Accurate local estimation of compressed breast thickness in digital breast tomosynthesis using an iterative reconstruction approach

Lambert Leong[1,2], Thomas K Wolfgruber[1], Shane Spencer[1], Serge L Muller[3], John A Shepherd[1]

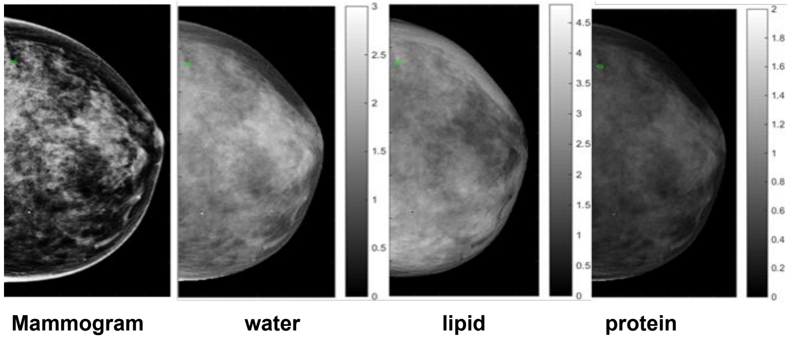
[1] University of Hawaii Cancer Center, Honolulu, HI, USA; [2] Molecular Bioscience and Bioengineering, University of Hawaii, Honolulu, HI, USA; [3] GE Healthcare, Buc, FR

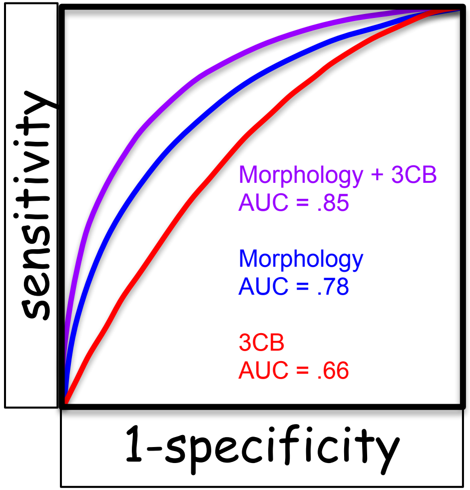
UNIVERSITY OF HAWAI‘I CANCER CENTER

SHEPHERD RESEARCH LAB

Importance of breast thickness for evaluating composition

- 3 Compartment Breast (3CB) model
  - Dual energy full field digital mammography technique
  - Create lipid, water, and protein maps
- Compositional features of breast lesions were shown to be diagnostically significant
  - Invasive breast cancers were shown to have a unique lipid, water, and protein compositions when compared to other lesion types
- Accurate breast thickness estimates are important for deriving the compositional maps and features





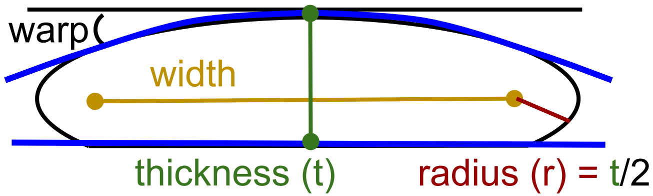
Drukker, Med Phys. 2014 Mar; 41(3): 031915.

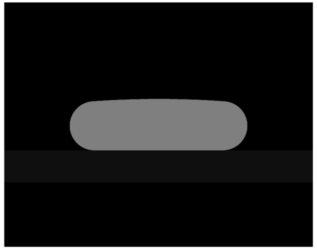
3 compartment breast for tomosynthesis

- **Goal**:
  - Apply the 3 compartment breast methods and algorithm to tomosynthesis to create lipid, water, and protein volume fractions
- **Problems**:
  - Tomosynthesis has poor resolution in the z-axis thus making it difficult to get accurate thickness measurements
  - Full field, 2D, techniques we developed are limiting when moving to 3D
- **Hypothesis**:
  - Tomosynthesis images contain enough information from which thickness and other geometrical measurements can be derived using sinograms.

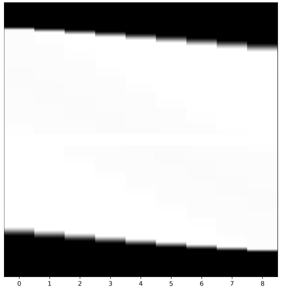
Approach with simulation

- We created a virtual breast object for which we can define the cross sectional geometry parameters of a compressed breast
  - Parameters: thickness, width, and warp
- We use Matlab simulation to create simulated sinograms from the virtual breast object we define
- Sinogram - A set of projections under different angles organized in 2D
  - Each pixel column, from the chest wall to the nipple, is a cross sectional slice and has a corresponding sinogram

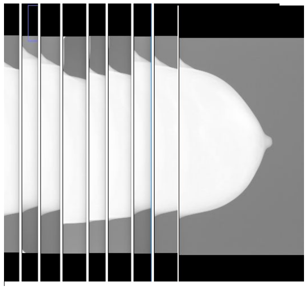




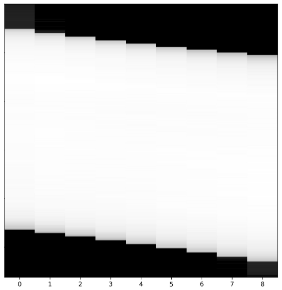
Virtual Breast Object



Simulated sinogram



9 projections



Real sinogram

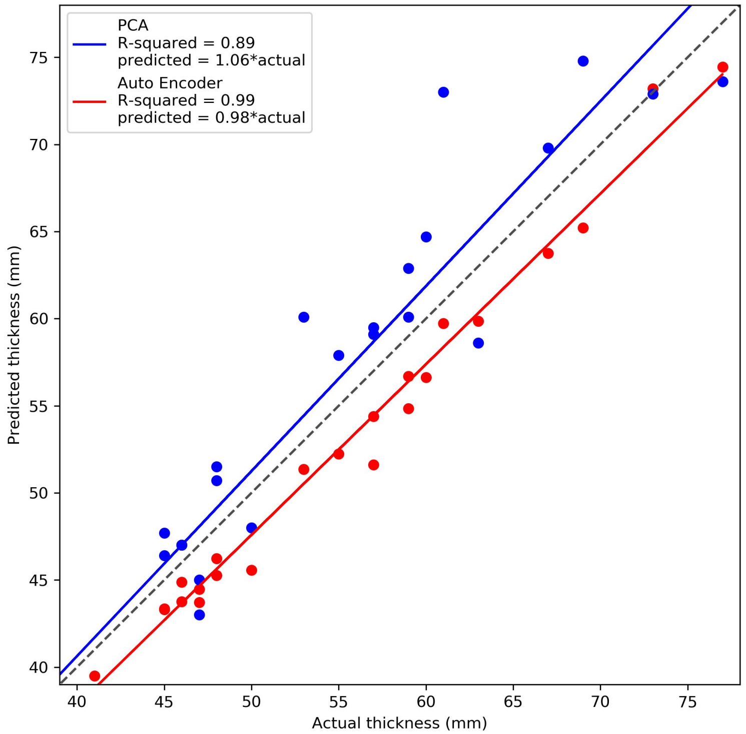
Prediction and modeling approaches

- Method 1: Iterative reconstruction
  - Virtual breast object and its simulated sinogram was generated and compared to the real sinogram until error was minimized
  - Regenerating new breast objects of different parameters (width, thickness, and warp) and its sinograms to match the real sinogram was computationally expensive.
- Method 2: Machine learning
  - Sampled the search space of possible breast parameters to generate a training set of 13107 sinograms and a validation set of 3277 sinograms
    - width: .1 - 200 mm,
    - thickness: .1 - 80 mm,
    - warp: 0 - 4 degrees
  - Models:
    - Principal components analysis (PCA)
    - Auto encoder

Results for Method 2: PCA and auto encoder thickness predictions

- Evaluation Data set:
  - 24 real patients scans
    - Cranial Caudal (CC) view
    - Taken on General Electric's (GE) SenoClaire Tomosynthesis system
  - Thickness compared to DICOM header field (0018, 110A), 'body part thickness'

	Mean DICOM Header Thickness (mm)	DICOM header - Predicted Mean (mm)	Standard Deviation (mm)	Minimum Difference (mm)	Maximum Difference (mm)	RMSE (mm)
PCA Thickness Estimate	**53.76**	**-0.84**	**3.85**	**-5.10**	**5.40**	**3.86**
Auto Encoder Thickness Estimate	**53.76**	**2.67**	**0.90**	**1.12**	**4.16**	**2.56**



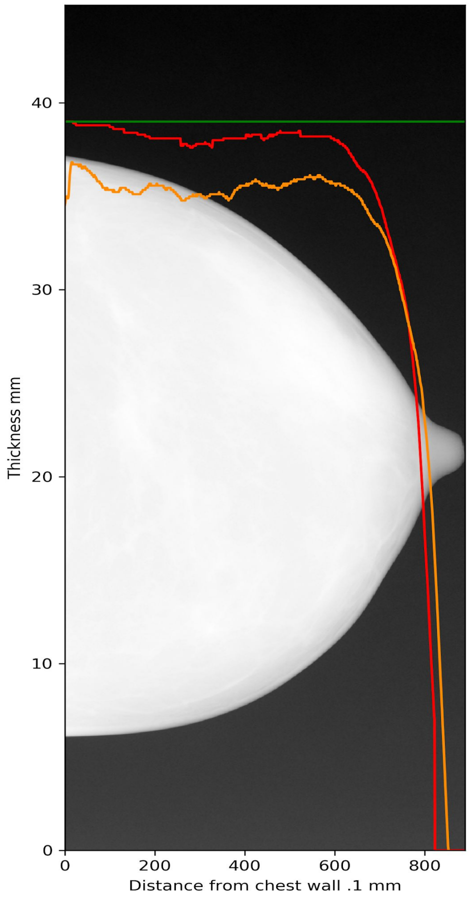
Full thickness estimates examples

- Final PCA and auto encoder models were used to predict all cross sectional slices from the chest wall to the nipple for a single patient

Green - Thickness recorded in the DICOM header

Red - Thickness estimated via auto encoder

Orange - Thickness estimated via PCA



Tilt and warp geometrical predictions

- Calculating tilt:
  - We assume that the breast is in contact with the compression paddle out to ⅔ distance from the chest wall.
  - We exclude 1 cm from the chest wall due to chest wall artifacts such as muscle and skin
  - A slope can be calculated by the change in thickness as we move away from the chest wall

	Units	Mean	Standard Deviation	Minimum	Maximum
Auto Encoder Warp Estimates	**Degrees**	**0.11**	**0.04**	**0.08**	**0.23**
Auto Encoder Tilt Estimates	**Degrees**	**0.06**	**0.61**	**2.7 E-04**	**1.02**

Concluding remarks

- We have demonstrated an ability to derive the geometrical parameters (thickness, width, warp, and tilt) of a compressed breast from its sinograms using an auto encoder
- With an accurate thickness model, we can work towards creating 3D lipid, water, and protein volumes of the breast
- We have shown how simulation and simulated data can be used to build translational models which can benefit from addition of real data downstream.

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