UNIVERSITY OF HAWAI‘I
CANCER CENTER

Learning a Clinically-Relevant Concept Bottleneck for Lesion Detection in Breast Ultrasound

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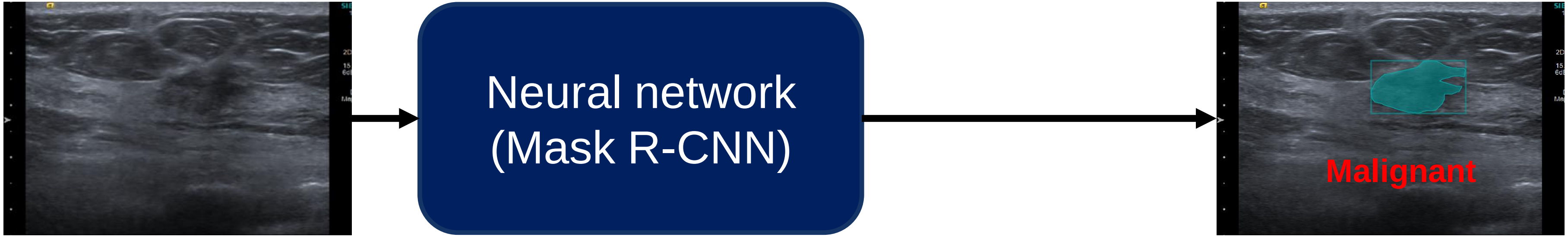
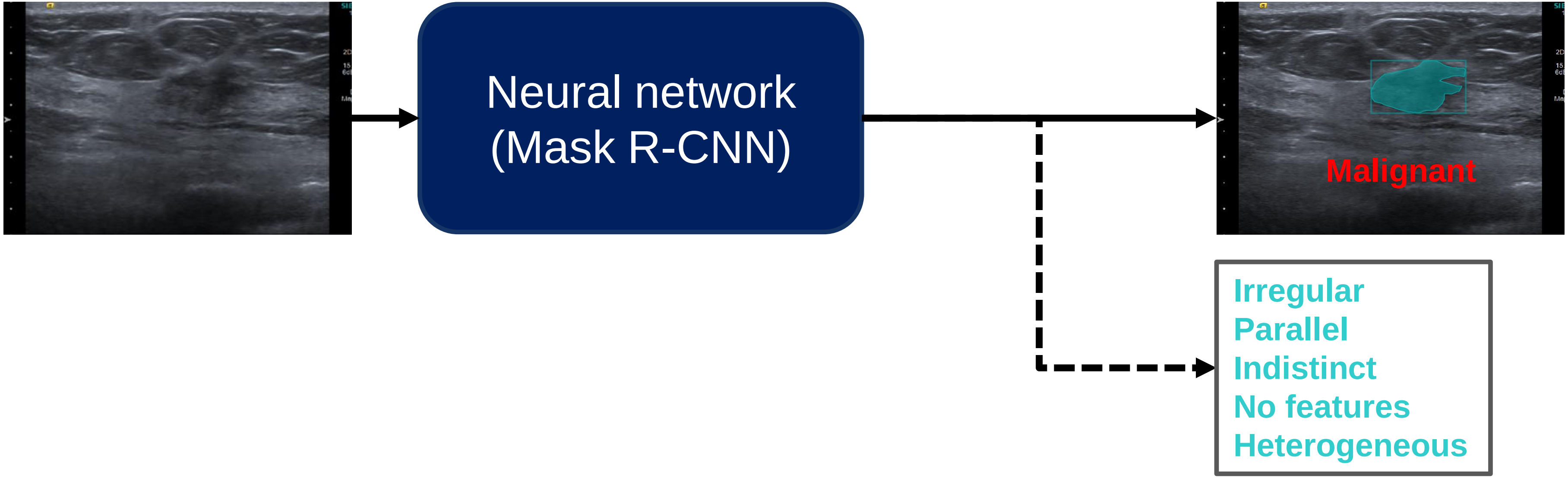
Goal

Detect and classify lesions in breast ultrasound imaging in an explainable way.



Clinical Explainability

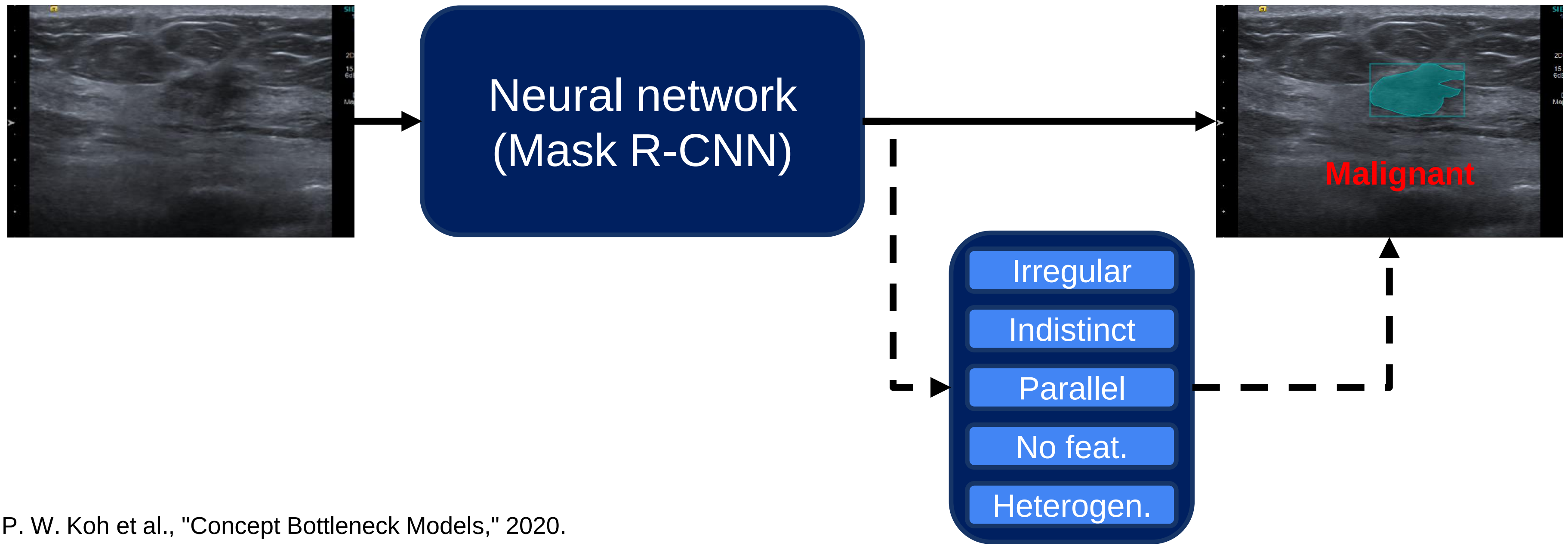
We can predict existing, clinically-relevant reporting guidelines as concepts.



Concepts

Concept Bottleneck Models[1]

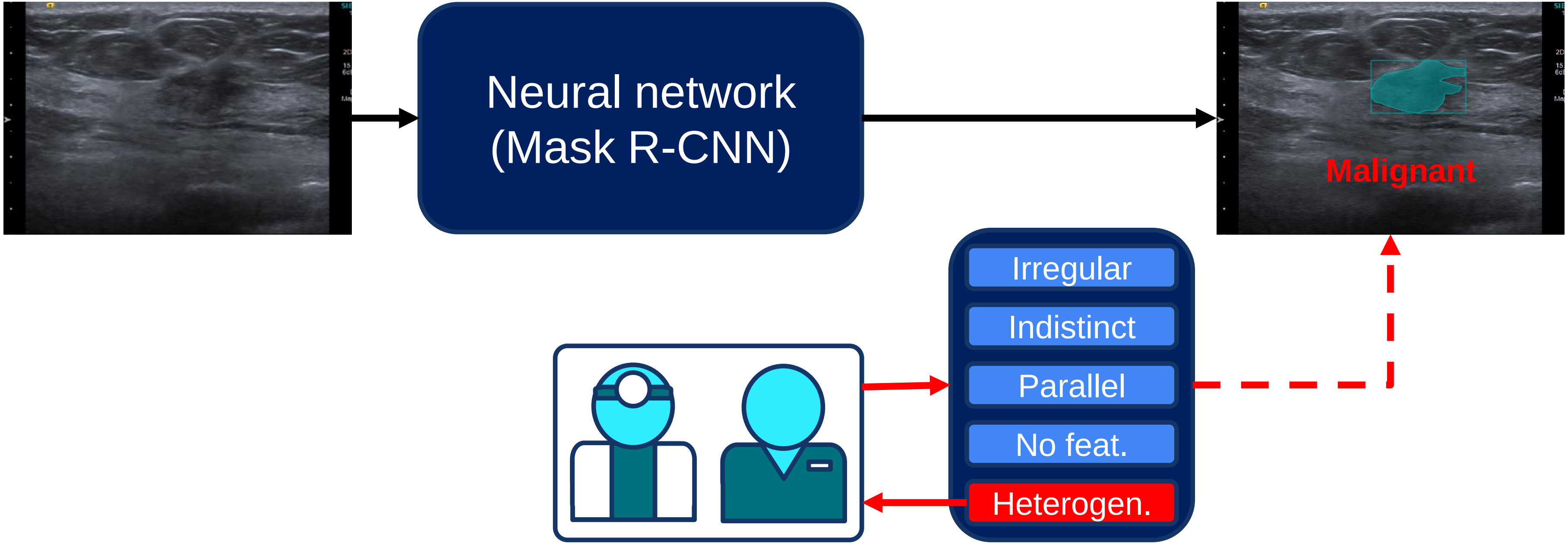
CBMs align intermediate model representations with these human-defined concepts.



1. P. W. Koh et al., "Concept Bottleneck Models," 2020.

Steering with Concepts

CBMs allow for steerable, physician-in-the-loop AI to be used in the clinic.



Clinical Concepts for Breast US

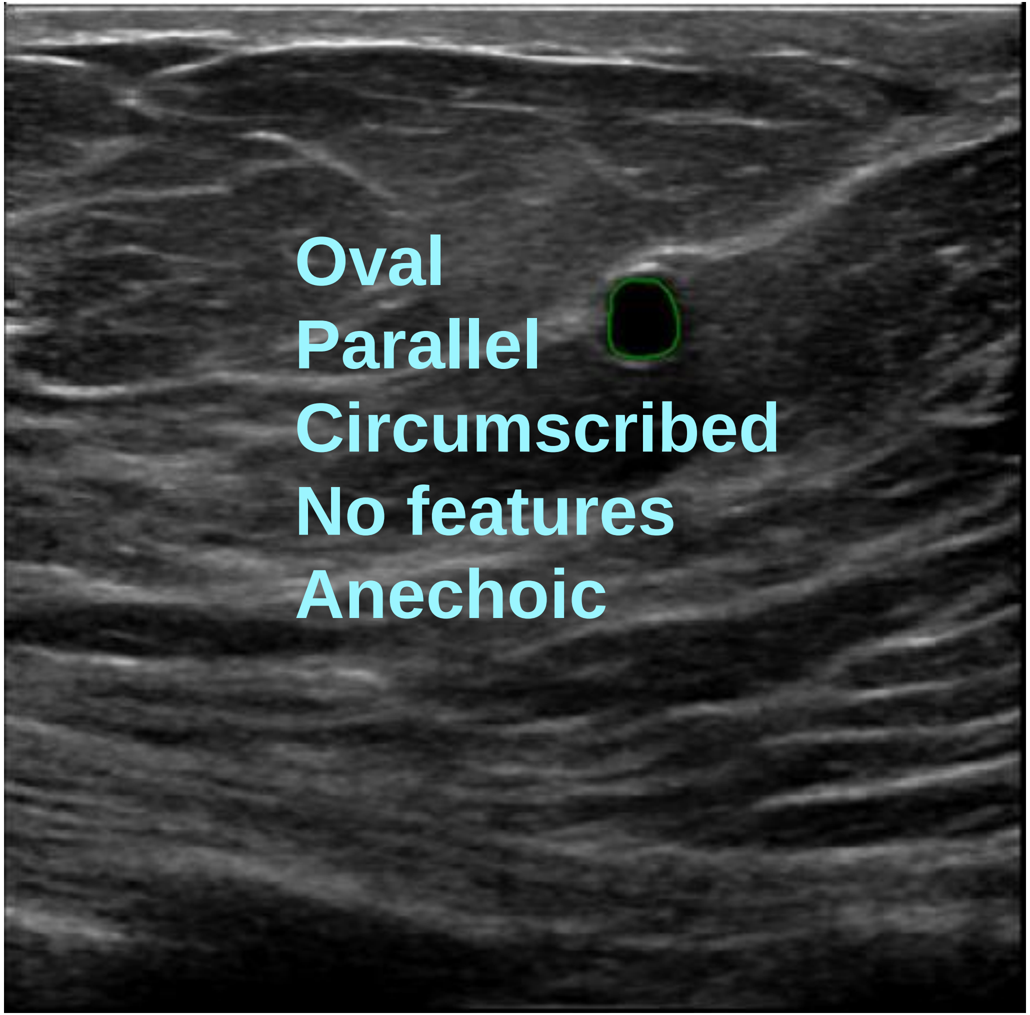
C. D'Orsi, L. Bassett, and S. Feig, "Breast imaging reporting and data system (BI-RADS)," *Breast imaging Atlas, 4th edn. American College of Radiology, Reston,* 2018.

Concepts defined with lexicon of Breast Imaging-Reporting and Data System Masses (BI-RADS)

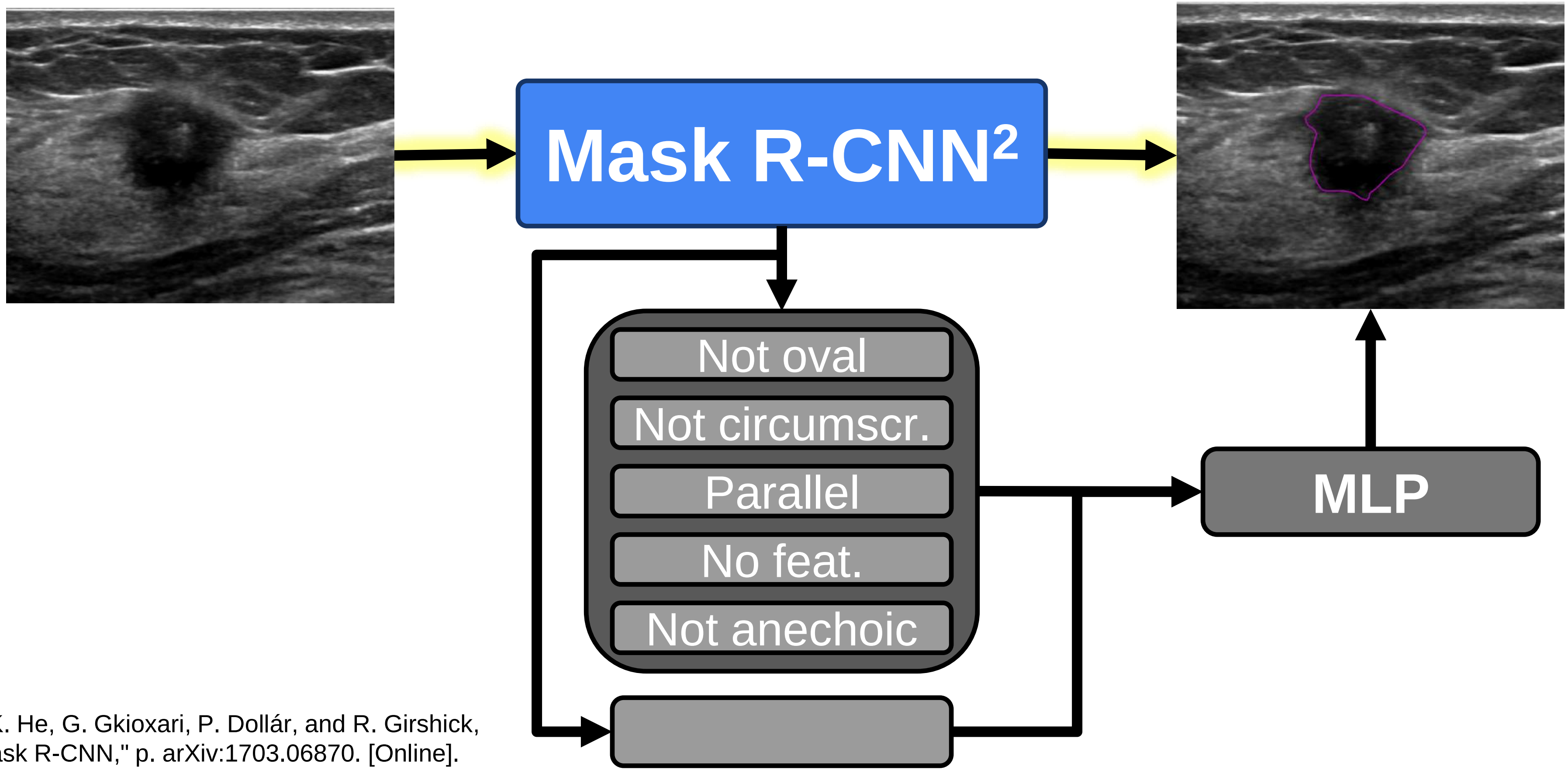
Indicative of malignancy

Indicative of benignity

Attribute	Categories
Shape	***Oval*** **Round** **Irregular**
Orientation	***Parallel*** **Not parallel**
Margin	***Circumscribed*** **Not circumscribed**
Echo Pattern	***Anechoic*** **Hyperechoic** **Complex cystic and solid** **Hypoechoic** **Isoechoic** **Heterogeneous**
Posterior Features	***No posterior features*** **Enhancement** **Shadowing** **Combined pattern**

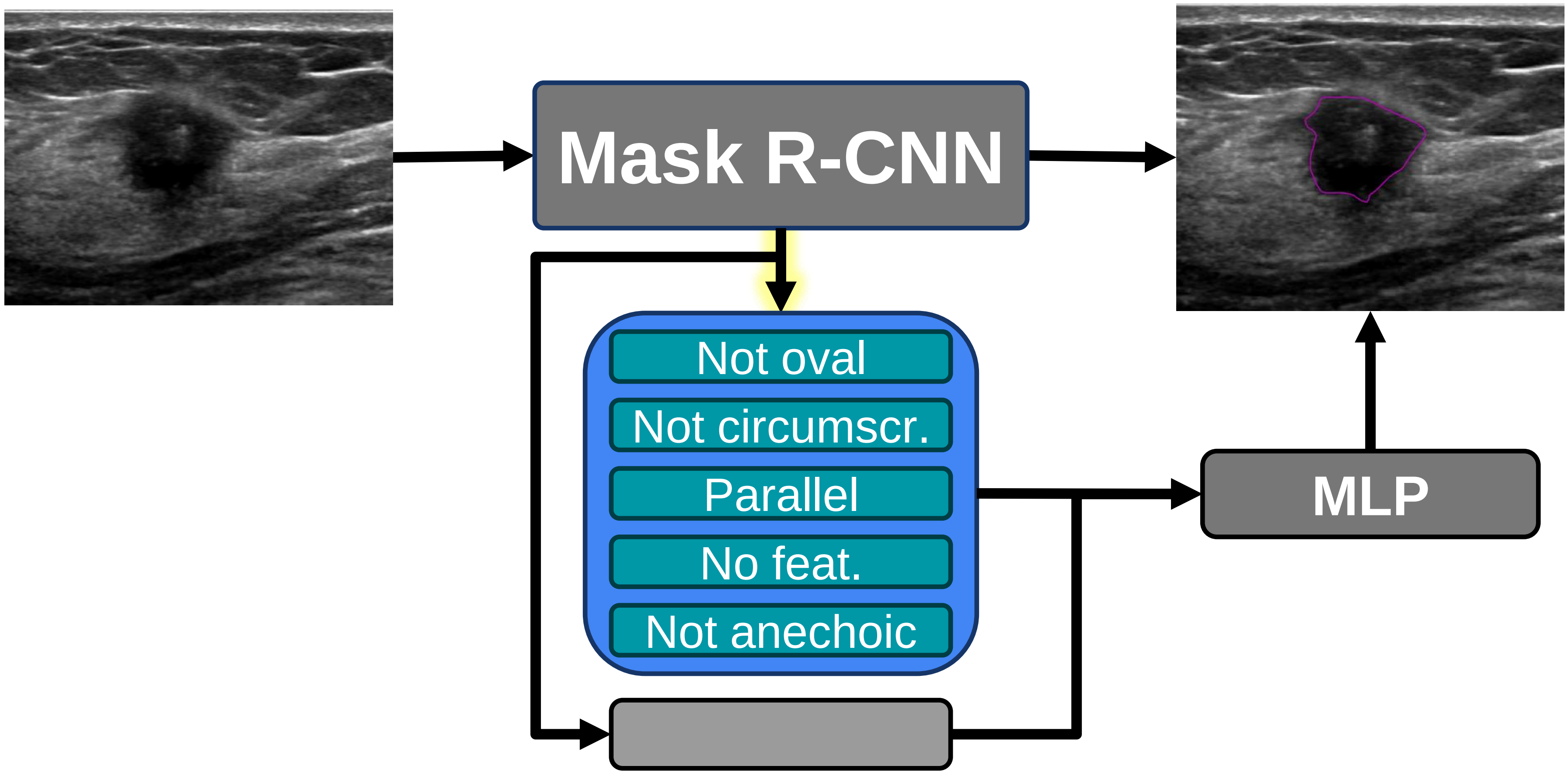

Oval
Parallel
Circumscribed
No features
Anechoic

Stage 1: Lesion detection

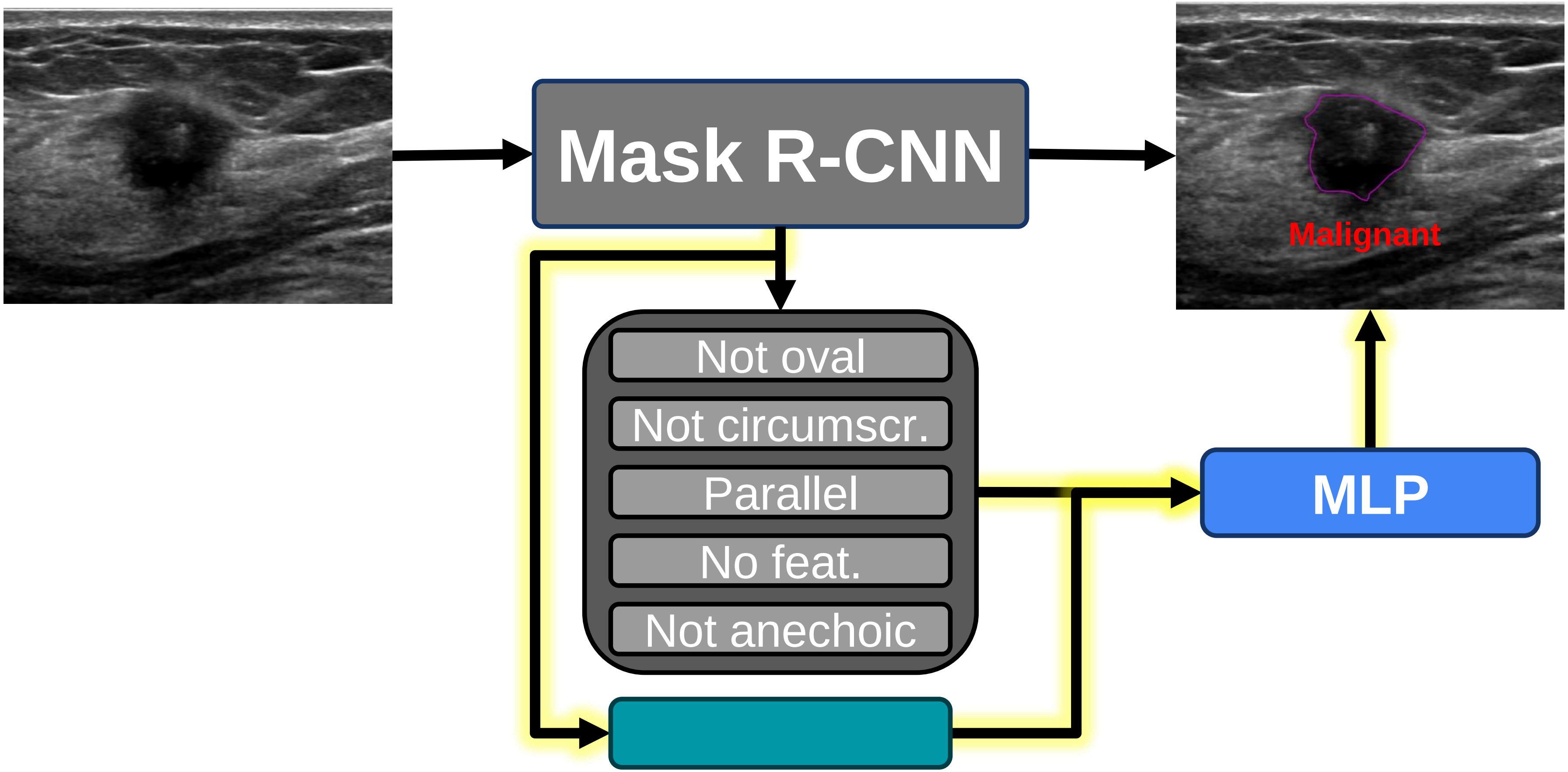


2. K. He, G. Gkioxari, P. Dollár, and R. Girshick, "Mask R-CNN," p. arXiv:1703.06870. [Online].

Stage 2: Concept classification

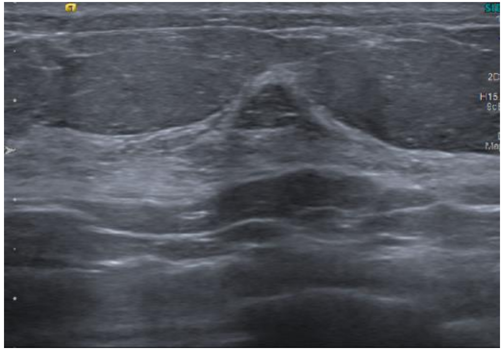


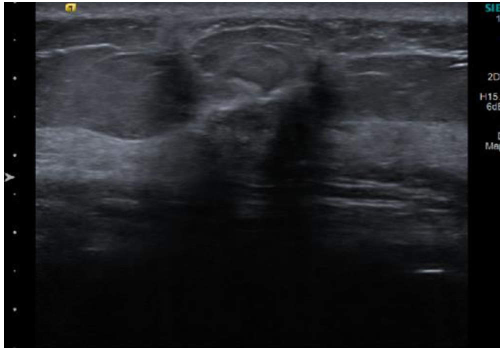
Stage 3: Cancer classification

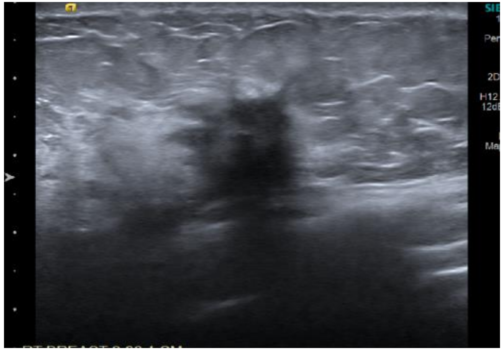


Breast US Dataset

- Data from Hawai‘i and Pacific Islands Mammography Registry[3]
- 994 women with 8,854 images
- Matched by birth year and ultrasound machine type
- Split 70% train, 10% valid, 20% test

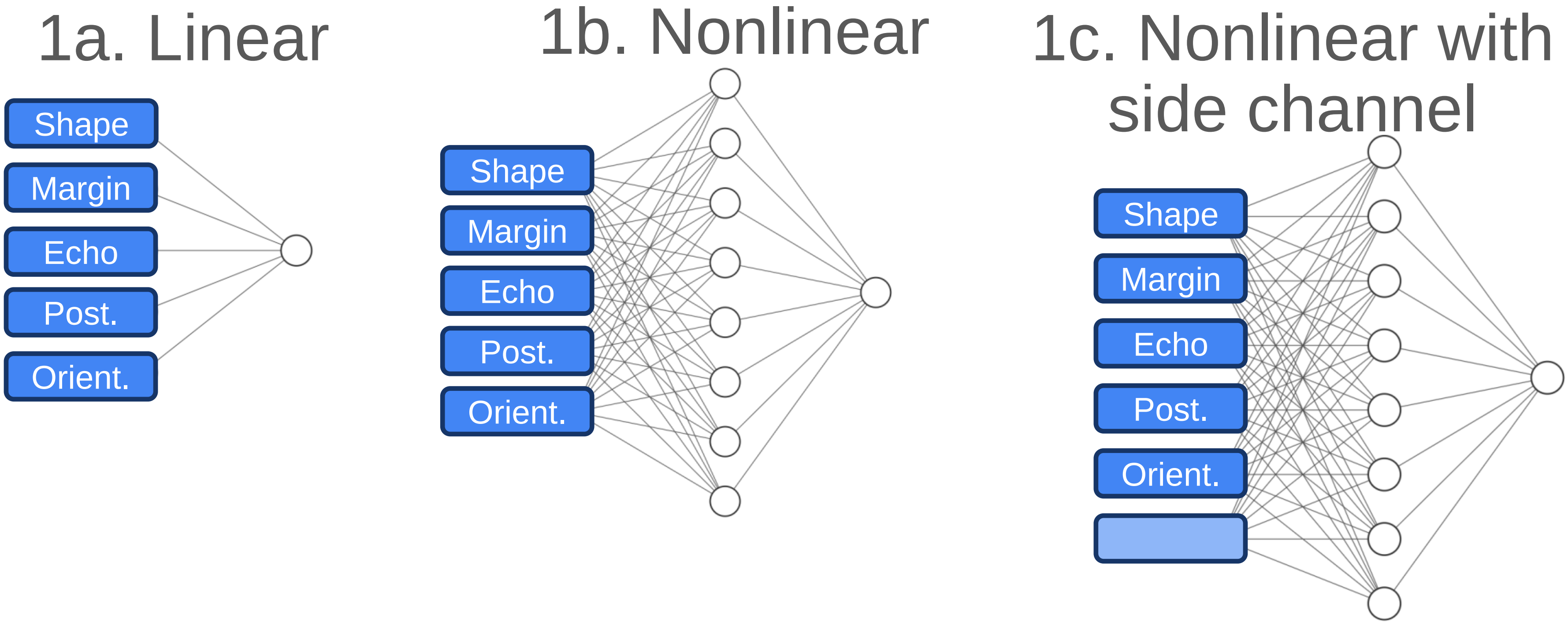




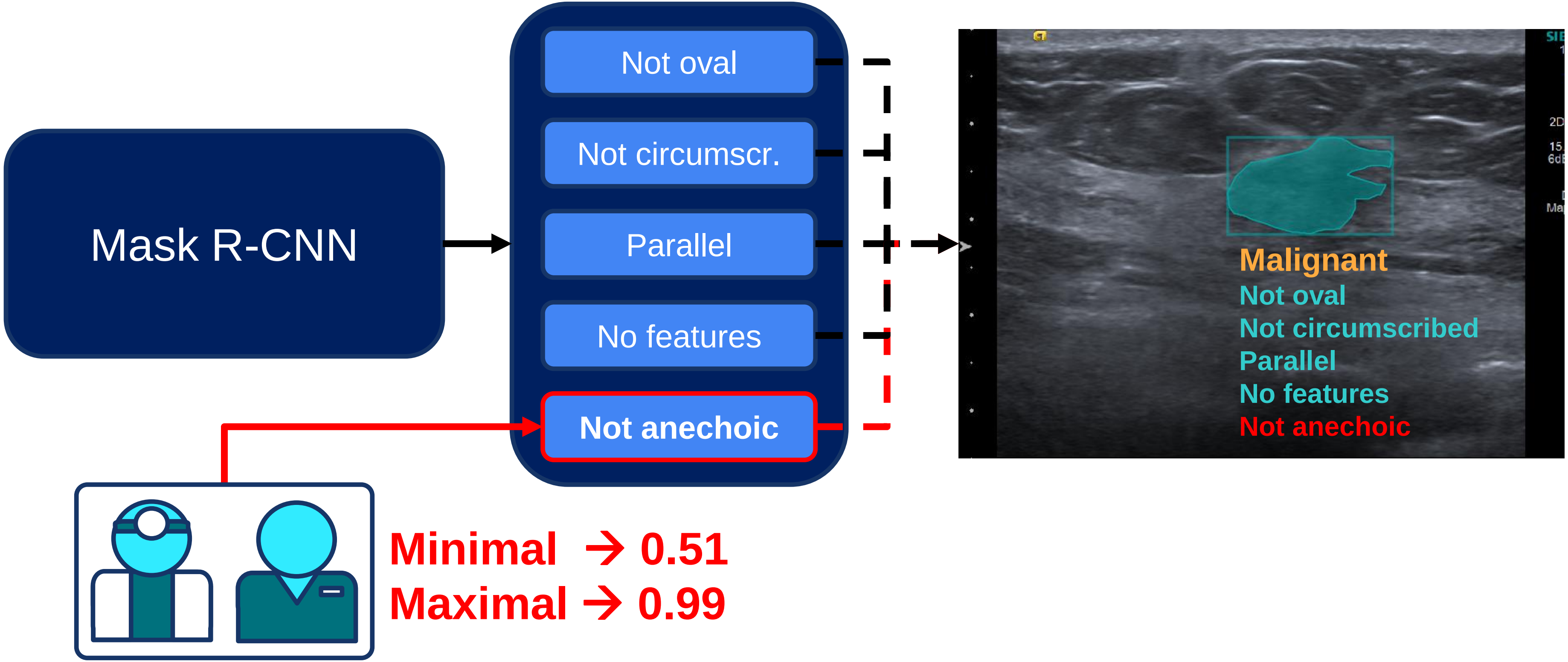


3. Hawai‘i and Pacific Islands Mammography Registry
https://hipimr.shepherdresearchlab.org/

Experiment 1: Post-bottleneck design



Experiment 2: Concept steering



Performance in lesion detection

Model	Average Precision		Average Precision$_{75}$	
	Segm	BBox	Segm	BBox
BI-RADS CBM	**0.49**	**0.47**	**0.55**	**0.53**
STNet (Qin et. al 2023)	N/A	0.40	N/A	0.43
CVA-Net (Lin et. al 2022)	N/A	0.36	N/A	0.39

CBM = Concept Bottleneck Model

C. Qin, J. Cao, H. Fu, R. M. Anwer, and F. S. Khan, "A Spatial-Temporal Deformable Attention Based Framework for Breast Lesion Detection in Videos," in *International Conference on Medical Image Computing and Computer-Assisted Intervention*, 2023: Springer, pp. 479-488.

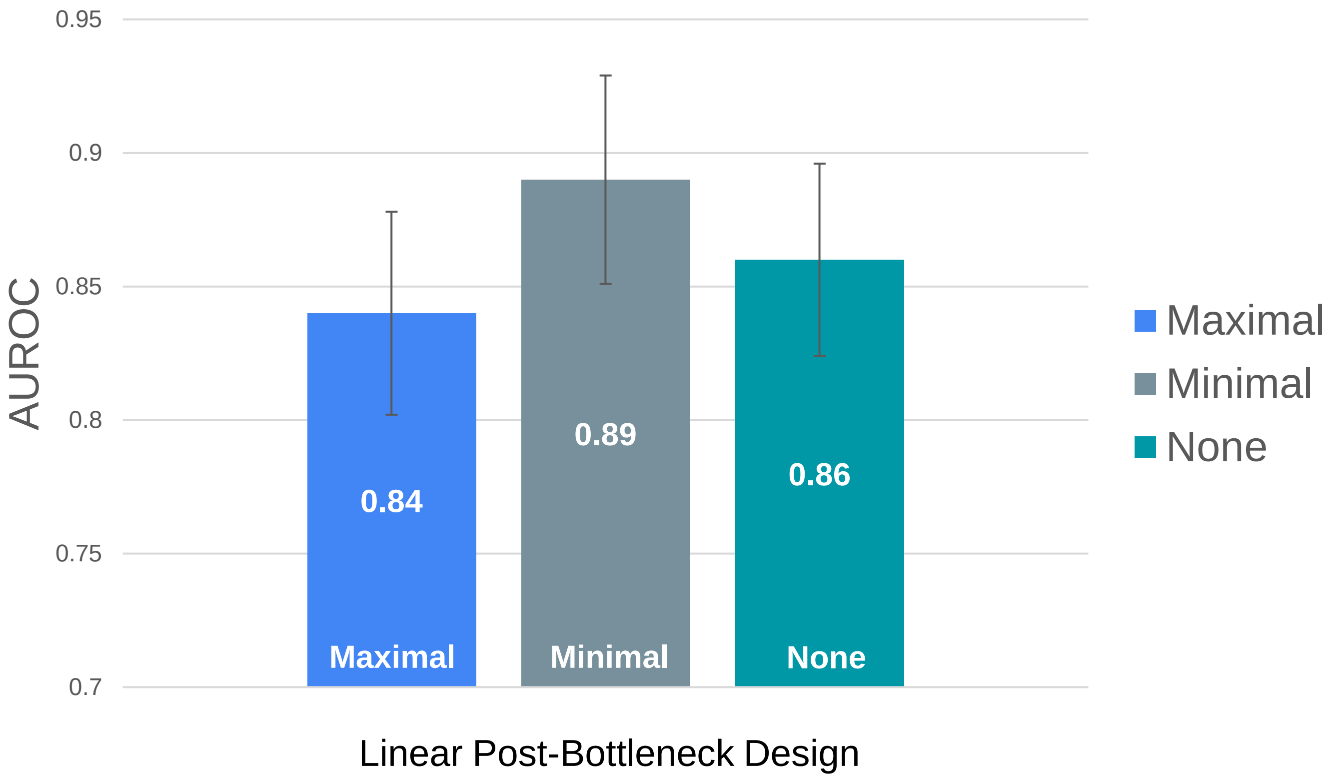
Z. Lin, J. Lin, L. Zhu, H. Fu, J. Qin, and L. Wang, "A New Dataset and a Baseline Model for Breast Lesion Detection in Ultrasound Videos," in International Conference on Medical Image Computing and Computer-Assisted Intervention, 2022: Springer, pp. 614-623.

Concept bottleneck does not degrade performance and aids interpretability.

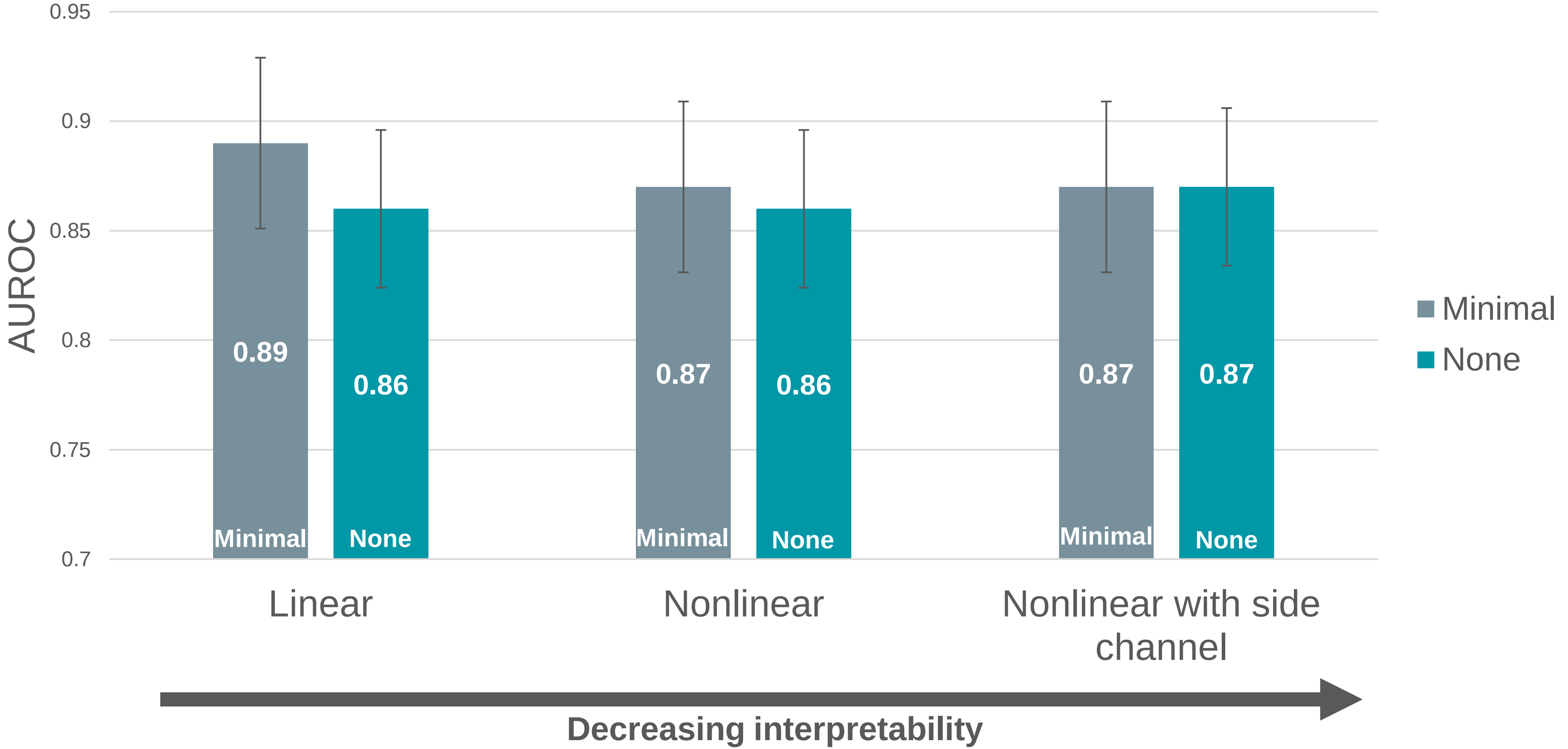
Model	Side channel?	Nonlinear?	AUROC @ IoU = 0.75
Baseline	N/A	N/A	0.88 (0.85, 0.91)
BI-RADS CBM	No	No	0.86 (0.82, 0.90)
BI-RADS CBM	No	Yes	0.86 (0.83, 0.90)
BI-RADS CBM	Yes	Yes	0.87 (0.84, 0.91)

CBM = Concept Bottleneck Model

Experiment 2: We can intervene on concepts and improve model performance.



Experiment 1: The effect of the intervention differs based on model complexity.



Questions?

https://github.com/hawaii-ai/bus-cbm

BI-RADS CBM presents an explainable AI solution for lesion detection, description, and classification from breast US.

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