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2方向レーザ走査による形状測定

Shape Measurement by Two Directional Scanning Method

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A two-direction scanning method has been developed to reduce the shadow effects in laser triangulation probes. This method uses an acousto-optic deflector (AOD) as a scanner to allow a diffracted beam to scan an object from two directions, and a position sensor to detect the shift of a spot projected from these two directions alternately by a time-sharing technique. We applied the method to measure the cross-sectional shape of a half-ball button, and compared the results with those obtained using a conventional one-direction scanning laser triangulation method.

One of the most common principles of commercial three-dimensional sensing is laser triangulation because of its simplicity and robustness. A laser beam projects a spot of light on a diffuse surface of an object, and a lens collects part of the light scattered from this surface to image the spot on a position sensor. Unfortunately, the method prevent continuous profile measurements due to severe shadow effects. In laser triangulation, there are two shadow effects: (a) points on the surface that the projection beam cannot reach; and (b) points on the surface that the position sensor cannot detect.

What we propose here is a new *two-direction scanning* (2DS) method, in which an *acousto-optic deflector* (AOD) is used as a scanner to allow the diffracted beam to scan an object from two directions, and a position sensor is used to detect the shift in the spot position projected from two directions alternately by a time-sharing technique. The shadow effects are thus reduced by this two-direction projection.

Figure 1 shows the configuration of the 2DS method, which consists of a 25-mW He-Ne laser, three mirrors (M_1, M_2, and M_3), an AOD scanner, a collective lens of focal length f=50 mm, and a position sensor. The AOD is used as a diffractive scanner. Due to the acousto-optic effect, the laser beam passing through the AOD is diffracted in direction α, which depends on the voltage of the input electrical signal, V_i. Here, the voltage-controlling oscillator (VCO) is used as a signal processor to provide the AOD with the required driving power and frequency of an ultrasonic field. By adjusting V_i, we can use the diffracted beam to scan the object. We call this beam a *scanning laser beam* (*SL beam)* and the diffractive angle a *scanning angle*.

At the origin of system, a lens focuses the light on the position sensor that is aligned parallel to the *x*-axis and at position *s* along the *y*-axis. If we input a ramp wave to the VCO, the SL beam from the AOD will scan between $\alpha_0+\Delta\alpha$ and $\alpha_0-\Delta\alpha$ as shown in Fig. 1. When α varies from $\alpha_0+\Delta\alpha$ to α_0, the SL beam reflects from M_3, and then scans the object from point A to point B. According to the law of reflection, this beam can be assumed to originate from O_L. Similarly, when α varies from α_0 to $\alpha_0-\Delta\alpha$, the SL beam reflects from M_1 to M_2, and then scans the object from point B to point A. Again, the beam can be assumed to originate from O_R.

From the lines defined by O_LQ and by QP, we obtain:

$$x = \frac{pc\tan(\theta_L - \Delta\alpha_1) + pd}{p\tan(\theta_L - \Delta\alpha_1) + s}, \tag{1}$$

$$y = \frac{sc\tan(\theta_L - \Delta\alpha_1) + sd}{p\tan(\theta_L - \Delta\alpha_1) + s}. \tag{2}$$

where p is the distance that the spot shifts on the position sensor, c is x-coordination of O_L, d is y-coordination of O_L, and s is the distance between lens and position sensor. Similarly, from the lines defined by O_RQ and by QP, we obtain

$$x = \frac{pa\tan(\theta_R - \Delta\alpha_2) - pb}{p\tan(\theta_R - \Delta\alpha_2) - s}, \tag{3}$$

$$y = \frac{sa\tan(\theta_R - \Delta\alpha_2) - sb}{p\tan(\theta_R - \Delta\alpha_2) - s} \tag{4}$$

where a is x-coordination of O_R and b is y-coordination of O_R. We assume here that the system parameters s , θ_R, and θ_L, and the coordinates $O_R(a,b)$ and $O_L(c,d)$ are calibrated before measurement. We extracted data by "minimum sample space" criterion. Namely, we compared measured distances between adjacent points obtained by a SL beam from O_R and that from O_L, and then extracted data that has shorter distance. It means that we obtained maximum sample points, so that minimum shadow effects. We use a time-sharing technique in which the position of spots projected from both O_R and O_L are detected by the same position sensor, thus achieving a high signal-to-noise ratio and also making the system compact.

We confirmed the applicability of the 2DS method by using it to measure the cross-sectional shape of a 7.5-mm-diameter half-ball button. We attached the button to a piece of cardboard and measured the cross-sectional shape of it. Figures 2a~2c show the results measured by a SL beam from O_R, from O_L, and from O_R and O_L alternately, respectively. These results clearly show that the shadow effects from the separate beams (Figs. 2a and 2b) were reduced by using this 2DS method (Fig. 2c).

This method reduces the shadow effects caused by the scanning beam not being able to reach the object and by the position sensor not being able to detect the spot. Using a time-sharing technique, in which the spots projected by the SL beam from two directions are detected by the same position sensor, generates a high signal-to-noise ratio while making the system compact.

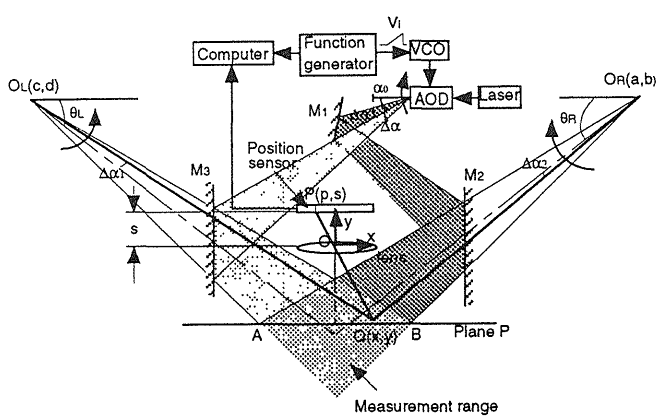
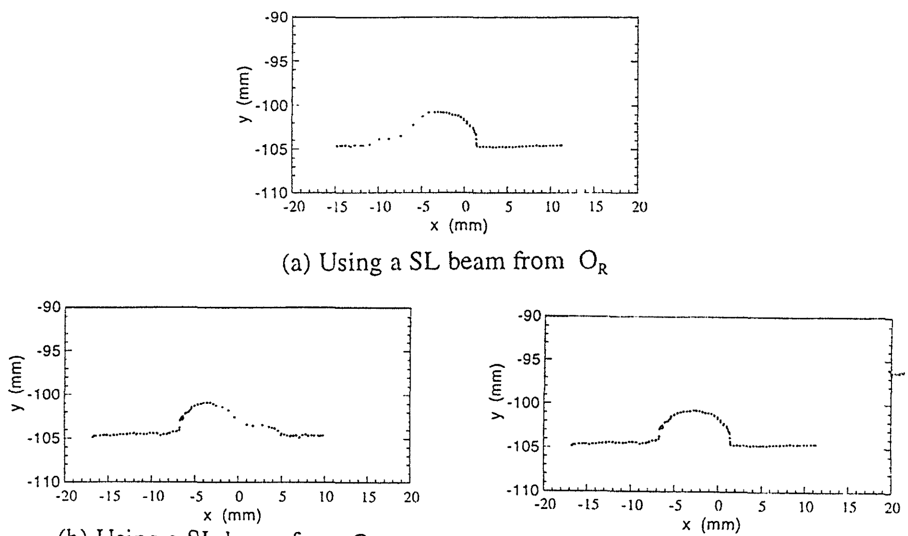


Fig. 1 Configuration of the two-directional scanning (2DS) method



(a) Using a SL beam from O_R

(b) Using a SL beam from O_L

(c) Using 2DS method

Fig. 2 Shape measurement of a hald-ball button