Dimensional Metrology by Digital image Processing using Labview

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Abstract: ***Ring gauges are measured using vernier caliper, inside micrometer, precision coordinate measuring machine, length measuring machine (horizontal metroscope) in order of accuracy required and quality of the ring gauge. The accuracy obtained with these devices varies between 0.020 mm and 0.0005 mm. However, all these instruments/ devices are traceable to the length standards through gauge blocks. The necessity for such a method is mainly due to modern production technology which is taken more and more art to the hands of specialized metrologists. The latter asks for a high degree of confidence in the availability of the measuring instruments, which for economic reasons often have to work near their performance limits. An attempt has been made to measure the precision ring gauges directly by image processing technique with conic kernels and their orientation, which gives a more accurate non contact apparatus. This paper presents a general framework for analyzing structural asymmetry of ring gauge.***

Keywords: Conic kernel and steerable filters, Spatio – temporal, 3 D orientation

1. Introduction

A large variety of methods for calibration and measuring dimensions of Ring Gauge, Plug Gauge Length bars have been suggested and applied to furnish comprehensive information of the measurement but require much time, efforts and skill. Huda M. Jawad et al [1] developed measuring object dimensions and its distances based on Image processing. Dipti Nilesh Aswar [2] developed the device for measuring the dimensions of mechanical component using image processing techniques, Measurement.. He introduced automated process for measuring the dimensions of mechanical component. The proposed method includes image pre-processing techniques, edge detection technique, hough transform technique for circle detection and stereo vision concept is used for hole depth measurement of mechanical component. Bin Li [3] developed geometric dimension measurement system of shaft parts based on machine vision. Tonghai Wu [4] developed Bearing defect inspection system based on machine vision. Yunfan Wang et al [5] developed rotational speed measurement through digital imaging and image processing. M Ricci et al [6] developed Magnetic imaging and machine vision NDT for the on-line inspection of stainless steel strips. En Hong eta al [7] developed Non-contact inspection of internal threads of machined parts. There is still lacking of multipurpose method so far which is easy to use, quick, economical and can give better uncertainty of measurement [8]. Among these, non-contact optical systems have attracted well-deserved attention because of their particularly good adaptation to specific applications. In a number of branches of industry, knowledge of the diameter of small holes is an essential prerequisite for the quality of the products to be manufactured specially in the industries like wire, textiles, car etc. In addition, the metrological trace ability requirements as per ISO guidelines must be compiled with [9]. The necessity for such a method is mainly due to modern production technology that is taken more and more art to the hands of metrologists and integrated into the manufacturing process. The latter asks for a high degree of confidence in the availability of the measuring instruments, which for economic reasons often have to work near their performance limits.

We are introducing a new 3D kernel of 3D orientation for dimension measurement of ring gauges. In the Cartesian coordinates, the kernel has a shape of a truncated cone with its axis in the radial direction with very small angular support. In the local spherical coordinates, the angular part of the kernel is a 2D Gaussian function. A set of such kernels is obtained by uniformly sampling the 2D space of azimuth and elevation angles [9-10]. The projection of local neighborhood on such a kernel set produces a local 3D orientation. The kernel's local support enables the resulting spatio-temporal analysis to possess higher orientation resolution than 3D steerable filters. Consequently, maxima and minima can be detected and localized accurately. We describe the experiments, the superiority of the proposed kernels compared to Hough transformation or expectation-maximization detection. Radiometric differences are taken into account through an additive intensity field. We present an efficient multi-scale algorithm for the joint estimation of structural and radiometric asymmetry of ring gauges of different sizes. The initial results are quite satisfactory. More comparable calibration of this method against standard method is in progress. The motivation of our approach is the local detection and estimation of multiple planes in spatio-temporal imagery. In this paper, we focus on the estimation of multiple planes from the spatio-temporal orientation aspect. It is pointed out that dimensions of 3D objects can be measured from spatial-temporal orientation.

2. Theory

The algorithm for calculating ring guage dimension is based on Hough Transform and Conic Kernel. **Modified Hough transform circle detection:** Images with edges are further processed for circle extraction using modified Hough transform. The Hough transform can be used to determine the parameters of a circle. A circle with radius R and center (a, b) can be described with the parametric equations

$y = R\cos(\theta) + b \; z = R\sin(\theta) + c$

The traditional Hough Transform is to transform the feature points into the parameter space. When the angle θ sweeps through the full 360 degree range the coordinates points (x, y) trace the perimeter of a circle. If an image contains many points, some of which fall on perimeters of circles, then the job of the search program is to find the parameter triplets (a, b, R) to describe each circle. The fact that the parameter space is 3D makes a direct implementation of the Hough transform technique more expensive in computer memory and time. Modified Hough transform is used which improves the performance of the Hough transform by making algorithm to work for the specific range of the radius. **Curve fitting** Feature identification approach to solve problem correspondence. For calculating depth of the hole first we need to locate hole's top and bottom edges from camera lens center. Top edges of the hole get identified as circle in both left and right image. Use centres of these circles as reference point for calculating disparity for hole top edges. Bottom edges of hole get identified as circle in left image whereas bottom edges look like elliptical arc/curve in right image. Use the center point of circle and center point of the curve as reference point for calculating disparity for hole bottom edges. Hough Transform has already identified the circles and located their centers. Identifying and locating the bottom elliptical curves corresponding to each hole is difficult problem. Following approach is used.

a) Identifying and locating the bottom elliptical curves
Identifying the contours in the image. Contour is list of pixels or points that can represent a curve in a digital image, in a structured way. Large numbers of contours are detected in image. As large number of the contours are detected we need to identify the possible candidate contours which can fit to elliptical curves of hole bottom. Also these large numbers of contours are filtered for the purpose of the performance improvement and to avoid the false detection[11-14].

The recognition, location, and description of 3D objects from natural light images are often difficult to obtain.In this paper we put forward an approach based on 3D conic kernel.

3. Conic Kernel

There are several equivalent coordinates to represent 3D orientation. They differ in the number and form of orientation variables. For example, a 2D polar angle and an implicit elevations angle (between the polar radius and z-coordinate) are used together to describe 3D orientation in the cylindrical coordinates, while three directional angles, (i.e. three angles between three Cartesian coordinate[3-4]). For orientation analysis, we believe that the orientation variables should be as small as possible to alleviate the complexity of indexing and visualization. Thus, we choose the spherical coordinates in which only two angles (azimuth and elevation) are needed to represent 3D representation.

The input data for plane analysis and measurement can be either the local image derivatives space (i.e. a space coordinated by partial derivatives of images with respect to different axes). They are the same for filtering purpose. For simplicity, we use the same representation $I(x,y,z)$ for both kinds of input data. Here we assume that $I(x,y,z)$ is correctly obtained for every (x,y,z). Thus, the error in obtaining image derivatives or spectrum is not considered. For orientation analysis we start by computing a local spherical mapping on the input data through cartesian coordinate to polar coordinate by following steps

$$I(x,y.z) \rightarrow (r,\theta,\phi),$$

$$\text{when } r = \sqrt{x^2 + y^2 + z^2}, \theta = \arctan(y/x), \; \phi = \arctan(z/\, x^2 + y^2) \quad (2)$$

In order to have fine orientation resolution we use conic kernels with small angular support to sample the orientation space locally these kernels are radial-angular separable. A conic kernel centered at (θ_i, ϕ_j) reads

$$k(\theta,\phi)(r,\theta,\phi) = \frac{G_o^{\theta i,\phi j}(\theta,\phi)}{N_{R_{min}R_{max}}^{(\theta_i,\phi_j)}(r)}$$

Where $N_{R\max,R\min}^{\theta i,\phi j}(r)$ is a compensation function along the radial direction. First we focus on the angular part of the kernel, which is a 2D Gassuian function [4-5] in (θ,ϕ) – space

$$G^{(\theta_i,\phi_j)}(\theta,\phi) = \frac{1}{2\pi\sigma^2}\exp\left(\frac{-(\mu(\theta,\theta_i))^2 + (\phi-\phi_j)^2}{2\sigma^2}\right) \quad (3)$$

As the azimuth angle θ is periodic, we define a $a\mu(.)$ to represent the minimal circular difference between θ and θ_i $(\theta,\theta_i \in [0^o, 360^o])$,

$$\mu(\theta,\theta_i) = \min(|\theta-\theta_i|, |\theta-\theta_i - 360^o|, |\theta-\theta_i + 360^o|)$$

3.1 Conic Kernel response to 3D planes

In the 3D coordinate systems, a plane passing through the origin (0,0,0) with a unit normal vector
$N = (n_1, n_2, n_3)^T$ reads $xn_1 + yn_2 + zn_3 = 0$

In order to represents a plane with (θ,ϕ) , we convert the Cartesian coordinates into spherical coordinates
$(x,y,z) \rightarrow (r,\theta,\phi)$ and $(n_1,n_2,n_3) \rightarrow (1,\theta_n,\phi_n)$.

After dropping out (r) we obtain an equation with variable θ and ϕ

$$\cos(\phi)\cos(\phi_n)\cos(\theta-\theta_n) + \sin(\phi)\sin(\phi_n) = 0$$

After horizontal and vertical planes with normal parallel to the co-ordinate axes, their corresponding representations in the (θ,ϕ)- space are straight lines. In 3d analysis, we usually encounter titled planes which turn into harmonic curves with different amplitudes and phases in the (θ,ϕ) -

space . The normal vector of each plane i.e. θ_n, ϕ_n is related to the extreme point θ_m, ϕ_m on corresponding curve as follows

$$\theta_n = \theta_m + 180^0$$

$$\phi_n = 90^0 - \phi_m$$

The titled phases parameters (u, v) can then be estimated using θ_n and ϕ

$$u = \cos(\theta_n)\cot(\phi_n)$$

$$v = \sin(\theta_n)\cot(\phi_n)$$

Further, each harmonic curve has two zero- crossing points on the θ axis with a distance of 180^0 and θ_m lies exactly in the middle of two zero-crossing points[12-13].

The extra geometry constraint is very useful in determining the number of points. Further, each harmonic curve has two zero-crossing points on the θ axis with a distance of 180^0 and θ_m lies exactly in the middle of these two zero-crossing points. This extra geometry constraint is very useful in determining the number of planes automatically as well as in obtaining reasonable initial values of plane parameters. In practice, we obtain a set of points in the $(\theta, \phi)-$ space. Extracting the parameters θ_n, ϕ_n form these points is then a standard fitting problem. For a simple curve, least square estimation is applicable [13-14].

4. Experiment and Result

The experimental set up consists of CCD camera and image grabbing card installed on Pentium Computer. Front and back illumination is provided to obtain proper illumination through the 3d object. The experiment is done on two standard ring gauge as shown in fig.1 and fig.2. It is analysed and measurement is done by the program developed in Labview . The analyzed image is shown in fig.1(b) and fig.2(b). The numerical data are obtained by scaling figure (1b) and figure (2b).

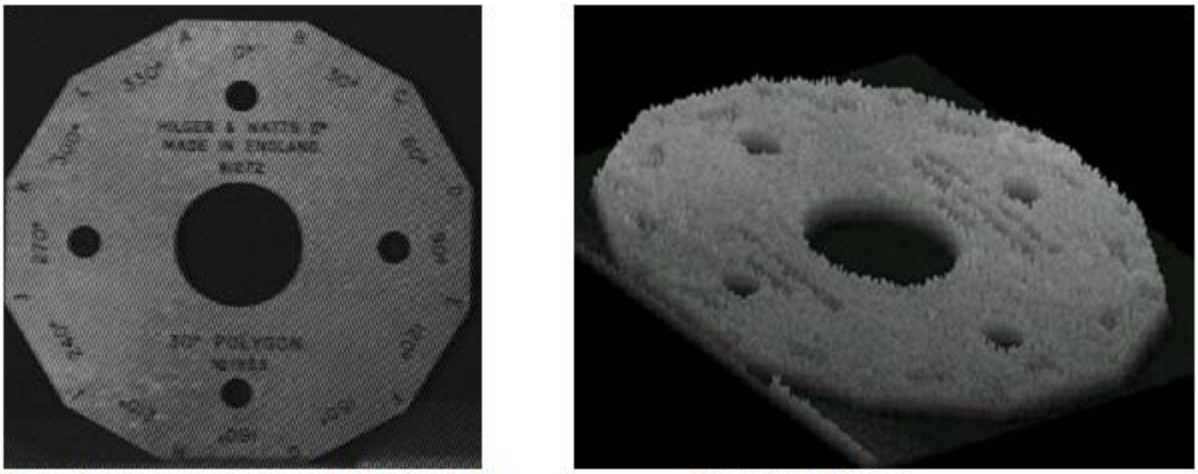

Figure 1: (a) Original image of Ring Guage1 (b) Analyzed image

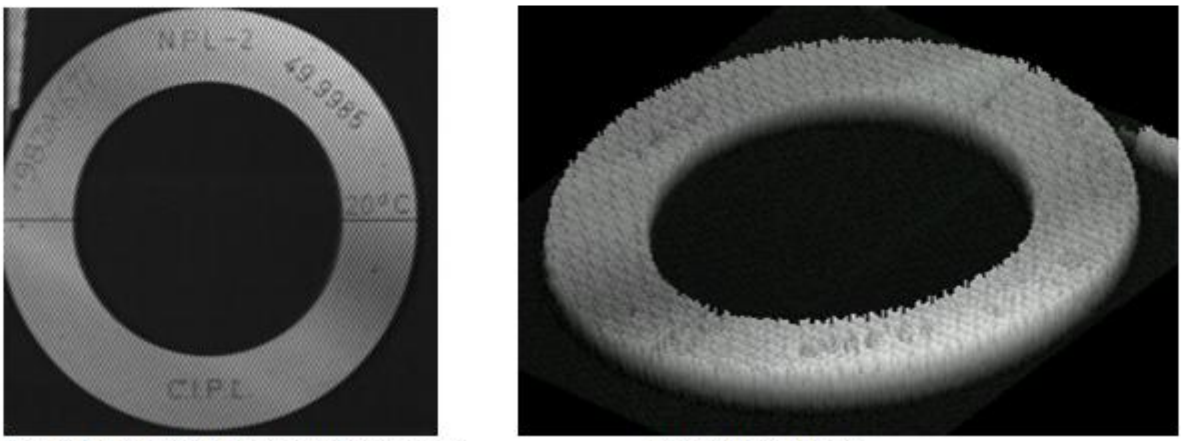

Figure 2 (a) Original image of Ring Guage2 (b) Analyzed image

5. Conclusion

Important measuring tasks in dimensional metrology for mechanical system have been identified in the non-contact optical systems. A non contact device have been developed for calibration and measurement of dimension of ring guages. Initial results are quite satisfactory and show the 3D-orientation measurement. The results obtained by image processing system is compared with the results obtained using optical profile projector. It is seen that repeatability in our scheme is better than the standard method (using optical profile projector). In our case standard deviation comes to be

0.0006mm and as compared to 0.001mm in the case of profile projector. Uncertainty of measurement in our case is ± 0.0001mm. It can replace the classical measurement techniques.

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