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MAGNETIC RESONANCE ELASTOGRAPHY AND INVERSE PROBLEM SOLUTION IN ELASTICITY

Zeynep AKALIN, *Student Member, IEEE*, B. Murat EYÜBOĞLU, *Member, IEEE*
Department of Electrical & Electronics Engineering
Middle East Technical University, 06531, Ankara, TURKEY, zakalin@eee.metu.edu.tr

Abstract— In this work, visualization of mechanical properties of soft tissues using nuclear magnetic resonance imaging (MRI) with mechanical compression is introduced. Then, reconstruction of elasticity distribution by linear perturbation method is explained. Simulation results show that the elasticity distribution of soft tissues can be reconstructed by utilizing the phase images obtained from MRI so that the biomechanical properties of soft tissues can be visualized.

Index Words— Elastography, elasticity imaging, inverse problem solution, linear perturbation method.

I. INTRODUCTION

Magnetic resonance elastography (MRE) is an imaging technique, which visualizes the mechanical properties of tissues. Because the stiffness of soft tissues and tumor tissues differ greatly, MRE can be used in detecting tumor tissue, especially, in thyroid, breast and prostate cancers [1].

In MRE, the displacement of each pixel due to applied compression is detected [1]. To reconstruct elasticity distribution from displacement images linear perturbation method can be used [2].

In this work, first MRE, then the elaticity image reconstruction are explained and the proposed method is tested with simulations.

II. MAGNETIC RESONANCE ELASTOGRAPHY

In MRE, a motion sensitizing gradient (G_m) is added to the conventional spin-echo pulse sequence. Meanwhile, the object is compressed in the same direction as G_m which is the intended direction of displacements to be imaged. The object is released when G_m is terminated. So that a term, that is related to the applied compression and G_m, is added to the MR phase image.

If an *x-y* plane image is taken and the displacements in *x* direction are to be imaged, a phase term of $\phi=\gamma G_m \tau \Delta x$ can be obtained when the ratio of the images with compression and without compression are taken, from which the displacements can be evaluated.

III. INVERSE PROBLEM IN ELASTICITY

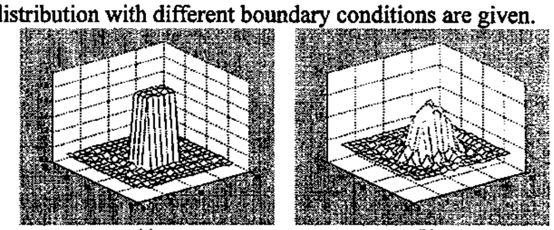
The solution of the forward problem (FP) in elasticity, is calculation of displacements for a known elasticity distribution, deformation and boundary conditions. In this work, the FP is solved by finite element method (FEM). In the inverse problem (IP), elasticity distribution is reconstructed using the displacement images with known boundary conditions and deformation.

In the IP solution, a material having homogeneous elasticity distribution with E is assumed as an initial condition. If compression is applied to this object, displacement distribution of $U=(u,v)$ will be obtained. If this compression is applied to a material having an inhomogeneity ΔE, then $U+\Delta U$ displacement distribution will be obtained. If this inhomogeneity is small, an assumption can be made that there is a linear relationship between the perturbation in elasticity and displacement distribution, like $\Delta U=S\Delta E$. Here, S is the sensitivity matrix. To find the elasticity distribution pseudoinverse of S is multiplied with ΔU and added to initial elasticity distribution.

An iterative method can also be used by updating elasticity distribution in each iteration.

IV. RESULTS

A phantom which has a stiffer object at the center of a soft background is chosen for simulations. In IP, the displacements obtained by FP are used. In Fig. 1, images of the same elasticity distribution with different boundary conditions are given.



(a) (b)

Fig. 1. Displacements in y direction at y=18 are –3.6 and at y=0 are 0, in both figures. On the otherhand, displacements in x direction are taken zero at x=0 and x=18 in (a). The images belong to the 20th iteration at which they converge. The singular values that are smaller than 1% of the maximum value are truncated. (All lengths are in centimeters)

V. CONCLUSION

As can be seen from simulation results with sufficient boundary conditions elasticity distribution can be obtained accurately. As the iterations proceed, the error degrades. In an 18×18 grid, the sum squared error is 5.9 in the 1st iteration, and it is 1.95 in the 10th iteration (for Fig. 1(a)). As the displacement of less boundary nodes are constrained the reconstructed image becomes noisier.

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