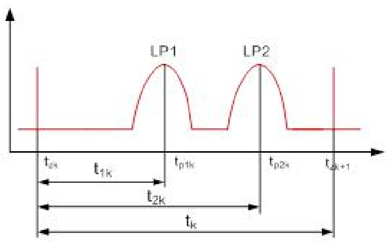

Figure 2: Time characteristic angle transformation relationship of photoelectric sensor.

Let the normal vectors of the initial plane of the two laser planes in the transmitter coordinate system o-xyz be N1 = (A1, B1, 1) and N2 = (A2, B2, 1). When the transmitter rotates around the z-axis at the ω speed, a reference signal will be generated every revolution, as the time origin of the subsequent time measurement, and the corresponding angle is 360 °. When the laser plane Lp1 and LP2 pass through the point P to be measured, the sensor generates a pulse signal. The difference between this signal and the time origin is recorded, which is called the characteristic time. From,, and ω, the plane equation of the laser plane passing through the P-point in the transmitter coordinate system can be obtained. These two planes also determine a straight line through which point P passes under the transmitter coordinate system o-xyz. If there are multiple transmitters, the position coordinates of the points to be measured can be determined.

Where k corresponds to the transmitter number. Lp1 and LP2 represent the number of the current pulse generated on the receiver by the two laser planes of the transmitter. Taking the space zero pulse of the transmitter as the time origin, the peak position time corresponding to Lp1 and LP2 is tp1k and tp2k respectively, and tzk and tzk + 1 are the zero pulse time, which are called the characteristic angles measured by the system. Their relations are as follows: $\theta_{1k} = \left(t_{p1k} - t_{Zk}\right) / \left(t_{zk+1} - t_{zk}\right)$, $\theta_{2k} = \left(t_{p2k} - t_{Zk}\right) / \left(t_{zk+1} - t_{zk}\right)$ Therefore, the coordinate value of the point to be measured can be written:

$$\vec{x}_w = -\left(\begin{bmatrix} \vec{s}_{11}^T R_{t11} R_1 \\ \vec{s}_{21}^T R_{t21} R_1 \\ \vdots \\ \vec{s}_{1k}^T R_{t1k} R_k \\ \vec{s}_{2k}^T R_{t2k} R_k \end{bmatrix}^T \begin{bmatrix} \vec{s}_{11}^T R_{t11} R_1 \\ \vec{s}_{21}^T R_{t21} R_1 \\ \vdots \\ \vec{s}_{1k}^T R_{t1k} R_k \\ \vec{s}_{2k}^T R_{t2k} R_k \end{bmatrix} \right)^{-1} \begin{bmatrix} \vec{s}_{11}^T R_{t11} R_1 \\ \vec{s}_{21}^T R_{t21} R_1 \\ \vdots \\ \vec{s}_{1k}^T R_{t1k} R_k \\ \vec{s}_{2k}^T R_{t2k} R_k \end{bmatrix}^T \begin{bmatrix} \vec{s}_{11}^T R_{t11} T_1 + 1 \\ \vec{s}_{21}^T R_{t21} T_1 + 1 \\ \vdots \\ \vec{s}_{1k}^T R_{t1k} T_k + 1 \\ \vec{s}_{2k}^T R_{t2k} T_k + 1 \end{bmatrix}$$

3. Omnidirectional Mobile Platform with Mecanum Wheel

The omni-directional intelligent mobile equipment is driven by multiple omni-directional wheels independently. Through the combination of rotation speed and steering of different wheel groups, it can move in a two-dimensional plane with any attitude. It is a kind of remote control equipment that can move in any direction of two-dimensional plane without any rotation of the car body. It can go straight, crosswise and skew. It can rotate at any angle in place in the way of zero radius of rotation. It can walk to the required position along any continuous track on the plane. The movement is very flexible and it can adjust the position slightly to meet the requirements of precise positioning and high-precision track control.

Figure 3: Omnidirectional mobile platform with Mecanum wheel.

The omni-directional intelligent mobile platform is driven by four omni-directional wheels independently. Through the combination of rotation speed and steering of different wheel groups, it can move in two-dimensional plane with any attitude. When the four omni-directional wheels rotate at the same speed, the platform moves forward or backward; when the left front wheel and the right rear wheel rotate backward, and the right front wheel and the left rear wheel rotate forward, the platform moves to the left, and vice versa; when the two diagonal omni-directional wheels rotate forward at the same speed, the other two wheels rotate forward at a speed different from the speed, and the platform moves to the side front; when The left front wheel and the left rear wheel rotate backward. When the right front wheel and the right rear wheel rotate forward, the platform rotates counterclockwise in the way of zero rotation radius, and vice versa.

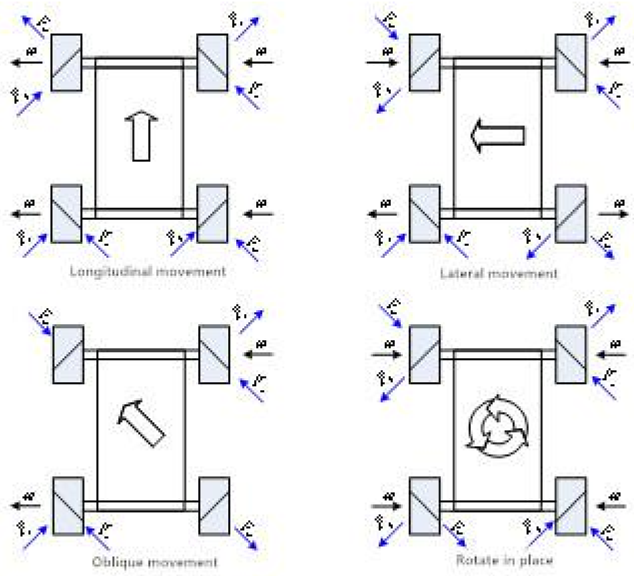

Figure 4: Schematic diagram of omnidirectional motion.

The omni-directional wheel is in the form of Mecanum wheel. It looks like a helical gear, and there are many small rollers on the rim. The axis of these rollers is tangent to the circumference of the wheel and can rotate freely. When the motor drives the wheel to rotate, the wheel moves in the normal direction perpendicular to the driving shaft, and the rollers around the wheel rotate freely along their respective axes. The omni-directional wheel has the active driving ability in one direction, while the other direction also has the motion characteristics of free movement (passive movement)[9][10].

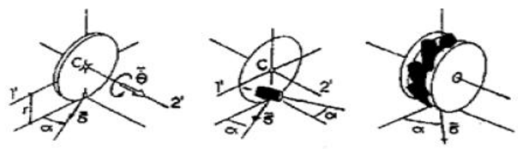

Figure 5: Structure diagram of omnidirectional wheel.

The kinematic equation of AGV system is as follows:

$$\begin{bmatrix} v_x \\ v_y \\ \omega_c \end{bmatrix} = \frac{R}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & 1 \\ \frac{-1}{L_1+L_2} & \frac{1}{L_1+L_2} & \frac{-1}{L_1+L_2} & \frac{1}{L_1+L_2} \end{bmatrix} \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix}$$

As:

ω_1: 1^{st}wheel angular speed，rad/s

ω_2: 2^{nd}wheel angular speed，rad/s

ω_3: 3^{rd}wheel angular speed，rad/s

ω_4: 4^{th}wheel angular speed，rad/s

ω_c: AGV rotationangular speed，rad/s

R: Wheel radius，mm

L_1: Half the distance between front and rear wheels，mm

L_2: Half the distance between left and right wheels，mm

v_x: AGV speed in X direction，mm/s

v_y: AGV speed in direction，mm/s

v_c is the combined velocity of $v_x$and v_y， $v_c$can be divided into yaw angle $\emptyset$ （(the angle between v_c and the vehicle body's central axis） and velocity value V. AGV can move freely in the plane of motion by adjusting $(\emptyset, \omega, V)$.Among them $\emptyset$ is related to the distance deviation of follow-up path tracking e_d and the running angle along the target path α. And ω is related to the angle deviation of the target path e_θ.

4. System Composition and Path Solution

According to the principle of rigid body kinematics, four receivers need to be installed at the front and back ends of the platform center line to measure the platform's running attitude. Each receiver is fixed by a fixture support integrated with the trolley. During the guidance process, ensure that each receiver can receive the information of at least two stations, so as to obtain the coordinate values of four points, as shown in Figure 6. Before the installation of the receiver, the three-dimensional coordinates of each receiver target ball in AGV car coordinate system are calibrated as the standard values of digital and analog. When the receiver is installed on the platform, the measured value of the key point and the standard value of the digital analog are used as the corresponding points to calculate the attitude registration relationship of the rigid body where they are, that is, the yaw angle of the platform and the three-dimensional coordinates (x, y, z) of the platform in the control field.

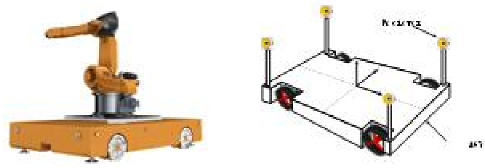

Figure 6: Layout of measuring points.

The control system is mainly composed of omnidirectional intelligent mobile platform controller, iGPS navigation module, main control computer, hand-held controller and so on. The navigation module is mainly used for the reception of iGPS signals and coordinate calculation; the main control computer is mainly used for path planning, coordinate transformation, navigation strategy calculation, etc.; the omni-directional intelligent mobile platform controller is mainly used for the walking control of the platform; the handheld device is mainly used for the omni-directional mobile control of the platform under the manual control mode. Wireless communication mode is adopted for data transmission among navigation module, main control computer, omnidirectional mobile platform controller and handheld device, as shown in Figure 7

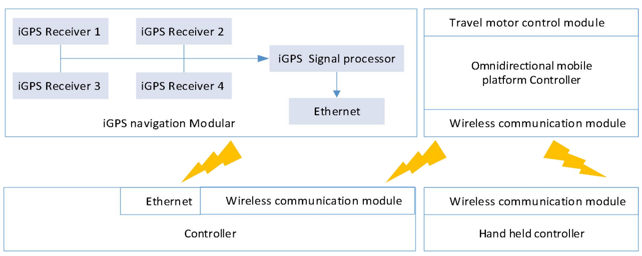

Figure 7: Control system block diagram.

4.1. AGV Center Coordinate Calculation

This section focuses on the mathematical modeling of the platform center position and pose calculation. In order to simplify the calculation, the coordinate system is established with the plant as the datum, and this coordinate system is set as the iGPS coordinate system. Set the coordinates received by the iGPS installed at the four corners of the platform as (X_1, Y_1), (X_2, Y_2), (X_3, Y_3), (X_4, Y_4). The receiver is installed on the four corners of the rectangle centered on the center of the trolley, and the installation position is known. Therefore, as long as one receiver solves its coordinate value, it can calculate the center position coordinate of the platform. If two or more receivers solve its coordinate value, it is more convenient to calculate the center coordinate of the platform. Next, take the coordinates of the receiver with two known diagonal points as an example The calculation method of platform center coordinate (X_0, Y_0) is as follows:

$$x_0 = x_2 + \frac{x_4 - x_2}{2} \tag{1}$$

$$y_0 = y_2 + \frac{y_4 - y_2}{2} \tag{2}$$

4.2. AGV Pose Angle Calculation

In order to calculate the pose angle of the platform, it is necessary to know the coordinate values of any two or more receivers, and then calculate the pose angle β of the platform with the known coordinates of receivers 1 and 4, that is, the included angle with the positive direction of Y-axis and counterclockwise, $\alpha = arc\tan\left|\frac{x_1 - x_4}{y_1 - y_4}\right|$, Figure 8 shows four different postures of AGV, and the calculation method of postural angle β is as follows:

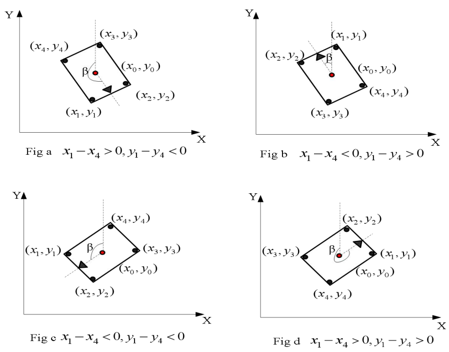

Figure 8: Four positions of AGV.

In Fig a，when x1-x4>0，y1-y4 <0， $\beta = 180^{\circ} + \alpha$;

In Fig b，when x1-x4<0，y1-y4 >0， $\beta = \alpha$;

In Fig c，when x1-x4<0，y1-y4 <0， $\beta = 180^{\circ} - \alpha$;

In Fig d，when x1-x4>0，y1-y4 >0， $\beta = 360^{\circ} - \alpha$;

4.3. AGV Path Solution

Through the above calculation, the current position and attitude of AGV can be analyzed, so the AGV path solution can be further carried out. The navigation path planning is completed by the path planning module on the main control computer. According to the position and attitude information and path planning of the current platform, the navigation module can solve the relationship between the platform and the next target position and the set final attitude. The platform will adopt reasonable The specific path calculation process is as follows:

Let γ be the angle between the target position and the positive direction of y-axis counterclockwise, and the coordinate of the target position is（xaim,yaim）, $\theta = arc\tan\left|\frac{x_{aim} - x_0}{y_{aim} - y_0}\right|$ Figure 9 shows the path planning of four different target locations of AGV.

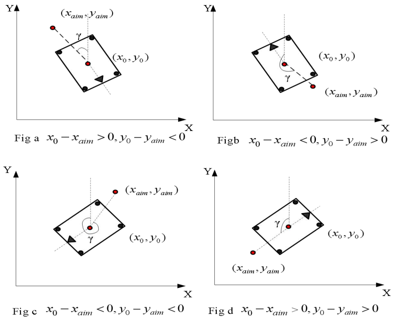

Figure 9: Schematic diagram of AGV path planning.

In Fig a，when x0-xaim>0，y1-yaim <0，

$\gamma = \theta$;

In Fig b，when x0-xaim<0，y1-yaim >0，

$\gamma = 180^\circ + \theta$;

In Fig c，when x0-xaim<0，y1-yaim <0，

$\gamma = 360^\circ - \theta$;

In Fig d，when x0-xaim>0，y1-yaim >0，

$\gamma = 180^\circ - \theta$;

Because the mobile platform used in this paper is omni-directional mobile platform, according to the calculation results, we can use straight, horizontal, oblique, rotation and two kinds of combined motion to achieve the smooth and accurate navigation control of the platform.

5. Analysis of Experimental Results

The AGV test platform based on IGPS developed independently is adopted for the test, as shown in the figure.

Figure 10: AGV test platform based on IGPS.

The test environment is the factory floor paint. In order to verify the effectiveness of the modified method and the positioning accuracy of IGPS guided AGV, 200 consecutive stops were made at the same location, and the laser tracker was used for the test. The location coordinates of the laser tracker at the location point were (- 2307.8771179.287, - 677.001). The actual distance error between the location and the location of AGV is shown in Figure 11. It can be seen that the positioning error is within ± 0.5mm.

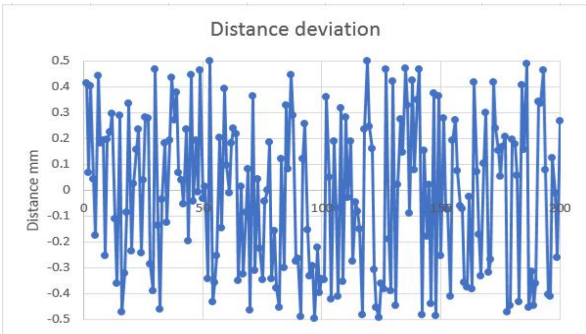

Figure 11: Experimental results.

6. Conclusions

The omni-directional mobile platform based on IGPS has the characteristics of convenient path planning, high measurement accuracy, flexible movement, high navigation control accuracy, which can meet the needs of high-precision navigation and positioning of mobile stations such as automatic drilling and riveting, and can be widely used in the application of high-precision navigation such as cabin docking, automatic assembly, and also in the application of automatic logistics, with better application Prospects.

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