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Intelligent Combination Location for Automated Inspection of Interior Assembly Structures of Complex Products

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***Abstract*—Nondestructive test, machine vision and image processing make it possible to realize online automated inspection of interior assembly structures of complex products in engineering. The paper proposes one combination technique of 3-point in hardware and local area projection in software to locate the product quickly and accurately. During recognition stage, the paper obtains the orderly image sequence of the product with multiple orientation views and extracts the projections of the sequence in vertical direction as recognition features to establish library for identifying of the assembly structures. Based on this method, the first domestic automated X-ray digital radiography detection system has been developed, and it is effectively applied in online testing some complex products.**

Keywords-Combination location; recognition; 3-point; local area projection

I. INTRODUCTION

As is known to all that the developments of manufacturing system and assembly system are both evolving towards those of intelligent systems, but most of plants are dependent on manual process to inspect the assembly structures interior finished products. X-ray Digital radiography (DR) nondestructive test, machine vision and image processing make it possible to online inspect the assembling structures interior complex products in engineering[1-13]. In intelligent inspection environment, a vision system for parts identification and recognition interior products is required to be both fast and robust. The system must perform accurate and unambiguous parts recognition and meet needs of continuous operations performed at high speeds.

The recognition for 2D images has many successful techniques and it has been widely applying in many fields such as face recognition[15-22], character recognition, moving object tracking and etc.[14]. In the field of X-ray nondestructive test, the Single view X-ray DR inspection system is the most common system for parts recognition. However, a single view may not contain sufficient features to identify it unambiguously since only one side of an object can be seen from any given viewpoint[10].

The paper mainly studies the question of online checking of some axis form products. The problem of products assembling correctness can be resolved by studying whether there is a certain part inside product at specific position, which embodies the removal of parts inside product and the change of gray level in its gray image.

In this paper, firstly, a method based on the combination of 3-point location in hardware and local area projection in software is proposed for fast location of the target product. And the paper then presents one approach that calculates the multiple view projections of the image sequence in vertical direction and establishes the character sequence library. Finally adopts the bisearch method to find the optimum solution to the target object in the library to realize recognition.

II. INSPECTION SYSTEM

Fig. 1 shows a general paradigm of a traditional computer vision system[2]. The system includes on-line and off-line processes. In an off-line process, a description of a standard object is established as the model object. In an on-line process, the input data are represented by the same description method that is used for the model description in the off-line process. The input object description and the model description are then compared in the matching stage and come to the conclusion of recognition.

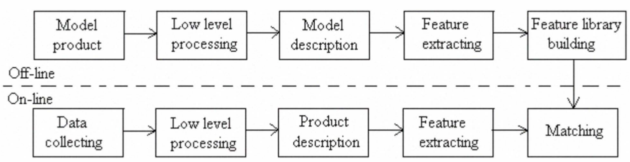

Figure 1. Detection program

We proposed an X-ray DR system that used multiple views technique from static camera, as shown in Fig.2. X-ray source are fixed at the center of the big turntable, The turntable is a circular horizontal platform that can be rotated 360 degree. Products are placed at the locations signed as "×" and differ 24 degree from each other. All the image system is shielded in a lead room, only the right-bottom part of the outside is for supplying products.

Once one product is coming, X-ray source emits an X-ray beam and sends it onto the target object. After it penetrating through the object, the beam is weakened and it takes the interior structure information of the object. When the weakened X-ray comes to the screen in front of image intensifier, it makes the screen emit visible light. The visible light is intensified and exported to the collecting circuit and

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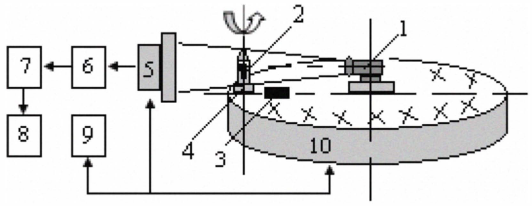
finally is transported to computer for analyzing and processing.



1 X-ray source, 2 Objects within product,
3 Location setup, 4 Small turnplate,
5 Image intensifier, 6 Sampling circuits,
7 Computer, 8 Monitor, 9 Control system
10 Big turntable

(a) Schematic diagram of the X-ray DR detection system

(b) Appearance

(c) Current Detection Location

Figure 2. Detecting system

III. PRODUCT LOCATION

A. *Orientating with 3-point in hardware*

Firstly the turning precision is necessary for the big turntable, and it should have much small side face and circular run-out. The base of the small swivel table is directly jointed with the transmission screw rod under the left of big turntable. The special nylon pallet is placed on the base by twin orientation pins with big clearance fit, as shown in Fig.3. Suppose that diameters of the pins and holes are d and D, then the difference $\Delta d = D - d$ is the redundancy to compensate the error from the big turntable and other factors. Δd, the small fork, and the fixed point A are used to realize 3-point orientation.

During the working time period, the big turntable automatically rotates around its axes in intermittence manner. Worker places product onto the pallets on the small swivel table, after the product is transmitted to the furthest left, turntable halts. The orientation small fork is driven by air pressure forwards until to the position B and C. B、C and the fixed point A come to 3-point orientating, shown as Fig.4.

The light brake between image intensifier and the station opens automatically and allows X-ray penetrate through the object. The image intensifier acquires DR gray image. The transmission institution under the big turntable drives the screw and the product together rotating in clockwise or counterclockwise direction at any degree. While the images of multiple views are acquired, the following works are carried out simultaneity: (1) closes the light brake and deliver the image data to computer for dealing with and recognizing; (2) stops the small swivel table and draws back the fork, turns the big turntable to the next station. The system then repeats the operation above.

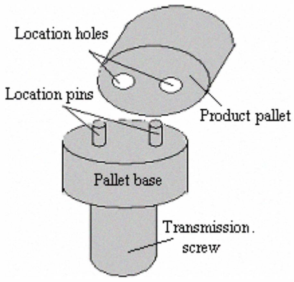


Figure.3 Small swivel location set

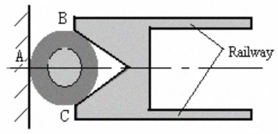


Figure.4 3-point locating

B. *Locating with sub-area projection in software*

The hardware set mentioned above approximately guarantees the same coming position of different stations. It also makes sure that less computing consumption and high velocity in software process. Aiming at the minuteness of parts inside product and the assembly complexity, this study presents an approach to resolve the precision locating based on sub-area integral projection.

Suppose that the size of a whole image is $M \times N$, and the object is $m \times n$, we choose one sub-area of recognition with the size of $K \times L$, which is a little bigger than the object, then remember the left-top point $A(x_1, y_1)$ and the right-bottom point $B(x_2, y_2)$, shown as Fig.5. Do the vertical project as:

$$V(x) = \sum_{y=y_1}^{y_2} I(x,y) \quad (x_1 \leq x < x_2) \qquad (1)$$

Where (x, y) denotes the coordinates of the pixel, and $I(x, y)$ is the gray value of the pixel. It is obvious that the vertical projecting is to add the gray of pixels in one list.

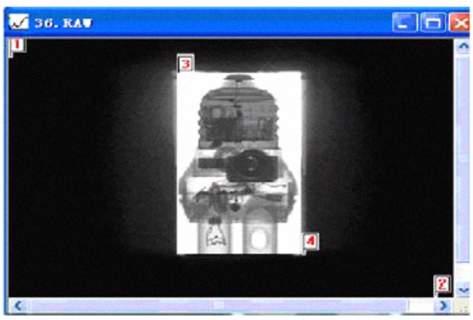


Figure.5 Locating recognizing area

From the vertical projection of formula (1), the staircase edge is obtained. Calculate the absolute difference of $V(x)$ as follow:

$$D_V(i) = |V(i+1) - V(i)| \quad (x_1 \le i < x_2) \qquad (2)$$

Combing all the values of the difference $D_V(i)$ from left to right, the left border of the product image is the position of the first maximum value noted as X_L, and the last maximum is the right border noted as X_R. The range of the product image in horizontal direction is $xScope = X_R - X_L$.

When ascertain the datum plane in vertical direction, we can draw a horizontal line where the bright and shade show a striking contrast in vertical direction, mark down the position of the horizontal line in vertical direction. Obtain the horizontal projection of the image around in vertical direction and find the position of the most and least extremum, the position is the standard line marked as y_0, and the range in vertical direction of the product image is $yScope = (y_0 + h_2) - (y_0 - h_1)$, the magnitude of h_1 and h_2 are relative to the size of the product and concrete position of y_0. The point (X_L, y_0) is considered as datum mark in the whole image.

IV. Circumference Orientation and Matching

A. Learning process

Learning image is to obtain the image sequence of a standard swatch of the product. Firstly the imaging system images the standard swatch once at interval of $N°$ in circumference orientation, then the image sequence of $ImageNum = 360/N$ pictures come into being. The parameter N is ascertained by experimentation according to the complexity inside products and checking requirement.

After locating and orientating of the product, the computer automatically calculates the projection of each target object image of the sequence in vertical direction and establishes the order projection character library, thus receive a one-dimensional matrix $Standard[]$, which capacity is $xScope \times ImageNum$.

B. Detecting process

First of all, the imaging system obtains one gray image of product at any random circumferential orientation and takes its projection in vertical stored in matrix *test[]*, which length is $xScope$.

Due to the Study Process is a gradual change process in the orientation range from 0° to 360° with step $N°$, the character library is orderly. Firstly, finds the orientation location of the optimum of the product tested in the standard library with the method of bisearch; then calculates the correlation coefficient between the product tested and the standard swatch one. Finally come to conclusion that the part tested is disqualification directly under the condition of the coefficient is less than the threshold enacted. If the coefficient is bigger than the threshold, then rotate it about 90° and re-checks. The particular program is as follows:

1) Sets the parameters *i*, *MaxR* and *Num* as *0*.

2)Takes $xScope$ number of array elements in $Standard[]$ between the elements of $Standard[ImageNum \times (i/4) \times xScope]$ and $Standard[(ImageNum \times (i/4) + 1) \times xScope - 1]$ to $Temp[]$, and these data are taken as vertical projection of the standard swatch in $ImageNum \times i/4$ circumferential orientation.

3) Calculates the correlation coefficient R_{XY} of the vertical projections of the standard swatch and the one tested in $ImageNum \times i/4$ circumferential orientation;

$$R_{XY} = \frac{\sum_{k=0}^{xScope-1} Temp[k] \cdot Test[k]}{\sqrt{\sum_{k=0}^{xScope-1} Temp[k]^2 \sum_{k=0}^{xScope-1} Test[k]^2}} \qquad (3)$$

5) If $MaxR > R_{XY}$, turn to the next step; else the value of $MaxR$ is replaced by R_{XY}, and the value of Num is replaced by i, then continues;

6) if $i = 3$, turn to the next step; else the value of i is added 1 then turn to 2);

7) From upwards flows it can be obtained which the orientation scope of the optimum of the product tested current projection character in the orderly library;

8) Determines a threshold value R_{TH} according to the assembling complexity and the detection requirement, if $R < R_{TH}$, the product is assembled mistaken, else rotates it about 90° and re-images and rechecks it furthermore.

V. Conclusion

Experiments show that the method of location and recognition mentioned in this paper could accomplish online detection of the assembling correctness of axis form product and need not labor detecting, Utilizing one PC with the attribute: Pentium(R)4, CPU 2.80GHz, EMS memory 256MB, and under the Visual C++6.0 workspace, Aiming at one certain product which image obtained is 768×576, The velocity of studying process is less than 20 second per one, and the velocity of product identifying is less than 2 second.

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