Image Analysis of Full-Field Vibration and Strain Data

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Recent advances in measurement techniques such as digital image correlation, automated photoelasticity, electronic speckle pattern interferometry and thermoelastic stress analysis allow full-field maps (images) of displacement or strain to be obtained easily. This generally results in the acquisition of large volumes of highly redundant data. Fortunately, image decomposition offers feasible techniques for data condensation while retaining essential information. This permits data processing such as the validation of computational models, modal testing or structural damage assessment efficiently and in a straightforward way. The selection, or construction, of decomposition bases (kernel functions) is essential to data reduction and has been shown to produce features, or descriptors, of the full-field image that are effective in reproducing the measured information, succinct in condensation and robust to measurement noise. Among the most popular kernel functions are the orthogonal Fourier series, wavelets and Legendre polynomials, which are defined on continuous rectangular domains, and Zernike polynomials and Fourier–Mellin functions, which are defined on continuous circular domains. The discrete orthogonal polynomials include Tchebichef, Krawtchouk and Hahn functions that are directly applicable to digital images and avoid the approximate numerical integration that becomes necessary with the sampling of continuous kernel functions. In practice, full-field measurements of the engineering components are usually non-planar within irregular domains – neither rectangular nor circular, so that the classical kernel functions are not immediately applicable. To address this problem, a complete methodology is described, consisting of (1) surface parameterisation for the mapping of three-dimensional surfaces to two-dimensional planar domains, (2) Gram–Schmidt orthogonalisation for the construction of orthogonal kernel functions on arbitrary domains and (3) reconstruction of localised image features, such as regions of high strain gradient, by a windowing technique. Further information on shape descriptors and their application to full-field vibration and strain measurements is available in the literature [1-7]

In vibration testing, 3D DIC provides non-contact full-field measurements on complex surfaces whereas conventional methods employ point-wise frequency response functions. A particular case study is that of an irregularly-shaped car bonnet liner (typical of many engineering structures) from which modal properties are determined using responses in the shape-feature space captured by a DIC system. The complex bonnet-liner surface on which the displacement responses are measured is essentially a 2-manifold. It is possible to apply surface parameterisation to 'flatten' the 3D surface to form a 2D planar domain. Image processing techniques are defined on planar domains and used to extract features from surface displacement patterns. An adaptive geometric moment descriptor (AGMD), defined on surface parametric space, is able to extract shape features from a series of full-field transient responses under random excitation. Approximately 14 thousand data points of raw DIC measurement are represented by 20 shape feature terms at each time step. Shape-descriptor frequency response functions (SD-FRFs) of the response field and the loading field are derived in the shape feature space. It is seen that the SD-FRF has a similar format to the conventional receptance FRF. The usual modal identification procedure is applied to determine the natural frequencies, damping factors and eigen shape-feature vectors from the SD-FRF. Natural frequencies and mode shapes from a finite element (FE) model are correlated with the experimental data using the cosine distance between the shape feature vectors with 20 terms. There are numerous benefits of using image decomposition to analyse 3D DIC measured data, including the determination of the FRF of any point on the specimen by the use of the full-field shape features.

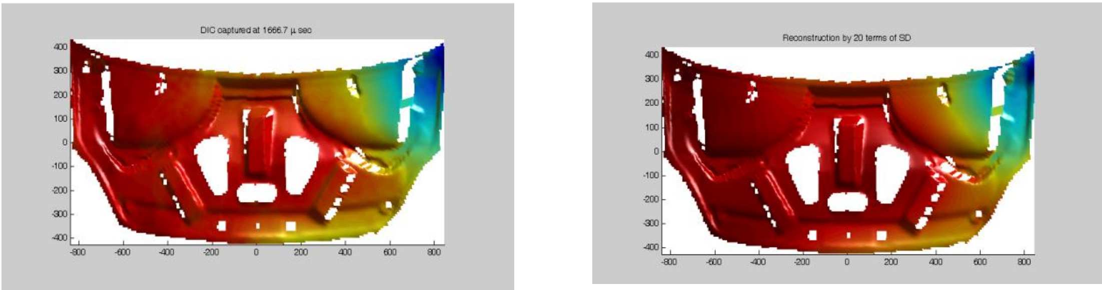

Figure 1. Examples of Measured and Reconstructed Vibration Images

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