Design and Error Analysis of Material Sorting System Based on Machine Vision

Zhang Weifen, Li Yongmei, Qian Ru

School of Mechanical and Electrical Engeering, Southeast University Chengxian College, Nanjing, Jiangsu 210088, China

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Abstract: A material sorting system based on machine vision technology is designed in the paper, which is mainly used in the packaging sorting industry. The material sorting system was built using assembly line belts, speed control motors, photoelectric sensors, ccd, mechanical arm, controllers, etc. The coordinate system involved in the system and the method of tracking and grabbing by the mechanical arm are introduced in the paper. Experiments were carried out on the material system and the relevant errors were analyzed in detail. DH model calibration error, tool coordinate system calibration error, CCD-ROBOT calibration error, CCD static data error, CCD dynamic data error, conveyor belt and manipulator calibration error are all anaylyzed. Finally, the overall error is analyzed. The experiment shows that the system can meet the needs of the mechanical arm to grab materials.

1. Introduction

Machine vision technology refers to the use of cameras to simulate the visual function of the human eye to measure and judge objective things[1].The combination of vision technology and sorting system in automated production lines is more and more widely used in industry. It has the characteristics of fast detection speed, high reliability, good real-time performance, no contact, and non-destructive testing[2].This paper designs a material sorting system, which is mainly used in the packaging sorting industry. It uses common assembly line belts, speed control motors, photoelectric sensors, ccd, mechanical arm, controllers, etc. to identify product models and detect position coordinates through machine vision. The mechanical arm tracks the movement, and the material is conveyed without stopping, and the material is placed at the corresponding position.

2. Design of the Material Sorting System

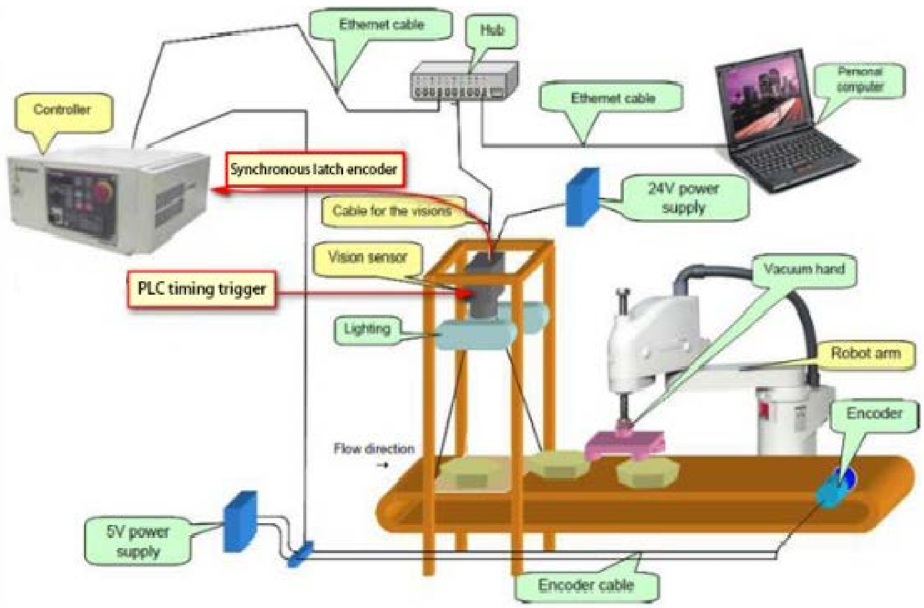

Figure 1 Material sorting system composition

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Figure 1 shows the composition of the material sorting system. In the figure, the photoelectric sensor detects the material and triggers the ccd to shoot the material type, and detects its position coordinates on the conveyor belt. The visual software identifies the material type and position, and the camera triggers the robot controller at the same time. The encoder value is latched. The conveyor encoder is used to feed back the running speed, distance and direction of the conveyor belt, and send the workpiece position to the robot controller. The controller is used to calculate the material dynamic coordinates in real time and control the mechanical arm movement. The robot performs tracking and the mechanical arm uses When the material enters the work area to track and grab the material, the clip is used for the take-up and discharge operations.

The system transmits data through the network port SOCKET mode and the visual controller communication. The mechanical arm controller acts as the server and the vision software is the client. The mechanical arm controller can access the line-driven encoder input signal with an AB phase difference of 90 degrees. In terms of following speed, the mechanical arm should be able to grab material normally when the conveyor speed is below 300mm/s.At a certain conveyor speed, the accuracy of the position and attitude following the material after grabbing is as follows: 0--100mm/s, XY error <=0.5mm, angle A error <=0.2 degrees, 100--200mm/s, XY error <=0.7mm, angle A error <=0.4 degrees, 200--300mm/s, XY error <=0.8mm, angle A error <=0.5 degrees. When the controller or device is powered off, the application function can be restored without recalibration and debugging.

3. The Coordinate System and Mechanical Arm Tracking and Grabbing

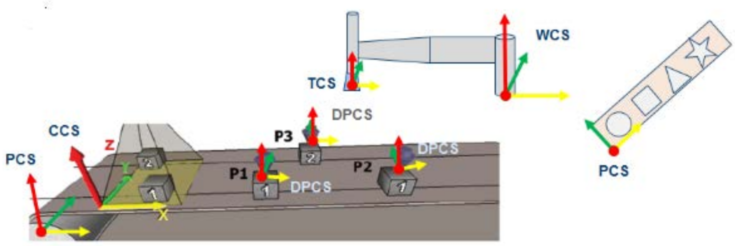

Figure 2 Each coordinate system in the system

In order to ensure that the mechanical arm can grab the material in real time, it is usually necessary to define the following coordinate systems to realize the coordinate transformation. the coordinate system is shown in Fig. 2. The WCS is the world coordinate system of the mechanical arm or the geodetic coordinate system. Sitting in the center. The TCS tool coordinate system is the center of the gripper or sucking disc of the mechanical arm and has a fixed positional relationship with the mechanical arm's world coordinate system.CCS is a visual coordinate system and is the reference for the field of view corresponding to the camera image. The PCS workpiece coordinate system is the coordinate system of the conveyor belt and the item placement point.DPCS is a dynamic workpiece coordinate system that establishes a position in the updated and dynamic coordinate system for each material on the conveyor. In this paper, the camera calibration algorithm in the OpenCV algorithm library is used to transform between pixel coordinates and mechanical arm coordinates.

When the material is driven by the conveyor belt, its position is constantly changing, so that the current position coordinates of the material need to be fed back to the mechanical arm in real time, so that the mechanical arm can accurately track the grab target[3].The system detects the movement of the target following conveyor belt by adding a rotary encoder on the conveyor belt to realize the real-time tracking of the target position. The conveyor belt is in the moving process, the sampling time of the encoder reading is short enough, and the alternate target position is continuously refreshed, so that the material position can be tracked in real time[4].After obtaining the real-time position of the material, the material can be dynamically captured. The pid algorithm is used in the system to achieve the target capture of the material on the conveyor belt. The control procedure is as follows.

```
Start_receive_task(); // Start the receiving task in the background
    While (tracking_enable) // Tracking enable is always looping
    { wait_object_in_tracking_range();
      Tracking(); //Track artifacts, speed synchronization
      switch_io();
      Graping(); // grab the object, synthesize motion
      PTP_unload(); // move to the unloading position
      Switch_io(); // Drop the object
      PTP_wait(); // move to wait position}
```

4. The Material Sorting System Experiment and Error Analysis

The actual situation of the material sorting system experimental platform construction is shown in Figure 3.The ccd completes the image acquisition work, transmits the target image to the computer, and processes and extracts the target contour in the image by the computer, calculates the target position by combining the specific contour information, and then grabs the corresponding material through the mechanical arm.

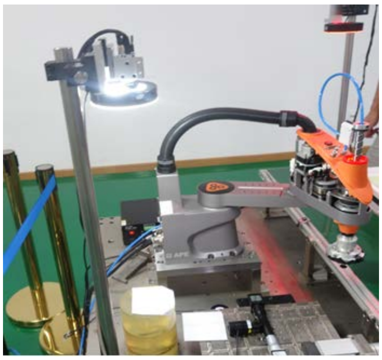

Figure 3 Material Sorting System

The errors of the material sorting system mainly include: the error of the mechanical arm such as the position accuracy and repeatability of the mechanical arm , the calibration error of the dh model, the accuracy of the moving distance, the fluctuation of the moving speed, etc., the error of the suction cup of the mechanical arm Such as the calibration error of the tool coordinate system, the center of rotation of the tool Error, nozzle jig intersection error, etc., visual errors such as visual calibration error, visual detection position error, image distortion and tilt error, etc., conveyor belt errors such as conveyor belt movement distance accuracy, conveyor belt and mechanical arm coordinate system calibration relationship error.

4.1 DH model calibration error analysis

Verify that the error of the DH model calibration is measured by a manipulator walking straight line using a steel ruler.The test method is shown in Figure 4.

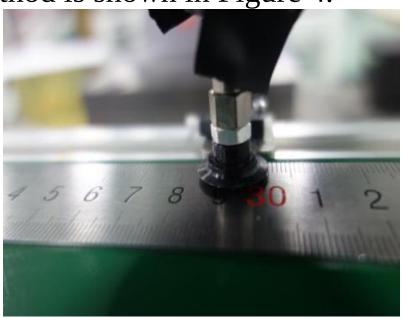

Figure 4 dh model calibration error analysis

Keep X, Z and A constant between the two points, so that the Y values differ by 300mm and the mechanical arm goes straight.From the distance between the test result and the actual straight line of the manipulator, it is considered that the apparent data difference is not visible to the naked eye, and it can be considered that the straight line of 300 mm is taken, and the mechanical arm error is within 0.5 mm.

4.2 Tool coordinate system calibration error analysis

The tool coordinate system is marked on the suction cup. Select a position as the initial verification value and draw the current position of the nozzle with the blue line, as shown in Figure 5 below, and record the point information in the current tool coordinate system.

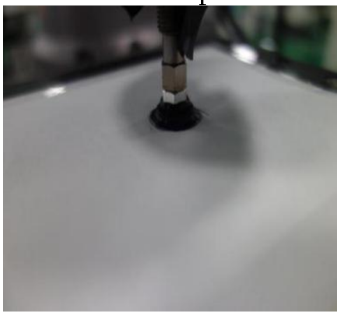

Fig. 5 Tool coordinate system calibration error analysis 1

Figure 6 Tool coordinate system calibration error analysis 2

Use the red line to draw the current position of the nozzle after the angle A is rotated 90 degrees in the tool coordinate system, and record the point information in the current tool coordinate system.Use the green line to draw the current position of the nozzle afteri the angle A is rotated 180 degrees in the tool coordinate system and record the point information in the current tool coordinate system.Figure 6 shows the coincidence of the circle drawn by the nozzle at three angles (indicated by blue, red and green lines) in the tool coordinate system.As can be seen from the figure, the calibration error of the tool coordinate system is within 0.5 mm.

4.3 CCD-robot calibration error analysis

After photographing the CCD, Coggnex software was used to capture the midpoint of the 9 holes selected on the calibration plate, as shown in Fig. 7.The mechanical arm reaches the top of the 9 holes through the suction cups of the established tool coordinate system, as shown in Fig. 8.By comparing the XY coordinates of the center point of the 9 points photographed by the CCD and the value of the mechanical arm coordinate and calculating by Cognex software, the RSM value is 0.207197, which is somewhat larger from the RMS error, but within the available range, the camera adopts Gray point camera.

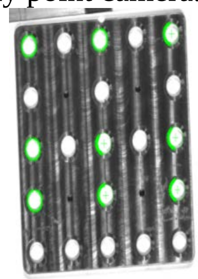

Figure 7 ccd-robot calibration error analysis 1

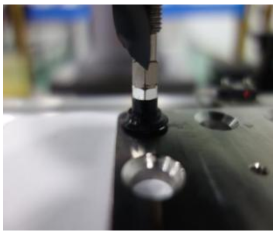

Figure 8 ccd-robot calibration error analysis 2

4.4 CCD dynamic data error analysis

Fix the position of the material, keep the conveyor moving at a constant speed, put the object to be photographed under the CCD, automatically trigger the photo, take 32 sets of data, record the XY data of 32 times of photographing, and make the X and Y values of the 32 sets of data recorded separately. In the curve, the results are shown in Fig. 9and Fig. 10, respectively. From the figure, the repeatability error of X can be calculated to be 0.145 mm, and the repeatability error of Y is 0.1478 mm.

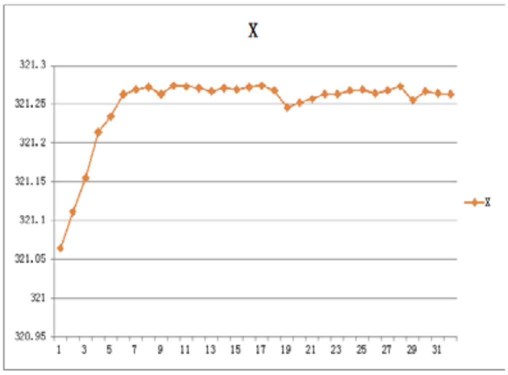

Figure 9 ccd dynamic data error analysis -x direction diagram

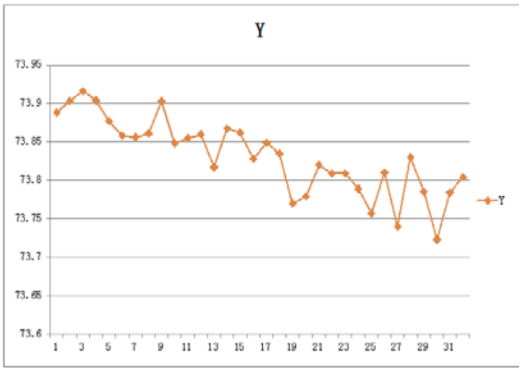

Figure10 ccd dynamic data error analysis- y direction diagram

4.5 Analysis of calibration error between conveyor belt and manipulator

Take a point on the conveyor belt, use the nozzle of the mechanical arm to reach its corresponding position, record the coordinates of the current mechanical arm in the tool coordinate system and the encoder value of the conveyor belt, move the conveyor belt to a position, and the nozzle of the mechanical arm reaches the point just again. The coordinates and encoder values are also recorded, and then the ratio of the angle between the angle and the encoder value is calculated. The error is the error of the nozzle of the mechanical arm , and the error is within 0.5 mm, which will cause the encoder ratio (pulse/mm) Error.

4.6 The overall error analysis

The overall error of the conveyor belt following is caused by the accumulation of error in each part. The test process is the analysis of the continuous reliability running data through the continuation of the above data.The CCD is used to analyze the multiple X and Y deviation values of the photographed data when the mechanical arm grasps the object in place.The whole test process is as follows: the mechanical arm receives the mechanical arm oordinate value of the object on the conveyor belt and triggers the CCD1 photo transmission, and the data latched by the encoder and the pulse value of the conveyor belt movement. After the mechanical arm picks up the object to the corresponding position, the object is placed under the CCD2, and the CCD2 takes a picture. Obtain the X and Y deviation values from the center of the object and the center of the CCD2.The CCD2 captures the center of the object using ObjectGauge. The screenshot of the photographing effect is shown in Figure 11. The analysis of the data shows that the repeatability of the X direction is 1.84 mm, and the repeatability of the Y direction is 1.05 mm. This error is the total accumulation. error.Since the mechanical arm end effector is a pneumatic suction cup, the mechanical arm an suck the target object within a range of 5 mm[5]. Therefore, the system can realize dynamic gripping of the mechanical arm.

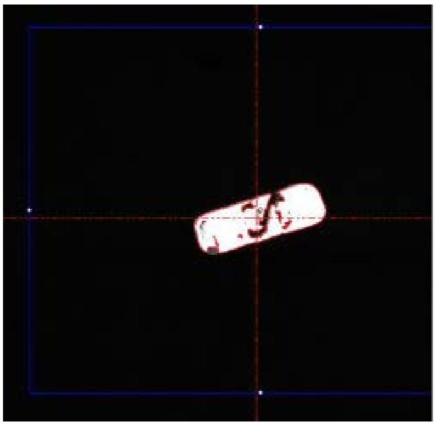

Figure 11 photo effect screenshot

5. Conclusion

In this paper, the material sorting system is built based on machine vision, and the error in the system is tested and analyzed in detail. The analysis shows that the system can realize the dynamic grabbing of the mechanical arm .It provides a reference for the practical application of machine vision and mechanical arm.

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