NASA Tech Briefs

Official Publication of
National Aeronautics and
Space Administration
Volume 16 Number 1

Transferring Technology
to Industry and
Government
January 1992

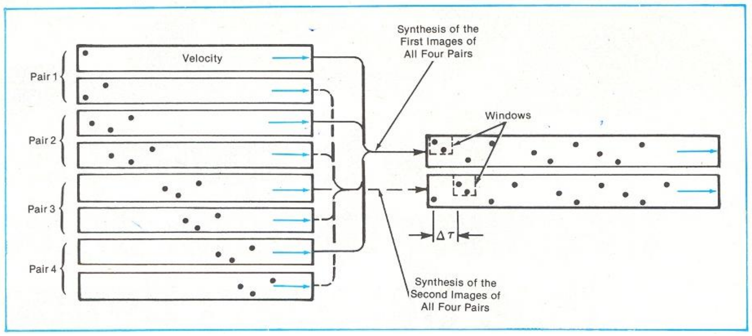
Digital Correlation in Laser-Speckle Velocimetry

A periodic recording helps to eliminate spurious results.

Marshall Space Flight Center, Alabama

An improved digital-correlation process extracts the velocity field of a two-dimensional flow from laser-speckle images of seed particles distributed sparsely in the flow. Some prior methods of laser-speckle velocimetry have involved various combinations of optical and electronic techniques, have tended to be slow, and have required considerable intervention by analysts. A more recent method that led to the present improved method involved the semiautomated digital correlation, on a desktop computer, of speckle images recorded at equal intervals of time. This predecessor method was relatively fast because, unlike methods that included optical techniques, it did not require mechanical scanning of images. The new method, which involves the digital correlation of images recorded at unequal intervals, can be completely automated and, therefore, has the potential to be the fastest yet.

Digital correlation is a method for the recognition of patterns, in which a small portion of a first image is located and identified in a small portion (called the "window") of a second image, which could be distorted and displaced with respect to the first image. In this case, the images are the laser-speckle patterns taken at two slightly different times, and the second pattern is slightly distorted and translated with respect to the first one because of the flow. The resemblance between the second and first images is measured via a coefficient of correlation:



Laser-Speckle Images of seed particles are recorded in pairs, with an equal interval within each pair and unequal intervals between successive pairs. A synthesis of the first images of all the pairs is then correlated with a synthesis of the second images to obtain the velocity field.

$$\boldsymbol{\rho}(m,n) = \frac{\Sigma_x\Sigma_y[f(x,y) - <f>]}{\{\Sigma_x\Sigma_y[f(x,y) - <f>]^2} \cdot \frac{[w(x-m,y-n) - <w>]}{\Sigma_x\Sigma_y[w(x-m,y-n)<w>]^2\}^{1/2}}$$

where $\boldsymbol{\rho}(m,n)$ is the coefficient of correlation for a window centered at coordinates m,n in the second image, $f(x,y)$ is the intensity of the second image at point x,y within the window, $w(x-m, y-n)$ = the intensity of the first image at the corresponding point, $<f>$ is the average intensity of the window portion of the second image, and $<w>$ is the average intensity of the corresponding part of the first image. The position *m,n* for which $\rho(m,n)$ is a maximum is the position at which the second image is considered to match the first image best.

In the basic approach to velocimetry via digital correlation, systematic matches of intensity samples are extracted from a sequence of digitized speckle patterns recorded at different times. Displacements between matched patterns are then divided by the increments of time between exposures to obtain a velocity field.

When the speckle images are recorded at equal intervals of time, periodicity and sparseness in the spatial patterns can give rise to false correlation peaks. To suppress the tendency toward false correlations, images can be enriched and partly randomized. The images are still recorded in pairs with the interval between the first and second images in each pair equal to the interval between the first and second images in every other pair. However, the pairs are recorded at unequal intervals (see figure). An enriched, randomized first image is synthesized by adding together the intensity patterns of the first images of all the pairs. An enriched, randomized second image is synthesized similarly from the second images of all the pairs (see figure). Then the correlation is performed between the synthetic first and second images to obtain a velocity field more nearly free of errors.

This work was done by John A. Gilbert of the University of Alabama in Huntsville and Donald R. Mathys of Marquette University for **Marshall Space Flight Center**. *For further information, Circle 114 on the TSP Request Card.*
MFS-26122