Computer Aided Diagnosis with Breast Ultrasound

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Richard Ellis, Mayo, La Crosse, WI

Team

Leadership

- Jeff Baggett: Professor, Math and Statistics.
- Song Chen: Associate Professor, Math and Statistics.
- Richard Ellis: Clinical Breast Radiologist and Researcher.

Masters Degree Students (Data Science and Applied Statistics)

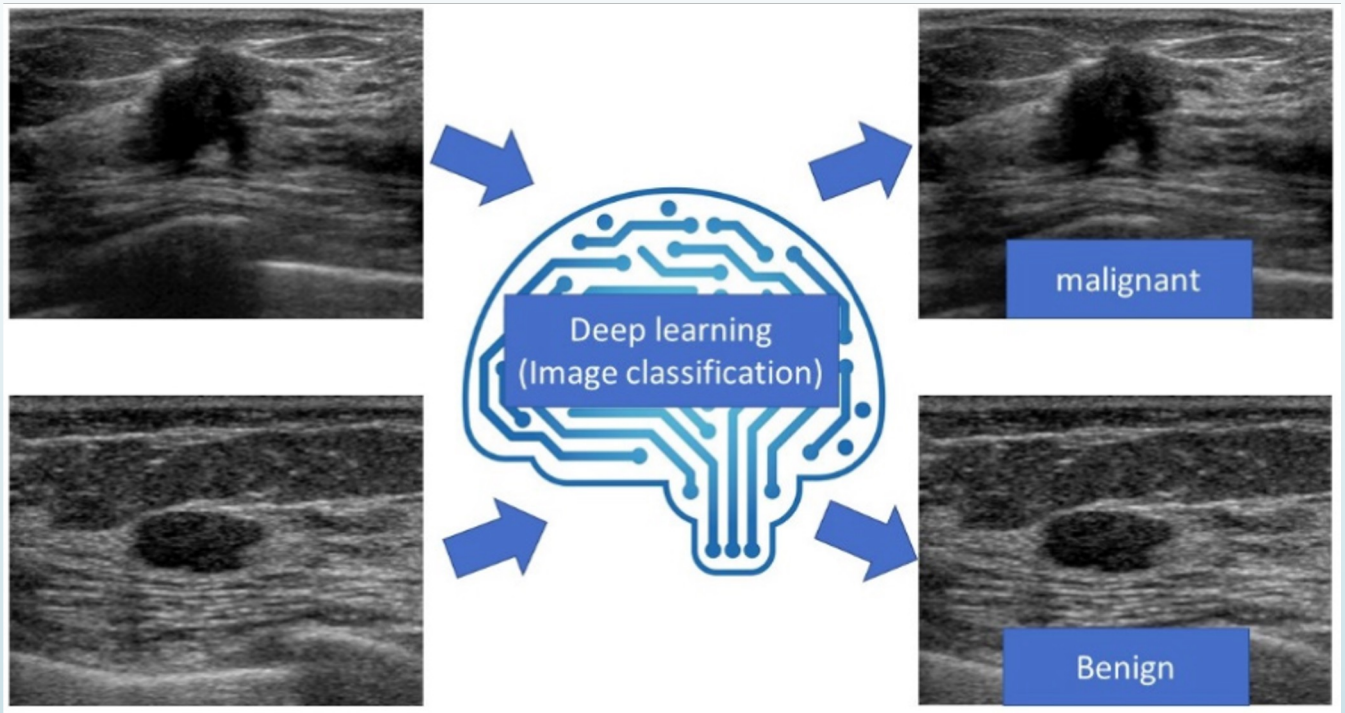
- David Halama: computer programmer (WI).
- Justin Hall: data scientist at Centra Health (VA).
- Suriya Mohan: software engineer at Dropbox (CA).
- Adam Silberfein: software developer (WA).
- Lucas Spellman: ML algorithm developer at USGS (WI).

Goals of Feasibility Study

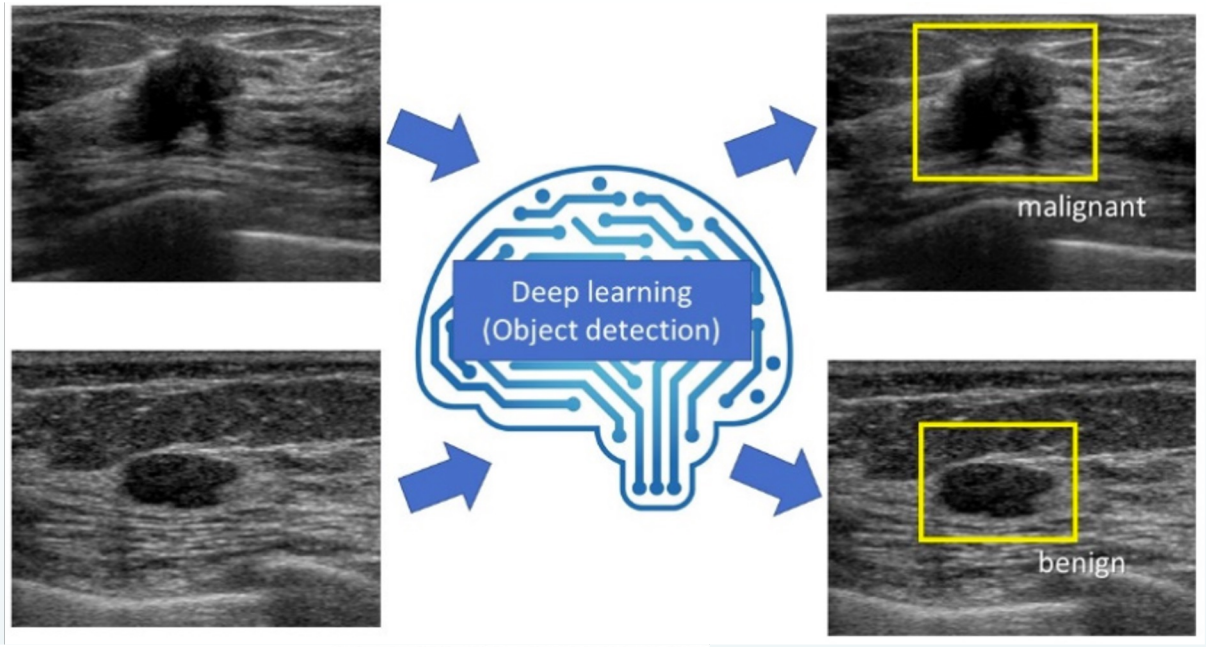
- Build prototype software to classify lesions at least as well as experts
- Obtain **explainable** results using the Breast Image-Reporting and Data System (BI-RADS, American College of Radiology)
- Focus on usable product
  - Computer Aided Diagnosis
  - Teaching Tool

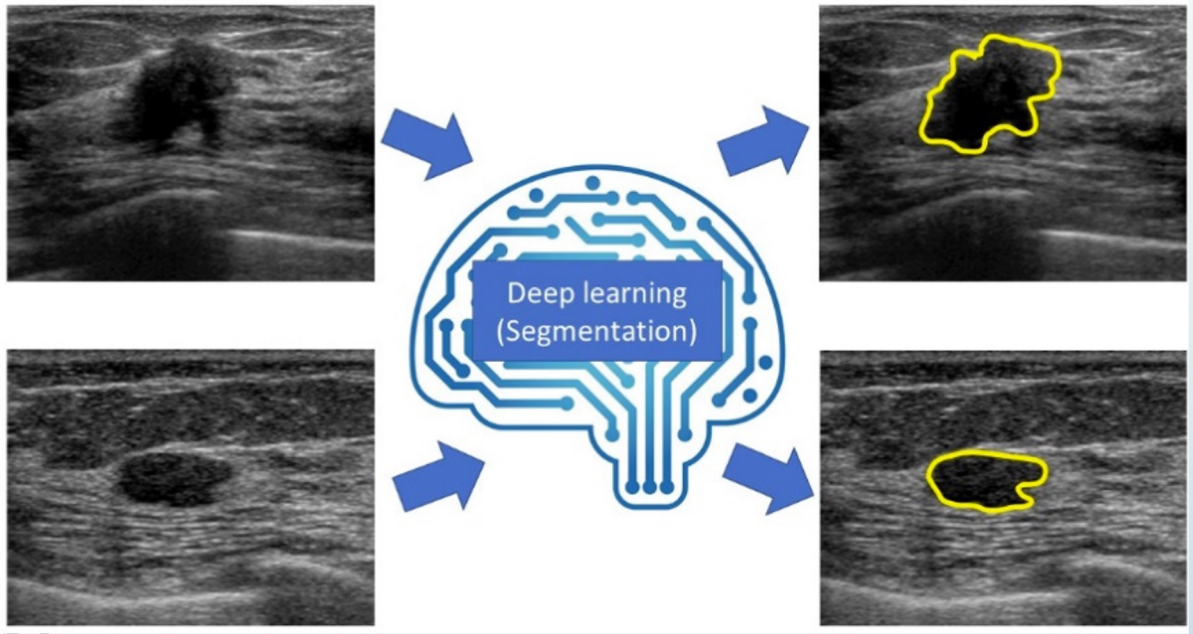
Existing Research

- "deep learning breast ultrasound" returns 8,470 results since 2020 on Google Scholar
- > 90% accuracy, sensitivity, and specificity may be possible



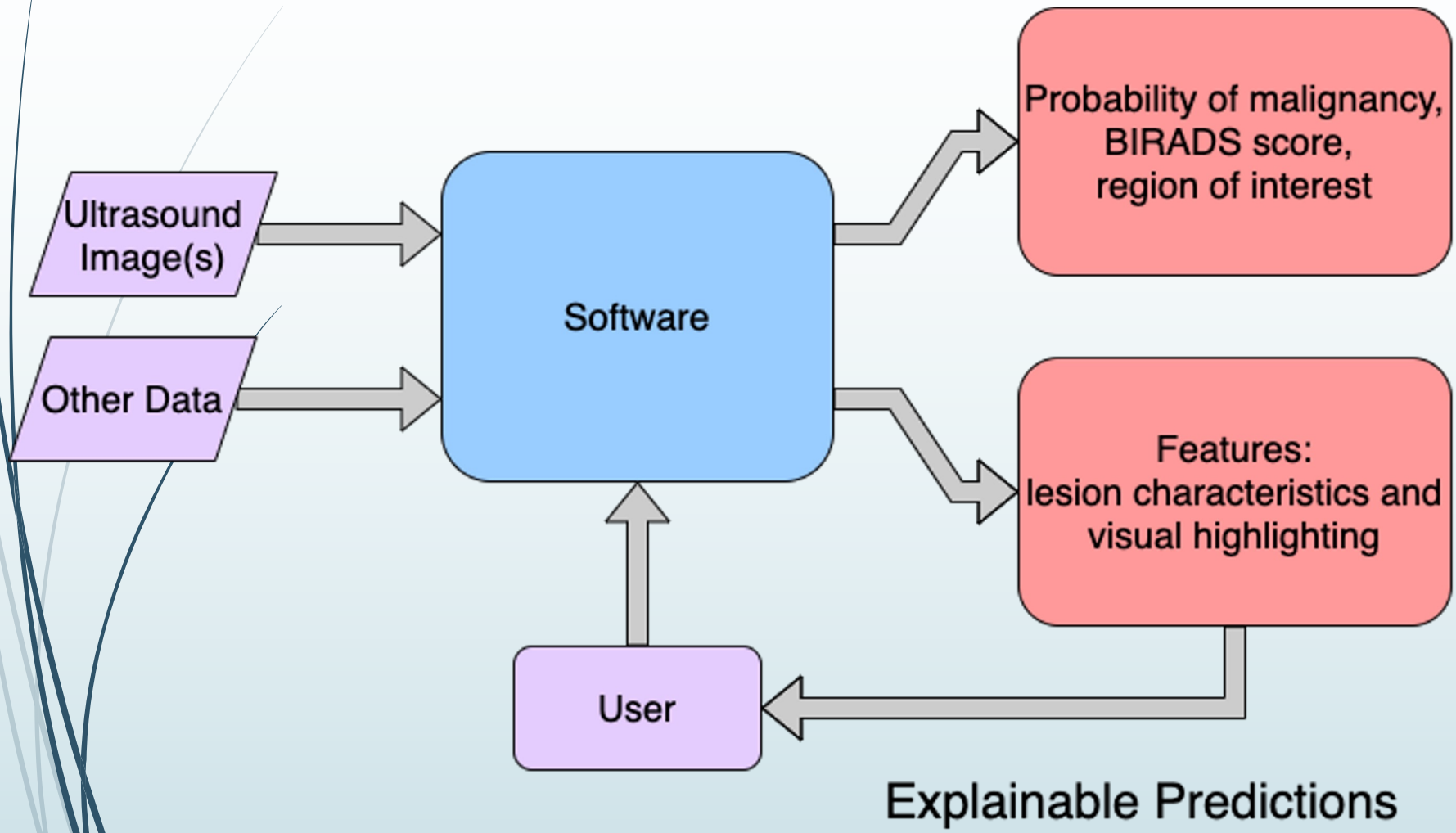
Picture from "The Utility of Deep Learning in Breast Ultrasonic Imaging" at mdpi.com





Pictures from "The Utility of Deep Learning in Breast Ultrasonic Imaging" at mdpi.com

Our Software (Idea)



Breast Imaging-Reporting and Data System (BI-RADS)

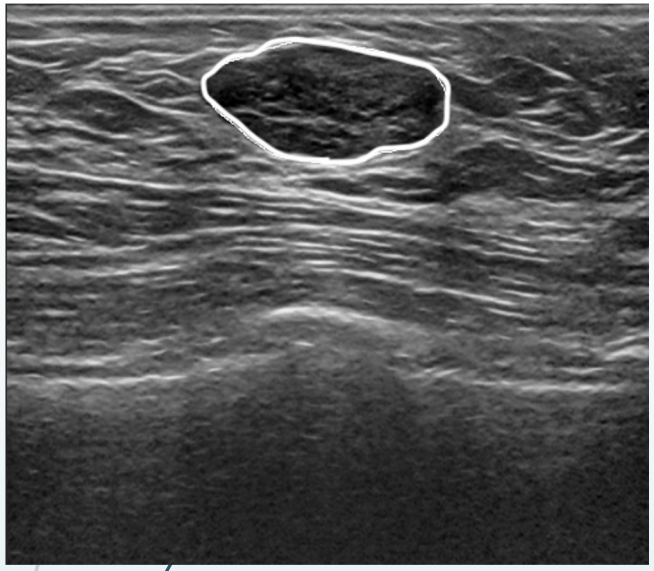
Final Assessment Categories			
Category		**Management**	**Likelihood of cancer**
0	Need additional imaging or prior examinations	Recall for additional imaging and/or await prior examinations	n/a
1	Negative	Routine screening	Essentially 0%
2	Benign	Routine screening	Essentially 0%
3	Probably Benign	Short interval-follow-up (6 month) or continued	>0 % but ≤ 2%
4	Suspicious	Tissue diagnosis	4a. low suspicion for malignancy (>2% to ≤ 10%) 4b. moderate suspicion for malignancy (>10% to ≤ 50%) 4c. high suspicion for malignancy (>50% to <95%)
5	Highly suggestive of malignancy	Tissue diagnosis	≥95%
6	Known biopsy-proven	Surgical excision when clinical appropriate	n/a

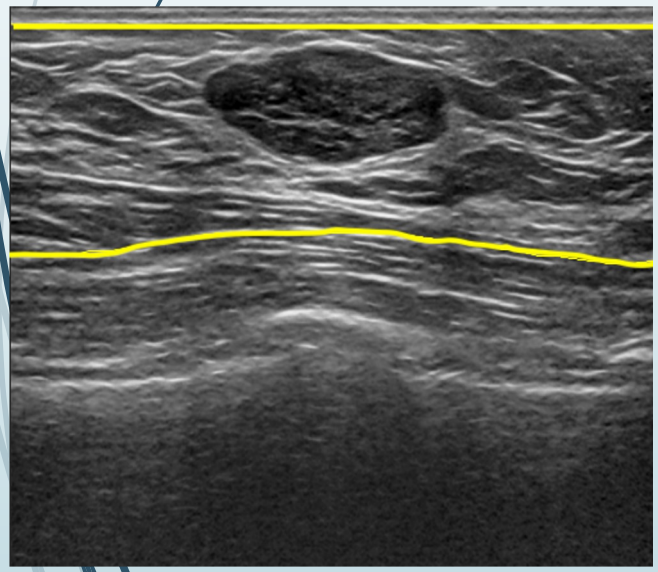
Ultrasound Lexicon		
Breast composition	a. homogeneous - fat b. homogeneous - fibroglandular c. heterogeneous	
Mass	**shape**	oval - round - irregular
	margin	Circumscribed ***or*** Not-circumscribed: indistinct, angular, microlobulated, spiculated
	orientation	parallel - not parallel
	echo pattern	anechoic - hyperechoic - complex cystic/solid hypoechoic - isoechoic - heterogeneous
	posterior features	no features - enhancement - shadowing - combined pattern
Calcifications	in mass - outside mass - intraductal	
Associated features	architectural distortion - duct changes - skin thickening - skin retraction - edema - vascularity (absent, internal, rim) - elasticity	
Special cases *(cases with a unique diagnosis)*	simple cyst - clustered microcysts - complicated cyst - mass in or on skin - foreign body (including implants) - intramammary lymph node - AVM - Mondor disease - postsurgical fluid collection - fat necrosis	

How do we succeed?

- More and better data: high quality imaging with expert annotation means improved deep learning
- Explainable predictions that allow user to make adjustments
- Emphasis on usable product instead of new theory
- Strong supply of eager master's degree students who want real-world experience

Data and Annotation (Dr. Ellis)





BI-RADS Assessment Rubric

Mass	**shape**	oval - round - irregular
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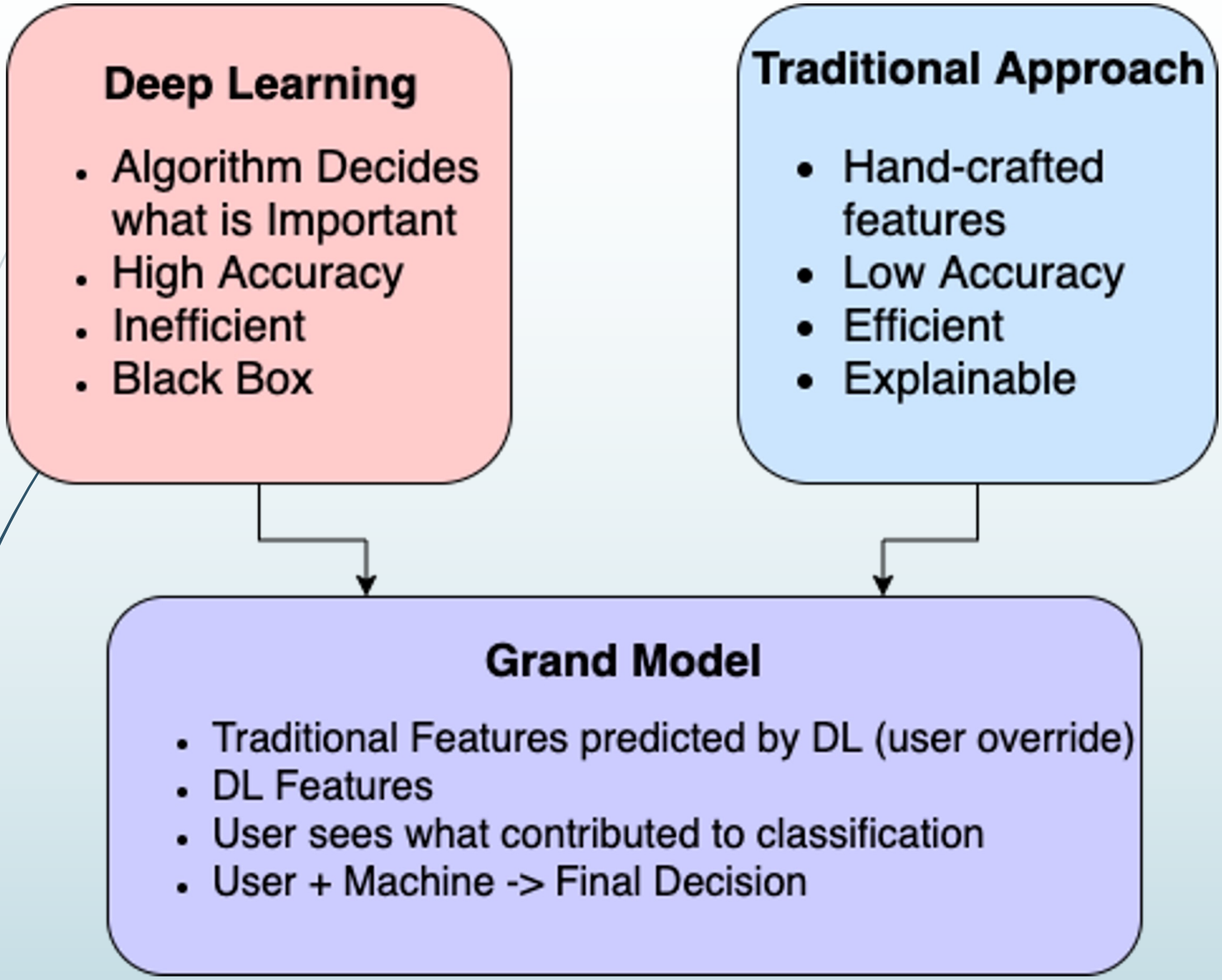
BI-RADS 3 - benign

Blackbox and Explainability



Product-Oriented Approach

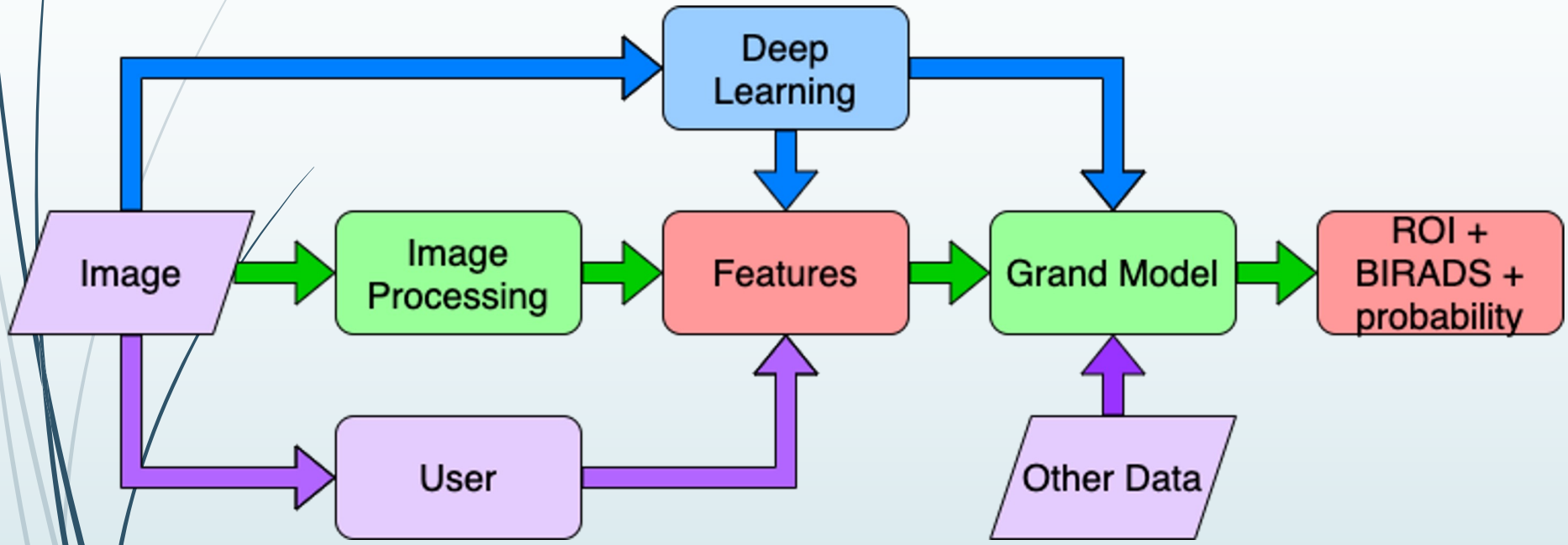
Research

- Goal: Publication
- Original techniques are important here
- Innovative in theory
- Code that works
- …

Products

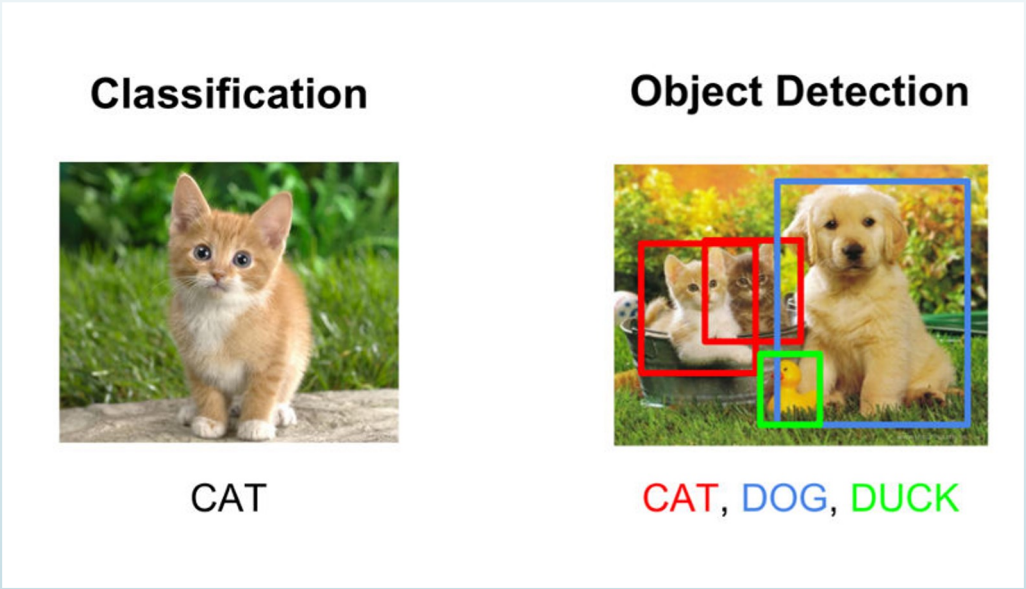
- Goal: Useful Product
- Use proven techniques where possible
- Innovative in engineering
- Code that is efficient and robust
- …

Under the Hood



Deep Learning

- Goal: Extract meaningful representation from imagery
- Uses:
  - Identify where lesion(s) are an ultrasound
  - Classify each lesion as malignant or benign
- Cons: Requires a lot of labeled images



Models Tested

- Add table of models tested here

Top losses

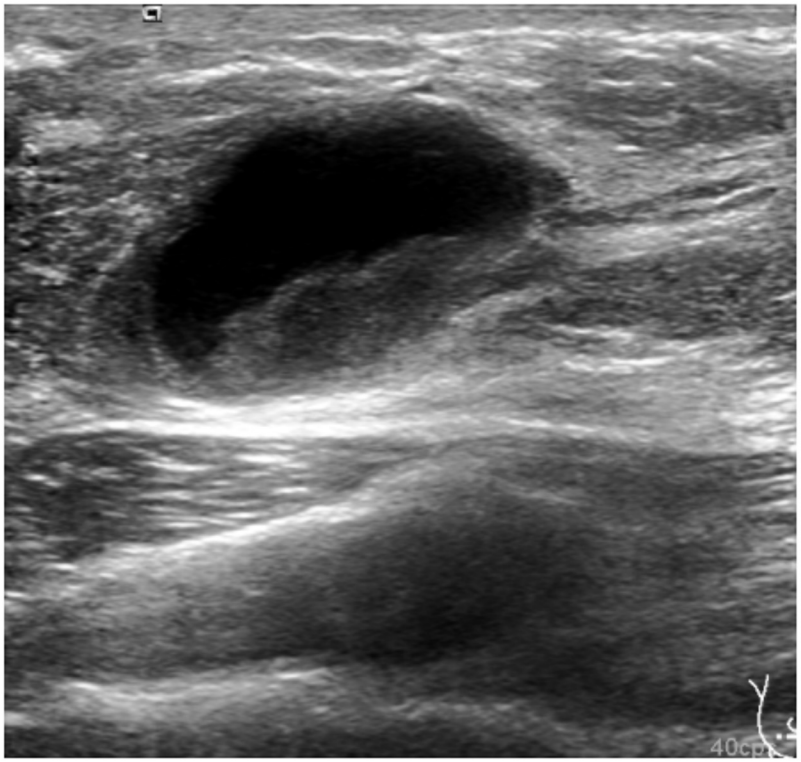
Model Interpretation

Details

- Algorithm: Convolutional Neural Network (CNN)
- CNN's are neural networks used to process images

T

Automatic Segmentation with Mask R-CNN



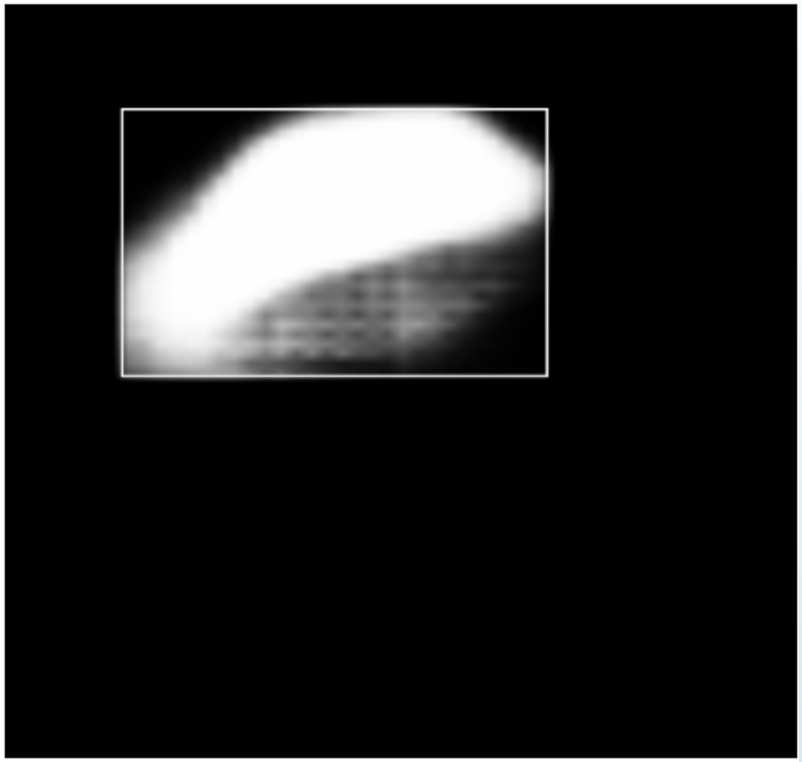
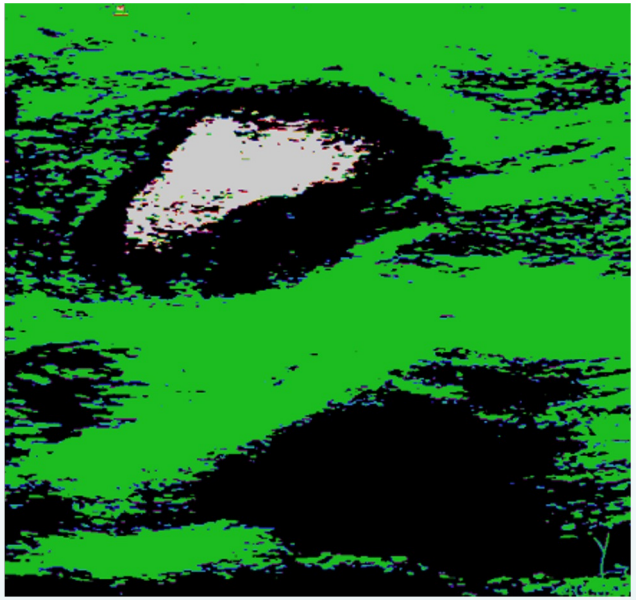


Image Processing and Grand Model Team

Adam, David, Lucas

- Filtering
- Region growing
- Denoising
- Fourier analysis
- …
- Bayesian Belief Networks
- Decision Trees
- …

Image Processing Segmentation



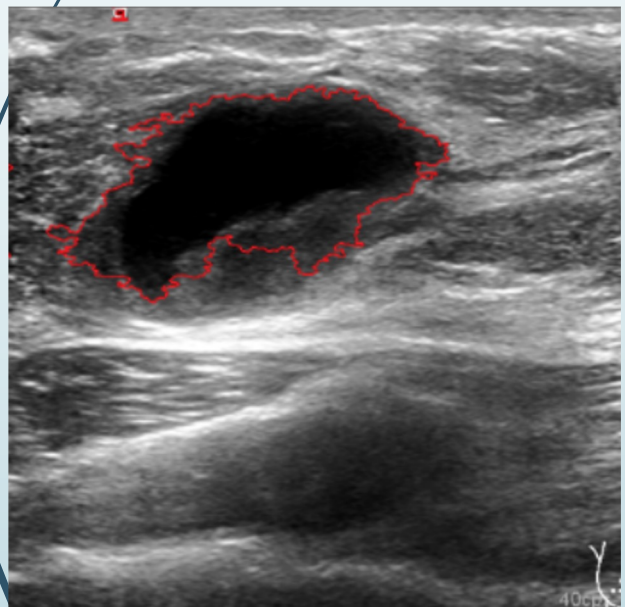
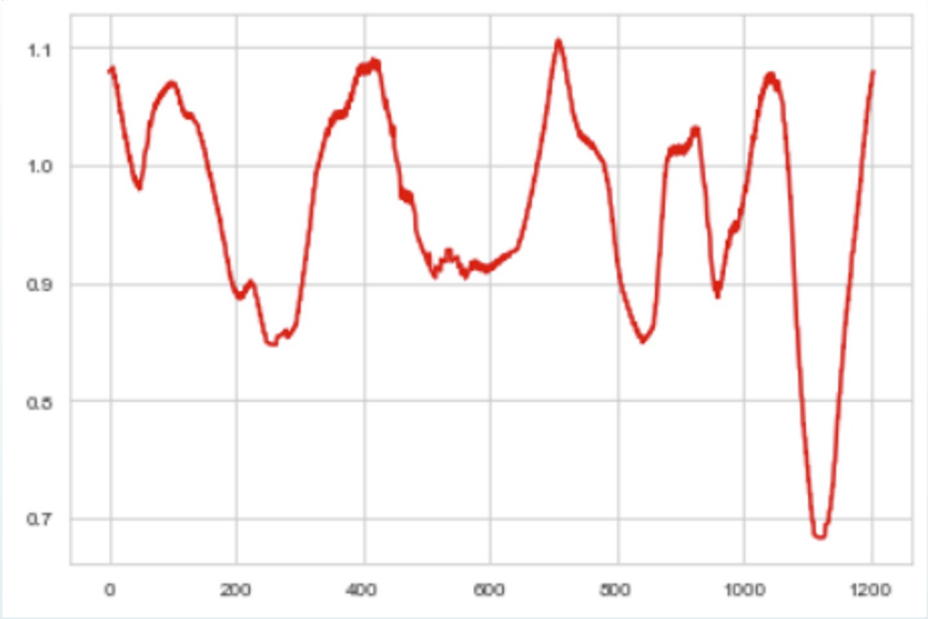


Image Processing for Features



- Irregular Boundary

Grand Model

- Decision Rules (Dr. Ellis)
- ML models: Bayesian network, decision tree …
- Update prediction when modified

Size: 14 mm (**)
ShapeACR: round (***)
PFACR: enhancement
Shape TS: round (*)

Normal	Benign	Malignant
4%	70%	26%

Size: 14 mm (**)
ShapeACR: irregular (***)
PFACR: enhancement
Shape TS: round (*)

Normal	Benign	Malignant
0%	14%	86%

Imagio Ultrasound

US Peripheral Zone	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
US Capsular or Boundary Zone	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6	Reference Key
US Shape Score	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
US Internal Texture	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
US Sound Transmission	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key

Opto-Acoustic

OA External Peripheral Zone Vessels	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
OA Capsular or Boundary	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5 ○ 6	Reference Key
OA Internal Vessel Score	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
OA Internal Hemoglobin Score	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key
OA Internal Blush Score	○ 0 ○ 1 ○ 2 ○ 3 ○ 4 ○ 5	Reference Key

Other

Mammogram-BIRADS	○ NA ○ 0 ○ 1 ○ 2 ○ 3 ○ 4a ○ 4b ○ 4c ○ 5
Patient Age	-- age --
Lesion Size (cm)	-- size --
Lesion Posterior Depth (cm)	-- depth --

SenoGram Likelihood of Malignancy

Black line corresponds to estimated 98% Sensitivity

0% 100%

https://senomedical.com/rsna_2020/senogram/

Prototype App

Peripheral

Peripheral Zone ACR

Duct changes

Peripheral Zone TS

Normal Tissue

Marginal

Marginal Zone ACR

Duct changes

Boundary Zone ACR

Normal Tissue

Marginal Boundary Zone TS

Well circumscribed

Internal

Size(mm)

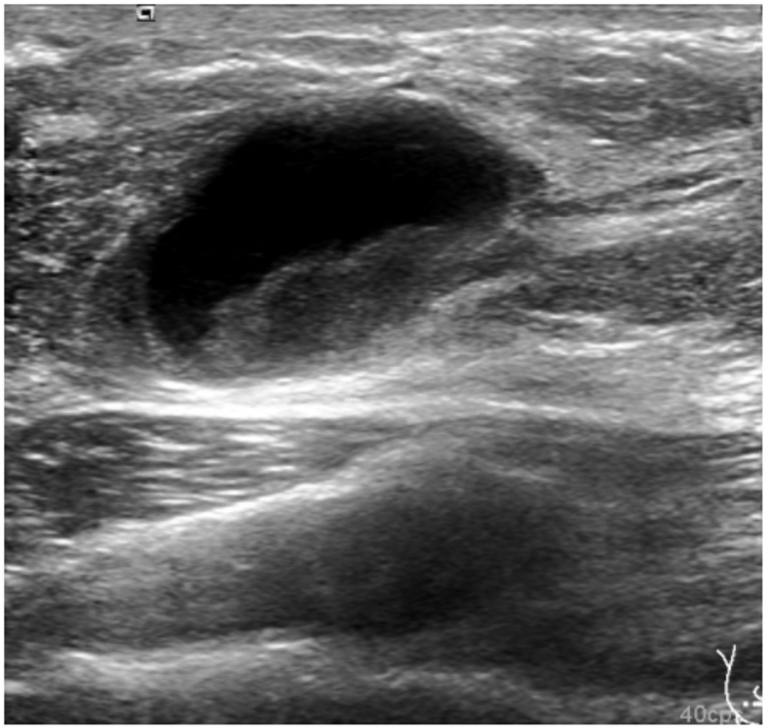
23

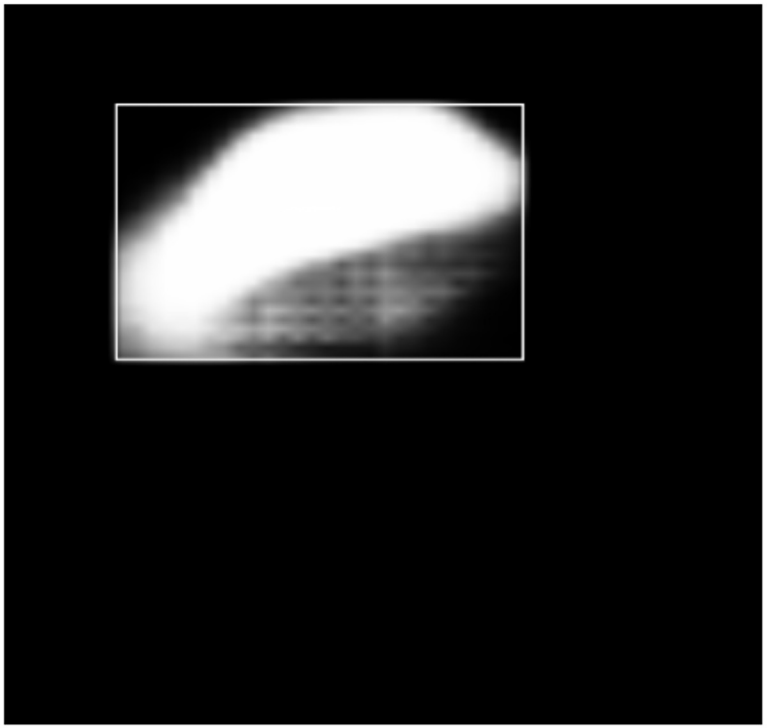
Shape ACR

Oval

Predictions

Normal %	Benign %	Malignant %
40.74	31.48	27.78





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Thank you!