Design of Visual Search and Positioning System Based on Labview + PLC

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Abstract. Aiming at the problem that the fixed lens cannot achieve full-area shooting recognition and obtaining the target position within the target area. This paper proposes using a moving vision lens to perform shooting recognition at fixed points and sub-regions within the set search path to determine the target object's visual coordinates and use PID calculation to drive the actuator to complete the target workpiece grabbing. The system has high positioning accuracy through experimental verification, and the correct identification and capture can reach 100%.

1. Introduction
In the food packaging industry, food must be sorted before the packaging process to determine whether it is qualified. Most food companies use manual sorting, minimal and medium-sized enterprises. To a certain extent, manual sorting is not only labour intensive but also prone to secondary pollution. Today, with high labour costs, many companies need machines that can perform automated sorting. This article introduces a sorting system based on machine vision and robots for sorting and picking flat randomly distributed foods and proposes a solution.

The design principles use machine vision to take a picture of the target body, process the image through visual processing software, and obtain image-related data. Then it is compared and analyzed with the visual image data of the standard workpiece. After a certain algorithm, the actuator is driven to complete the functions of visual recognition, positioning and grasping. In the design of the vision system, the size of the recognition range of the vision lens has a negative correlation with the accuracy of item recognition. This article will propose the optimal solution through experiments.

With the advent of Industry 4.0, machine vision technology has become more widely used in intelligent manufacturing, dramatically improving the flexibility and automation of production. Machine vision mostly takes pictures of the target body. It then processes the image through visual processing software to obtain image-related data and then compares and analyzes the standard workpiece's visual image data [1]. After a specific algorithm, the actuator is driven to complete functions such as optical recognition, positioning and grasping.

There are generally two types of photographing of a target, static photographing and dynamic photographing. However, due to the poor quality of photographing under emotional conditions, and the extremely high requirements for the configuration of the photographing device's pixels and image processing equipment, the static photographing method is currently mostly adopted. However, the static photography method has the defect of a limited lens recognition range, which significantly limits its application.

This paper proposes a solution for visual recognition and positioning in which the workpiece storage area is large, and the workpiece placement position is random, which a single photo cannot recognize.
Taking pictures at fixed points and sub-regions within the prescribed path through the moving vision lens, to a certain extent, solves the problems of the fixed vision lens being challenging to take pictures of the whole area and the moving vision lens not taking photographs. First, take pictures at a fixed point to obtain the visual coordinates of the target workpiece, and then calculate the deviation from the standard visual coordinates for PID calculation, and then send the PID calculation output value to the PLC to drive the actuator action to complete the capture of the target workpiece and realize the screening function. This dramatically improves the speed of calculation, recognition, positioning and grabbing.

2. System scheme design
This system will simplify the processing on a plane, using a PC equipped with Labview as the host computer[2], Siemens S7-1500CPU as the controller, and Basler industrial camera as the image acquisition device. Two sets of Siemens V90 servo motors with screw drive were selected as the mobile search mechanism to form the X-axis and Y-axis coordinates, moving in a plane. The Z-axis is a cylinder with a suction cup. When searching and moving to above the centre point of the workpiece, the cylinder stretches out. The sucker sucks the workpiece and then rises. The X-axis and Y-axis move to send the workpiece to the discharge conveyor belt driven by the G120 frequency converter, complete grasping function. The schematic diagram of the system structure was shown in Figure 1.
2.1. Standard positioning visual coordinate calibration

As shown in Figure 2, no matter where the workpiece M is, when the cylinder sucker moves directly above the workpiece M, the visual coordinate \( P_0(x_0, y_0) \) of M is fixed, and it is set as the standard positioning visible coordinate. For other workpieces not directly under the suction cup, such as workpiece N in Figure 2, its vision coordinates are \( P_1(x_1, y_1) \).

Deviation of MN

\[
\Delta P = \begin{vmatrix} x_1 - x_0 \\ y_1 - y_0 \end{vmatrix}
\] (1)

When \( \Delta P = 0 \) indicates that the positioning is complete. In calculating this system, the workpiece's visual coordinate calculation has always been used, and the conversion calculation of multiple coordinates is not required.

2.2. Determination of the search path

Because the workpiece storage area is relatively large, the place that the lens can recognize is small. If the lens is moving for photo recognition, the photo image quality will be poor, and the distinction will be complex.

Therefore, the entire area should be divided into recognizable size. The sum of each small block area should not be less than the total area Subtotal (there is overlap between the edges of adjacent visual pictures).

The lens moves to the centre point of each block and stops for photo identification [3]. If there is a workpiece in this block, it will be positioned and grabbed. When there is no workpiece, the next block will be scanned until it is all completed.

The connection between the centre points of each block forms a scanning path, as shown in Figure 3.

\[
S \leq S_1 + S_2 + S_3 + ... + S_n = \sum_{n=1}^{n} S_n
\] (2)

2.3. System software design

The system is powered on, or the reset button is pressed, the system executes initialization and returns to the original point, and the start button is pressed, and the mechanism execution starts to area A for identification (Figure 3). Judge whether there is a target workpiece. If there is a workpiece, identify the centre coordinate of the workpiece, and move the actuator until the suction cup is directly above the workpiece, suck the workpiece and send it to the discharge conveyor. Then, return to area A to continue identifying and grab the workpiece until the machine takes all the workpieces that need to be identified in area A. Then, the device scans the next area B and loops like this. When all sizes have been specified and captured, the system will output an alarm signal to indicate that the entire area had identified and arrested. The system execution process had shown in Figure 4.
3. System programming

3.1. System program architecture

The system program includes the Labview image processing program, OPC UA communication control, PLC control program three parts, as shown in Figure 5.

The Labview image processing program had divided into three parts. The first part includes image recognition, image processing, the comparison between the recognized image information data and the image data set by the standard, the control of the lens, and the target workpiece centre point's visual coordinate output. The second part is the PID calculation of the difference between the visual coordinates of the target workpiece centre point and the standard positioning visual coordinates; The third part is the monitoring operation interface, including various control buttons, image monitoring, positioning coordinate display, and setting of the type of workpiece to be searched.

The PLC control program includes the manual control program for the actuator, executes the scan control program for each area according to the set path in Figure 3, accepts the Labview to do the PID
operation output value to control the actuator positioning program, and controls the cylinder sucker to suck the workpiece to the output conveyor belt program.

OPC UA communication is mainly to set up a communication database so that Labview and PLC can communicate with it to complete data exchange. Labview does the PID calculation output value and sends it to the PLC to control the servo motor's running speed and running direction. Simultaneously, the movement data and status of the actuator owned by the PLC are sent to Labview and displayed through the monitoring interface.

3.2. Labview control program

3.2.1. Image processing and location information extraction. Use Vision Assistant software on the collected images to perform image photographing, binarization, repair segmentation, threshold adjustment and other visual processing following the procedures to obtain workpiece image-related data (Figure 6 shows the results of the hexagonal red block processing). In the process of acquiring image data by Labview, to speed up the system's data processing speed, the image is compressed, and a lens switch control program is added. When comparing with the standard image data, the visual coordinate position of the target workpiece is output. The control procedure had shown in Figure 7.

![Figure 6. Visual image processing](image1)

![Figure 7. Image location information acquisition of target workpiece and lens control control program](image2)

3.2.2. Visual positioning algorithm. The visual coordinates of the target workpiece obtained through the visual search were compared with the calibrated standard coordinates, and the deviation value $\Delta P$ was obtained. The sign of the deviation controls the direction of operation of the servo motor. Perform PID calculation on the deviation value $\Delta P$ [4], and the calculated output value controls the running speed of the servo motor. The larger the output value, the faster the running speed; When the deviation is very small, a certain output value can be obtained through integral calculation; when the deviation $\Delta P$ is 0, the operating speed of the actuator is 0, the positioning is completed, and then the cylinder and the suction cup are driven to complete the grasping function. In this process, if the workpiece is moving, as long as the deviation value $\Delta P$ exists, the actuator will proceed with the workpiece until the positioning
and grasping are completed to realize the positioning and tracking of the workpiece. The specific algorithm is as follows:

(a) **Direction control**

X axis deviation \[ \Delta P_x = X_1 - X_0 \]  

When \( \Delta P_x > 0 \), X axis running in the positive direction, when \( \Delta P_x < 0 \), X axis positive and negative running.

Y axis deviation \[ \Delta P_y = Y_1 - Y_0 \]  

When \( \Delta P_y > 0 \), Y axis running in positive direction, when \( \Delta P_y < 0 \), Y axis positive and negative running.

(b) **Speed control**

Carry on PID operation to \( \Delta P_x, \Delta P_y \) respectively, take the output value and absolute value to control the running speed of the actuator.

\[
u(t) = K_p \left( \Delta P(t) + \frac{1}{T_i} \int_0^t \Delta P(t) dt + T_D \frac{d(t)}{dt} \right)
\]  

\( u(t) \) — PID controller output signal;  
\( K_p \) — Proportional gain;  
\( T_i \) — Integration time constant;  
\( T_D \) — Differential time constant;  
\( \Delta P(t) \) — X-axis, Y-axis deviation value.

The above algorithm was transformed into a Labview program operation. The X-axis control program was shown in Figure 8, and the Y-axis control program has the same structure.

![Figure 8. Visual positioning control program (X axis)](image_url)

### 3.3. **OPC UA communication control**

OPC UA is an industrial technical specification and standard produced to solve the communication between application software and various device drivers. It uses a client/server system based on Microsoft's OLE/COM technology and provides a set of standard interfaces for hardware manufacturers and application software developers [5].

This system calls NI OPC Servers software to establish an OPC communication database, activates the OPC server and client on the PLC side so that both PLC and Labview can access the OPC database. Labview can transmit the output value through PID operation to PLC. The PLC operation's actual coordinates can be transferred to Labview and displayed through the interface to realize the communication between Labview and PLC.
3.4. **PLC control program**
The PLC end mainly controls the X-axis and Y-axis operation and feeds back the coordinate data of the two axes to Labview for display. Using Siemens’ structured programming ideas, the X-axis and Y-axis are respectively made into two program blocks, as shown in Figure 9.

![Figure 9. PLC control program](image)

4. **Experimental verification**

4.1. **Experimental architecture design**
In order to verify the actual operation effect, an experimental platform, as shown in Figure 10, was built. The two-axis servo serves as the X-axis and Y-axis, which can move in a plane, and one cylinder is the Z-axis, which can run up and down. The cylinder was equipped with suction cups. The workpiece was sucked, and a lens is fixed on the cylinder frame. In order to test different colours and different shapes of workpieces for testing, four types of workpieces were selected, namely red hexagon, blue triangle, yellow circle, and black square. There are 12 workpieces of each class, which are randomly placed on a platform. The data were shown in Figure 11.

![Figure 10. Test experiment platform](image) ![Figure 11. Test artifact](image)

4.2. **Experiment procedure**

4.2.1. **Visual tracking path determination:** Due to the limited range of lens recognition, the entire area to be recognized is divided into four parts. As shown in Figure 12, the lens scanning path is O→A→B→C→D→O, where the coordinates of point A is \((x_A, y_A)\), point B is \((x_B, y_B)\), and point C is \((x_C, y_C)\), the coordinates of point D is \((x_D, y_D)\).
4.2.2. Calibration standard visual coordinates: $P_0(210,105)$.

4.2.3. Graphic recognition size: the calibration value of the optical recognition range is about (130mm, 100mm), and the graphic image pixel size is (320, 240).

4.2.4. Different colour workpiece threshold adjustment value: Threshold adjustment is the key to determine whether the workpiece can be accurately identified [6]. The experiment recognizes the workpiece by colour. To verifying the practical effect, all four colours are tested, and the four different colours' threshold is adjusted through the Vision Assistant software. The specific point is shown in Figure 13.

4.2.5. Execute the program to complete the capture: Put 12 workpieces on the pallet at random (as shown in Figure 11), set the workpiece to be recognized, press start, the system runs according to the set program, and scans until such kind of all the workpieces has been taken out.

4.3. Experimental results and error analysis
In actual operation, the grabbing success rate of red, blue, and yellow workpieces is 100%, and the specific operation results are shown in Table 1-3. It can be seen from Table 3 that the most significant visual deviation is 4.66 pixels, which is converted into an actual distance of 0.19mm, so the visual tracking and positioning accuracy are high.
Table 1. System visual tracking test results of red hexagonal workpieces

| Number of experiments | Workpiece standard value coordinates | Grab the actual visual coordinates of the red hexagon | Deviation |
|-----------------------|--------------------------------------|------------------------------------------------------|-----------|
| 1                     | (105, 210)                           | (103.000, 209.615)                                   | (2.000, 0.385) |
| 2                     | (105, 210)                           | (103.788, 210.785)                                   | (1.212, -0.785) |
| 3                     | (105, 210)                           | (103.184, 211.568)                                   | (1.816, -1.568) |

Table 2. System visual tracking blue triangle workpiece test results

| Number of experiments | Workpiece standard value coordinates | Grab the visual coordinates of the blue triangle | deviation |
|-----------------------|--------------------------------------|-------------------------------------------------|-----------|
| 1                     | (105, 210)                           | (101.974, 210.627)                               | (3.026, -0.627) |
| 2                     | (105, 210)                           | (103.533, 210.048)                               | (1.467, -0.048) |
| 3                     | (105, 210)                           | (103.067, 211.411)                               | (1.933, -1.411) |

Table 3. System visual tracking yellow round workpiece test results

| Number of experiments | Workpiece standard value coordinates | Grab the visual coordinates of the yellow circle | deviation |
|-----------------------|--------------------------------------|-------------------------------------------------|-----------|
| 1                     | (105, 210)                           | (100.866, 209.764)                               | (4.134, 0.236) |
| 2                     | (105, 210)                           | (103.697, 213.863)                               | (1.303, -3.863) |
| 3                     | (105, 210)                           | (100.34, 208.432)                                | (4.660, 1.568) |

5. Conclusion
The design of this system is based on visual recognition and search and positioning functions, which solves the problem that the lens recognition range is small, and the workpiece storage area is significant, and it cannot be recognized all at once. This paper proposes a solution to design a search path using a moving lens and proposes an algorithm for high-precision and fast positioning. It can be used to identify, locate, and grasp the workpiece in a specific area. It has a wide range of applications. The search efficiency is high through experimental verification, the correct identification and grasping can reach 100%, and the positioning accuracy is high.

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