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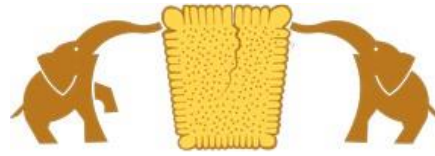
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3D Dynamic Displacement Full-Field Measurement by Optical Slicing Tomography and Digital Volume Correlation in gelatin samples: Data for Analysis by (Magnetic Resonance) Elastography

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Abstract — The aim of this work is to provide 3D dynamic displacement measurement of harmonic loading for comparison with Magnetic Resonance Imaging (MRI) methods. A soft cubic gelatin sample is monitored and loaded by a fast-acquisition setup that includes a piezo actuator and a translatable laser beam. Displacement fields are measured by Digital Volume Correlation and the viscoelastic properties fields are identified using a Finite Element Model Updating (FEMU) method.

Keywords — DVC, 3D dynamic measurement, harmonic loading, optical tomography, elastography

Introduction

Magnetic Resonance Elastography (MRE) is a modality that allows the mapping of the mechanical properties of soft tissues from Magnetic Resonance Imaging (MRI) data. This paper presents an optical tomography setup specially developed to measure 3D harmonic displacement fields by Digital Volume Correlation in homogeneous and heterogeneous samples made of gelatin. Previously, we have developed two optical tomography devices, one with a slicing by translation (OST [1]) and a faster version with rotational slicing (ORST [2]). We have adapted the first device and made a new dedicated device to be able to study a harmonic solicitation up to 100Hz. In this paper, we present the samples, the setup, the image acquisition procedure and the displacement measurement process. In the presentation, we will show the acquired 3D displacement fields measured on homogeneous and heterogeneous samples with a focus on the identification of the viscoelastic properties fields.

Methods

Laboratory gelatin samples are cast in a transparent box. Their shape is a parallelepiped with a basis of 100x100mm² and a height of 90mm. The gelatin concentration is 4.8% gelatin per water weight, which approximately corresponds to a 2 kPa modulus. The heterogeneous samples include a stiffer 1 cm radius spherical inclusion at the center. Particles of white polyamide (150 μ m diameter) are added during sample preparation. A 3D speckle is obtained by scattering light from a planar laser beam generated by an optical setup (Figure 1-a). This setup is composed by two convergent lenses (to allow filtering of the laser beam) followed by a cylindrical lens creating the planar laser beam. The beam is translated by a motorized translation stage in order to scan the whole sample. A high-speed camera is set perpendicularly to the beam and records the scattered light emitted by each illuminated slice with an exposure time of 1/1000s. A volume is generated by the juxtaposition of 940 slices of 1024x1024 pixels with a resolution of 120 micrometers per voxel. Samples are loaded by a harmonic displacement applied on the lower basis of the sample by a piezo actuator with a frequency of about 20Hz. 20 volume images are recorded during a period of the harmonic loading (figure 1-b). An Arduino card is used to synchronize the camera and the translation stage according to the loading frequency. Displacement fields are measured by Digital Volume Correlation parallel homemade software (CorreVol [3], 20 voxels grid step and a square subset with 31 voxels side). A statistical analysis on static images gives an uncertainty of displacement measurement equal to 0.03 voxel along x and y directions (in a slice) and 0.08 voxel along z, the scanning direction.

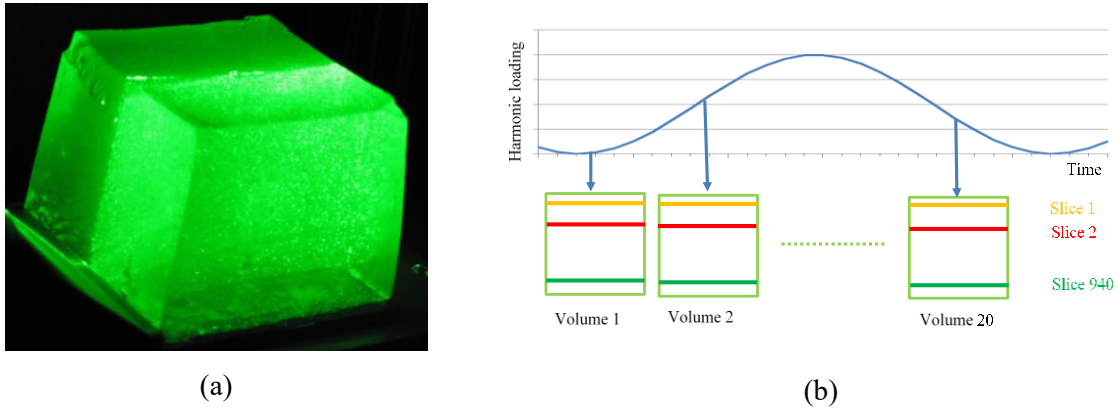


Figure 1: (a) Gelatin sample lightened by the plane laser beam, (b) Recording of different volumes

Results and Discussions

Figure 2 gives the first results obtained on a homogeneous sample and on a heterogeneous sample with a stiffer spherical inclusion. Displacement fields along x , the direction of harmonic sollicitation, are shown in the middle slice of the volume.

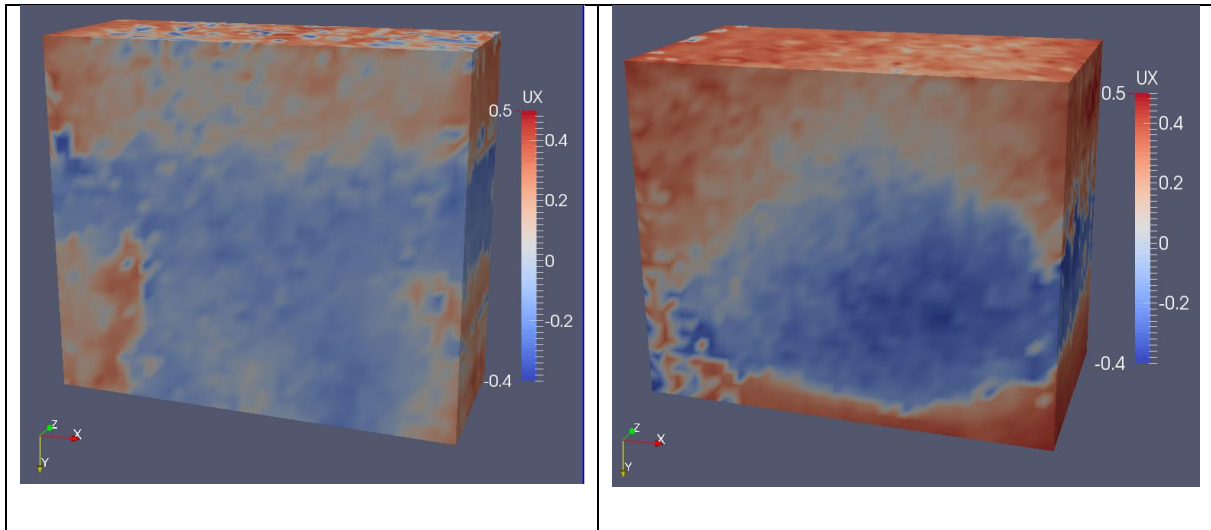


Figure 2: 3D displacement fields (voxel) for step 7 (a) homogeneous sample (n°8, 14.7Hz), (b) heterogeneous sample (n°14, 13.9Hz)

The displacement fields are filtered using harmonic functions in order to increase the signal to noise ratio. The resulting data are then used to identify the field of viscoelastic properties using a Finite Element Method Updating approach [4]. The robustness and the resolution of the identification approach will be discussed in the presentation.

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