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Design and Research of a Multi-functional Robot Arm for Automatically Grabbing Fans

Yiqian Gao, Peijun Jiang, Ao Luo

School of Electrical and New Energy, China Three Gorges University 43002, China.

ABSTRACT

This program solves the problems of manpower demand and low efficiency in the manufacturing process of ready-to-eat fan blocks by designing the three processes of ready-to-eat fan blocks, namely, grasping, weighing and forming problems.

First of all, for the fans' crawling problem, this product will be designed and solved from two aspects: 1. Visual recognition: In this design scheme, the visual recognition uses OpenMV3 system, and the OV7725 model camera is used first. The free integrated development environment (IDE) is used to debug the program. The SIFT algorithm is used to achieve visual target positioning and accurately identify the position of the fans to facilitate the grasping of the robot arm. 2. Path control of the manipulator: Through the RBF neural network algorithm, a large amount of training is performed on the manipulator, and the robot arm path is automatically controlled to realize the process of grabbing the fan and putting it into the fixed container.

Secondly, in response to the weighing problem of fans, this product will incorporate a gravity sensor to realize the gravity sensing of the robot arm to capture fans, and convert the quality of the fans into digital signals for system processing and analysis. The use of constant temperature town empty warehouse not only ensures the quality and safety of fans, but also maintains the precision of each weighing quality.

Finally, the robotic claws of the robot arm are used to control the rotation of the robot by multiple bionic control.

Keywords: Fan grabbing; Weighing and Forming; RBF neural network algorithm

1. the System overview
1.1 Research background and significance

Artificial intelligence is an important part of the rapid development of today's technology, and intelligent robots are an important branch of artificial intelligence. Simply put, the robot does a lot of complex life in the Sims by simulating the human arm. The host computer acts as the main brain of the robot, and through its own sorting and processing of information, it analyzes and controls the working trajectory and circuit of the working environment such as the robot arm. In the actual industrial production process, labor efficiency and fineness are difficult to guarantee for the working environment of large-scale inspection, production and processing of products. The monitoring program such as machine vision greatly improves the efficiency of the factory and makes the degree of automation popular.

In this project, the simulated robotic arm system, as a part of industrial production, needs to be integrated into the entire control system. This control system is applied to three processing scenarios on the industrial production line, namely the inspection, weighing and molding of ready-to-eat fans. How to use the mechanical arm to replace the original widely used manpower production process, and to achieve the process precision, the efficiency of the production, is worth exploring and research.

For this project, the implementation of the project will effectively save the manpower and time resources of the traditional factory, and help to explore the implementation of the visual inspection of the smart factory; for the team members, through the construction of electronic control, vision system, students to industrial vision How the system works and how it can be applied to the entire pipeline control system will have a deeper understanding.

1.2 Scheme design scope

The program can identify the type, quality, shape and other information of the standard sample. By comparing the identified data with the real demand data, the product can be detected and continuously improved, and a smart instant snack production system can be designed to make the system Can achieve the following functions:

(1) Machine system visual design: detecting the types of fans;

(2) Machine sensing system design: automatic sorting and weighing of the fixed weight of the fans;

(3) Machine control system design: control the molding of fans;

2. the Functional design process
2.1 Fan sorting implementation
2.1.1 Visual Target Positioning Based on SIFT Algorithm

In the large-scale automation of actual industrial production, the positioning problem of the product is the first problem of the mechanical arm participating in the work. It is necessary to clearly understand the position of the mechanical arm itself and the position of the product to be processed, and clearly between the two. The relative position can complete a given task, that is, the precise positioning of the manipulator is the premise and basis of all manipulator control. There are many known methods of mechanical vision positioning: inertial navigation, internal sensor based odometry, infrared based positioning and vision based positioning, ultrasonic based positioning based on external sensors, and the like. Among these methods, the inertial navigation method will have the problem of time drift. The accuracy of ultrasonic and infrared positioning is not high, and the cost and environmental requirements are too high, which does not meet the actual production situation of large factories,

and the odometer method will be Constant accumulation leads to excessive errors. With the development of the times, the use of camera technology for image recognition, its positioning cost is not only gradually reduced, and the amount of information conveyed is large, the accuracy is reliable, and it is widely used by the machine vision of the robot arm.

2.1.2 Principle of visual ranging for SIFT algorithm

Before studying visual ranging, first establish three coordinate systems according to the actual situation:

1) World coordinate system (X_W, Y_W, Z_W): It is the absolute coordinate system, which is the coordinate system with the base coordinate as the origin. The coordinate direction and the origin are not changed by the change of time and space, which is enough to describe any point in the objective world environment.

2) Camera projection coordinate system (X_c, Y_c, Z_c): take the center of the camera on the robot arm as the origin, and the axis perpendicular to the camera is the axis. The camera projection coordinate system and the world coordinate system maintain a relationship similar to the link.

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} = \begin{bmatrix} R & t \\ 0^T & 1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix}$$

3) Image coordinate system (x, y): The acquired two-dimensional plane image is a plane, and the picture storage unit pixels are used as a unit. Each picture includes a group of pixels, and the information value of each pixel including $M \times N$ information such as brightness gray level is positioned as coordinates. (u, v)

In the process of actually establishing the coordinate system, the origin of the image coordinate system does not coincide with the origin of the actual pixel coordinates, and the actual positional relationship is as follows:
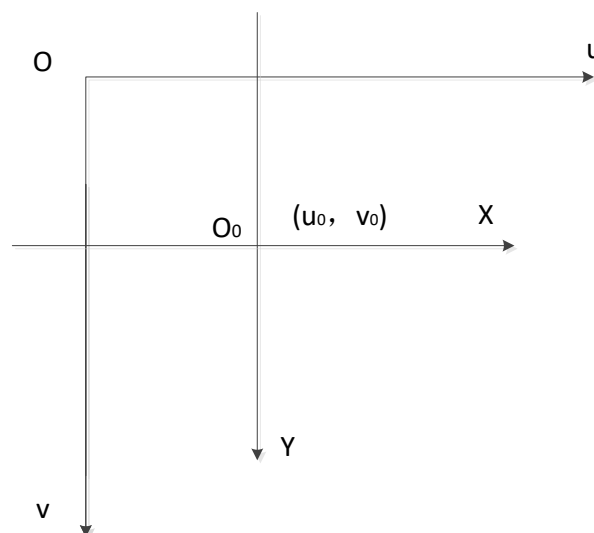
Pixel coordinate and image coordinate origin position diagram

As shown in the figure, the O_0 origin of the image coordinate system is set at the upper left corner of the origin of the pixel coordinate axis. The unit physical quantity of each pixel in the image coordinate system is dy and dx. Using the coordinate translation theory, the pixel coordinates of any point on the image can be obtained as:

$$\begin{cases} u = \dfrac{x}{dx} + u_0 \\ v = \dfrac{y}{dy} + v_0 \end{cases}$$

……(4.1.2.1)

$$\begin{cases} x = udx - u_0 dx \\ y = vdy - v_0 dy \end{cases}$$

……(4.1.2.2)

Converting (4.1.2.1) (4.1.2.2) into two forms:

$$\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \dfrac{1}{dx} & 0 & u_0 \\ 0 & \dfrac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} dx & 0 & -u_0 dx \\ 0 & dy & -v_0 dy \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u \\ v \\ 1 \end{bmatrix}$$

2.1.3 Image capture module of Direct Show technology

Before talking about DirectShow technology, we must first understand DirectX technology. DirectX technology is an excellent technology, Direct is to say what I mean, and X can represent a lot of things. Directshow simplifies media playback, format conversion and capture. At the same time, when a custom solution is required, it gives the application the right to use the basic flow control system. Directshow technology provides high-quality capture and playback of multimedia streams; supports multiple multimedia formats; captures media streams from hardware; automatically detects and uses video and audio acceleration hardware. Therefore, Directshow technology can make full use of the performance of the media, improve the speed, and can simplify the media playback, format conversion and media capture without physical examination. At the same time, he has great scalability and flexibility.

Users can create components themselves and add this component to the DirectShow structure to support new formats or special effects. Moreover, DirectX also adopts the component object model standard, which has good openness and expandability. Software developers can easily develop codec components that conform to specific algorithms. Directshow technology is in windows. The software technology for multimedia applications such as playback of various media format files and audio device acquisition on the stage. The original intention of DirectShow technology design is to free the development personnel from complex data transmission, hardware differences, synchronization, etc. The overall application framework and the underlying work are completed by DkrectShow technology, and finally the development of multimedia applications based on this technology. Made easy to develop.

DirectShow technology system block diagram.

As shown in the figure, the largest block in the figure is the DirectShow system. Below the dotted line is the hardware configuration of the Ring0 privilege level. Above the dotted line is the application layer of the Ring3 privilege level. The DirectShow system is located on the application layer. It uses a model called Fliter Graph to manage the entire data flow. The various functional modules involved in data processing are called Fliter. Each Fliter is composed of one or more Pins in the Fliter Graph. Filter is connected to other Filters. Such a connection point is called Pin, and Pin is also a COM object. The connection, Filter, forms a sequential link and delivers multimedia data information. Depending on the function of each Filter, you can roughly divide them into the following three categories: Source Filter, Transform Filter, and Rendering Filte.

In addition, there is a key component in the Direct Show, Filter Graph Manager, which the application uses to create and control the Filter Graph. The Filter Graph Manager is also used to coordinate state transitions between Filters, establish a reference clock, pass events to the application, and provide the application with a way to create a Filter Graph.

2.2 Fan Grab Implementation

2.2.1 Adaptive robot arm trajectory tracking control based on NCC model

The neural network control method is an automatic control method that uses an artificial neural network as a controller or an identifier. In many fields such as process control, pattern recognition, economic forecasting, and robot control, neural networks are regarded as important methods and approaches.

The industrial robot arm control system is a strongly coupled, multivariable complex nonlinear dynamic system. At the same time, it is still affected by many uncertain factors. It is difficult to establish an accurate mathematical model. The reason is that the dynamic model of the mechanical arm is still not Perfect or time-varying model parameters. During the control of the manipulator, even if the manipulator model can be established, it is difficult to solve the model because the model is too complicated and the calculation amount is too large. The general control method based on the robot arm object has a strong dependence on the mathematical model of the robot arm, so it is difficult to accurately realize the robot arm trajectory tracking control. Since the emergence and development of artificial neural networks, it has provided a new and effective way to solve some problems in the control of robotic arms. Artificial neural network is very suitable for solving the modeling and control problems of the mechanical arm system because of its own characteristics of self-adaptation, self-learning and large-scale parallel processing.

The process of using neural network algorithms to control the robot arm is as follows: A is the learning phase and B is the control phase. In the learning phase, the neural network is trained by adjusting the weights and thresholds between the relevant neurons to generate the desired mapping, that is, to correct the mode of propagation of the input module between the neurons. The mapping between input and output can be trained to achieve arbitrary precision through the training of a large number of samples. The control phase is to input the ideal position and obtain the corresponding joint angular displacement through neural network training to achieve the purpose of adaptive inverse model control.

2.2.2 Manipulator Neural Network Control

NNC (Neural Networks Control), also known as artificial neural network control system, neural network-based control or simply neural control, refers to the use of neural networks to achieve complex nonlinear object modeling, control and optimization calculations, etc. . Such a control system is called a neural network control system.

The main system form of neural network control system is negative feedback regulation. The basic structure of the system is mainly divided into open loop and closed loop. Its general structure is shown in the figure, the controller, the recognizer and the feedback link in the figure can all be composed of a neural network.

The neural network control is different from the traditional control system design idea, and it is a mathematical model control method that does not need to be controlled. In a control system, a neural network acts as a controller or recognizer. The neural controller is highly intelligent, so the

neural network control system can also be used as an intelligent control system. It is a system with deep learning ability, also known as a learning control system. The learning process is a training and The process of remembering the training results. Neural controllers have significant advantages and disadvantages compared to traditional controllers and other modern controllers. The biggest advantage is that the design of the neural controller is independent of the mathematical model of the controlled object, which is the biggest advantage that the neural network can show in automatic control. The disadvantage is that the neural network needs to use a large amount of sample data for learning training, and use the training results for system design. This training relies to a large extent on the accuracy of the training samples, while the selection of training samples is random and artificial.

2.2.3 Mechanical arm neural network control method

Basic control of the robot arm includes manipulator position control, torque control, and steering rotation control. Most industrial manipulators use a joint space-based control structure that first obtains joint variables by inverse kinematics and then expects the speed, velocity, and displacement of the joints.

The study of robotic arm control begins with position control. The position control is embodied in the method of controlling the system when the robot arm tracks and controls the trajectory. It mainly consists of a control system based on the three variables of speed, velocity and displacement of the joint and a control system based on relative position. The former is studied in the joint space, and the latter is in the operating space.

2.2.4 Design of the robot arm control system

In the robot arm control system, the neural network controller is mainly used for system non-linearity and uncertainty compensation. In order to overcome the problem of inaccurate control accuracy due to the unknown model of the manipulator, the combination of NNC and MRAC is adopted. The mechanical neural network model reference adaptive control structure is shown in the figure. RBFNNI is used to identify unknown robotic arm systems. It can be realized by offline learning and online operation. After the network is trained with a large amount of sample data, it can be used to replace the role of the real robotic arm system. The RBFNNC provides a control signal to the system that enables system control so that the output of the robotic system tracks the output of the reference model and limits the tracking error to a small range.

RBFNNI and RBFNNC are each composed of an RBFNN, and the RBF learning algorithm is used to train and weight the units. RBFNNI uses offline training and online operation to identify unknown models of the robot arm. When RBFNNI is trained in a large amount of sample data, it can be used to replace the role of the real robotic arm system. The training of RBFNNC must combine the deviation between the control amount at each moment and the actual required control amount, that is, the correction error u of the control signal generated by the system. Since the real model of the manipulator is unknown, the training of the RBFNNC requires an error between the actual output of the system and the output of the reference model, but it is difficult to determine the exact value of the error. The solution is to use RBFNNI to combine the control deviation u generated by RBFNNI after a large amount of sample training, and pass the negative feedback adjustment to u, and then participate in RNFNNC training.

3.3 Fan weighing implementation

3.3.1 Overview of basic processing methods of signals

For the automatic sorting and weighing of the fixed weight of the fans, the weight sorting is realized by installing the gravity sensor on the robot arm, transferring the quality of the fans into a digital signal and transmitting it to the receiver, and then adjusting the threshold of the maximum gravity of the arm. jobs. The gravity sensor uses CG-5 gravimeter, which is derived from the digital gravimeter developed by Canadian company. The instrument has the characteristics of digital data acquisition, automatic measurement automation, global measurement range and intelligent data processing.

Fans want accurate 50g weighing to require accurate gravimeter sensors. Here we are mainly divided into three types of gravimeter sensors: temperature sensor, gravity sensor, tilt sensor. Each type of sensor will transmit a voltage signal, which is converted into a corresponding digital signal by the converter, and finally converted into a response temperature and gravity reading result.

3.3.2 Gravity digital signals are converted to relative gravity values

The basic structure of the gravity sensor is as shown above. Its main components are fused quartz springs and variable capacitors, where the variable capacitance is the shaded part of the figure. The object to be measured is connected to a quartz spring in which the gravity acting on the object is balanced with the electrostatic restoring force generated in the variable capacitor. When the gravity changes, the position of the test object changes, and the changed position is sensed by the capacitive displacement function converter, and the generated feedback voltage continuously generates a restoring force even if the measured object returns to an equilibrium state under the action of the electrostatic force. The feedback voltage is the measurement of relative gravity at the station, where the relationship between the digital signal and the voltage value into which the gravity value is converted in the digitizer is:

$$R_g = \frac{C_g * S_g}{f_g}$$

R_g is the gravity reading value, the unit is $10^{-5} ms^{-2}$; C_g is the scale factor of the gravimeter, is stored in the instrument after calibration, and the unit is th$10^{-5} ms^{-2}$.e digital signal output by the gravity analog-to-digital converter; f_g is the gravity analog-to-digital converter of the gravimeter The maximum quantized value corresponding to the rate is 536870912.

3.3.3 Tilt sensor digital signal is converted to tilt angle

The tilt sensor is installed in the gravity tester to sense and collect the tilt angle voltage in the gravimeter in time, and the tilt angle voltage is converted into a digital signal by two analog-to-digital converters, thereby outputting the tilt angle value in the instrument.

(1) X-axis tilt angle

The relationship between the tilt angle and the X-axis tilt sensor signal is

$$q_x = \left[(S_x - x_0') \cdot 0.000076295 - 2.5 \right] \cdot L_x \quad (2)$$

Where, the X-axis tilt angle of the instrument; is the signal value output by the X-axis tilt analog-to-digital converter; the sensitivity of the X-axis tilt sensor is the X-axis horizontal zero compensation of the tilt sensor, and the value is stored in the device after being adjusted by the instrument inspection Calculated, ie

$$x_0' = \frac{x_0}{0.000076295 \cdot L_x}$$

(2) Y-axis tilt angle

The relationship between the tilt angle and the Y-axis tilt sensor signal is

$$q_y = -\left[\left(S_y - y_0'\right) \cdot 0.000076295 - 2.5\right] \cdot L_y \quad (2)$$

In the formula, the Y-axis tilt angle of the instrument; is the signal value output by the Y-axis tilt analog-to-digital converter; the sensitivity of the Y-axis tilt sensor is the horizontal zero compensation of the tilt sensor Y-axis, and the value is stored in the device after being adjusted by the instrument inspection Calculated, ie

$$y_0' = \frac{y_0}{0.000076295 \cdot L_y}$$

3.3.4 Temperature sensor digital signal is converted to compensation temperature

The temperature sensor is also in the gravity sensor, preferably placed in a constant temperature vacuum chamber for sealing, so that the gravity measurement is not affected by the ambient temperature and the surrounding atmospheric pressure as much as possible, ensuring that the normal working range temperature of the instrument is large, and the temperature sensor will eliminate the residual by software. The effect of temperature on weight measurement. The temperature sensor also collects the current temperature in time, converts the temperature value into an output voltage, and also converts it into a digital signal through an analog-to-digital converter. The relationship is:

$$T = \left(S_t \cdot T_f\right) - T_B - T_0$$

Where T is the compensation temperature value in mK; St is the signal value output by the temperature analog-to-digital converter, and Tf is the 24-bit (5-bit additional bit) digital-to-analog converter quantization unit corresponding to 1 degree of full-scale, ie 1000/ 536870912, TB is the temperature offset, the unit is mK, the temperature offset of the instrument is 500mK, T0 is the temperature correction, each CG-5 gravimeter has its own T0 parameter.

3.4 Fan shaping implementation
3.4.1 Overview of fan formation

For the fan molding process, firstly, for the container in the box in the previous step, the corresponding mechanical arm steering pawl is designed, and then the self-rotation of the steering arm of the mechanical arm is realized by the stm32 controller, and the box is rotated by high-speed rotation. The fans form a nest.

3.4.2 Design of the steering arm of the mechanical arm

For the fan-in-box molding, the corresponding robot arm steering pawl is designed according to the measurement of the fan container parameters of a specific specification. The container parameters mainly measure the following aspects:

1. The opening and bottom radius of the container.

2. The radius of curvature of each position of the container.

3. Container depth and capacity.

According to the above parameters, the gray relational analysis method is used to analyze the optimal opening radius of the steering arm of the mechanical arm.

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