Breast Cancer Detection Using Electrical Impedance Tomography

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Introduction

Research on freshly-excised malignant breast tissues and surrounding normal tissues in an in vitro impedance cell has shown significant differences in the frequency spectrum of the admittivity between normal or non-malignant tissues and cancerous tumors. This contrast may provide a basis for breast cancer detection using electrical impedance imaging in frequency scanning. We develop a prototype method for the classification of electrical impedance spectroscopy (EIS) data collected from breast cancer patients using our electrical impedance imaging system (ACT4). Various parameterizations of the shape of the EIS curves have been used as inputs to a variety of basic classification techniques. We present the initial results in the development of the first stages of our classification problem.

Data Collection

The EIT group at Rensselaer has developed the Adaptive Current Tomograph 4 (ACT4) [4], [3]. This system has the capability to apply voltage up to 72 electrodes simultaneously and record the resulting currents. ACTA can apply distinct voltage patterns at frequencies between 30 Hz to 1 MHz, allowing reconstruction algorithms to take advantage of frequency dependent properties of the body. Recent work has focused on collecting EIT data simultaneously with mammography data. For this reason, a set of opposing radiolucent electrode arrays have been designed to be placed on the top and bottom of a patients breast [4]. These arrays are constructed to be mounted on the digital tomosynthesis machine at MGH. Both EIT and tomosynthesis data can be collected concurrently, and some measure of co-registration can be accomplished (see Figure 1).

Thus, for each frequency, we can reconstruct the three dimensional admittivity of the interior of the breast on a 10x12x5 array of voxels. The geometry for the reconstruction can be seen in Figure 2. The admittivity values can be plotted with the real component on the x-axis and the imaginary component on the y-axis to give an electrical impedance-spectroscopy (EIS) plot for the voxel.

Complex Admittivity Reconstruction

In order to obtain information about the frequency dependent admittivity throughout the domain, one must first reconstruct the admittivity at one frequency. There are many methods of performing these reconstructions, and the best choice and method is a topic of ongoing research. Below, we provide several reconstructions of a copper cube with 1 cm sides in a saline filled (200 mS/m) mammography shaped tank at 33 kHz. The cube is centered top to bottom, on the edge of the array in the horizontal direction, and 3mm away from one of the electrode arrays.

A main part of all the reconstruction methods is to first produce a set of voltages corresponding to a homogeneous domain. We call it a diffusion image if this homogeneous set is measured, and diffuse if we use simulated voltages. The simulated voltages are produced by either the Ave-Gap or complete electrode models (CEM). Then we present two reconstructions methods. The first is a Newton’s one step error reconstruction method called NOISER. This method uses the standard Newton’s approach. The second approach is denoted Calderon’s method. It assumes that the solution is a small perturbation from a class of exponential solutions that satisfy the Laplace equation. It results in, essentially, only needing to take an inverse Fourier transform of the Dirichlet-to-Neumann map.

The Cancer Classification Problem

Once we have reconstructed the admittivity on the interior of the breast, we desire to use this information to detect whether the tissue is cancerous or non-cancerous. It has been shown that cancerous breast tissue differs from non-cancerous tissue in the shape of its EIS plot. A sample EIS plot is shown below. We can construct a plot such as this for each voxel of our reconstruction mesh. Our goal is to use pattern classification techniques to approximate the difference in shape between cancerous and non-cancerous voxels. We are limited by the high dimensionality of our sample space (7 complex values, one for each frequency), and the relatively low number of samples we have available to us. For this reason we pursue dimensionality reductions as shown in Table 1. Preliminary classification results can be seen in Figure 3.

Importance of the work and technology transfer:

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Conclusions and Future Work

Clearly we are at the very outset of classifying our new patient data. Our work thus far has focused on tasks 1 and 2 from our problem statement. We are confident that the parameterizations we have chosen accurately describe the shape of the EIS plot for each voxel. Which parameterization we choose will depend on the quality of the results we achieve from tasks 2 and 3. Although progress has been made to accurately label cancerous voxels, significant focus will be placed on continuing to improve this capability for our data. Finally, we will shortly begin selecting standard classification algorithms which we can train using our labeled parameterizations in the hopes of showing that electrical impedance spectroscopy has diagnostic merit for breast cancer detection.

References:

Publications Acknowledging NSF Support:


Other Publications:


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Table 1. A listing of parameterizations of EIS plots that we are currently experimenting with

<table>
<thead>
<tr>
<th>Parameterization</th>
<th>Number of Parameters</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admittivity</td>
<td>11</td>
<td>Real and imaginary parts of each of the normalized admittivities</td>
</tr>
<tr>
<td>Polyfit</td>
<td>3</td>
<td>Fit a third order polynomial to the data. We ignore the constant term due to normalization</td>
</tr>
<tr>
<td>Curvature</td>
<td>5</td>
<td>For each set of three consecutive points we fit a circle and set the curvature to the inverse of the radius</td>
</tr>
<tr>
<td>Slopes</td>
<td>6</td>
<td>We use the slope of the lines connecting consecutive frequency points</td>
</tr>
<tr>
<td>Angles</td>
<td>6</td>
<td>We use the angles between consecutive frequency points</td>
</tr>
</tbody>
</table>

Figure 1. ACT 4 with the mammography unit (top left), radiolucent electrode array [4] attached to the lower compression plate (upper right), one slice of the tomosynthesis image made with the electrode arrays in place of the left breast from human subject HS14 (lower left) and tomosynthesis image with an overlaid grid showing the location of the active electrode surface (lower right). Note that the copper leads and ribbon cables are visible on the left and right of the tomosynthesis images[2] but the radiolucent portion of the arrays is not visible.

Figure 2. Side view of volume and mesh elements between the arrays used in patient studies. Reconstructions [3] from layer 3 (labeled III above) are displayed in the figures below.

Figure 3. 2 most significant principle components of the Angles parameter. Gray dots represent voxels from non-cancerous breasts, while all other markers represent voxels from cancerous breasts.