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Experimental Research on the Sucker's Positioning in the Lens's Assembly System

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Abstract: This study studies the problem of the sucker's positioning in the mobile phone lens's assembly system. To solve this problem sufficiently will make a contribution to improving product quality, production efficiency and avoid a lot of manual operations. This study presents a vision-guided method of the sucker's positioning and provides a quality prediction method for the sucker's positioning based on a back propagation artificial neural network. The traditional mobile phone lens's assembly equipment assembled the lens without the sucker's positioning signal feedback, or used some simple sensors to detect the sucker's positioning signal mechanically; These old methods are always lack of intelligence, flexibility, robustness. The sucker's positioning experiments are conducted with a vision-based mobile-phone lens's assembly experimental setup and a back propagation artificial neural network is applied to predict the sucker's positioning quality in the assembly system. The results show that the vision-based sucker's positioning system is feasible and effective.

Key words: Positioning, machine vision, artificial neural network, back propagation

INTRODUCTION

Machine vision is a relatively new technology which is concerned with the engineering of integrated mechanical-electronic-optical-software system (Zhang *et al*., 2013; Zhang, 2005). Since the 80's of last century many researchers have made a lot of achievements in scientific research on the field. Lahajinar and Kovacic (2003) presented a machine vision system that has been designed for the precise positioning and the reliable verification of industrial parts. Lee *et al.* (2008) presented a critical dimension measurement system for TFT-LCD patterns. Rosati *et al.* (2009) presented a novel on-line measuring system for dimensional verification of small metallic subassemblies for the eyeglasses industry.

This study focuses on the sucker's positioning technology with the lens's vision-based coordinates, addresses the problem of the precision of the sucker's positioning coordinates and a BP ANN (back propagation artificial neural network) is proposed to predict the sucker's positioning quality.

In recent years, there is a greater interest in using ANN as problem solving algorithm. The flexibility of neural network predestines them to deal with difficult non-linear problems and any kind of data. Babu and Hanratty (1993) used ANN to generate models of batch processes relating product quality to process input variables and processing conditions, presented an architecture for a shrinking horizon model predictive control of batch processes (Edwards and Murray, 2001). Woll *et al.* (1996) presented an alternative online technique for part quality monitoring that focused on the analysis of complete data patterns, ANNs were successful in predicting part quality based on data patterns.

METHODS

Coordinate transformation model: Figure 1 displays an automatic mobile-phone LENS and BARREL's assembly experimental setup based on machine vision.

Figure 2 shows the geometry of the transformtion model of the sucker's positioning system which consists of six kind of coordinate systems.

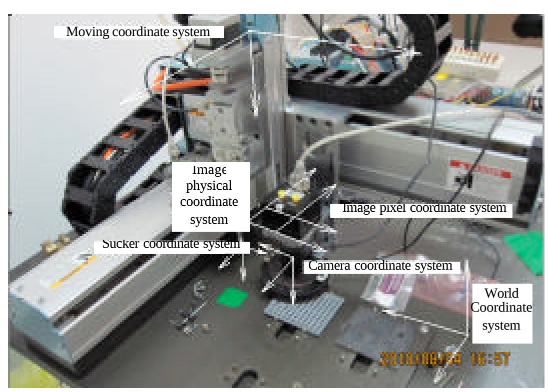

Fig. 1: Experimental setup

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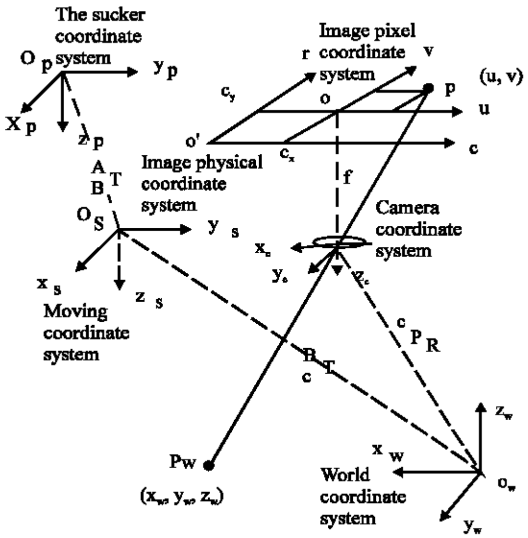

Fig. 2: Geometry of transformtion model

The coordinate transformation from the sucker coordinate system to the image pixel coordinate system can be descried as the following steps (Steger *et al*., 2008):

- The coordinate transformation from the sucker coordinate system to the moving coordinate system is a rigid transformation (a rotation followed by a translation)
- The coordinate transformation from the moving coordinate system to the world coordinate system is a rigid transformation, too
- The coordinate transformation from the world coordinate system to the camera coordinate system is also a rigid transformation,which can also be described with a rotation matrix R and a translation vector T as follow:

$$\begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix} = R \begin{pmatrix} x_w \\ y_w \\ z_w \end{pmatrix} + T \qquad (1)$$

- The coordinate transformation from the camera coordinate system to the image physical coordinate system is described as follow:

$$\begin{aligned} u &= f * x_c / z_c \\ v &= f * y_c / z_c \end{aligned} \qquad (2)$$

where, f is the effective focal length of the camera

- If k is the lens radial direction distortion coefficient, the coordinates $(\tilde{u}, \tilde{v})^T$ are modified as follow:

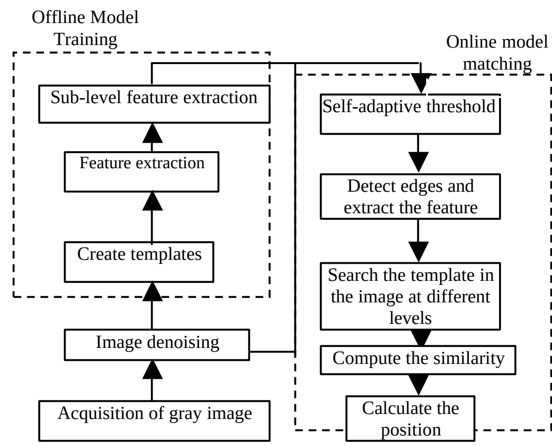

Fig. 3: Flow chart of LENS's matching

$$\begin{aligned} \tilde{u} &= 2 * u / (1 + \sqrt{1 - 4 * k * (u^2 + v^2)}) \\ \tilde{v} &= 2 * v / (1 + \sqrt{1 - 4 * k * (u^2 + v^2)}) \end{aligned} \qquad (3)$$

- The coordinate transformation from the image physical coordinate system to the image pixel coordinate system can be described as follow:

$$\begin{aligned} c &= \frac{\tilde{v}}{s_x} + c_x \\ r &= \frac{\tilde{u}}{s_y} + c_y \end{aligned} \qquad (4)$$

where, $(c_x, c_y)^T$ is the origin point of the image physical coordinate system; S_x and S_y are the physical size of each pixel along the X and Y axes, respectively.

As usual, the sucker's coordinates are always calculated from the coordinates in the image pixel coordinate system, but the sucker's coordinates are not always accurate because the two coordinates do not exist in the same coordinate system.

Mobile-phone lens's assembly process: The flow chart of the LENS's matching process is shown in Fig. 3, which can be described as three steps (Steger *et al*., 2008).

Offline model training: At this step, the main task is to prepare an appropriate model for matching:

- Firstly, select the target area as the template in a LENS's image
- Secondly, extract the feature of the region of interest (ROI)

- Thirdly, calculate the direction vectors $d_i = (t_i, u_i)^T$, the affine transformtions $d_i^{'} = (A^{-1})^T d_i$ and all this templates at the other pyramid levels

On-line matching: The LENS's similarity s is calculated by the following steps:

- Detect the edges and extract the feature of the acquired image, calculate the direction vector:

$$e_{q+p'} = (v_{r+r_i, c+c_i}, w_{r+r_i, c+c_i})$$

- Search the template in the acquired image from higher pyramid level to lower pyramid level and the LENS's similarity *s* is computed as follow:

$$s = \frac{1}{n}\sum_{i=1}^{n}\frac{d_i^{'T} e_{q+p'}}{\|d_i^{'}\|\|e_{q+p'}\|} \quad (5)$$

where, n is the number of points in the ROI of the template.

- Choose an appropriate threshold of the similarity T, If the similarity s = T, an instance of the template has been found
- If a is a pose parameter, calculate the pose parameter of the instance by way of minimizing the following least-squares adjustment function:

$$d_{(a)} = \sum_{i=1}^{n}[t_i(r_i^{'}(a) - r_i) + u_i(c_i^{'}(a) - c_i)]^2 \quad (6)$$

The flow chart of the sucker's positioning process is shown in Fig. 4.

The LENS's center coordinates in the image pixel coordinate system are always used to position the sucker in the sucker coordinate system. The image pixel coordinate system and the sucker coordinate system are not the same coordinate systems. And so, all the coordinates calculated in the image pixel coordinate system will only affect the sucker's position indirectly.

Because the adventure of No Good (NG) products will increase with the poor quality of the sucker's positioning process, it's extremely important to predict the sucker's positioning quality in the lens's assembly process. And so, it's necessary to establish an appropriate method to deal with the coordinate transformation relationship from the sucker coordinate system to the image pixel coordinate system. In this study, a BP ANN is applied to predict the sucker's positioning quality in the vision-based mobile-phone lens's assembly system.

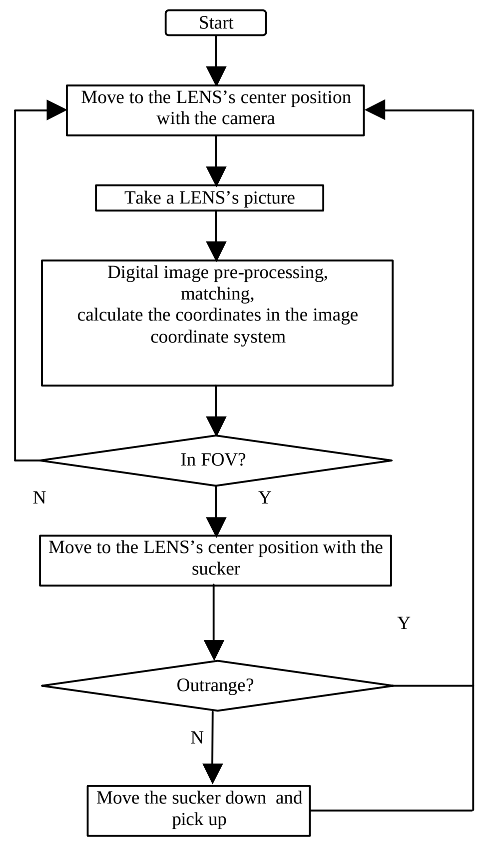

Fig. 4: Flow chart of positioning process

RESULTS AND DISCUSSION

Sucker's positioning experiment: Figure 5 shows the process description of the sucker's positioning experiment. All the LENS's pixel coorinates in the experiment have been recorded in a database, which are shown in Table 1.

Calculate the mean value of coordinates by the Eq. 7 as follow:

$$\bar{x} = \frac{1}{50}\sum_{i=1}^{50} x_i \quad (7)$$

The LENS's mean coordinates are shown in Table 2.

Experimental results for the sucker's positioning are shown in Fig. 6. In Fig. 6a, the maximum error is less than 1 pixel, namely 0.0085 mm. Figure 6b-c take on a regulation that with the level of the image score getting lower, the points make a more difference in the distribution of coordinates and position.

Simulation by MATLAB program: BP ANN is a generalization of the Widrow-Hoff learning rule to

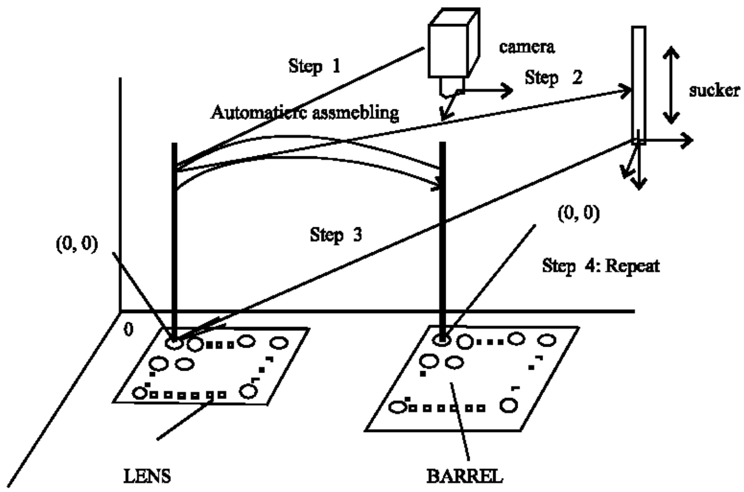

Fig. 5: Process of the sucker's positioning experiment

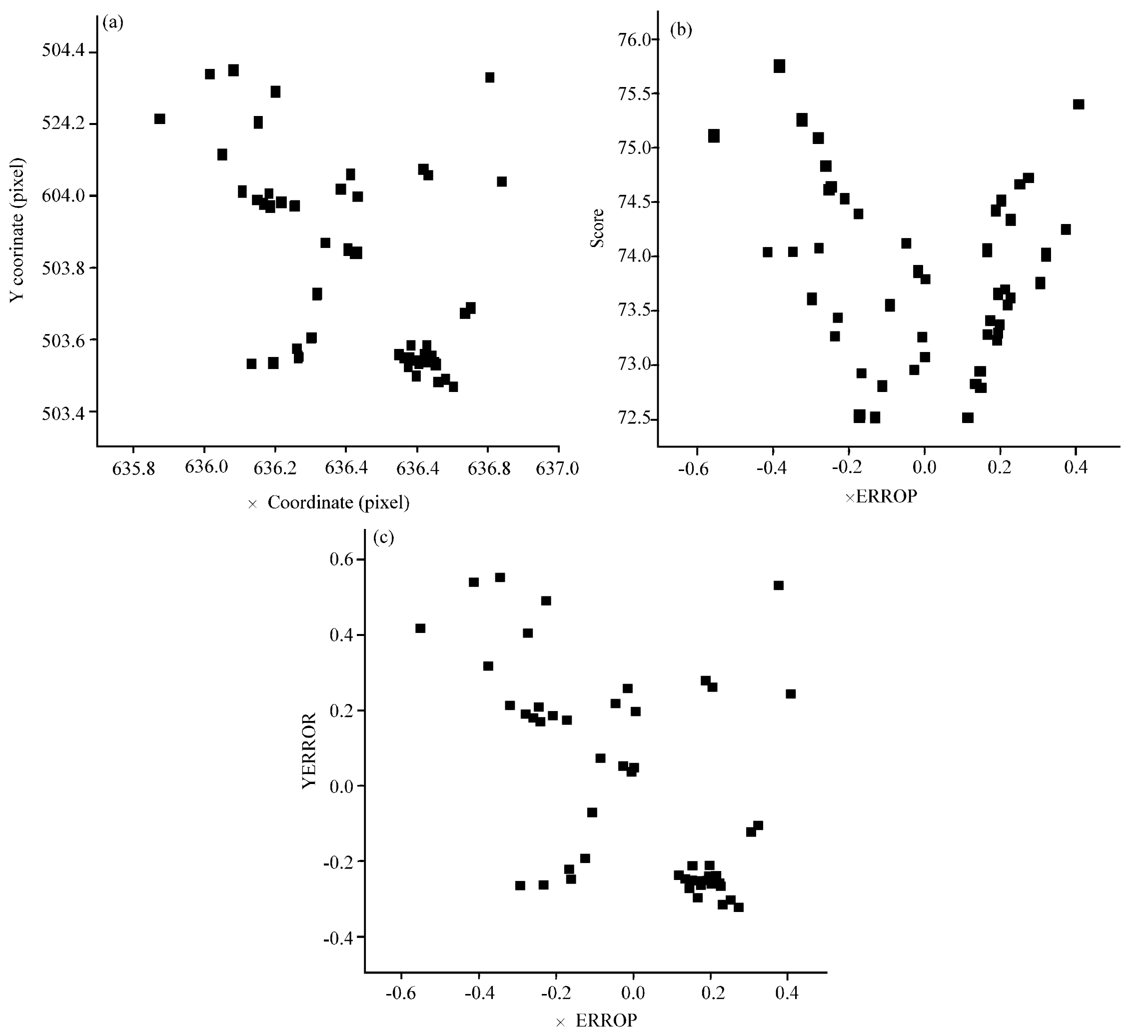

Fig. 6(a-c): Experimental results for the sucker's positioning setup, (a) LENS's position distribution, (b) The least measure error of LENS's coordinates variation and (c) Relation between LENS's x error and y error

Table 1: LENS's pixel coorinates (pixel)

No.	X	Y	Score	No.	X	Y	Score
1	636.1937	503.5323	73.27226518	9	636.1326	503.5304	73.60956897
2	636.2636	503.5497	72.9311141	10	636.5938	503.4964	74.06706406
3	636.2588	503.5728	72.54509014	M	M	M	M
4	635.8735	504.2151	75.11079785	M	M	M	M
5	636.5765	503.5457	72.9496002	47	636.0144	504.3389	74.06012427
6	636.5968	503.5399	73.28711574	48	636.1798	504.0042	74.62856153
7	636.6026	503.5328	73.4196892	49	636.2172	503.9824	74.53804311
8	636.6269	503.5376	73.37618381	50	636.2541	503.9719	74.40411809

Table 2:Mean value of LENS's coordinates (pixel)

$\overline{X}$	$\overline{Y}$
636.4273	503.797

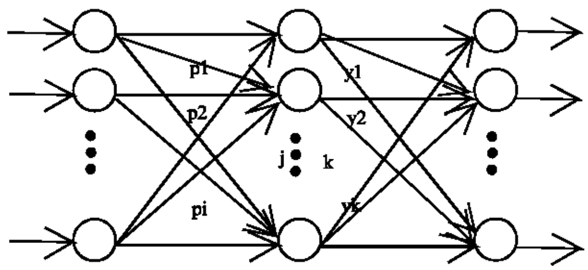

Fig. 7: Structure of BP network

multiple-layer networks and nonlinear differentiable transfer functions. A typical multilayer perceptron consists of an input layer, one or more hidden layers and one output layer, which is shown in Fig. 7. A BP ANN can be regarded as an excellent nonlinear function mapping from the input to the output (Wang, 2011). The network's learning consists of two procedures: Positive spread; Converse spread.

The key characteristic parameters of the sucker's positioning in this experiment include:

- The LENS's similarity s:s, an important characteristic parameter, is calculated by the Eq. 5
- The LENS's coordinates $(X, Y)^T$ in the image pixel coordinate system: At a different location of the mechanical movement, each of the mechanical parts in the assembly system has a different acceleration with a different load force. The LENS's center coordinates in the image pixel coordinate system have been used to position the sucker in the sucker coordinate system. And so, the LENS's coordinates $(X, Y)^T$ in the image pixel coordinate system are taken into consideration and selected as two input characteristic parameters

Fourty training samples and 10 testing samples are obtained from the above experiment. Figure 8 shows the simulation results.As the iteration number increases in the net's training, the trend of MSE is shown in Fig. 8a. At

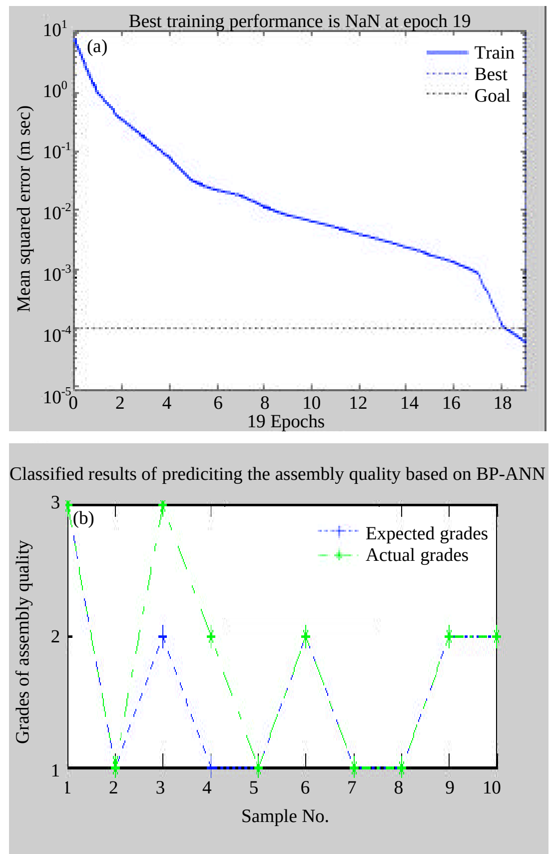

Fig. 8(a-b): Simulation results, (a) Trend of MSE when training and (b) Classification testing

epoch 19, MSE reaches the expected (10^{-4}). The testing classification of the sucker's positioning quality prediction based on BP ANN are shown in Fig. 8b. The prediction accuracy (%) is about 80-90.

DISCUSSION

To further increase the accuracy of the BP network in this experiment, some other characteristic parameters should be taken into consideration in future research, which can affect the accuracy directly or indirectly. The parameters include: The complexity of mechanical system and its mechanical deformation; The kinematics parameters; The number of the training samples and others.

CONCLUSION

Machine vision has been an effect technology. This study proposes a new approach for the sucker's positioning based on machine vision and proposes a novel method based on a BP ANN to predict the sucker's positioning quality in the vision-based mobile-phone lens's assembly system. Results show that the vision-based sucker's positioning system is feasible and effective.

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