

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

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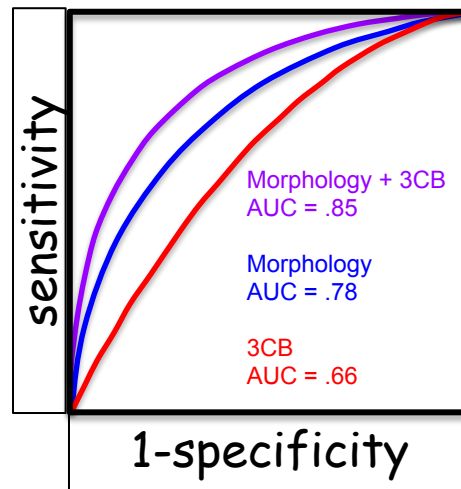
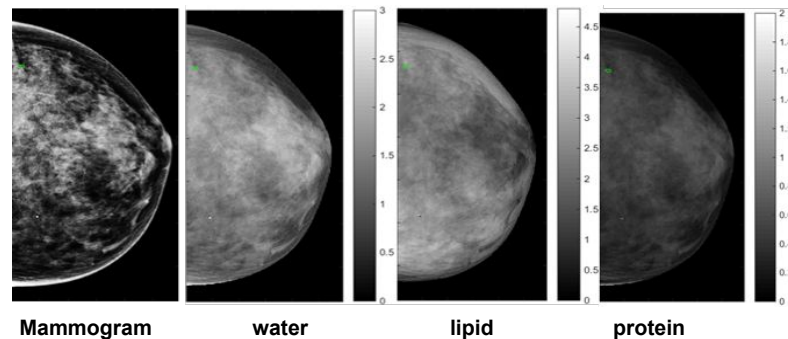


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# Importance of breast thickness for evaluating composition

- 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





# 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

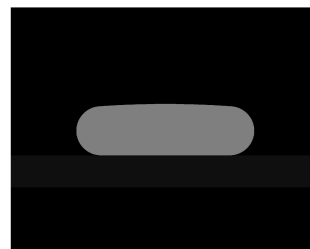
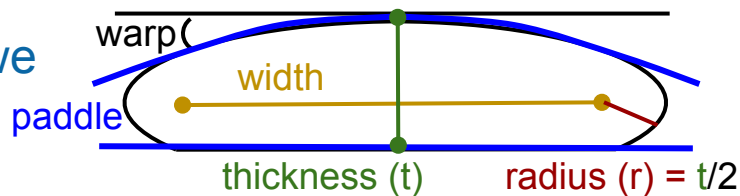
- **Hypothesis:**

- Tomosynthesis images contain enough information from which thickness and other geometrical measurements can be derived using sinograms.

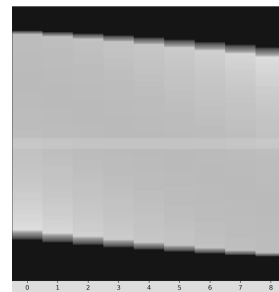


# Approach with simulation

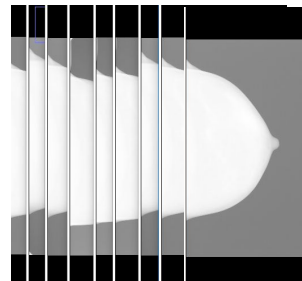
- We created a virtual breast object for which we can define the cross sectional geometry parameters of a compressed breast
  - Parameters: **thickness**, **width**, and **warp**
- We use Matlab simulation to create simulated sinograms from the virtual breast object we define
- Sinogram - A set of projections 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



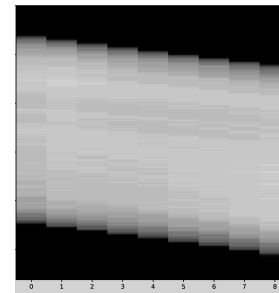
Virtual Breast Object



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

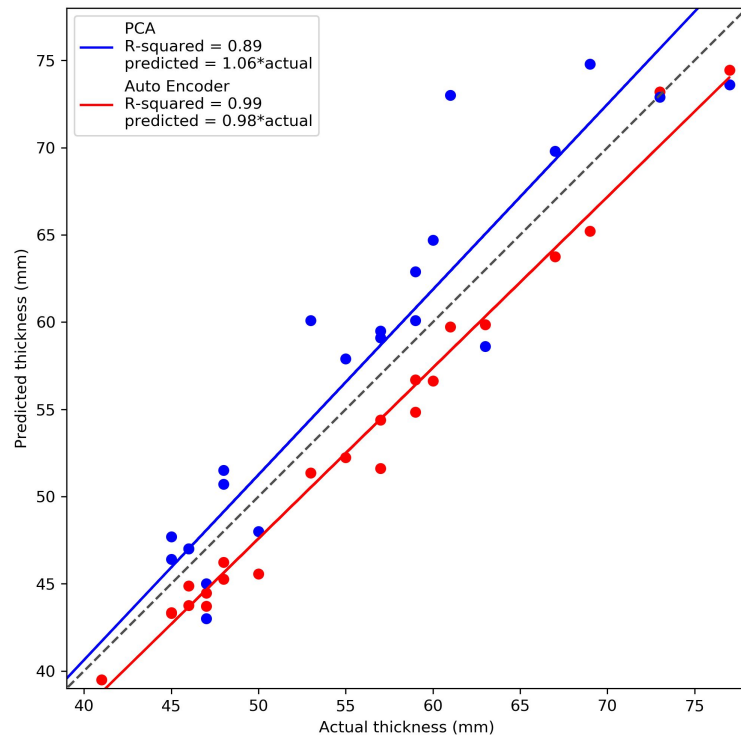
- Sampled the search space of possible breast parameters to generate a training set of 13107 sinograms and a validation set of 3277 sinograms
  - width: .1 - 200 mm,
  - thickness: .1 - 80 mm,
  - warp: 0 - 4 degrees
- Models:
  - Principal components analysis (PCA)
  - Auto encoder



# 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

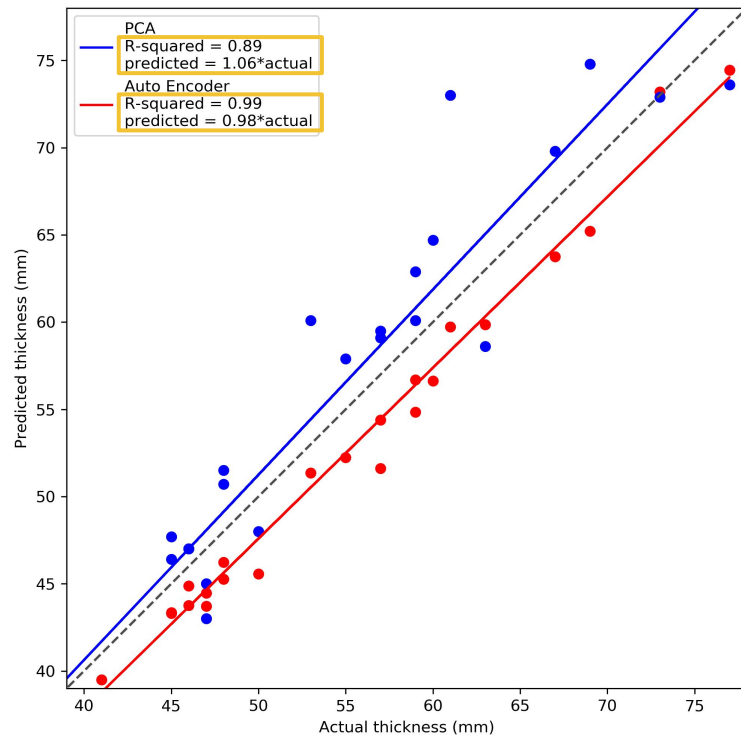




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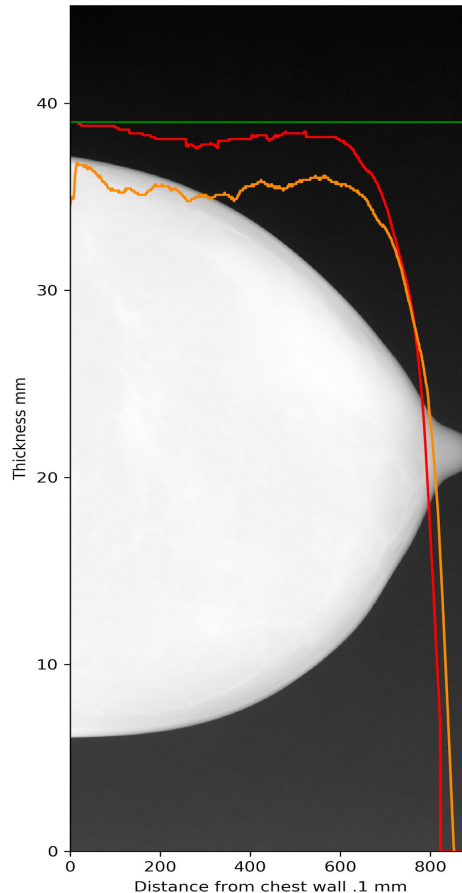
# Full thickness estimates examples

- 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  $\frac{2}{3}$  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
  - Fully comprehensive compositional breast (3CB) model



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