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Novel Approach of Surface Unfolding for Ceramic Bowls

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Abstract

Recent years, the significant advantage has been taken by ceramic industrial from the strong evolution in automation. All production phases have been addressed through various technical innovations, with the exception of the final stage of the manufacturing process. When applying computer vision on ceramic product quality inspection, the different kind of product of ceramic makes it difficult, especially on ceramic bowls, which have a curved surface. It is difficult to analyze rapidness and catch the production rate. This paper proposed an approach for automatic surface imperfection inspection of ceramic products. The bowl's curved surface unfolding model was discussed derived from helicoid unfolding method. Experiment shows that this method can be nicety.

Index Terms: Imperfection inspection; surface unfolding; classification; unfolding mechanism

1. Introduction

The process of producing ceramic products from raw materials concerned on fire and high-temperature in different kilns, so there maybe have lots of surface imperfections on the finished product. In the final stage of the manufacturing process, the generally accepted manual method of ceramic inspection is labor intensive, slow and subjective. How to replace artificial product classification by machine classification, which requires measurement accuracy, cannot be weaker than the artificial testing. There have some research on this project, but most of them are focus on building ceramics, especially on ceramic tile[1-3], there are all for flat product.

When applying computer vision method to detect the imperfection of ceramic bowl's surface, we found it is difficult. Because the surface of ceramic bowl is a curved surface, which can't be analyzed rapidness and catch the production rate. This paper proposed a novel method to unfold ceramic bowl's curved surface, which can form a flat image, and which can effectively analyzed. This paper focus on how to design the hardware system, which is suitable, be implemented online, on product line. This paper propose a hardware system prototype,

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including a CCD linear camera, a computer, and some controller device, and the surface unfolding model was discussed with a helicoid unfolding method, unfolding control functions were analyzed.

2. Hardware System Structure

Based on image processing and analysis, imperfection detection is developing very rapidly in recent years. Ceramic bowl's surface imperfection including blemish, blister, burr, crack, crawling, crazing and so on[4], each of them has clear difference on the appearance. The imperfection detection operation induces that the entire surface of every bowls must be imaged and analyzed. Therefore each bowl needs to be imaged individually without any sampling operation. The image acquisition must be achieved directly on the line, in real time, and the image analysis algorithms must be fast enough to follow the production rate.

This paper is concerned with the problem of automatic inspection of ceramic bowls using computer vision. It must be noted that detection of defection in textured surfaces is an important area of automatic industrial inspection that has been largely overlooked by the recent wave of research in machine vision applications. So, this paper aims to create a system that is capable of classifying bowls effectively, objectively and repeatedly, with sufficient rapidness and low costs and the ability to adapt autonomously to changes in materials.

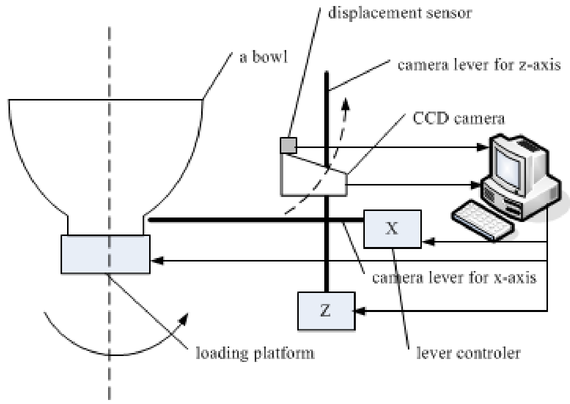

Fig 1.Schematic of system structure

The main task of this paper is to create a device which can create new images that are more suitable for the purposes of human visual perception object detection and target recognition can be used in the classifying or sorting process at the industry. Among the wide variety of available products for tiling, an important part present a glossy surface induced by polishing or glazing operations. Observing the surface under low angle lighting allows controlling the quality of the gloss. The ceramic bowls have been captured through the online camera held on the production line in the industry. Fig. 1 shows a schematic for the visual inspection system held on the production line. The image captured will convert to other kinds of images (Binary, and Gray scale) to be suitable for the various defect detection algorithms used for the different types of defects[5, 6].

3. Unfolding Surface Mechanism

A. Approach

The imperfection detection operation induces that the entire surface of every bowl must be imaged, in order to get images of the curved surface of a bowl , unfolding the surface is necessary. When scanning the surface using a linear CCD camera, it should be confirmed that the relative displacement to the surface and the linear speed of scanner to the surface is the same value. Basically this approach is derived from helicoid unfolding method[7].

In the hardware system, bowls on the loading platform can rotate at different angular velocity, which can maintain the same linear velocity when camera move from bottom to top. When bowls rotating, Camera move from bottom to top on the normal section of the axis of rotation. Fig. 2 is the sketch map of the unfolding system, and Fig. 3 shows the basic model of the unfolding system.

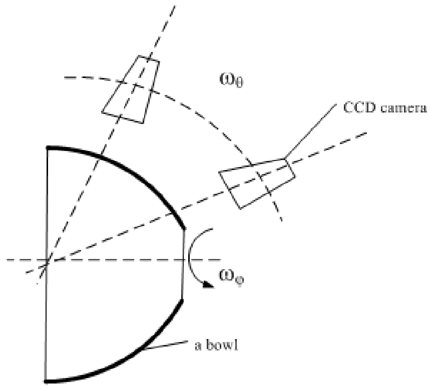

Fig 2. Sketch map of unfolding system

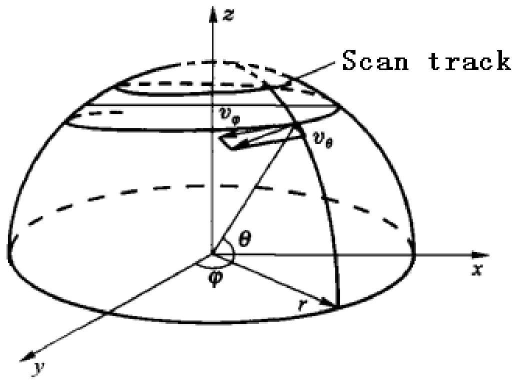

Fig 3. Unfolding model schematic

Like satellite scan the moon, we using a camera scan the surface of a bowl, normally we build our model under a spherical surface. According to Fig. 3, we can easily get the equation of motion for every point on the surface at t moment.

$$\begin{cases} r = d/2 \\ d\phi = \omega_\phi(t)dt \\ d\theta = \omega_\theta(t)dt \end{cases} \quad (1)$$

With represent the dais of the model ball, and $\omega_\phi(t)$ is the angular velocity of bowls at t moment along the weft direction, and $\omega_\theta(t)$ is angular velocity of camera at t moment along the meridian direction. Then we can get the locus equation as in (1) for every point on the surface.

$$\begin{cases} r = d/2 \\ d\theta = \dfrac{\omega_\theta(t)}{\omega_\phi(t)} d\phi \end{cases} \quad (2)$$

Simply maintain the value of $\dfrac{\omega_\theta(t)}{\omega_\phi(t)}$ unchanged, it can represent a equidistant spiral as in (2), and total point on the scanned surface composed a spiral belt. While the camera moves from bottom to top, the total surface would be unfolded on this spiral belt.

B. Scanner Control Device

The unfolding model and method is based on the spherical surface, how to maintain the relative displacement between camera and bowl surface, and precisely control the camera's motion, we place a Fiber

Optic Displacement Sensor at the Z axis direction of camera, and make sure they are on same position at X axis direction. Fig. 4 shows the device.

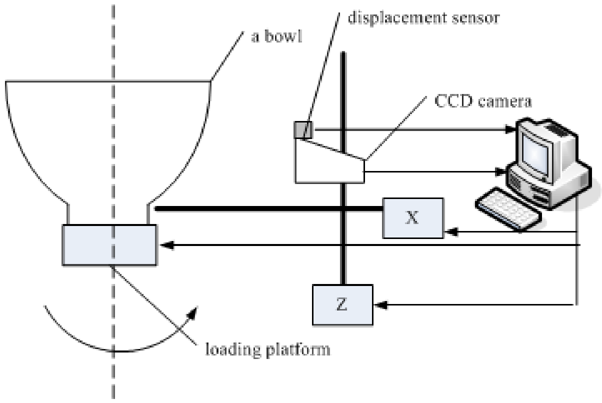

Fig. 4. Camera control system

Table I. Efficient experiment result

Items	AAA class(p)	Time cost(sec)
Artifical detection	61	1050
Machine detection	42	200
different	-19	-850

The Fiber Optic Displacement Sensor calibration the distance of camera to bowl surface through the strength of the reflected light radiation[8, 9]. The distance information can be used to control the camera control lever motion at the X axis direction.

4. Control System

When unfolding surface, error of the motion control system is avoidless, two operating parameters may affect less or more on the quality of unfolding. According to the unfolding model, with $\alpha_\theta \times \alpha_\phi$ represents the scanned surface, s represents the camera scan rate, then the camera scan speed v can be calculated.

$$v = s\alpha_\phi \tag{3}$$

Then we transform the locus equation with the geometrical sphere, $\omega_\theta(t)$ is calculated.

$$\omega_\theta(t) = \omega_\phi(t)\left(\arcsin\frac{\alpha_\theta}{d}\right)/\pi \tag{4}$$

Under the unfolding model equation, as in (3), the equation of motion is calculated.

$$v^2 = v_\phi^2(t) + v_\theta^2(t) = \\ [\omega_\phi(t)\cos\theta(t)d/2]^2 + [\omega_\theta(t)d/2]^2 \tag{5}$$

According the above equations, if $\omega_\theta(t)/\omega_\phi(t) > \arcsin(\alpha_\theta/d)/\pi$, which means the faster angular velocity, then the bowl surface have space which can't be scanned. Contrary, the spiral belt from the bowl surface have overlapped area, the overlapped area is necessary to kept total surface has been scanned, but it must be cut when compose an image from spiral belt.

5. Experiment and Analysis

The approach in this paper is used in product line to replace artificial product classification, the validation and efficiencies should be tested.

Mixing 100 ceramic bowls, half of them are good bowls; half of them are normal bowls. Artificial detection group have 4 members, each of them is skilled person. We record their detection time by individual. Artificial detection cost almost 10sec/per ceramic bowl, every ten ceramic bowls will cost another 10 sec to pile them, so 1050 second is used to detect these bowls. Normally, machine detection should faster then artificial detection. With an average diameter of 15 cm per bowl and a spacing of 5 cm between two bowls, a belt speed of 2.4 m/min is required as lowest speed, but that speed is really a slow speed. We have been tested that the speed can reach our belt's best speed 6 m/min. Table 1 show the result.

Machine detection shows its efficiency both on the time cost and the precision, long time detection task will tire the worker, different angle of sight will also cause different result, and many factors can reduce the efficiency of artificial detection. Machine detection won't, it can keep same efficiency under same condition.

6. Conclusion

The imperfections of ceramic surface have clear difference appearance, it can apply computer vision method to detect then, but surface image acquisition is difficult, must be achieved directly on the line, in real time to follow the production rate. This paper creates a machine vision system that is capable of detection the imperfection of bowl surface effectively, with sufficient rapidness and low costs and the ability to adapt autonomously to changes in materials. A PC based prototype has been build in lab, experiment shows that the approach has more efficiency and nicety than artificial detection, which is the final stage in real manufacturer.

There have much paper have discussed the software system with image segmentation and pattern recognition[3, 5, 10-13], we prefer to using wavelet analysis to build the visual inspection software system, which have sufficient rapidness and precisely[3, 11].

Acknowledgments

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