ESTIMATION OF THE BIOMECHANICAL PARAMETERS OF THE HUMAN LIVER AVOIDING INVASIVE MEASURING METHODS

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Introduction

Location of liver tumours is crucial in some treatments of liver cancer. The liver is deformed due to the patient breathing, patient positioning, etc. Finite Element (FE) modelling of the liver deformation could allow the location of the tumour if we are able to establish the boundary conditions and the physical properties of the liver, which is not an easy task. This paper describes a process to obtain the biomechanical parameters of the liver avoiding invasive measurements of its mechanical response.

Methods

An ex vivo human liver was placed in an artificial human torso that recreates the respiratory liver motion. Two CT studies were performed equivalent to the total inhalation and total exhalation of the human breathing process. Simpleware 4.2 was used to obtain both FE meshes. Afterwards, a point set registration algorithm, the Coherent Point Drift (CPD) [Mironenko, 2010], was used to obtain the boundary conditions of the external nodes of the liver FE mesh. The set of external nodes from the liver in exhalation (source) were iteratively compared to the set of external nodes of the liver in inhalation (target). Afterwards, FE simulations were carried out using the above-mentioned boundary conditions within an optimization routine in order to estimate the mechanical properties of the liver. In order to validate the method, a simulated target liver was used in this work where the model parameters were taken from the literature [Martínez-Martínez, 2012b].

Genetic Algorithms were used to find the biomechanical parameters of the Ogden model (Eq. 1) using as objective function a modified version of the Geometric Similarity Function (GSF) presented in [Martínez-Martínez, 2012a].

$$W = (\lambda_1^{-\alpha}+\lambda_2^{-\alpha}+\lambda_3^{-\alpha})\mu/\alpha + (1/d)(J-1)^2 \qquad (1)$$

GSF compares the voxelized FE mesh of a synthetic tumour (a marble introduced inside the liver) from the target liver to the synthetic tumour from the source liver. GSF was formulated using the Jaccard coefficient (JC) and the modified Hausdorff distance (MHD). The modified version of GSF function presented in this work was formulated as follows:

$$GSF = \ln\big((1-JC)MHD\big) \qquad (2)$$

Results

The error committed by Genetic Algorithms regarding to the Ogden parameter estimation was 4.57% for μ and 2.56% for α.

Discussion

The results seem acceptable taking into account that the variability among the mechanical response of several samples from the same liver is around 30% [Martínez-Martínez, 2012b]. The results also show that the modified version of GSF is a very appropriate function to estimate the parameters of the biomechanical models.

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