057 AN INVERSE DEFORMATION METHOD FOR THE VISUALIZATION OF REAL-TIME 3D LUNG DYNAMICS.

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Aims: Physically accurate simulation of 3D lung dynamics is an effective tool for guidance in clinical maneuvers. Technical advances in medical imaging techniques have led to the availability of 3D high-resolution lung models. The main focus of our research is to simulate a patient's normal and patho-physical lung dynamics using physically based deformation methods. However, for accuracy and smoothness in simulation, physically based deformation methods are required to deform lungs using human subject specific elastic parameters. Such estimations may also be an early indicator for patients' disease states such as COPD and tumor. The focus of this paper is on the estimation of elastic tissue properties of a normal human subject's lungs from a sequence of high-resolution 3D lung models. Such estimation would facilitate accurate simulations of the 3D lung dynamics. The approach adopted for such estimation is to use a deformation algorithm that can account for the morphological changes from one 3D model to another during breathing.

Background: The method previously used for lung deformations was based on Finite Element Methods (FEM), NURBS, and Green's Formulation (GF) [1]. While the FEM is computationally expensive, NURBS is not a physically based deformation method. Thus, in this paper, we use a GF based deformation for modeling lung dynamics which is a convolution of the force applied on each node and a transfer matrix traditionally referred to as either transfer function or operator. The force applied on each node represents the air-flow and is based on the distance from the resting surface (due to gravity) [2]. This paper presents a method for inverse analysis using spectral decomposition of a GF based deformation using spherical harmonic (SH) transformations. A key property of the transfer matrix is that the row of this matrix forms a converging sequence. Thus, the SH coefficients of every row also form a converging sequence which can be approximated using Dirichlet integrals [3]. The usage of this approximation allows us to simplify the GF.

Methods: For mathematical analysis the GF is represented in a continuous domain. A polar coordinate representation is used for representing each node in the Green's Formulation. The displacement of every node is taken as input from the CT data. The force applied on each node is estimated for a supine position. They are then re-represented in frequency space using SH transformations and plugged into the GF. The SH coefficients of the deformation are now represented as a direct product of the SH coefficients of the applied force and a summation of a set of SH coefficients of the transfer matrix's row which can be computed for a known applied force and displacement. The individual SH coefficients of this summation are then estimated using Dirichlet integrals as shown in [3]. Thus, for a known applied force the SH coefficients of the transfer function can be computed, and the original transfer function can be estimated.

Results: The proposed method is used for a sequence of 3D lung models obtained from a 4D HRCT [4]. The number of 16 SH coefficients is used for the analysis. An initial estimation of the transfer matrix shows that the actual deformation from a 3D model to another and the re-simulated deformation match closely with less than 1% RMS error.

Conclusions: The method presented in this paper allows us to estimate the elasticity of high-resolution 3D lung models of normal human subjects. The average range of elasticity of human lungs can be estimated for set of patients.

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