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## A PGD variable separation approach for the time regularization of digital image correlation.

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**Abstract** — The aim of this work is to develop a new regularized digital image correlation (DIC) method for time dependent measurements. The unknown time-resolved displacement field is searched for as a sum of products of space and time functions, similarly to the Proper Generalized Decomposition in computational mechanics. It is shown that the space fields are less sensitive to noise as time regularity acts as a physical regularization of the space fields. As a first application, the performance of the proposed method is highlighted on vibration measurement under harmonic excitation in 2D-DIC and stereo-DIC.

**Keywords** — digital image correlation, proper generalized decomposition, vibrations, dynamics

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Dynamic tests are often instrumented by accelerometers, strain gages or laser vibrometers because of their excellent measurement resolution. However, in a context of validation and dialogue with simulations, these tools provide a relatively small amount of point data when compared to the abundance of data resulting from finite element simulations. As a result, the instrumentation of dynamic tests based on digital DIC, and in particular in the field of finite element 2D DIC [1] or even more recent finite element Stereo DIC [2], seems to be an increasingly credible technique, since (a) it is contact-less (no modification of the dynamics of the analyzed structure) and (b) it simultaneously produces a full 3D displacement field expressed on the same mesh as the one which may be used for simulation. The disadvantage is obviously that the measurement resolution is in general not comparable with that of the above mentioned tools [3]. Special attention must therefore be paid to reduce measurement uncertainties when attempting to develop a new DIC method in this context.

In the field of time-dependant problems, DIC usually consists in using camcorders of high speed digital cameras that can provide a series of images ; one (pair of) image(s) for each time step according to the chosen acquisition framerate. This yields a large amount of data that is usually analyzed incrementally, namely each image pair is analyzed independently. Having a temporal resolution much lower than the characteristic time of the observed mechanical phenomena does not really improve measurement uncertainties, even if at this scale, the evolution of the displacements is smooth. In this work, we thus propose to prescribe time-smoothness as a physical regularization technique in the space domain. More precisely, the method starts from a space-time formulation of DIC [4]. Then the displacement is searched for as a sum of product of separated space and time functions over the full time interval[5]. It can be seen as an extension to the space-time domain of the Proper Generalized Decomposition (PGD) method previously proposed in DIC [6] where the dimensions of space were separated in the same way.

As a first application, the case of vibrations under harmonic excitation is studied. A rank one PGD approximation along with a sine time evolution is thus considered for the separated representation. To illustrate the performance of the method, we show below the results obtained when analyzing the eigenmodes of a clamped-free beam using 2D-DIC. In order to measure the first mode shape, a naive *a posteriori* approach is to perform a Least Square (LS) projection of the incrementally measured field on the considered space-time separated representation. We observe that this FEMU-like two-step approach spreads and propagates noise instead of actually reducing it (see Fig. 1(top)). As a remedy, the proposed *a priori* time-space separated DIC resolution is then applied to the same dataset, which enables to drastically alleviate the noise over the whole time interval (see Fig. 1(bottom)). These results demonstrate that the proposed *integrated*-like method acts as a physical regularization technique in the space-time DIC

minimization problem. During the presentation, more complex applications will be treated such as the 3D mode shape measurements using stereo DIC.

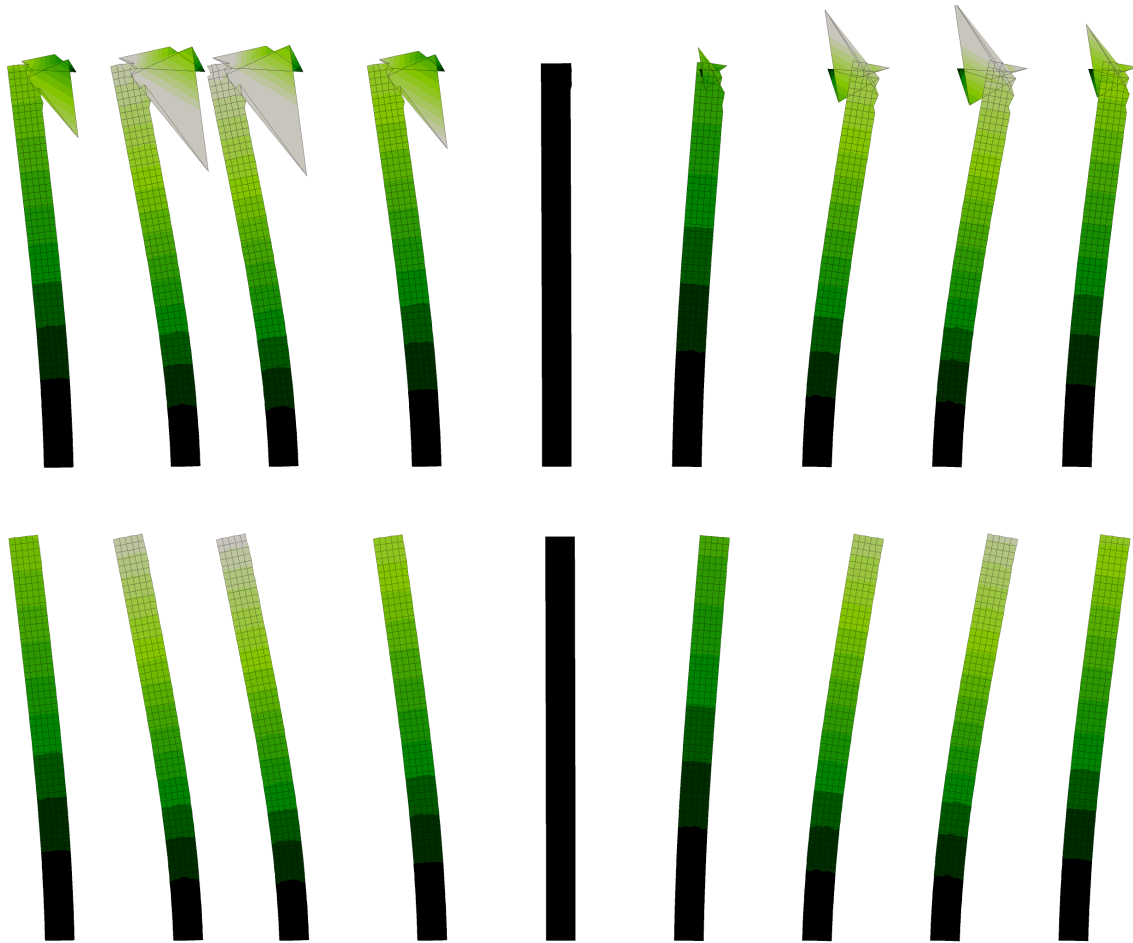


Figure 1: (top)  $LS$ -projection of the incrementally measured displacements and reconstruction of displacements over one period; (bottom) Proposed separated time-space modal measurement reconstructed over one period. (amplification factor: 30).

## References

- [1] Y. Sun, J. Pang, C.K. Wong, F. Su. Finite element formulation for a digital image correlation method. *Applied Optics*, 44:7357-7363, 2005.
- [2] J.E. Pierré, J.C. Passieux, J.N. Périé. Finite element stereo digital image correlation: framework and mechanical regularization. *Experimental Mechanics*, 53:443-456, 2017.
- [3] M.N. Helfrick, C. Niezrecki, P. Avitabile, T. Schmidt. 3D digital image correlation methods for full-field vibration measurement. *Mechanical Systems and Signal Processing*, 25:917-927, 2011.
- [4] G. Besnard, S. Guérard, S. Roux, F. Hild. A space-time approach in digital image correlation: Movie-dic. *Optics and Lasers in Engineering*, 49:71-81, 2011.
- [5] J.C. Passieux, R. Bouclier, J.-N. Périé. A space-time PGD-DIC algorithm: Application to 3D mode shapes measurements. *Experimental Mechanics*, submitted.
- [6] J.C. Passieux, J.N. Périé. High resolution digital image correlation using Proper Generalized Decomposition: PGD-DIC. *International Journal for Numerical Methods in Engineering*, 92:531-550, 2012.