Special session - Supporting simulations with strain measurement (CEN WS71)

193 Generalised decomposition of strain fields in complex components

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Abstract. A technique is demonstrated for decomposing data obtained from experiments and simulations of components with complicated geometries. The decomposition technique removes the need for interpolating data and has been built into a graphical software package to simplify the process of comparing experimental and simulation data.

Introduction

Load bearing structures typically have complicated geometries. One of the causes of this complexity is weight optimisation, where unnecessary material is removed from a design. As demand for greener vehicles increases, the levels of geometric complexity is likely to increase. This presents difficulties when validating computer simulations in solid mechanics, as it is difficult to translate simulation data and experimental data into a common coordinate system and array of data points. These difficulties are compounded when capturing the experimental data, as the presence of other components may obstruct the view of the structural element that is of interest. This means that experimental data may not be available at all the locations that simulation data is available.

Orthogonal decomposition is a technique for projecting the experimental and simulation data onto a set of orthogonal polynomials [1], resulting in a set of coefficients that indicate how much of each polynomial is required to reconstruct the original dataset. This has the benefit of eliminating issues associated with differing density of arrays, as well as dimensionally reducing the data. However, complex geometries create problems when using orthogonal decomposition because polynomials can only be orthogonal over a particular domain, such as a rectangle for Chebyshev polynomials or a disk for Zernike polynomials. If the component has a geometry that is not the same as the domain of the polynomials then the simulation or experimental data associated with that component are difficult to decompose.

A solution to this problem is to modify the polynomials such that they are orthogonal on a domain that is the same shape as the component [2], but this technique requires the experimental and simulation data to be on the same array. It also involves tailoring of the polynomials to the specific shapes and thus requires substantial user input. In this study the approach is simplified such that different arrays of data points can be used for experimental and simulation data with the minimum of effort by the user.

Numerical Method

In previous studies, Gram-Schmidt orthonormalisation has been used to modify polynomials, such that they are orthogonal on irregular shaped domains [2]. This technique is numerically unstable and thus inaccurate when large numbers of coefficients are required to describe the data. In this study, a related but numerically stable mathematical technique called QR decomposition has been used, allowing data to be decomposed into feature vectors using polynomials that are orthogonal for a particular geometry. A convenient feature of the technique is that it generates a simple transform which can be used to convert the feature vectors so that they relate to a common set of polynomials. This means the converted feature vectors can be compared as part of a validation methodology and eliminates the need for interpolation when processing data, even in situations where one dataset contains substantial areas of missing data. It also reduces the amount of expertise required to perform comparisons between simulation and experimental data for complex components.

Discussion

The decomposition technique was applied to experimental and simulation data from two components: a car bonnet liner, which had been impacted by a projectile and is shown in Fig 1, and an I-beam which had been subject to three-point bending. Both components have cut-outs resulting in complicated geometries that are difficult to decompose using conventional decomposition techniques. In both cases, the experimental data was obtained using digital image correlation and thus had a lower spatial resolution than the simulation data from finite element models. The new technique was capable of decomposing the data without interpolating it onto a common array of data points. The user was only required: to select the simulation and experimental data, align it and then specify how many coefficients are required from the decomposition. This is significantly less work than required when using a technique based on the Gram-Schmidt orthonormalisation.

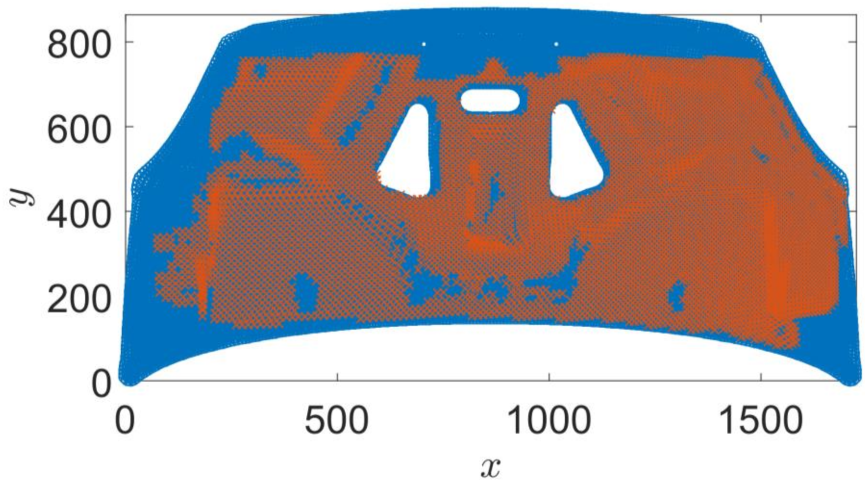

Fig 1: A map indicating the locations at which simulation (blue) and experimental (orange) data is available for a car bonnet liner.

The mathematical techniques used have been incorporated into a software tool with a graphical user interface that can be used to: align the two datasets; determine the overlapping regions at which data is present in both data sets; decompose the data; and finally compare the resulting feature vectors. This software tool is being developed for public release.

Conclusion

A decomposition technique has been developed for processing experimental and simulation data prior to using a validation methodology. The decomposition technique does not require any interpolation of data onto specific data arrays and is simple to use, thus reducing the amount of expertise required for conducting the validation process. This could make it easier to conduct the validation process for high performance aerospace structures, where weight savings often result in complex geometries.

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