The Key Technical Research of Machine Vision Detection System--Based on Dimension Measurement of Thin Sheet Parts

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Abstract. This paper proposes a new detection method for accurate detection of dimension of thin sheet parts, breaks a traditional manual detection mode, comes up with a machine vision detection system, conducts research analysis of definition, application, principle and hardware structure of this detecting technique, develops a set of machine vision detection system of part dimension, further analyzes image acquisition, image processing and image recognition technology, ultimately analyzes the experiment of thin part dimension measurement and detection results, and puts forward reliability of machine vision detection for thin sheet part dimension. This paper has certain theoretical significance and application value.

Introduction

Manufacturing industry is a pillar industry of the entire Chinese industrial economy. Many enterprises establish a batch automatic production line of product parts and regard traditional manual visual inspection as a detection method. According to related data statistics, undetected appearance is the second largest reason for customers to return products and reaches up to 45.1%, occupying 14.3% of the entire external fault costs. In order to improve product quality and production efficiency of thin sheet parts, while ensuring detection precision of parts, it is necessary to conduct 100% of online detection on final dimension of thin sheet parts. Image of typical thin sheet parts is shown in Figure 1.

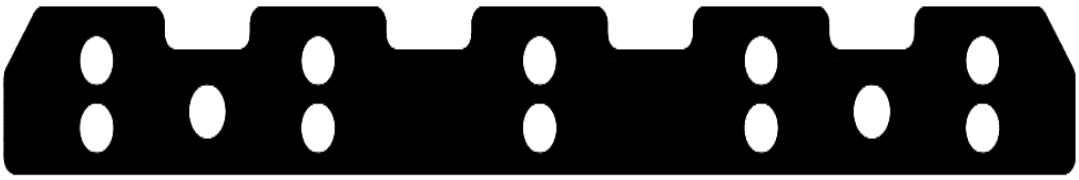

Fig. 1 Image of Typical Thin Sheet Parts

Machine vision detection technique has some advantages of no contact, high precision, high level of automation and intelligence, good flexibility, fast speed, and easy integration with design information and processing control information, etc., and satisfies detection requirements of thin sheet parts completely. The specific difference between machine vision detection and artificial detection is shown in Table 1. This paper makes use of machine vision detection system, lays stress on discussing application and effect of key technology on dimension measurement of thin sheet parts, and has extremely important theoretical significance and application value.

Table 1: Difference between Machine Vision Detection and Artificial Detection

Items	Artificial detection	Machine vision detection
Speed	Human eyes can't see fast moving objects clearly, due to persistence of vision.	Shutter time can reach microsecond level, camera frame rate can above thousand frames, and processor is fast.
Precision	Low precision and non-quantified	High precision, maximal micron order and liable to quantify
Environment requirements	Bad adaptation to environment temperature and humidity. In addition, some environments do harm to human body.	Have stronger adaption to environment and can add protective devices.
Sensitivity range	Visible light from 400nm-750nm	UV and infrared spectral range and X-ray
Color recognition	Stronger resolving power for color, liable to be impacted by psychology, and non-quantified.	Bad color resolving power and can be quantified
Gray resolution	Bad, only resolute 64 gray levels	Stronger, use 8 bit generally, namely 256 gray levels, also including other gray levels.
Space resolution	Worse, can't identify tiny targets	Match with optical lenses to observe target from micron order to aster level.
Subjectivity & Objectivity	Have stronger subjectivity, liable to be impacted by psychology and fatigable	Relatively objective and can work continuously.

Overview of Machine Vision Detection Technique

Definition and Application of Machine Vision Detection Technique

Machine vision detection technique is a newly-developing detection technique based on research basis of machine vision and is also an interdisciplinary integrated subject. The detection process of machine vision detection system refers to put detective objects into the uniformly illuminative controlled environment, obtain corresponding image information of detective objects by using a camera, and transfer image information of detective objects collected by image capture card to a computer. Then, related image processing software in the computer will process, analyze and output required detection results. Machine vision detection technique combines machinery, electronics, picture processing and computer technology, etc., multiple subjects and is widely applied to industry, biomedicine, robot navigation, military, aerospace, agriculture and transportation, etc., fields.

Machine Vision Principle and System Composition

In 1965, L. Robert published a famous article named Machine Perception of Three-Dimensional Objects and initiated the era of machine vision research. In 1970s, Professor D. Marr put forward the computer vision theory differing from "blocks world". During this period, some practical visual systems appeared. Beginning with 1980s, under the guidance of visual computation theory, climax stage of machine vision research was formed. The study of visual technology in our country dated from the beginning of 1980s and experienced development in three stages. At present, domestic application has been increased rapidly, such as semiconductors, electrons, computer accessories, consumer goods, foods, automobiles, metallurgy, packaging and pharmacy, etc. All of them start to look for visual detection solutions, resulting in several characteristics presented by development tendency of visual detection technique, namely timeliness, high precision, universality and

modularization, etc.

Machine vision mainly utilizes a computer or robot to replace human eyes to identify, judge and detect objects, involving in image acquisition of objects, processing of target objects' image information, detection and identification of target objects. Machine vision system converts adoptive targets to image signal through machine vision products, transfers it to dedicated image processing system, and transforms into digitized signal in line with pixel difference, luminance and color, etc., information. Image processing software conducts various operations on these signals to extract target characteristics, such as location, area, quantity and length, etc., transmits operation results to visual system control module, so as to realize field control on mechanical equipment.

Hardware parts of machine vision detection system mainly compose of a detecting instrument and a computer, including camera motion control system, image acquisition system, lighting system, detection workbench and support, etc. Under the guidance of modular design idea, it is compiled by using Visual C++ language in Windows operating system platform.

Key Technology Analysis of Machine Vision Detection System

Machine vision dimension measurement system mainly considers image of detected objects as means and carriers of detection and transitional information, and obtains physical dimension parameters of detected objects by processing image edge of detected objects. Therefore, image acquisition, image processing and image identification naturally become the key technology of machine vision dimension measurement system.

Image Acquisition

Image acquisition refers to a process that visual image of detected objects and internal features are converted into series of discrete data processed by a computer. For an image, the result of scanning in line with rectangular scanning gridding is to generate a two-dimensional integer matrix corresponding to the image. The position of every element (namely pixel) in the matrix is determined by scanning sequence. Gray value of every pixel is generated by sampling. Gray value of every pixel is represented in integer after quantization. Thus, results of image acquisition digitize a continuous image in nature and ultimately obtain digital images. This is one of key technologies of machine vision dimension measurement system.

Image Processing

Machine vision dimension measurement system obtains physical dimension parameters by processing image edge of detected objects. Thus, how to obtain high-precision image edge is one of key technologies of machine vision dimension measurement system. Acquisition of image edge is completed through image processing, which contains image preprocessing (including image calibration, image segmentation and image denoising, etc.) edge detection. Image preprocessing is the precondition of edge detection and makes preparations for edge detection. Edge detection is the foundation and key of detection system. Location accuracy of edge impact detection precision of dimension directly. With the continuous improvement of industrial inspection on required precision, pixel-level precision can't satisfy requirements of actual inspection any more. As a result, it is necessary to study an edge detection method with higher precision, namely the sub pixel edge detection method.

Image Identification

After images of detected parts conduct edge detection, pixel point sets of single pixel wide connection are obtained and belong to pixel constitution of single pixel wide connection in the same graphics primitive, such as straight line, arc and circle, etc., graphics primitives. Then, these graphics primitives constitute face profile. In machine vision dimension measurement system, physical dimension and tolerance of graphics primitives, form tolerance, position and tolerance between graphics primitives are detected. Thus, it is necessary to identify each graphics primitive of constituting face profile. Planar contour primitive recognition is one of critical steps of machine vision dimension measurement system. Precision degree of planar contour primitive recognition impacts accuracy of subsequent dimension measurement directly, while feature point detection of face profile is the key of planar contour primitive recognition.

Experimental Results and Analysis of Thin Sheet Parts Dimension Measurement

The paper uses visual detection system of thin sheet parts dimension to conduct dimension measurement on flexible arm's thin sheet parts. After this flexible arm's thin sheet parts use universal tool-measuring microscope to detect, it is an accepted product. Selecting typical dimension in numerous dimensions required for detection analyzes detection results. As shown in Figure 5, D1 is diameter of a circle and is physical dimension; D2 is deviation from circular form of a circle and is form error; D3 is the distance between two centers of a circle and is position dimension.

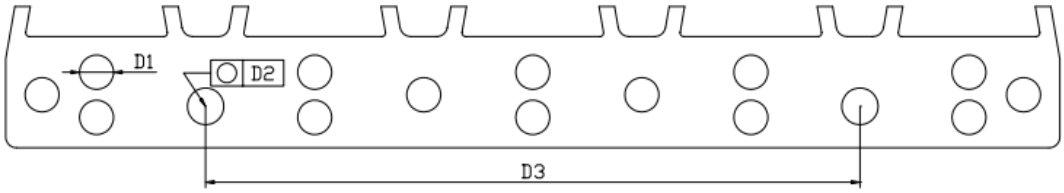

Fig. 2 Typical Thin Sheet Parts Dimension Schematic Diagram for Detection Result Analysis

By conducting 10 duplicate detections on thin sheet parts, detection results of D1, D2 and D3 are shown in Table 2:

Table 2: Detection Results of Thin Sheet Parts D1, D2 and D3

Test Items	D1 Detection results(mm)	D2 Detection results(mm)	D3 Detection results(mm)
1	2.3748	-0.0007	45.7199
2	2.3753	-0.0001	45.7204
3	2.3750	-0.0002	45.7201
4	2.3752	+0.0004	45.7203
5	2.3755	+0.0001	45.7206
6	2.3751	-0.0004	45.7202
7	2.3754	+0.0001	45.7205
8	2.3751	-0.0003	45.7202
9	2.3754	-0.0001	45.7205
10	2.3752	+0.0002	45.7203

According to the above-mentioned detection dimension results, the computational formula for averaging $\overline{x}$ is:

$$\overline{x} = \frac{\sum x_i}{n} \quad (1)$$

In the above-mention equation, x_i refers to detection results, n is times of duplicate detection, and computational formula of estimated value s for detection result standard deviation is:

$$s = \sqrt{\frac{\sum v_i^2}{n-1}} \quad (2)$$

Here, v_i refers to residual error, and $v_i = x_i - \overline{x}$. Computational formula of averaging standard deviation $\sigma_{\overline{x}}$ is:

$$\sigma_{\overline{x}} \approx \frac{s}{\sqrt{n}} \quad (3)$$

Measuring limit error calculation of average value is expressed as:

$$\Delta_{\lim \overline{x}} = \pm 3\sigma_{\overline{x}} \quad (4)$$

Hence, the detection results *x* of thin sheet part dimension are:

$$x = \overline{x} \pm \Delta_{\lim \overline{x}} \quad (5)$$

By detecting thin sheet dimension for 10 times repeatedly, it finds that detection results of dimension D1, D2 and D3 are within the tolerance range. The error between average value and

design value is very small. Moreover, average detection time of thin sheet parts is 2.377s, indicating that detection precision of thin sheet part dimension machine vision detection system can reach micro order, which satisfies requirements of real-time online detection completely. Detection results of thin sheet part dimension are shown in the following Table 3:

Table 3: Detection Result Analysis of Thin Sheet Part Dimension D1, D2 and D3

No.	Mean(mm)	Mean standard deviation(mm)	Measuring limit error(mm)	Design value(mm)	Tolerance value(mm)	Qualified/Unqualified
1	2.3752	0.07	±0.0002	2.3749	±0.0127 or -0.0076	Qualified
2	-0.0001	0.10	±0.0003	0	±0.0127	Qualified
3	45.7203	0.07	±0.0002	45.7200	±0.0051	Qualified

Conclusions

Dimension measurement technique for machine parts plays a decisive role on industrial manufacture. With the application of machine vision detection technology, it is easy to find that application of machine vision improves product quality greatly, reduces demographic dividend, lowers production costs to some extent, drives production processing industry to move towards a road of automation and intelligence. In application of machine vision, extraction of object features, accurate positioning and measurement of dimension are irreplaceable links in the production line.

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