CHAPTER

6

PARTICLE IMAGE VELOCIMETRY IN GEOTECHNICAL ENGINEERING

Abideen Adekunle Ganiyu, Ahmad Safuan A. Rashid, and Mohd Hanim Osman

6.1 INTRODUCTION

Particle image velocimetry (PIV) was originally developed in the fluid mechanics field to determine the velocity of fluid flow that is seeded with small particles. In recent years, the method has been utilised in geotechnical modelling using terms such as block matching and digital image correlation. The adoption of PIV by geotechnical researchers provides an innovative technique for the visualisation of failure mechanisms and the quantification of soil–structure interaction in geotechnical physical models and field monitoring tests (Ganiyu, 2016).

Particle image velocimetry is an image-processing technology that computes fields of incremental displacement by comparing two successive images through a precise identification of several minute parts in image space (pixel) which are later converted to object space (in millimetres). The performance of an image measurement system can be assessed by errors linked with its accuracy, precision, and resolution. Accuracy is the systematic difference between a measure's quantity and its true value. Precision is the random difference between multiple measurements of the same quantity while the resolution is the smallest interval that can be present in a reading. The accuracy and precision of PIV at reasonable resolutions have been established, however, precise calibration of the PIV algorithm and the camera are essential in order for the system to process the images perfectly and produce good results.

6.2 PRINCIPLES OF PARTICLE IMAGE VELOCIMETRY OPERATION

The methodology of dealing with images to assess the displacement between a pair is described below. The first image is partitioned into a lattice of test patches. Each test patch, I_{test}(U), comprises a trial image matrix, I(U), of size L X L pixels. To obtain the displacement of the test patch between images 1 and 2, a search patch I_{search}(U + s) is mined from the latter image. This search overhangs the test patch by a gap s_{max}, in the *u* and *v* paths, to delineate the zone in which the test patch is to be looked up (Figure 6.1). The cross-correlation of I_{test}(U) and I_{search}(U + s) is assessed and standardised by the square root of the sum of the squared values of I_{search}(U + s) over the extent of U dominated by the test patch.

In brief, measuring the displacement of images by PIV involves these steps; determining the area of interest and grid of patches, selecting a patch, translating each patch at 1-pixel intervals over a predefined search zone, evaluating the degree of match over the entire search zone, and evaluating the patch displacement to sub-pixel precision by spline interpolation in the zone of best match.

The dimension of the search patches selected is crucial as it dictates the expanse of measurement points within the plane of interest and also the accuracy of tracking. Bigger patches are more distinguishable in subsequent images as they produce a more precise correlation peak. The procedure for calculating a single displacement vector is repeated for the entire grid of test patches, producing the displacement field between the image pair (White & Take, 2002).

Subsequent to the displacement tracking in image space, the pixel coordinates of each soil patch are transformed into object space coordinates. Some kind of image correction takes place; this manifests in camera calibration in which the internal camera geometric and optical characteristics are determined. This is followed by the transformation from pixel coordinates to global coordinates. It incorporates corrections for radial/tangential lens distortion, non-coplanarity of the charged couple device (CCD) and object planes, CCD pixel non-squareness and refraction.

GeoPIV is a MATLAB-based module developed specifically for geotechnical applications. In GeoPIV, image processing algorithms are written to apply the PIV principles to the images of soil. It correlates a time-lapse sequence of images to a reference image; a grid of discrete patches is added to each image to track the displacement of these patches (Braim et al., 2016; White & Take, 2002). Stanier et al. (2016) recently developed GeoPIV-RG; an update of GeoPIV, which employs a reliability-guided computation scheme for the PIV algorithm and yields higher precision in measurements.

White and Take (2002) present the following steps for image analysis using GeoPIV software, capturing the images during testing using a digital still camera, defining mesh patches in the first image, setting up a launch file, running the PIV analysis, loading the PIV results, plotting PIV data, and removing wild vectors. A screenshot during the GeoPIV subroutine run is shown in Figure 6.1.

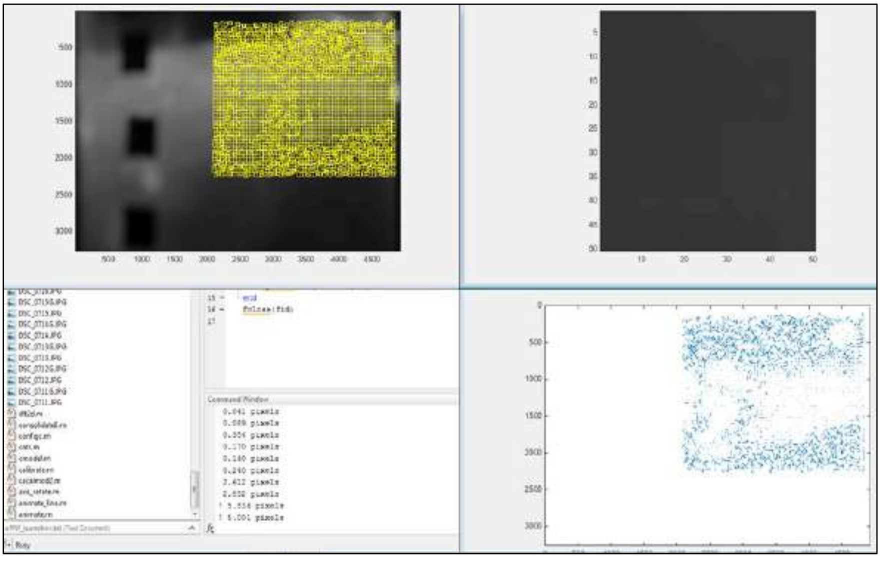

Figure 6.1 Screenshot during 'geoPIV8' subroutine run