Reconstructions of conductivity and permittivity from EIT data on a human chest by D-bar methods

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Abstract: A direct D-bar reconstruction algorithm is presented for reconstructing a complex conductivity from 2-D EIT data. The method is applied to simulated data and archival human chest data. Permittivity reconstructions with this new method and conductivity reconstructions with the fully nonlinear D-bar method based on [1] depicting ventilation and perfusion in the human chest are presented.

1 Introduction

In this work a direct nonlinear reconstruction algorithm using the D-bar method is presented for the computation of conductivity and permittivity on a chest-shaped domain. The conductivity and permittivity are modeled as a complex coefficient $\gamma = \sigma + i\omega\varepsilon$ in the generalized Laplace equation where ω represents the angular frequency of the applied current, σ the conductivity, and ε the permittivity.

There are two D-bar methods shown here. To obtain reconstructions of the real part of the admittivity for the human data, the D-bar method based on the global uniqueness proof by Nachman [2] is employed. Here, the fully nonlinear scattering transform is used for the first time with human data. To compute reconstructions of the permittivity, a direct method introduced in [3] was utilized. The method is based on the uniqueness proof by Francini [4], but equations relating the Dirichlet-to-Neumann to the scattering transform and the exponentially growing solutions are not present in that work. Such equations are derived in [5], and an alternative formulation with a different formula for the scattering transform from [3] is used here.

2 Methods

2.1 Algorithms

The conductivity was computed using the fully nonlinear D-bar method based on [1, 2, 6]. The permittivity was computed using a new D-bar method based on the elliptic system of complex geometrical optics (CGO) solutions introduced in the global uniqueness proof of Francini [4]. As in other D-bar methods, there is a direct relationship between the CGO solutions, and the coefficient in the generalized Laplace equation, which in this case is the admittivity. In this method, the scattering transform is a 2×2 matrix of functions with nonzero off-diagonal entries, related to the CGO solutions by a boundary integral equation. Here, a linearized scattering transform is used, which partially linearizes the method. The lengthy equations are omitted for brevity.

2.2 Data Collection

We consider two sets of 100 frames of archival data collected at 18 frames/s on the chest of an adult male sitting upright, using the ACT3 system at RPI [7]. One set was collected during breathholding to image perfusion, and the other set consisted of a deep slow inhalation followed by slow exhalation to image ventilation. In both cases, the trigonometric current patterns with current amplitude 0.85 mA were applied on 32 electrodes placed around the circumference of the chest.

2.3 Results

In Figure 1 a selection of five difference images of the conductivity and permittivity distributions in a healthy human subject during a slow ventilation maneuver. The first frame was chosen as the reference frame. Close agreement between the conductivity and permittivity images is observed, as may be expected in a healthy subject, and changes due the to increased resistivity during inhalation are clearly visible.

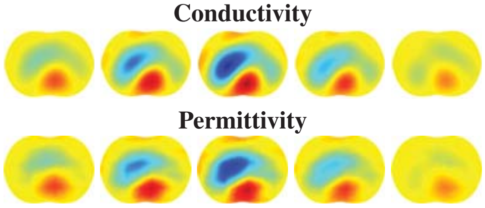

Figure 1: Top row: Red is high conductivity and blue low conductivity. Bottom row: Red is high permittivity and blue low permittivity.

3 Conclusions

We have presented a direct D-bar method for computing reconstructions of both conductivity and permittivity from human chest data on a 2-D cross-sectional domain. This constitutes the first fully nonlinear D-bar reconstructions of human chest data and the first D-bar permittivity reconstructions of experimental data. Difference images of ventilation and perfusion in a healthy human subject do not exhibit boundary artefacts and clearly show changes due to blood flow between the heart and lungs and gas exchange.

References

[1] Knudsen K, Lassas M, Mueller JL, and Siltanen S, *Inverse Problems and Imaging*, 3:599–624, 2009.
[2] Nachman AI, *Ann. of Math.*, 143:71–96, 1996.
[3] Herrera CNL, *PhD thesis, University of São Paulo, Brazil*, 2012.
[4] Francini E, *Inverse Problems* 6:107–119, 2000.
[5] Hamilton SJ, Herrera CNL, Mueller JL and Von Herrmann A, *Inverse Problems*, 28:095005, 2012.
[6] Siltanen S, Mueller JL, and Isaacson D, for the 2D inverse conductivity problem. *Inverse Problems*, 16:681–699, 2000.
[7] Edic PM, Saulnier GJ, Newell JC, and Isaacson D, *IEEE Trans. Biomed. Eng.*, 42:849–859, 1995.

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