Research on Robot Dynamic Handling System Based on Machine Vision and Online Tracking Technology

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Abstract. In this paper, a set of dynamic handling control system based on Fanuc robot is designed and studied, in which the conveyor line positioning mechanism, industrial robot and stability mechanism are connected together by Siemens 1500 PLC as the main control unit. The machine vision and Fanuc robot tracking function are used to make dynamic visual photographs of the robot, which compensates for the deviation of the hanging rod and increases the success rate of the moving product. The monotonous and repeated manual labor can be solved, and the production efficiency and production quality of the enterprise can be improved by replacing the artificial handling with the robot handling.

1. Introduction
In recent years, the complexity of industrial robot system applications has become higher and higher, and the transition from automation to intelligence has become a trend in robot applications. In the past, the products on the suspension chain production line were mainly handled by hand. However, during the operation of the assembly line, the cleaning or spraying process of the product was always in motion, which required the workers to maintain a high concentration of attention, and made workers very tired.

Aiming at the product handling problem of the hanging chain production line, this paper designs a method to replace the manual with the Fanuc robot. By researching the real-time tracking of the chain speed of the suspension chain, the visual judgment of the hook position, and the dynamic adjustment of the hook pitch speed, the automation and intelligentization of the dynamic handling of the suspension chain production line products are realized [1-2].

2. Overall system
The robot dynamic handling system is mainly divided into two parts: the suspension chain system and the robot online tracking and vision system. The suspension chain system includes loading conveyor, suspension chain and hanging rod stabilizer. The robot online tracking and vision system includes visual control unit, Fanuc 165F robot and robot hand mechanism. The overall system layout is shown in Figure 1. In the system, the chain speed of the hanging chain is 0-7 m/min, the distance between the hanging rods is 1 m; the industrial robot is Fanuc’s R-2000iB/165F, and the fastest tact of the whole handling is 8 seconds.
The robot is designed with two-handed jaws, the claw 1 is used to place the hub, and the claw 2 is used to take the hub. The stabilizing device can stabilize the hanging chain hanger and facilitate the accuracy of the visual photographing after Hanging rod hook is tracked by robot. The entire system action flow is as follows:

1. **Loading materials process**
   After the conveyor line comes to the hub, the centering is lifted to realize the accurate positioning for the hub, and then the robot grips the hub with the claw 1 to reach the waiting triggered position of the hanging rod. When the hanging rod passes the loading materials trigger switch, the tracking function of the robot is triggered, and the hanging rod is clamped the stabilizer so that it can stably advance with the suspension chain. After the robot and the hanging rod are kept in sync, the camera on the robot takes a picture of the hanging point of the hanging rod, and transmits the error offset value of the hanging point to the robot. After the calculation, the robot corrects the dynamic track in real time and accurately hangs the wheel hub to the hook.

2. **Unloading materials process**
   After the robot hangs the wheel hub, it returns to the reclaiming waiting position. When the hanging rod with the hub passes the blanking trigger switch, the robot tracking function is triggered. After the robot and the hanging rod are kept in sync, the positioning rod of the robot feeding claw 2 is inserted into the hanging rod, and is synchronously advanced in real time. After the photoelectric switch of the positioning rod senses the signal, the robot claw 2 performs the action of synchronously grasping the workpiece. Finally, the removed workpiece is placed on the conveyor line.

3. **Total control system**

3.1. **Hardware design**
   The main control cabinet adopts Siemens 1511C-1 PLC, KTP1200 touch screen, and configures CM1542-5 communication module. Through IO point to collect peripheral device signals and control peripheral device actions, but robot control cabinet uses Profibus-DP communication to realize data transmission between the robot and the main control PLC. The main control PLC controls V90 servo motor through Profinet, and realizes stability function of suspension chain hanging rod by collecting suspension chain speed. Robot uses encoder not only to capture real-time position of suspension chain,
but also calculate speed for tracking and synchronization.

3.2. Software programming
Software is mainly program of Siemens S7-1500PLC and program of HMI. Entire software part was written in Siemens TIA Portal V14 environment. Modular programming is adopted, in which OB1 is main loop program, it runs one by one in each cycle of program, and is divided into unconditional calling module and conditional calling module. Unconditional calling module is called every cycle, mainly including robot, loading machine, stabilizing mechanism and some logic function blocks of suspension chain. Conditional calling module is mainly module that is actively triggered under certain conditions, mainly including system fault monitoring, incident handling, communication blocks with robots and servos. In addition, it also includes initial organization block OB100, PLC diagnostic organization block, cyclic interrupt block for timing acquisition and processing of analog signals for peripheral devices. The function block diagram of PLC software is shown in Figure 3.

Design of touch screen program is mainly based on PLC program, which set two aspects of manual control for each unit. Mainly divided into four interfaces: robot, parameter setting, status monitoring and alarm query. Robot interface is mainly preparation conditions of robot’s signals and other equipment under automatic operating conditions. Parameter setting interface includes setting information for all peripheral devices. Status detection includes monitoring of all input and output signal points for PLC. Alarm queries can view alarm information for all devices.
4. Robot programming

4.1. Visual Design

Machine vision is the use of machines instead of human eyes for the recognition, judgment and measurement of target objects. It mainly studies the use of computers to simulate human visual functions. This article mainly uses the complete machine vision system to carry out online tracking and visual positioning of the hanging rod, thereby greatly improving the success rate of dynamic handling of the product. The light source, lens, CCD, and controller of the vision system use the complete set of equipment from Keyence, where the controller is the VC-X100A. The vision system is set on the KEYENCE visual platform, first selecting tools such as contour search, then registering the reference image, setting the search object, setting the search range, and pre-processing, and finally setting the decision conditions. The selected KEYENCE visual tools are shown in Table 1:

| ID   | Tool name            | Comment                               | Reference |
|------|----------------------|---------------------------------------|-----------|
| T100 | Contour search       | Hanging rod hook contour matching     | P2-23     |
| T101 | 1 CCD capture        | Robot vision application              | P2-356    |
| T102 | Shade detection      | Check if the hanger has a workpiece   | P2-317    |
| T103 | Numeral Calculations | Robot coordinate calculation           | P2-243    |

The nine-point calibration method is used to calibrate the vision and the coordinates of the robot, and the calibration data is loaded in the tool T101. The contour is searched and compared according to the contour of the standard coordinates, and the calculation function of the T103 tool is performed to obtain the position correction coordinate value required by the robot. The calibration process of the nine-point calibration method: the robot coordinates and circle pixel coordinates when the robot end is located at 9 circle centers are obtained by using a 3*3 9-circle calibration plate, so as to obtain the affine transformation relationship between the pixel coordinates and the robot coordinates, as shown in Equation (1),

\[
\begin{bmatrix}
  x' \\
  y'
\end{bmatrix}
= R \begin{bmatrix}
  x \\
  y
\end{bmatrix} + M
\]

In the formula: \(\begin{bmatrix}
  x' \\
  y'
\end{bmatrix}\) represents the robot coordinate, \(\begin{bmatrix}
  x \\
  y
\end{bmatrix}\) represents pixel coordinates, \(R\) is the rotation matrix, \(M\) is a translation matrix.

The rotation matrix \(R\) and the translation matrix \(M\) can be obtained by bringing the pixel coordinates of the center of the circle and the coordinates of the robot into Equation (1).

After the vision system is set, the data communication between the robot and the vision system is set, and the vision is used as a TCP server, and the robot is used as a TCP client. This requires the robot to use Fanuc's User Socket Messaging function to write the Socket communication interface and vision system for data exchange in Karel language. The main steps are as follows:

First, the host communication interface of the robot is performed, and the configuration of the TCP client is performed, and the local IP address and port, the destination IP address, and the port are mainly set. Use the MSG_CONNECT function to connect to the Socket. After the connection is successful, you can use the Write and Read functions to read and write the communication buffer data. In addition, you can use the MSG_PING function to diagnose the network connection, and use the MSG_DISCO function to test the network connection. The entire program structure is as follows.
PROGRAM loopc1
VAR
    Status: INTEGER
    Loop1: BOOLEAN
    ....
BEGIN
    MSG_CONNECT('C2:',status)
    loop1=TRUE
    IF status = 0 THEN
        FOR tmp_int=1 TO 10 DO
            Temp_str='photo'
            WRITE(Temp_str,cr)
            READ file_var(tmp_str::10)
        ENDFOR
    ELSE
        WRITR('Error Opening File',cr)
        Loop1=FALSE
    ENDFI
    END loopc1

After the entire program is compiled, a pc suffix program is generated, and the Fanuc robot can call this program to communicate with the vision system. Calling loopc1 in the robot tp tracking program can take 10 photos and get 10 coordinate values. Based on the values of these position registers, the robot can average the values to ensure the stability of the suspension chain hanging rod hook correction.

4.2. Online tracking settings
After configuring the J512 function, the Fanuc robot will have the Line Tracking online tracking function package. Here you need to set the suspension chain encoder and track tracking settings.

![Figure 4. Encoder settings](image-url)
Figure 5. Tracking settings

The encoder setting interface is shown in Figure 4. After the setting is completed, Rate sets a non-zero number and sets Simulate to On. Observe that the third item Current Count value changes continuously, indicating that the encoder connection is normal, otherwise the encoder connection is unsuccessful. Simulate must be set to Off during actual operation.

The tracking setting interface is shown in Figure 5. The main content is to set the tracking group where the robot is located, set the tracking type, set the tracking coordinate system, track the associated encoder, set the trigger signal DI, and set the tracking boundary. The Fanuc robot online tracking program is as follows, and the program for visual photographing and dynamic position calibration is performed in the tracking subroutine[3].

```plaintext
| LINE[1] ON ; | Turn on the encoder |
| WAIT DI[1]=ON    ; | Waiting for the sync trigger |
| LINECOUNT[1] R[1] ; | Record the encoder pulse to R[1] |
| SETTRIG LNSCH[1] R[1] ; | Record the current R[1] value as the synchronous trigger position pulse value |
| ELBOUND LNSCH[1] BOUND[1] ; | Select tracking boundary |
| CALL TRACKING    ; | Call trace track subroutine |
```

4.3. Program design

The robot program is mainly divided into TP and PC programs. The TP program is mainly the moving program of the teaching point of the robot action, and the PC program cannot be directly written by the teach pendant. It needs to be programmed by the simulation software and compiled into the PC suffix[5]. The open program, therefore, as a visual interface program, PC programs can effectively protect key technologies. The PC program can also monitor the data changes of the encoder in real time, and do some calculations and protection actions. According to the action flow of the whole system, the robot program is mainly divided into the following parts: initialization program, hand movement program, visual calibration program, data calculation program, tracking program, conveyor chain reclaiming program, and pickup attachment program.
The workflow of the entire robot is shown in Figure 6. The robot starts from grabbing the workpiece and waits for the hanging rod signal to trigger the tracking of the robot. After the robot and the suspension chain are synchronized, a visual photographing signal is sent. If the photograph is successful, the workpiece is hung on the hanging rod, otherwise the robot moves to the trigger waiting point to wait for the tracking trigger of the next hanging rod. Finally, the loop stop signal is sent, the robot returns to the origin, and the program ends.

5. Conclusion
This article mainly introduces the online tracking technology, and application of visual technology in the robot handling system. The robotic dynamic handling system which based on online tracking and visual technology was designed for a company's suspension chain handling. This system can solve the shortage of company's labor force, and it has been running stably in a wheel hub smart factory in Zhejiang. The efficiency and quality of dynamic movement for suspension chain are beyond the reach of manual methods. However, there are still many areas that need to be improved. The fixture and the impact of natural light on the vision have a greater impact on the stability of the entire system.

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