Research on Automatic Tool Delivery for CNC Workshop of Aircraft Equipment Manufacturing

Ping Zeng¹, Fei Wu¹, Tongxing Zhi¹, Le Xiao¹ and Shaowei Zhu²

¹Dalian Start Hi-tech Developing Co.,Ltd. Dalian 116023, P.R.China
²Avic Chengdou Aircraft Industial (Group) Co.,Ltd. Chengdu 610091, P.R.China

Abstract. Aiming at the inefficiency of tool distribution in CNC workshop of aircraft equipment manufacturing, and adapting to the particularity of distribution without large network environment, The solution of intelligent tool delivery using AGV based on machine vision and QR Code navigation is proposed. Image processing of AGV path ribbon, path navigation error analysis and QR Code position calibration are studied in the planned path to achieve machine vision plus QR Code redundant navigation positioning. The AGV can complete the accurate loading and unloading tool of the robot library through the QR Code interaction mode with the machine tool. To realize automatic distribution of tool in CNC workshop of aircraft equipment manufacturing.

1. Introduction

Tools are an important part of the machining system. Its variety in great quantities, usually wait before and after the processing, distribution and storage aspects consumes a lot of time, become the bottleneck of further shorten the production cycle, seriously impedes the development of NC machining efficiency and the realization of the mode of production on time. Therefore, the development of professional transport equipment to achieve tool distribution and production operations of close coordination and collaborative integration, To improve production efficiency and reduce production cost has important engineering value and practical significance. AGV (Automated Guided Vehicle) has many advantages of good flexibility, high degree of automation and high intelligent level. It is the main equipment for distributing tool in the CNC workshop at present. However, due to the special requirements of the aircraft equipment manufacturing industry, the workshop has no large network environment, which makes AGV unable to communicate with the tool distribution center in real time, It is difficult to realize effective scheduling and management. Therefore, the existing AGV can not directly meet the requirements of tool distribution in aircraft equipment manufacturing industry. Based on the production practice of aircraft manufacturing enterprises, AGV navigation [1,2] and QR Code redundant positioning technology in the absence of large network environment are studied on the basis of existing laboratory environment and resources. An automatic tool delivery and transportation system based on AGV scheduling was established [3], so as to realize the automatic delivery of tools in the CNC workshop of aircraft assembly manufacturing [4].

2. Research on AGV machine vision navigation technology

2.1. Realization principle

Visual navigation and guidance method is to brush the ribbon on the AGV driving path, and the ribbon should have obvious color difference with the driving path. A photographic sensor is installed on the
AGV to compare the pictures taken continuously with the stored pictures, and the offset signal is output to the driving control system. The control system corrects the direction of AGV by calculation, realizes the navigation of AGV[5], precise control and accurate position positioning. The process is shown in Figure 1.

![Flowchart](image)

**Figure 1.** Visual navigation AGV control flow chart

### 2.2 Image preprocessing

There are noise points in the collected images, we need to process the images.

#### 2.2.1 Grayscale processing of color map

In order to reduce the complexity of image recognition, we need to grayscale the image. It determined on the specific color values of the palette, and the three components of the grayscale are equal. When the image is 8 bits, there are 256 color values in the palette, each of which is exactly from 0 to 255, and all three components are equal. When the image is 4-bit, there are 16 color values in the palette, divided equally into 255 color values, three components are equal. When converted to two, the palette has four colors, equally spaced 255 colors, and three components are equal. When the image is 1 bits, there are two color values in the palette, which are 0 and 255, respectively, indicating black and white. With the formula \( Y = Y / (1 << (8 - \text{conversion digit})) \), the color image can be transformed into a grayscale image.

#### 2.2.2 Image enhancement

Image enhancement is to transform the information of the image, to highlight the image features of interest, to suppress the unnecessary image features, so that the information presented by the image can be highlighted. In the whole process of image enhancement, without considering the impact of image quality degradation, the image after processing will be different from the original image.

#### 2.2.3 Two value processing of grayscale image

Binary image processing is the processing of the image into black or white. The threshold value of the 256 brightness levels of the gray image is selected, and the contour features of the image can still be seen after binarization. In image processing, image binarization is very important, especially in the actual application of image processing, to binary image processing system has a lot of, want to undertake the greyscale image processing and analysis, the gray image binarization processing, image binarization, image characteristics exist in 0 or 255 pixels, and the data processing small, make processing is very simple. In order to get a relatively clear binary image, interconnecting regions are usually used. When the pixel value of the grayscale map is greater than the threshold value and is selected as the area of interest, its gray value is represented by
255, otherwise these pixel points are excluded from the area of interest, and the gray value is represented by 0. The threshold method can be used to distinguish certain objects from other objects if the gray value of a particular object is uniform and the same level as that of other objects. If the difference between an object and the image background cannot be reflected in the gray value, the feature difference can be transformed into the gray difference, and then the threshold segmentation can be used to process the image. The threshold can be adjusted dynamically, and the binarization of images can also be observed dynamically.

2.3 Edge detection of path labeling line image based on Laplacian operator

There are many kinds of operators for edge detection, such as Candy operator, Sobel operator, Laplacian operator, etc. Sobel operator uses the first derivative information, the extracted image edge is fuzzy; Candy operator edge detection is more accurate, but the processing of more data, poor real-time. Laplacian operator is a directionless operator. It uses second-order derivative information. Compared with Candy operator, Laplacian operator has less computation and strong real-time performance, and the edge information extracted is clear. Therefore, the Laplacian operator is used in this study.

Laplacian is used to detect the marker image by the second derivative of gray value. The identification line image has the characteristic of impulse edge, and the range of pulse edge is determined by detecting the upper and lower peak of the first derivative, and two edge points of the identification line are obtained by detecting the two second derivatives of the impulse profile. In the process of image processing, the Laplacian operator function can be realized by template convolution. In the template, the coefficient of the corresponding center pixel is positive, and the coefficient of other neighboring pixels is negative, and the sum of all coefficients is zero, so that there is no gray deviation [4].

Several operators, including Lpalacain, are applied to perform edge detection on the same identification line image. The results of edge detection are shown in figure 2. By comparing the detection results, the edge extraction of Laplacian operator is more accurate, and the extraction results of sobel and Canny operator are more clear, which provides convenience for the extraction of parameters of relative position of car body.

![Figure 2. Edge detection results of Laplacian operator](image)

2.4 Use parallelogram to find the deflection Angle

The parallelogram is extracted from the collected image, and the result is shown in Figure 3. Where O (x, y) is the intersection of two diagonal lines of a parallelogram, F (x1, y1) is the midpoint on the edge of cd. The abscissa of O (x, y) and the ordinate of F (x1, y1) are taken to mark y1, and the line segment OE obtained is perpendicular to the edge cd. The algorithm of AForge.NET is used to evaluate line segments OF, OE and EF, and cosine theorem is used to calculate the degree of angle α. As shown in Figure 3.
Therefore, the image acquired by the camera is processed, the path and background information are distinguished by threshold images, the path is obtained by binarization images, the parallelogram in the field of vision is judged, the central position of the car body is obtained according to the geometric principle, and the position information of AGV in the coordinate system is obtained[7].

3 Realization of precise navigation based on machine vision plus QR Code redundant location

QR Code is easy to control communication, has no interference with acoustooptic, can be reliably distinguished in oblique angle or dim light, and can also read code in the case of high-speed movement of the product. Therefore, the precise navigation of tool distribution is achieved by using ground color belt machine vision and QR Code redundancy positioning.

3.1 QR Code position calibration on path

For the distribution route layout of the workshop, it is necessary to mark the QR Code position at the intersection, turn and straight path. The QR Code information of path calibration includes attitude, control, position and other information[9]. As shown in Figure 4-5.

3.2 Realization of precise navigation and location

According to the experimental environmental conditions and application scenarios, the communication between the code reader on AGV and the AGV on-board control system is carried out in a small environment using protocols[6].
When AGV goes to the ground QR Code position, the vehicle's Code reader will feedback the ground QR Code position X-axis offset, Y-axis offset and Angle offset to the vehicle's control system. The control system will adjust the vehicle's position successively until it reaches the allowable error range [7]. The flow of its walking algorithm is shown in figure 6:

![AGV navigation and positioning process](image)

**Figure 6.** AGV navigation and positioning process

The following table is a ground QR Code calibration point (target position is 32 mm X axis, 5 mm Y axis, angle -10°), AGV travel speed of 1 km / h, nine times into the QR Code measured data. As shown in Table 1.

| Target Time | X(0.1mm) | Y(0.1mm) | A(0.1°) | result |
|-------------|----------|----------|---------|--------|
| 1           | 39       | 41       | 7       | OK     |
| 2           | 41       | 15       | 7       | OK     |
| 3           | 43       | 8        | 7       | OK     |
| 4           | 42       | -21      | 7       | OK     |
| 5           | 39       | 18       | 5       | OK     |
| 6           | 31       | 7        | 7       | OK     |
| 7           | 42       | 36       | 4       | OK     |
| 8           | 33       | 25       | 7       | OK     |
| 9           | 43       | 0        | 6       | OK     |

According to the accuracy test of the actual operation result of the workshop, the control precision of the running track is (+4 mm), which can maintain the precision control of the running track and ensure the running speed and stability. Meet the actual requirements of workshop tool operation. Compared with the traditional AGV navigation, this scheme is easy to install, low in cost, easy to maintain in the later stage and high in accuracy [8].

**4 Tool delivery and transportation process**

The workshop sets up the intelligent tool delivery system, hereinafter referred to as the dispatching system, which is mainly responsible for AGV scheduling and information acquisition.
Set the QR Code reader at the key node of the machine tool, and the reader is connected to the machine tool. The dispatching system can monitor and control AGV through communication with the machine control system and the QR Code reader[8]. As shown in figure 7.

![Figure 7. Information interaction between machine tool and AGV](image)

4.1 Tool delivery process

The dispatching system puts the machine task into the queue according to the priority. When the machine task is assigned to AGV, the dispatching system sends the QR code written with the logistics task information to the AGV display screen. At the same time, it generates the logistics route according to the task type, resource type and the target machine tool information, and writes it into the AGV navigation system. AGV receives task instructions, goes to the tool handling station to pick up the tool in accordance with the prescribed route, interacts with the QR code reading and writing terminal of the tool loading and unloading station, holds up the tool tray (loaded with the tool), and carries out transportation according to the path planning route [6], as shown in Figure 8. When the AGV reaches the target machine tool, it interacts with the QR code reading and writing terminal of the machine tool [10]. The robot next to the machine tool loads the tools on the AGV onto the tool holder. After completion, AGV returns to the tool loading and unloading station according to the original way, places the tool tray in the loading and unloading station, returns to the waiting area, the dispatching system reads the relevant information, and closes the task. As shown in Figure 8.

![Figure 8. AGV running to the position of the tool holder](image)

4.2 Tool recovery process

The dispatching system receives the task of recovering the tool sent by the machine tool and puts it into the task queue according to the task priority. When the task is assigned to AGV, the dispatch system sends the QR code of the logistics task to the display screen of the car. At the same time, the logistics route is generated according to the task type, resource type and target machine tool, and written into the AGV navigation system [7]. When the AGV receives the task, first go to the tool loading and unloading station according to the navigation route, and lift the tool tray, and then go to the position of the target machine tool according to the predetermined route. Adjust the position to the buffer area of the tool bank. After the machine tool QR code reader recognizes the task information of the car, unload the tool that needs to be unloaded to the tool tray of AGV. After unloading, AGV goes
to the tool loading and unloading station to unload the tool. The AGV returns to the waiting area, and the system reads the information and closes the task.

5 Conclusion
Redundant navigation positioning technology of machine vision and QR code not only enables AGV to maintain the accuracy control of running track along the planned path, but also ensures the running speed and stability of AGV. Moreover, it is easy to install and maintain. On the basis of accurate navigation, information interaction between AGV and machine tool via QR code. Realize accurate tool loading and unloading of the tool bank robot. In the process of tool distribution, recycling and loading and unloading, humanized operation is realized to avoid mistakes, cost is reduced, production efficiency is improved, and good implementation experience is provided for other CNC workshops without wireless network environment.

6 Reference
[1] Z.M. Wang, J.Y. Liu and H. Yue, Summary of research on mobile robot autonomous navigation technology, Journal of Tianjin vocational and Technical Teachers College, 2004, 6 (4): p.32-34.
[2] P. Zhou, Y.M. Wang, Y Zhao and Y.F. Xu, Two classes of segmentation methods in autonomous navigation of unstructured natural images, Journal of Agricultural Machinery, 2004, 4 (2): p. 12-14.
[3] H.G. Zhen, X.H. Qi. An intelligent vehicle path recognition algorithm based on non uniform line, Electronic products world, 2010, 11 (8): P 40-42.
[4] W. Wei, Intelligent control technology, Machinery Industry Press, 2007.
[5] W. Chen, B.C. Li and H.T. Sun, Research on AGV fuzzy optimal control based on visual navigation, China Mechanical Engineering, 2006.
[6] H. Qian. Design of mobile robot navigation system based on fuzzy control, Harbin Institute of Technology, 2013.
[7] Z.S. Zhang, Design and research of autonomous mobile robot based on visual navigation, Harbin Institute of Technology, 2008.
[8] Q.D. Liu, Research on AGV system guided by machine vision, Harbin Institute of Technology, 2008.