3-D Microwave Imaging using a Level Set Method for Breast Density Evaluation

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Piecewise models such as level sets (Dorn and Lesselier, Inverse Problems, 22, R67-R131, 2006 and Colgan et al., IEEE AP-S/URSI, July 2012) have been shown to accurately reconstruct the dielectric properties of 2-D numerical breast phantoms with a distinct boundary between different tissue types in 2-D. A level set is a real valued function that partitions the domain into regions with arbitrarily shaped boundaries. A single level set may be used to partition the domain into adipose and fibroglandular tissue types. This type of partitioning is directly relevant to breast density estimation.

High volumetric breast density, defined as a large percentage of fibroglandular tissue, is one of the strongest predictors of a patient's breast cancer risk (Kerlikowske, et al., J. National Cancer Inst., 99 (5), 386-395, 2007). Volumetric breast density is not accurately measured by current X-ray mammographic techniques that are based on 2-D. Furthermore, exposure to ionizing radiation is an additional risk factor for women who may already be at very high risk. MRI for density estimation is problematic or prohibited for some patients, not widely available, expensive, and time-consuming.

In the microwave frequency range the large dielectric contrast between fibroglandular and adipose tissue (Lazebnik, et al., Phys. Med. Biol., 52, 2637-2656, 2007) makes it possible to estimate breast density from a tomographic microwave image. However, most microwave imaging techniques are regularized in a way that forces a smooth transition between tissue types despite the large contrast. This blurring of the boundary distorts the size and type of tissue making it difficult to accurately estimate the volumetric density and monitor changes due to preventative interventions. Microwave imaging using level sets to preserve boundaries between tissue types is a promising alternative approach for estimating breast density.

We present a computationally efficient technique for extending existing 2-D level set-based microwave imaging algorithms to 3-D. We investigate this approach using a realistic 3-D numerical-phantom testbed where the density estimates are compared to the truth for phantoms from each of the four classes of BI-RADS density. Our 3-D results demonstrate the potential for safe and accurate estimate of a patient's volumetric breast density.