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Displacement Measurement of Interior Wall of Hollow Cylinder by Digital Image Correlation Method Using Fisheye Lens

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Abstract

In this paper we present a method to inspect the interior wall displacement and strain of hollow cylinder by digital image correlation (DIC) method using fisheye lens. The fisheye lens provides a long depth of field and wide angle of view that make it suitable for our work. We also present the relationship between incident ray from object space and image position on the image plane. We transform omnidirectional image into real size panoramic image. The real size panoramic image can be analyzed by the DIC method to extract the in-plane deformation and strain field. The displacement can also be computed from contour maps obtained before and after the rigid body rotation or translation. Furthermore the experimental setup is simple and compact size which makes it possible to use this method into automotive optical inspection and nondestructive testing.

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Keywords: Fisheye lens, Omnidirectional image, Panoramic image, Digital image correlation.

Nomenclature

(C_x, C_y) The centre of circle.
R_{min} The inner radius of the omnidirectional image.

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R_{mam}	The outer radius of the omnidirectional image.
(U, V)	The displacement fields in X and Y directions.
Θ	The rotating angle about a z-axis going through their centre of rigid body rotation.

1. Introduction

Full-field optical measuring is increasingly being popular measurement tools, such as digital image correlation (DIC) method. DIC method is an optical metrology that utilizes sub-pixel registration algorithms for accurate measurement of full-field deformation [1]. In the early 1980s, its invention is developed [1.2]. 2D-DIC is used to get in-plane deflection measurements. 3D-DIC provides the full 3D measurements [3], which are critical for accurately measuring true strains in these highly 3D materials and loading responses. For example, a multi-camera DIC system with semi-circular configuration is used to 3D surface reconstruction [4].

The capacity to capture large fields of view is often investigated in the vision systems. Generally, in order to capture the large view of scene need sequence images or multiple cameras for image stitching. As the camera's field of view is always smaller than large object, stitching pictures into panoramic mosaics existed since the beginning of photography. But those instinct and extinct camera parameters and camera model are also considered a complex issue of image stitching.

To avoid the complex issue of image stitching, a new omnidirectional methodology by using fisheye lens is presented. Only one-shot can capture the image in large field of view. Unlike standard lens, fisheye lens is an ultra-wide angle lens that provides very wide angle of view (at least 180°), which creates a wide panoramic or hemispherical image [5.6]. Fisheye lenses can provide a large area of the surrounding space by an omnidirectional image, and we can transform it to obtain the panoramic image. According to the pinhole camera model, we can find the relationship between incident ray from object space and image position on the image plane. By using the pinhole camera model, the real size panoramic image can be obtained. Therefore we can detect the in-plane deformation and strain field on the whole interior wall of the hollow cylinder. The panoramic camera has been widely used. For example, the catadioptric cameras based on parabolic or hyperbolic mirrors produce SVP panoramas [7].

In this study we present an omnidirectional imaging system which is integrated with fisheye lens, CCD camera and panorama image processing. The system using a simple idea that taking the inner and outer circle in the effective area of omnidirectional image and transform it into real size panoramic image. To verify the feasibility and the precision of our work, we take a few photo of the interior wall of hollow cylinder at few different positions. And transform the omnidirectional image into real size panoramic image. After that, we analyzed those images with digital image correlation (DIC) method to extract the in-plane deformation and strain field. The deformation can also be computed between contour maps obtained before and after the rigid body rotation and translation.

1. Experimental Theory

1.1. Digital Image Correlation Method

The DIC method uses the characteristic speckle pattern of a test specimen; the deformation of assigned points can be determined by searching most-likely sub-image from the corresponding deformed sub-image [8]. As shown in Fig. 2, in the reference image, there is a sub-image of pixels centered at the point . The matching procedure is to search the corresponding sub-image of the deformed image centered at the point . Algorithms, such as the predefined cross-correlation and the sum of squared differences criterion can be used to calculate the similarity between the sub-image in reference image and possible mapping sub-image in the deformed image [9].