Reconstruction of early stage breast tumour using an impedance tomography system and a level set reconstruction algorithm

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Abstract

Early detection of breast cancer is a difficult task. There is growing interest in using new and emerging imaging techniques for breast cancer monitoring, particularly for cases where X-ray mammograms may produce false negative results. In this paper we present a level set method applied to electrical impedance tomography imaging of a realistic breast model. The finite element models were developed based on real breast geometry, using MRI images where a tumour is present. Development of the level set technique will enable detection of smaller tumours and improve the accuracy of tumour boundary shape.

1.Introduction

There is a great deal of interest in early detection of breast tumours. This paper is focused on detection of tumours using electrical impedance tomography (EIT) [1],[2],[3]. We use an uncompressed realistic breast model to study reconstruction algorithms for tumour detection. We propose a shape based method rather than traditional image based methods. The shape-based approach offers several advantages compared to more traditional pixel-based approaches, for example well-defined boundaries. The incorporation of an intrinsic regularization in the form of a-priori assumptions regarding the general anatomical structures present in the medium reduces the dimensionality of the inverse problem and thereby stabilizes the reconstruction. The level set strategy [1], [5] (which is an implicit representation of the shapes) frees us from topological restrictions during this reconstruction process. We present numerical results in 3D which demonstrate the performance of our scheme in simulated realistic situations.

The forward problem is the simulation of measurement data for given values of excitation and material (conductivity and permittivity) distribution and the inverse problem is the imaging result for a given set of measurement data. To solve the inverse problem we need to solve the forward problem. The forward problem in EIT [4] is to solve

$$\nabla \cdot \sigma \nabla u = 0 \qquad (1)$$

where u is the electric potential and σ is the complex conductivity of the medium . The complete electrode model is used to solve the forward model [4].

2.Shape based method

Traditional pixel based image reconstruction methods [4] aim to reconstruct conductivity values of all pixels using EIT data. It is well known that EIT produces low resolution images, mainly due to the fact that the number of measured data are limited and the inverse problem of the EIT image reconstruction is ill posed. Additional regularizations are needed to stabilize the image reconstruction. Most regularization techniques assume some smoothing properties for the conductivity distribution. The smoothing will further blur the already low resolution EIT image, creating further uncertainties in EIT imaging results. The separation of two closely located objects is difficult, sharp edges of the objects are smoothed out and small sized object may not be detected at all.

For the above reasons, the shape based approaches seeking the interfaces between materials are becoming more popular [1]. Among the shape based methods the level set approach is the most promising technique. In this approach, the shape is represented by a higher order function (called the level set function) [1], [5]. The boundaries of the shapes are represented by the zero level set of this level set function f. The evolution of the shape is done in a way that minimizes the mismatch between measured and simulated data. A shape derivative instead of a Jacobian for pixels will be used to develop the minimization problem. Figure 1 shows the level set function and a perturbation applied to the shape.

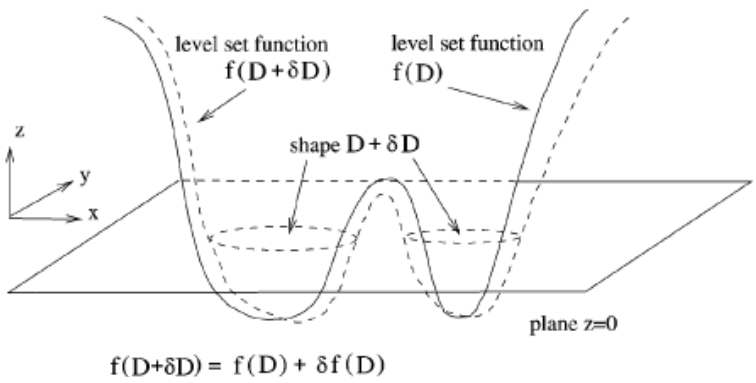

Figure 1: Perturbation of the level set function f

We use a Gauss-Newton optimization method for the minimization of the level set shape problem. A comprehensive detail of the inversion method, including the shape derivative formula for the EIT has been given in [8], [5]. In [8] performance of the level set method has been compared to pixel based method using experimental EIT data.

3. Results

The 3D images reconstructed from breast mimicking model represent a realistic clinical case (Figure 2). A background conductivity of .4 s/m is assumed for the breast and a tumour with conductivity of 2 s/m has been considered [7]. The size of the breast area is 130 x 136 x 60 mm (x,y,z coordinate), and there are 61171 tetrahedral elements in the mesh. A 16 electrode EIT system is used, so that we have 104 independent measurements in an adjacent current pattern. The electrodes are in a single plane at approximately z=-30 mm. In figure 3. a 6 mm (in diameter) spherical sized tumor has been simulated and reconstructed using the proposed shape based method. The tumour is located 6mm from the centre and centred at z=-30mm, the same level as the plane of electrodes. Figure 4 shows the reduction in cost function, which is the norm of the error between measured data and estimated data against iterations of level set shape method. The initial guess was a spherical tumour of 8 mm diameter, 13 mm away from the true tumour location. We consider a small noise level of 0.1 percent of the average of measure data. For the purpose of this study the same mesh was used for the forward and inverse problems.

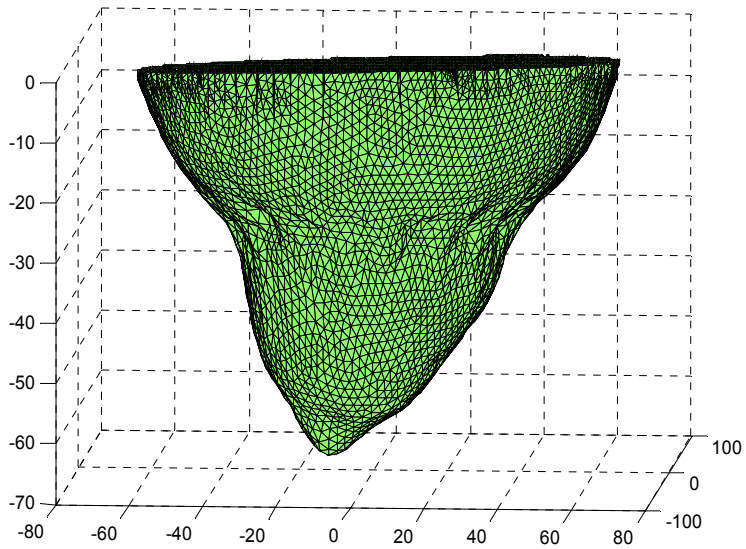

Figure 2: A 3D finite element mesh of a breast is shown, with indent impressions where the electrodes are in contact with the tissue.

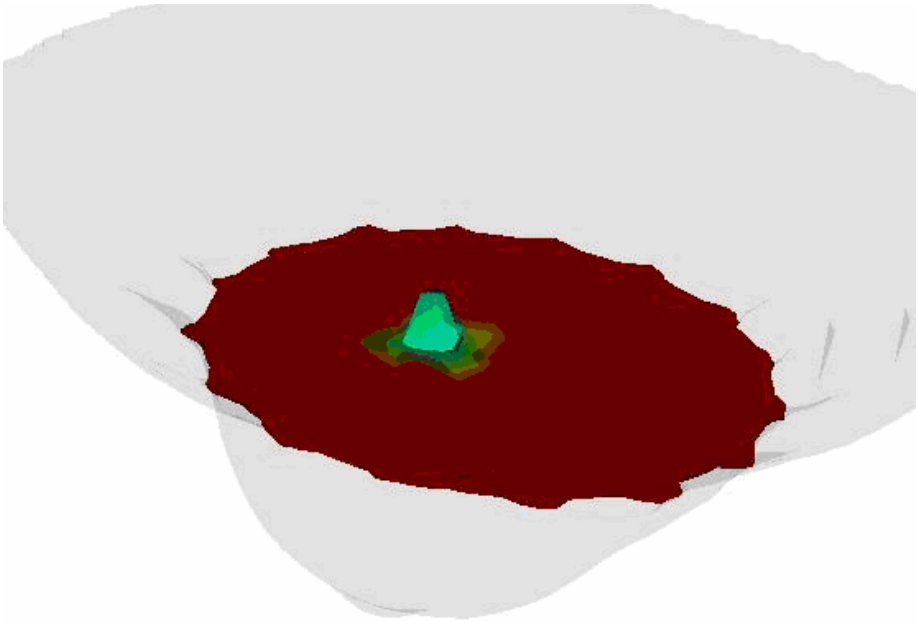

Figure 3: Reconstruction of tumour using shape based method.

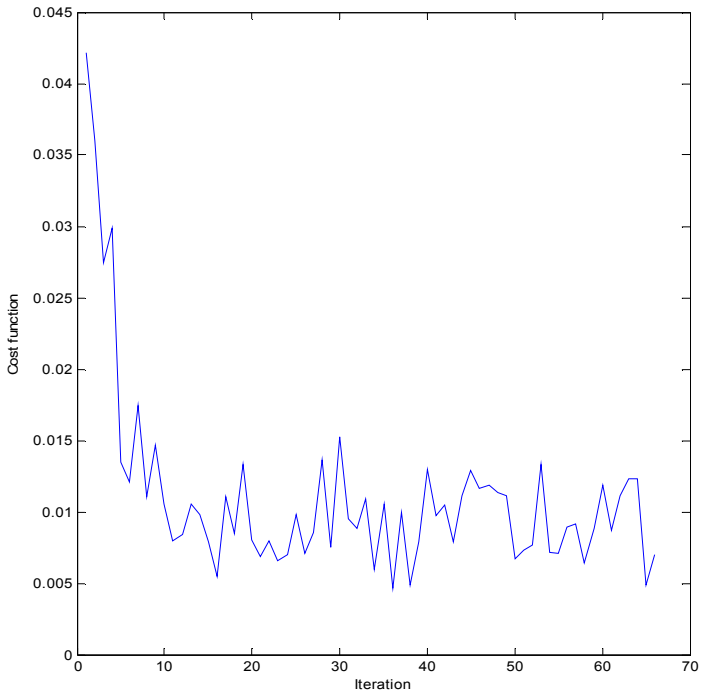

Figure 3: Minimization of the cost function by iteration

4. Conclusion

We have presented our preliminary simulation results of breast tumor detection using EIT data and a level set shape reconstruction method. We have shown the convergence of the level set method and that the level set method can locate the tumor. Further studies are required to test the algorithm against false tumor detections. A comparative study of the uncompressed version of EIT presented in this paper with the compressed breast EIT presented in [6] is our next

aim. This simulation model considered a homogenous conductivity value for the breast tissue and a high contrast for the tumor, more realistic values will be included to represent the multilayered structure of the breast tissue. Based on advantages the level set method can offer and our initial promising results here we will explore the full potential of the method for breast EIT application.

5. References

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