Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 79 (2014) 466 – 478

Procedia Engineering

www.elsevier.com/locate/procedia

37th National Conference on Theoretical and Applied Mechanics (37th NCTAM 2013) & The 1st International Conference on Mechanics (1st ICM)

Rectify Oblique Multi-view Image with a Planar Calibration Target for In-plane Displacement and Strain Fields

Chi-Hung Hwang[a], Wei-Chung Wang[b], Yung-Hsiang Chen[a,b*]

[a]*Instrument Technology Research Center, National Applied Research Laboratories, No.20, Yanfa 6th Rd., East Dist., Hsinchu City 30076, Republic of China (Taiwan)*

[b]*Department of Power Mechanical Engineering, National Tsing Hua University, No.101, Sec. 2, Kuang Fu Rd., East Dist., Hsinchu 30013, Republic of China (Taiwan)*

Abstract

In this paper, we demonstrate a 3D projective transformation to rectify oblique multi-view image with a planar calibration target for in-plane displacement and strain field measurement. The multi-camera semi-circular DIC system captures oblique multi-view image from three different view angles. Produce front view image from oblique projective image. The front view image can be analyzed by the DIC method to extract the in-plane displacement and strain field. The displacement can also be computed from contour maps obtained before and after the in-plane translation motion of rigid body. The experimental results show the measurement method is implemented to rectify oblique multi-view image for in-plane displacement and strain field.

Selection and peer-review under responsibility of the National Tsing Hua University, Department of Power Mechanical Engineering

Keywords: Planar calibration target, In-plane displacement, Strain field, Image projective transformation, Digital image correlation, Multi-camera.

Nomenclature

C1, C2, C3	captured image of camera 1, 2, 3
θ_{C1}, θ_{C3}	camera pivot angle of camera 1, 3
Ω_{C1}, Ω_{C3}	camera travel angle of camera 1, 3

* Corresponding author. Tel.: +886-3-5779911-570; fax: +886-3-5773947.
E-mail address: yschen@itrc.narl.org.tw

Selection and peer-review under responsibility of the National Tsing Hua University, Department of Power Mechanical Engineering
doi:10.1016/j.proeng.2014.06.368

(U,V)	displacement fields in X and Y directions
(U_X, U_Y, V_X, V_Y)	first order gradients of displacement
C_{NSSD}	sum of squared difference criterion (NSSD)
F_i	gray value in the reference sub-image
G_i	gray value in the deformed sub-image
$(\varepsilon_{xx}, \varepsilon_{yy}, \varepsilon_{xy})$	strain fields in X and Y directions

1. Introduction

Full-field optical measuring is increasingly being popular measurement tools, such as digital image correlation (DIC). DIC 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. In this paper, a multi-camera system with semi-circular configuration is proposed. With aids of the geometric constrain; the system is expected to take and reconstruct images with less calibration at filed. The system is also target to combine with DIC method to extract displacement/deformation and strain from reconstructed time-sequential images. Hence, the reconstructed error of the system is limited to meet the requirement for integrating digital image correlation method for deformation and strain analysis.

3-D reconstruction of the scene is need camera calibration. The most important in camera calibration is find camera model. Tsai proposed two calibration methods, where the pose of the 3-D or planar target with respect to the camera is being estimated [4-5]. Zhang’s approach [6] allows free motion of a known planar calibration target. Their formulation obtains an approximate solution for both the target pose and the camera parameters from the readily obtained object to camera hymnographies, by means of rigid body motion constraints. The calibration target is used to determine camera parameters, that included interior orientation of a camera and camera positions are exterior orientation of a camera. Camera calibration is the important process of estimating the calibration parameters, which can calculate an actual camera model.

In this paper, a 3D projective transformation to rectify oblique multi-view image with a planar calibration target for in-plane displacement and strain field measurement are introduced and discussed.

2. Measurement system

Fig. 1 shows the semi-circular constrained multi-camera DIC system. As shown in Fig. 1(a), a three-camera imaging system implemented with the semi-circular frame was built and used as imaging platform [7]. The center of the semi-circular frame is three optical axes of the cameras were designed to intersect. For discussing convenience, the cameras are labeled as C1, C2 and C3, from right to left were labeled in Fig. 1. The system consists of three cameras, four stepper motors with drivers, a semicircle camera frame, and image processing unit. The camera frame is semicircular with radius is 50 cm. Among all three cameras, C2 is defined as the reference camera and fixed at the middle-point of circular frame. C2 and C3 are mounted on the movable camera holders make C1 and C3 cameras can move along frame clockwise and contra-clockwise respectively. The range a camera can move along the frame is defined as camera traveling angle and can be labeled as Ω_{C1} and Ω_{C3}. Traveling angle $\Omega c1$ is defined as C1 moving clockwise away C2. Similar, Ω_{C3} is traveling angle defined as C3 move contra-clockwise away C2. The cameras rotate with respect to their fixed points on the camera holders and define the rotation angles as the pivot rotation angles in θ_{C1}, θ_{C3}.

The frame is used to support the cameras and confine the cameras to move along a circle. The cameras can be easily aligned with the geometric center of the frame as the reference point. Meanwhile, the system was designed to be intra-camera distances and angles adjustable with stepping motors. Moving cameras along the frame makes