

3D full-field strain measurements in soft tissues using Digital Volume Correlation

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Abstract:

Generally, mechanical problems are studied using two-dimensional measurements of displacement or strain fields on flat (2D) or curved ($2D\frac{1}{2}$) surfaces. In the case of complex problems, however (non-planar loading, complex geometries, or heterogeneous structures), surface analysis can be insufficient, especially for biomechanical research. To explain the phenomena entirely full three-dimensional (3D) fields of displacement, strain, and/or stress are often needed.

In this work, we present a new method to study the strain profile in soft tissues (i.e. arteries, muscle, skin) based on the Digital Volume Correlation (DVC) technique. This is a novel approach for full 3D strain and deformation measurements, already used for synthetic materials, wood or bones. In the case of human soft tissues, images are typically acquired from X-ray Computed Tomography systems, Multiphoton Microscopy, Magnetic Resonance Imaging, or 3D ultrasound technique. The quality of tissue optical signature is the main point to address; a specific robust implementation has been developed to get valid displacement vectors. Finally, our DVC code is a powerful non-intrusive technique for the identification of sub-surface material deformation and is capable of identifying defects, discontinuities or other material characteristics. DVC is also capable of yielding over one million displacement vectors per volume image pair.

To show how the proposed technique could be implemented, we quantified the heterogeneous strain distribution in the human ascending thoracic aortic aneurysm (ATAA) at various levels of pressure. The preliminary results demonstrate that the proposed technique can be used as a valuable tool to assess the mechanical properties of soft tissues. Additional investigations are necessary to develop a practical approach to quantify the stress field of the sample and will be the subject of future work.

Keyword optical technique: Digital Volume Correlation, X-ray Computed Tomography systems, Multiphoton Microscopy, Magnetic Resonance Imaging systems, 3D ultrasound technique

Keyword application: biomechanical analysis, strain measurements, displacement measurements