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A Maximum Likelihood Algorithm for the Detection of Breast Cancer Using Microwave Radar Measurements

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ABSTRACT

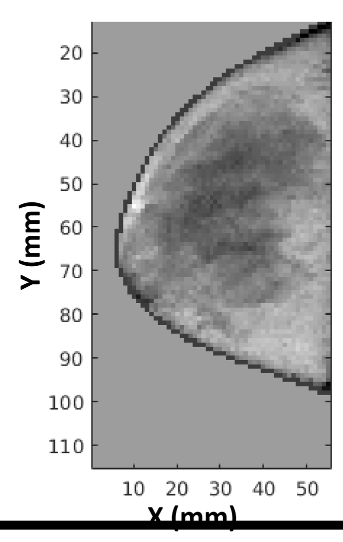
With over 1.7 million new cases annually, breast cancer is the leading cause of cancer death in women around the globe. Importantly, medical intervention has a greater chance of success if tumors can be detected during the early stages of the disease. This has led to a concerted effort on the part of the scientific community to develop advanced imaging technology which can detect smaller volumes of cancerous tissue.

The topic of this work is an algorithm designed to supplement the existing modality Digital Breast Tomosynthesis (DBT) with Microwave Radar (MWR) sensing. Using the DBT image, a physician would be asked to first identify any suspicious regions which may contain a tumor. Then a MWR computational model, such as Finite Difference Frequency Domain (FDFD), would be used with the DBT image to simulate two scenarios: a healthy case, and a diseased case with tissue dielectric constant increased to that of cancer over the suspicious region. The two results would then be compared to the actual measured MWR data to find the closest match using Maximum Likelihood Estimation.

In a preliminary numerical experiment, datasets representing MWR measurements with added Gaussian noise were generated using FDFD and openly available DBT data. In each of five cases, a team of undergraduate students, having no knowledge of the ground truth, correctly detected the presence (or absence) of a lesion using this algorithm. This result suggests that the algorithm has potential to augment existing technology. Ultimately, this information can be crucial for medical intervention.

BACKGROUND AND MOTIVATION

Breast cancer is a serious problem and a leading cause of cancer death in women. There is a need for improved breast cancer detection technology. Microwave Radar has shown promise for breast cancer detection [2-5] but there is a need for an algorithm which uses only one transmitter.



DBT Image of healthy breast tissue. The grayscale ranges from -3, which is black (skin), to 0, which is white (fat).

LEAST-SQUARED COST FUNCTION

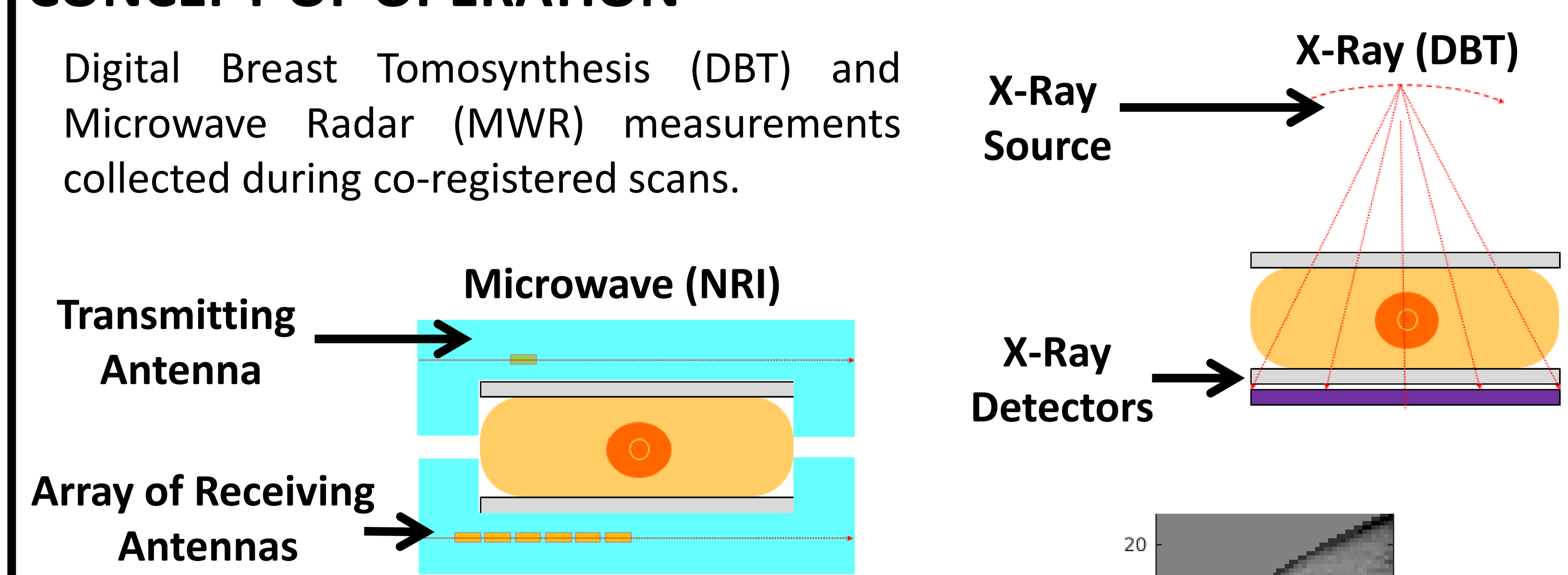
$$\mathcal{J} = \sum_{i=1}^{50} \| E^{(i)} - E^{(i)}_{\text{measured}} \|^2$$

$\mathcal{J}$	**least-squared cost function**
$E^{(i)}$	**simulated electric field**
$E^{(i)}_{measured}$	**measured electric field**

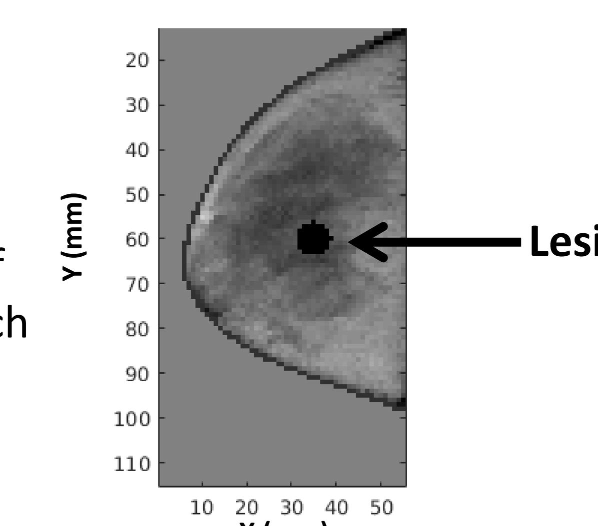
The least-squared cost function is used to determine which simulated DBT image is more similar to the measured case. The case with the lower cost determines if the actual tissue is healthy or diseased.

CONCEPT OF OPERATION

Digital Breast Tomosynthesis (DBT) and Microwave Radar (MWR) measurements collected during co-registered scans.



Lesion inserted into DBT image for Case 1 to simulate diseased tissue. The dielectric constant of the cancerous region has been changed to -3, which turns it black.



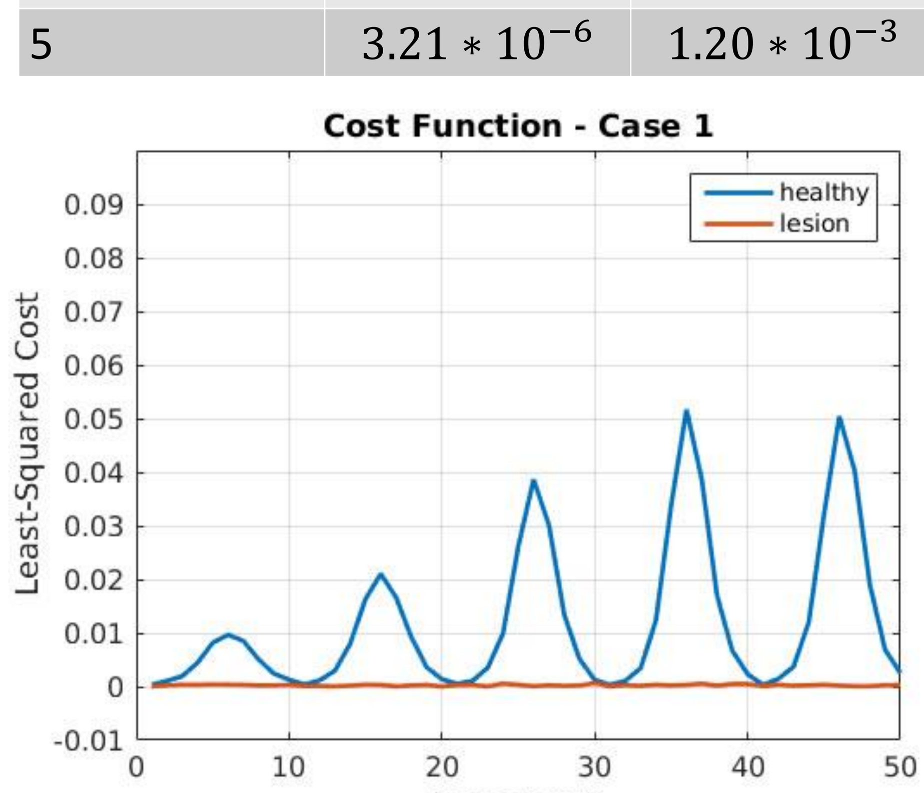
METHOD

Maximum Likelihood Algorithm for Breast Cancer Detection ⇨ Given: DBT Image, Lesion position, receiver positions ⇨ Create simulated healthy and unhealthy breast tissue DBT images ⇨ Use FDFD to calculate electric field for each case ⇨ Calculate receiver values for each case ⇨ Calculate cost for each case given measured receiver values ⇨ Which cost is smaller? ⇨ Determine which case is more likely for measured values

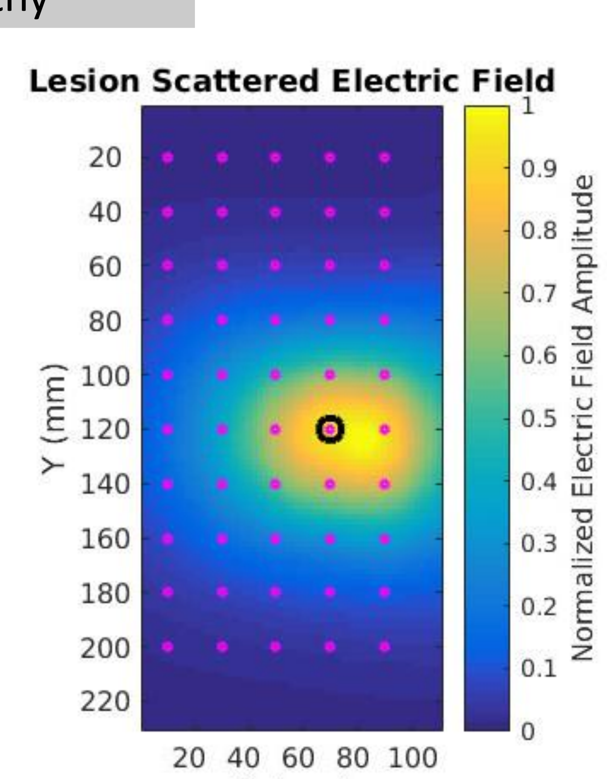
DATA AND RESULTS

Case	Healthy Cost	Diseased Cost	Conclusion
1	$8.20 * 10^{-3}$	$2.04 * 10^{-6}$	Diseased
2	$4.97 * 10^{-4}$	$1.89 * 10^{-6}$	Diseased
3	$1.89 * 10^{-6}$	$8.50 * 10^{-3}$	Healthy
4	$2.67 * 10^{-6}$	$2.82 * 10^{-6}$	Diseased
5	$3.21 * 10^{-6}$	$1.20 * 10^{-3}$	Healthy

Results of the Least Squared Cost Function for the healthy and diseased simulations for each case of measured data.



Least-Squared Cost for the receivers in Case 1. Since the red line representing the lesion data is close to zero, Case 1 is diseased.



Scattered electric field image of the lesion at the measurement plane for Case 1. The magenta circles show receiver positions and the black line shows the ground-truth lesion location.

CONCLUSION AND FUTURE GOALS

The algorithm can confirm the existence of a lesion based on a DBT image and the suspected size and position of a potential lesion. However, there may be circumstances in which the lesion size, position, and number are unknown, and future iterations of this program aim to fix this problem. The algorithm would test multiple permutations of lesion size, position, and number, and use the same maximum likelihood detection method to determine which case is the most likely.

The algorithm as it exists also does not account for noise in the microwave radar measurements. Further testing should be completed to analyze how well the algorithm functions as the noise levels increase to gain an understanding of how the technique would work in a real environment. This would result in more accurate and efficient treatment methods.

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