Workshop on Robust Recognition in the Open World

at the British Machine Vision Conference (BMVC) 2024

Unsupervised Feature Orthogonalization for Learning Distortion-Invariant Representations

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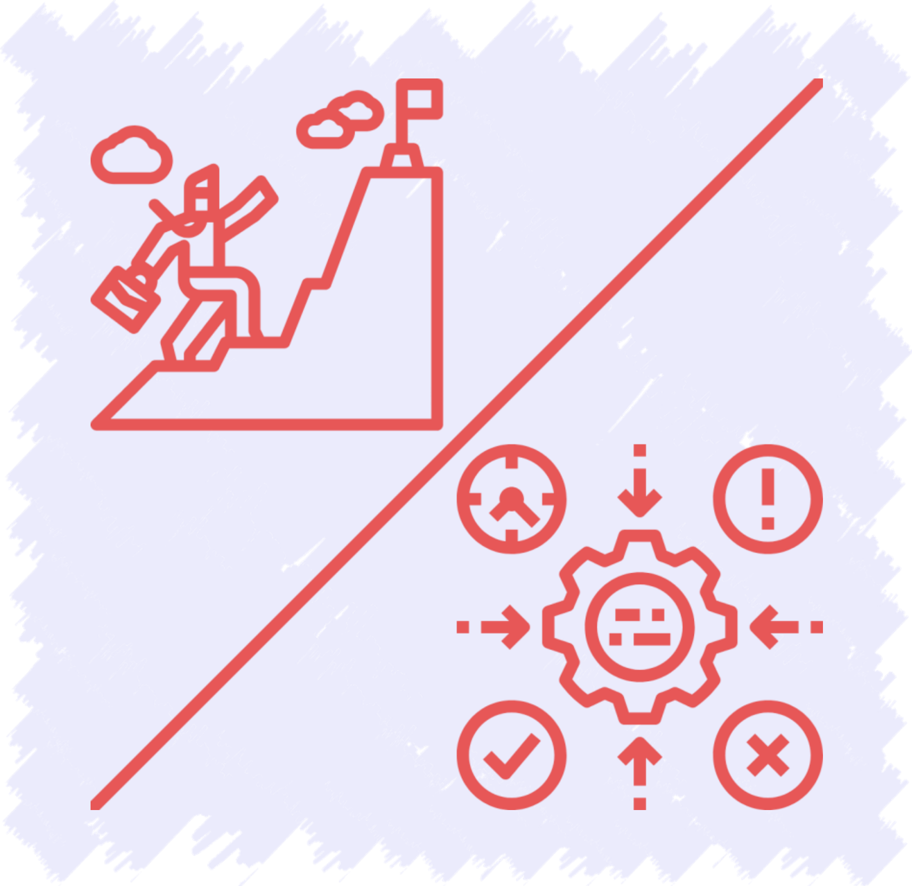
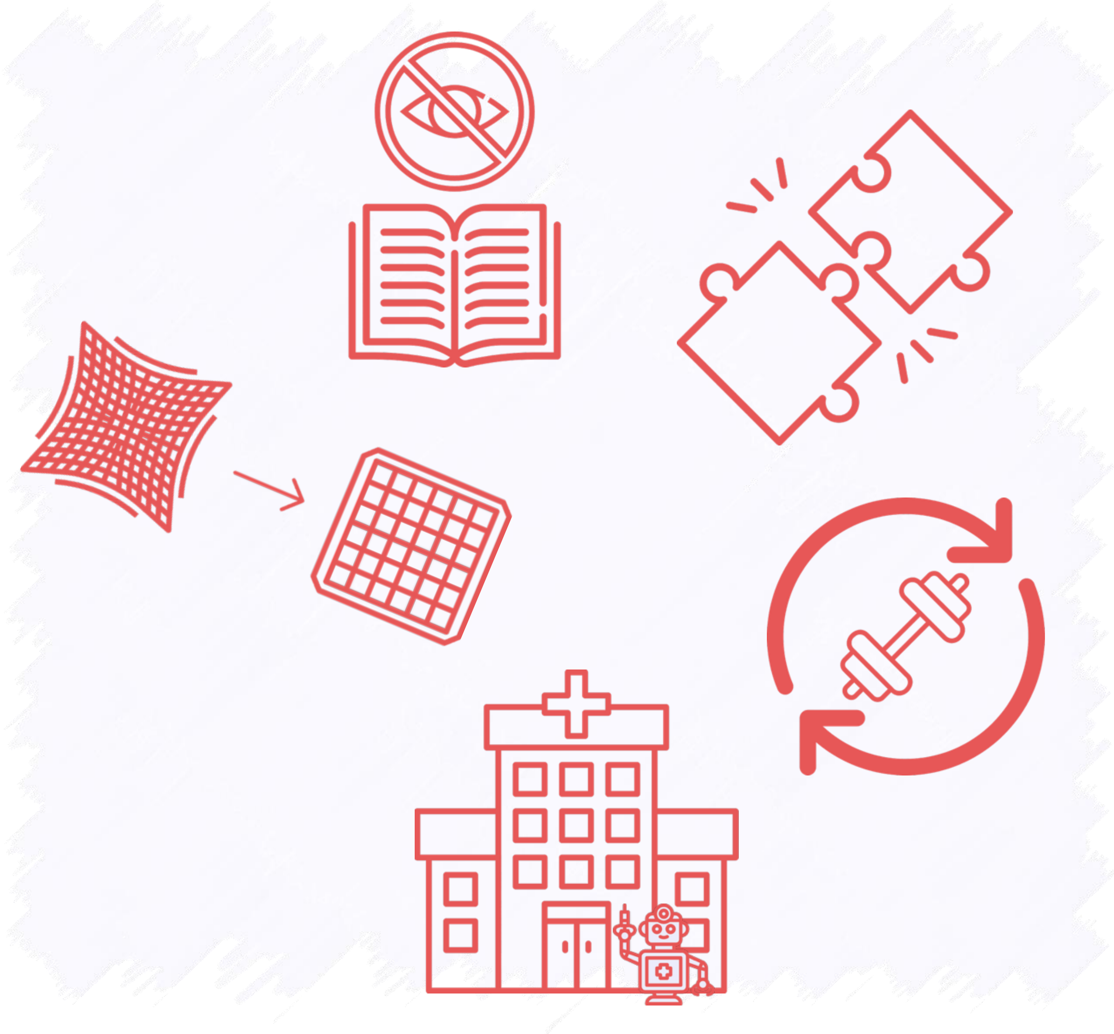
Motivation & Context



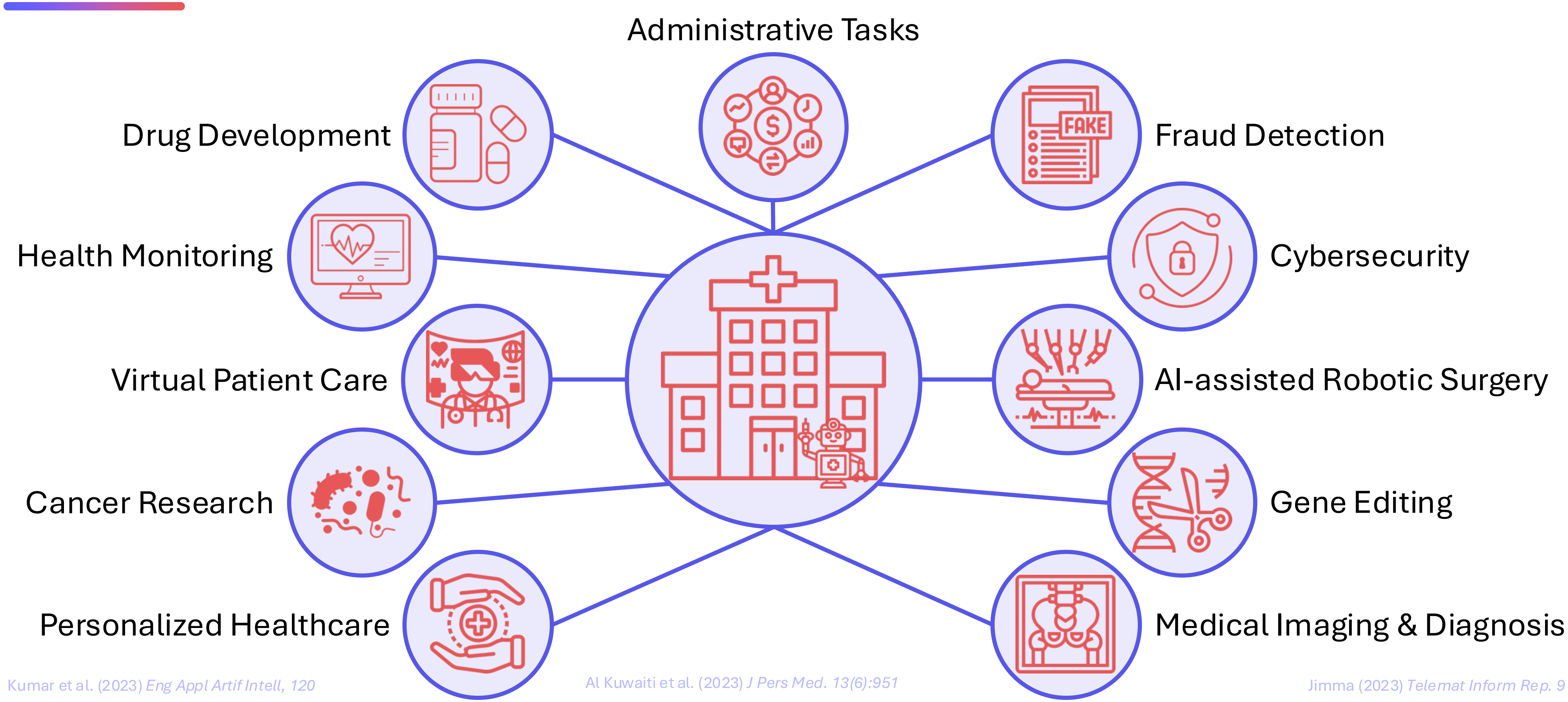
Categorization of Core Concepts

- Unsupervised learning
- Feature orthogonalization
- Distortion-invariance
- Robustness and generalizability
- Medical domain

→ With Deep Learning!



Areas of Impact for DL in Healthcare



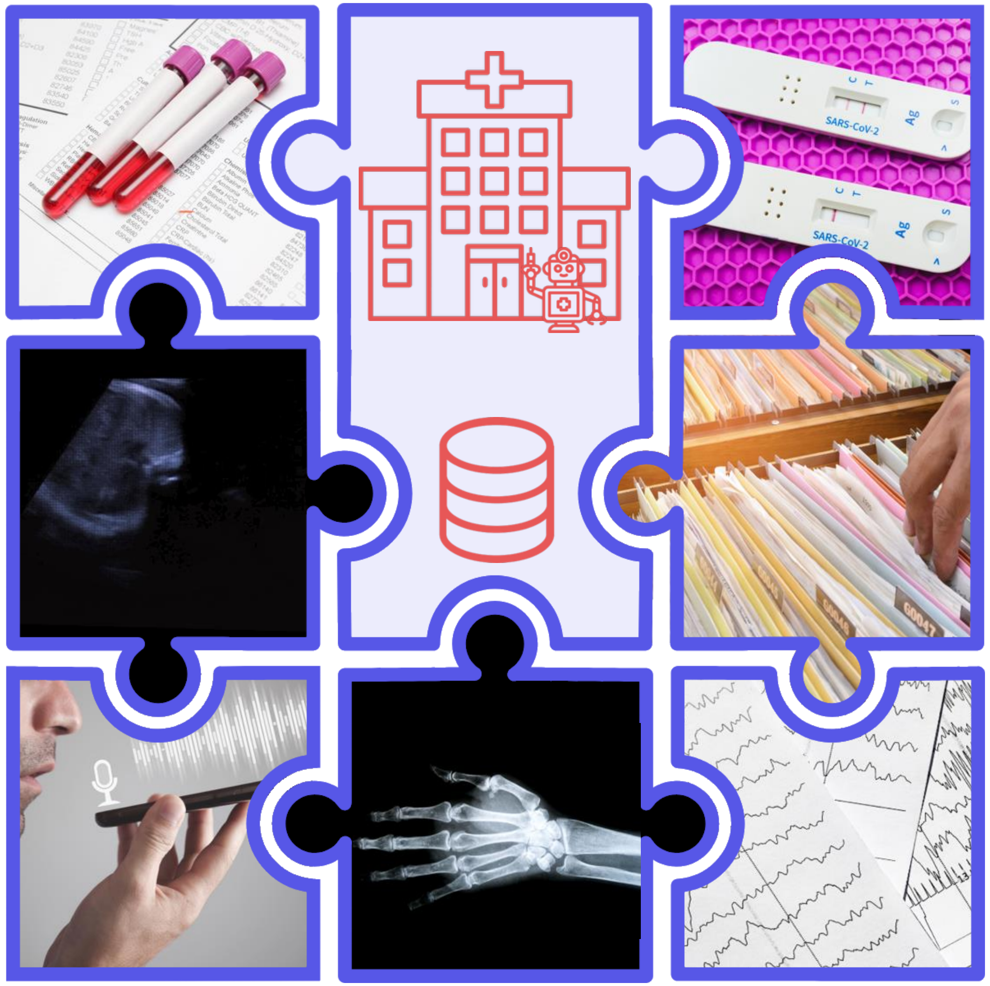
Kumar et al. (2023) *Eng Appl Artif Intell, 120*

Al Kuwaiti et al. (2023) *J Pers Med. 13(6):951*

Jimma (2023) *Telemat Inform Rep. 9*

Types of Medical Data with DL

- Video (e.g., Ultrasound)
- Text (e.g., anamnesis reports)
- Image (e.g., X-ray)
- Numerical (e.g., blood reports)
- Categorical (e.g., test results)
- Speech (e.g., doctor instructions)
- Signals (e.g., ECG)



Inherent Challenges with Medical Data

Ideal vs **Real**

- Large, diverse, high-quality datasets
- Homogeneous data acquisition
- Equal representation of disease classes and severities
- Equal representation of demographics
- Consistent imaging parameters and scanner models.

Zhou et al. (2024) *IEEE Conf Artif Intell Test. 120-131*

- Scarce and distorted data

Upadhyay et al. (2024) *Arch Comput Methods Eng. 31:1701-1719*

- Inhomogeneous data acquisition

Lafarge et al. (2017) *Lecture Notes in CS. 10553*

- Underrepresented disease classes and severities

Afrose et al. (2022) *Commun Med. 2:111*

- Underrepresented demographic groups

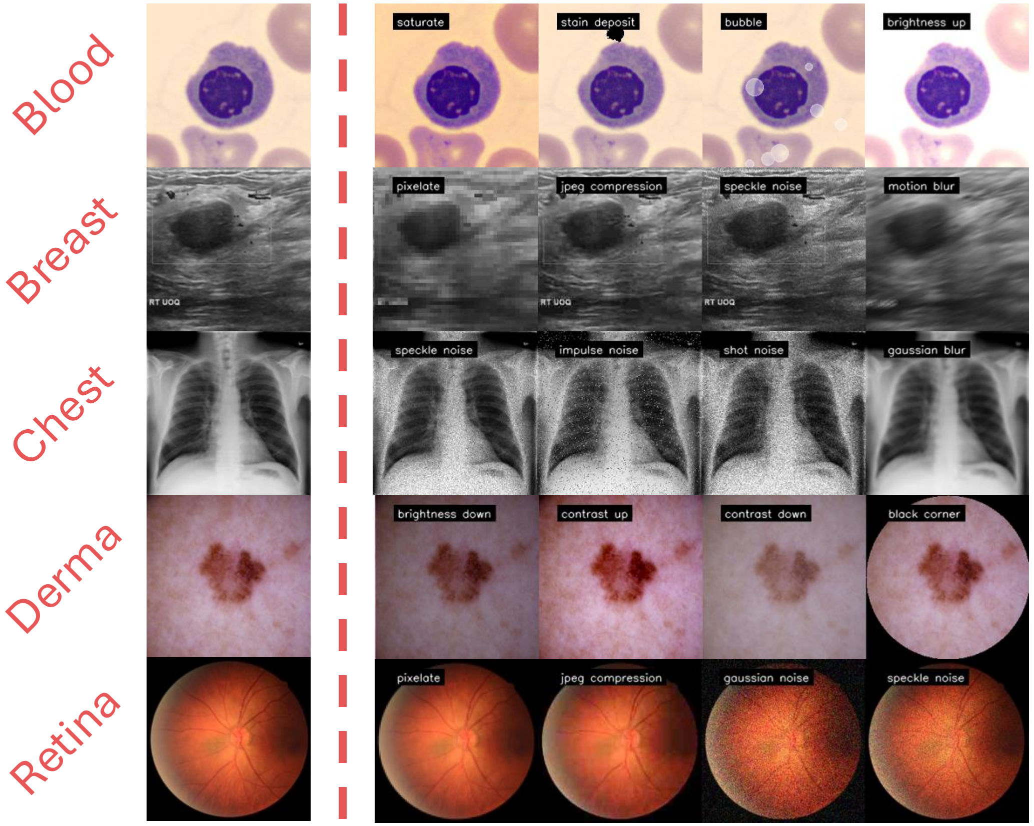
Moor et al. (2023) *Nature. 616:259-265*

- Scanner-induced domain shifts

Stacke et al. (2021) *IEEE J Biomed Health Inform. 25:325-336*

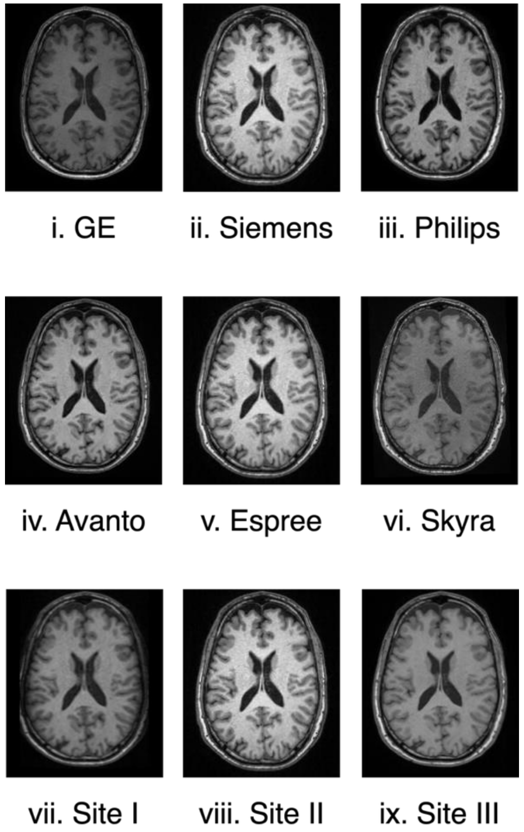
Distorted / Corrupted Data
Scanner-Induced Domain Shift

Image Corruptions



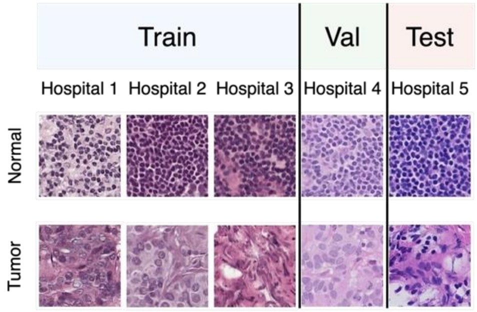
Di Salvo et al. (2024) *ADSMI @ MICCAI*

Scanner-shift



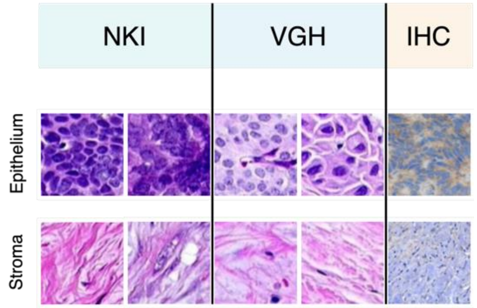
Doerrich et al. (2024) *RROW @ BMVC*

Hospital-shift



Doerrich et al. (2024) *MICCAI. 15010*

Processing-shift



Doerrich et al. (2024) *MICCAI. 15010*

Distorted / Corrupted Data
Scanner-Induced Domain Shift

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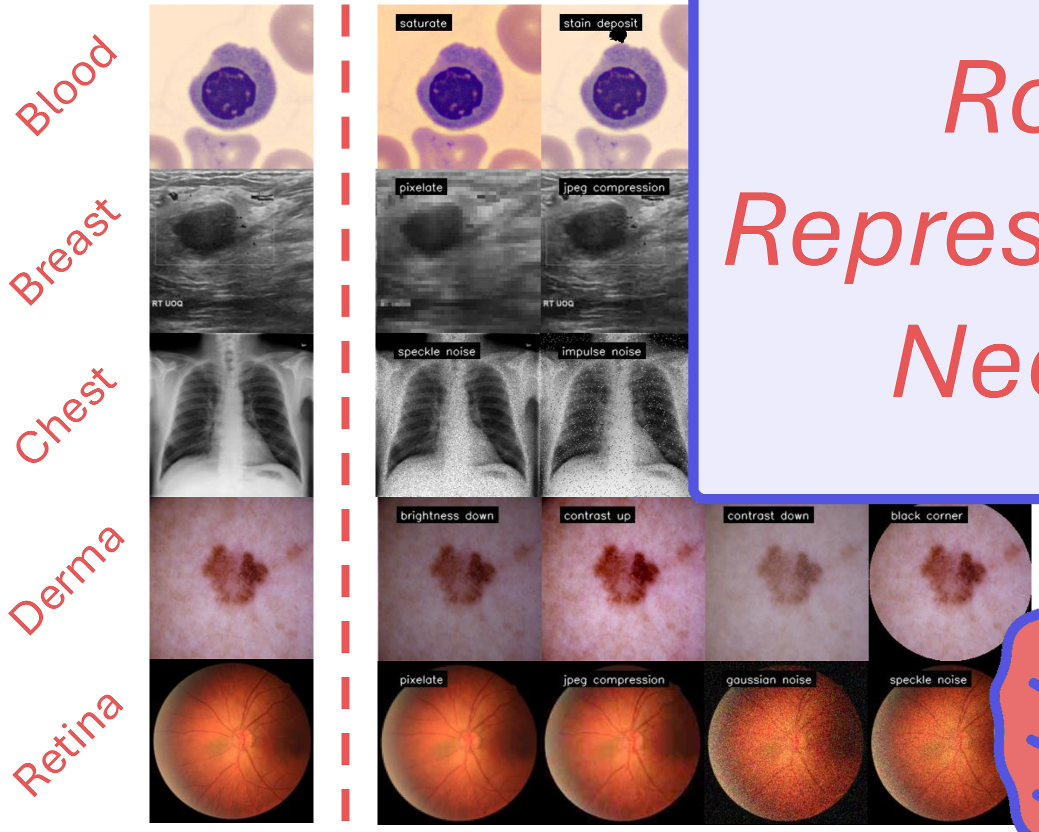
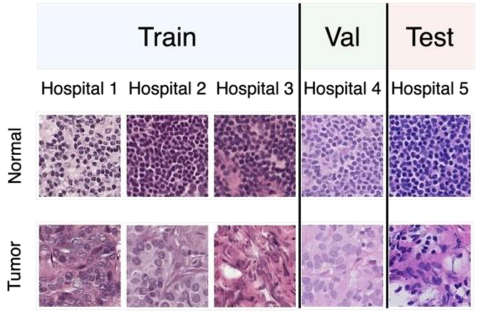


Di Salvo et al. (2024) *ADSMI @ MICCAI*

Scanner-shift

Doerrich et al. (2024) *RROW @ BMVC*

Hospital-shift



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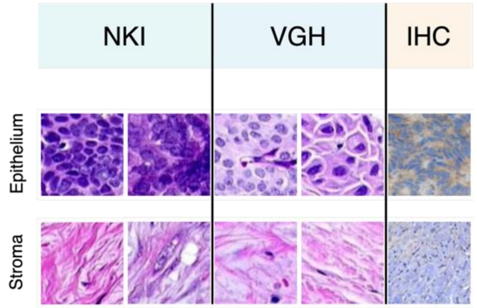
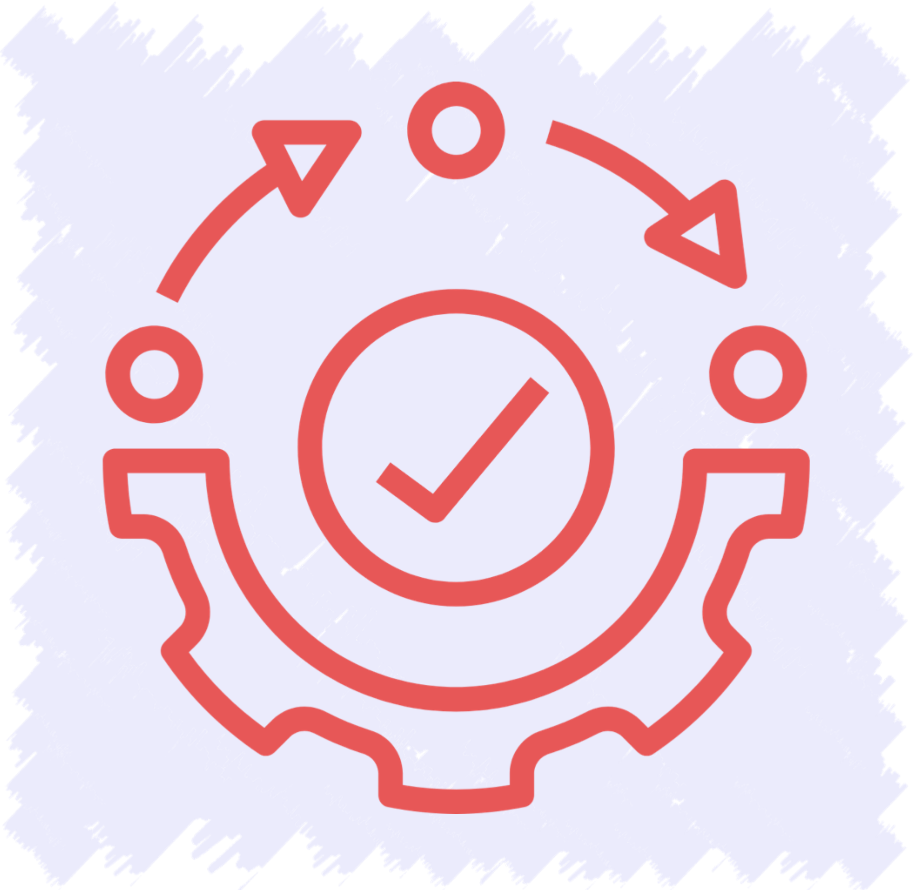


Doerrich et al. (2024) *MICCAI. 15010*

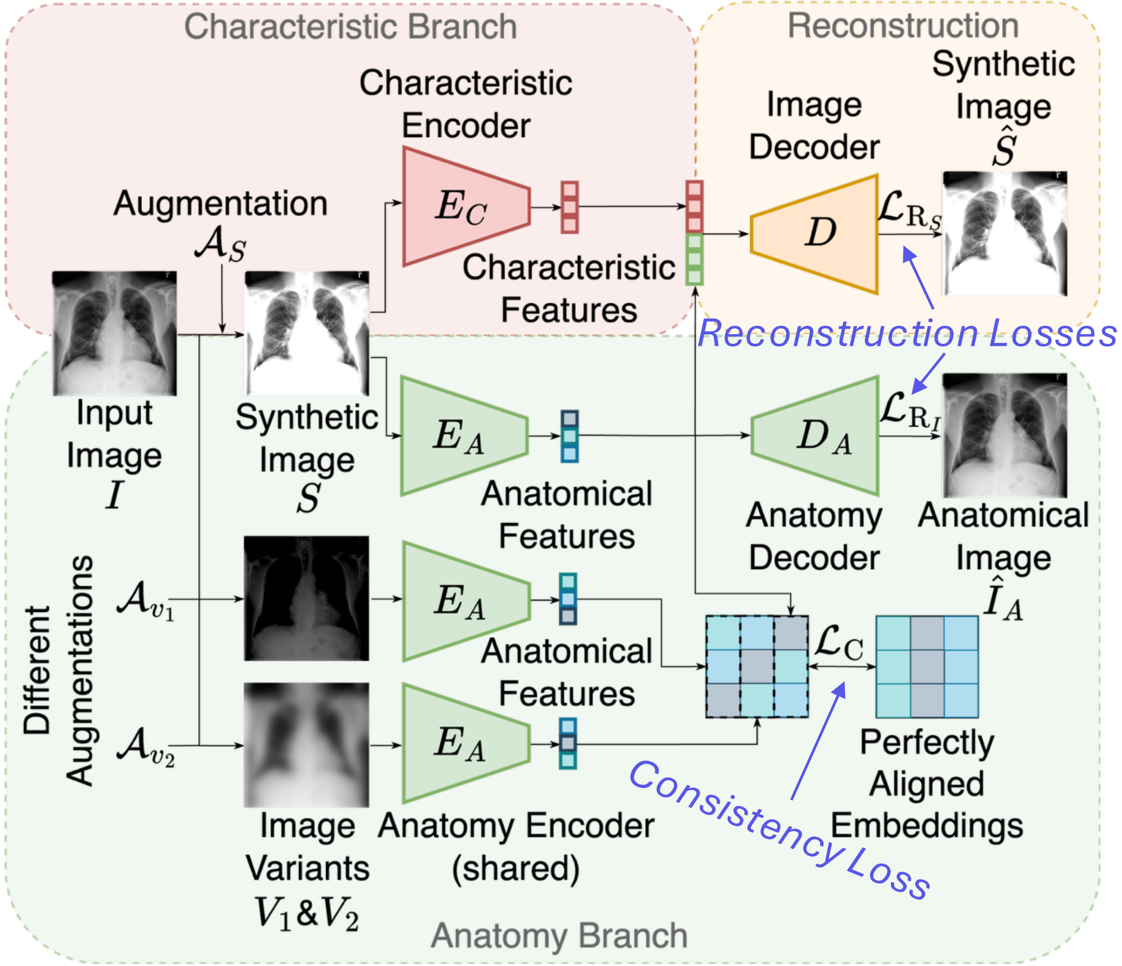
Method

Enforcing robust representations via strict disentangling of anatomy and image characteristic (style) features



unORANIC

Unsupervised Orthogonalization of Anatomy and Image Characteristic Features



Doerrich et al. (2023) *MLMI @ MICCAI. 62-71*

unORANIC

Unsupervised

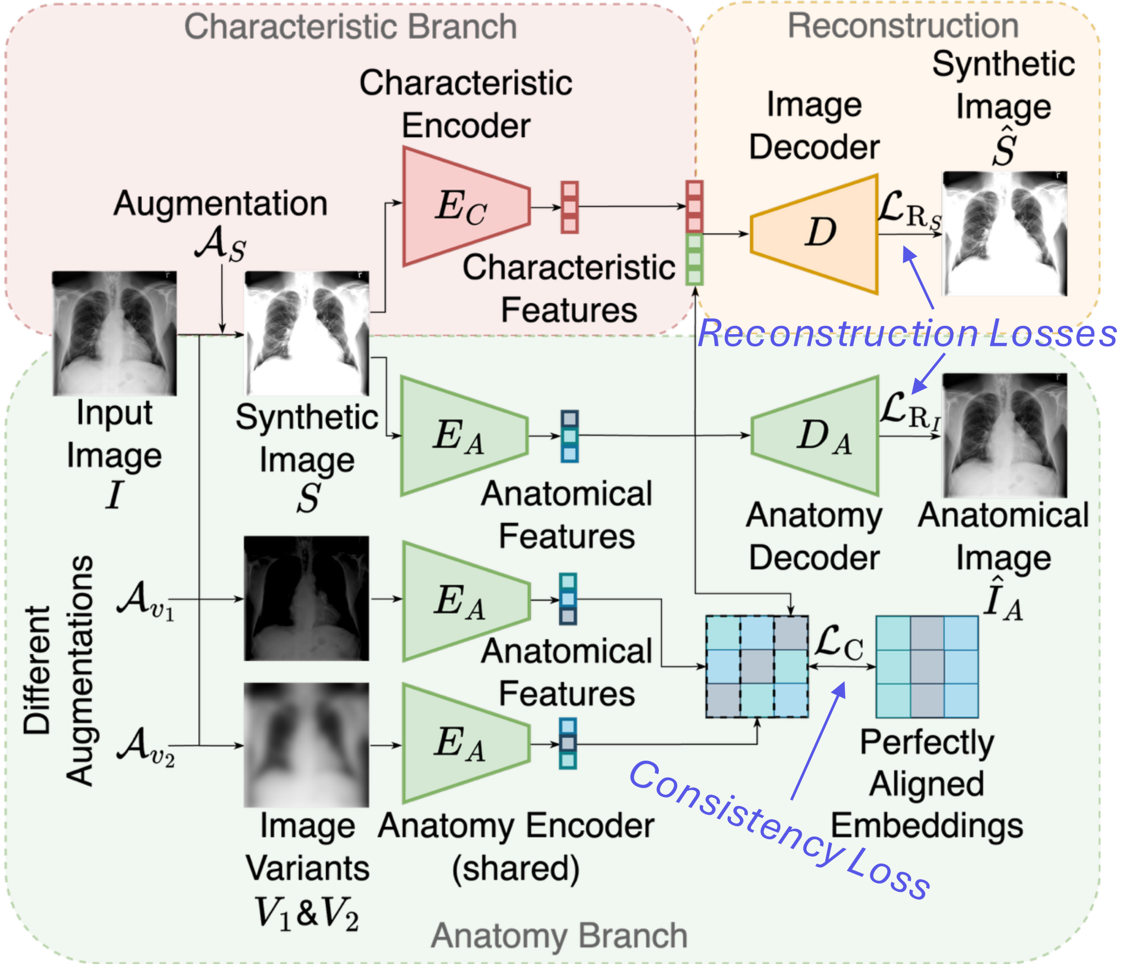
Orthogonalization

of Anatomy and

Image

Characteristic

Features

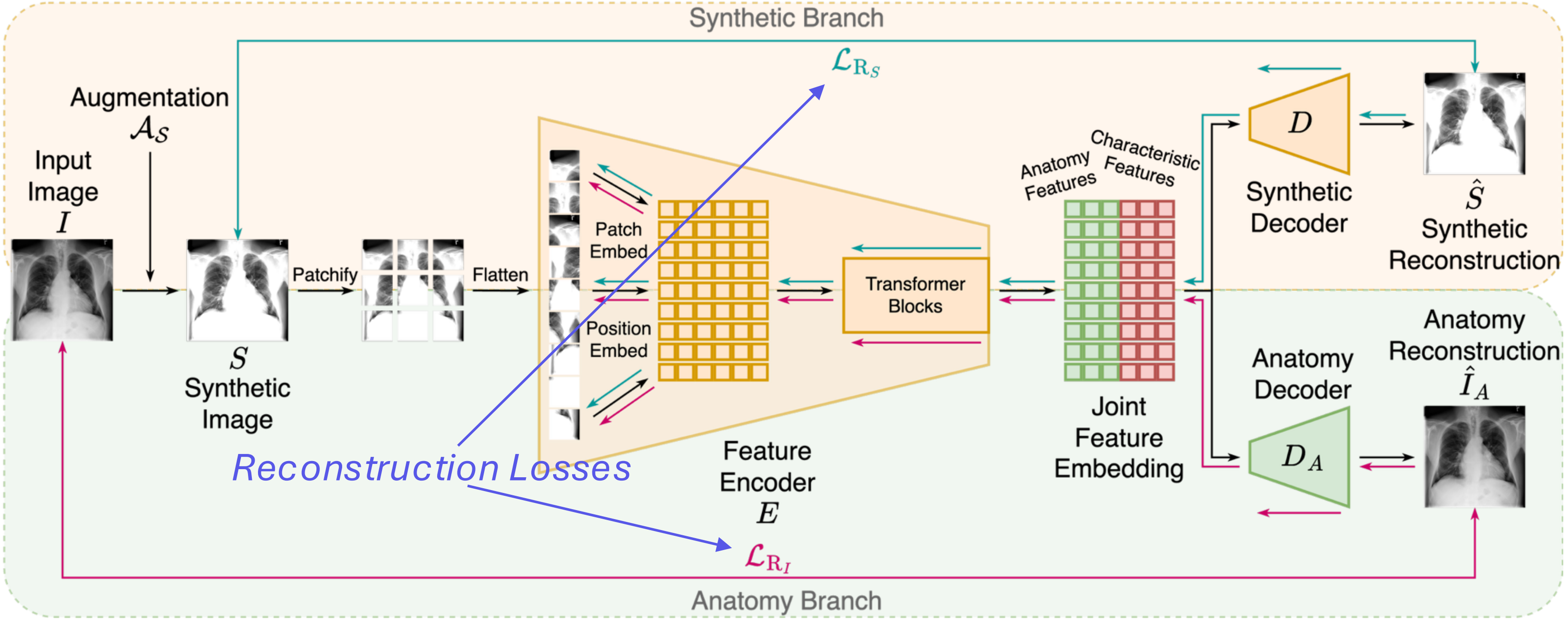


Doerrich et al. (2023) *MLMI @ MICCAI. 62-71*

- Robustness
- Generalizability
- Domain knowledge
- Paired data
- Labels

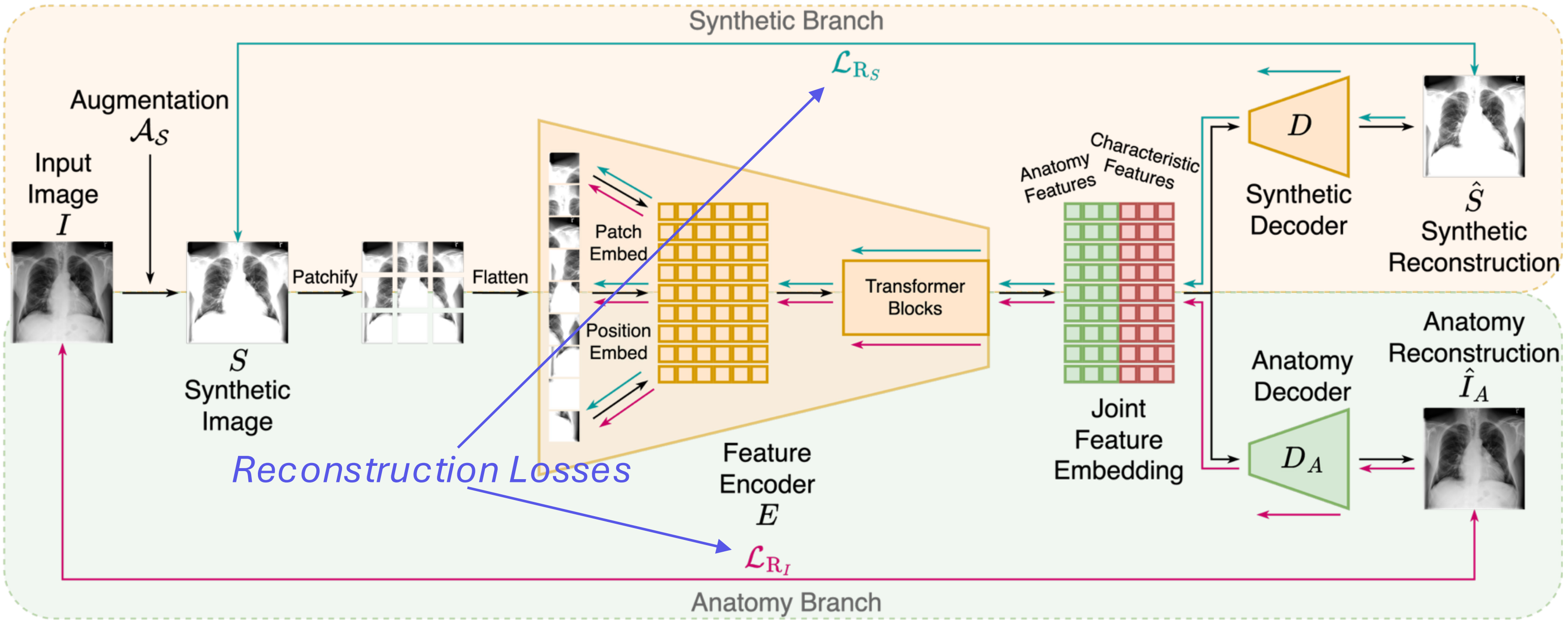
- Complexity
- Training difficulty
- Room for improvement

unORANIC+



Doerrich et al. (2023) *RROW @ BMVC*

unORANIC+



Doerrich et al. (2023) *RROW @ BMVC*

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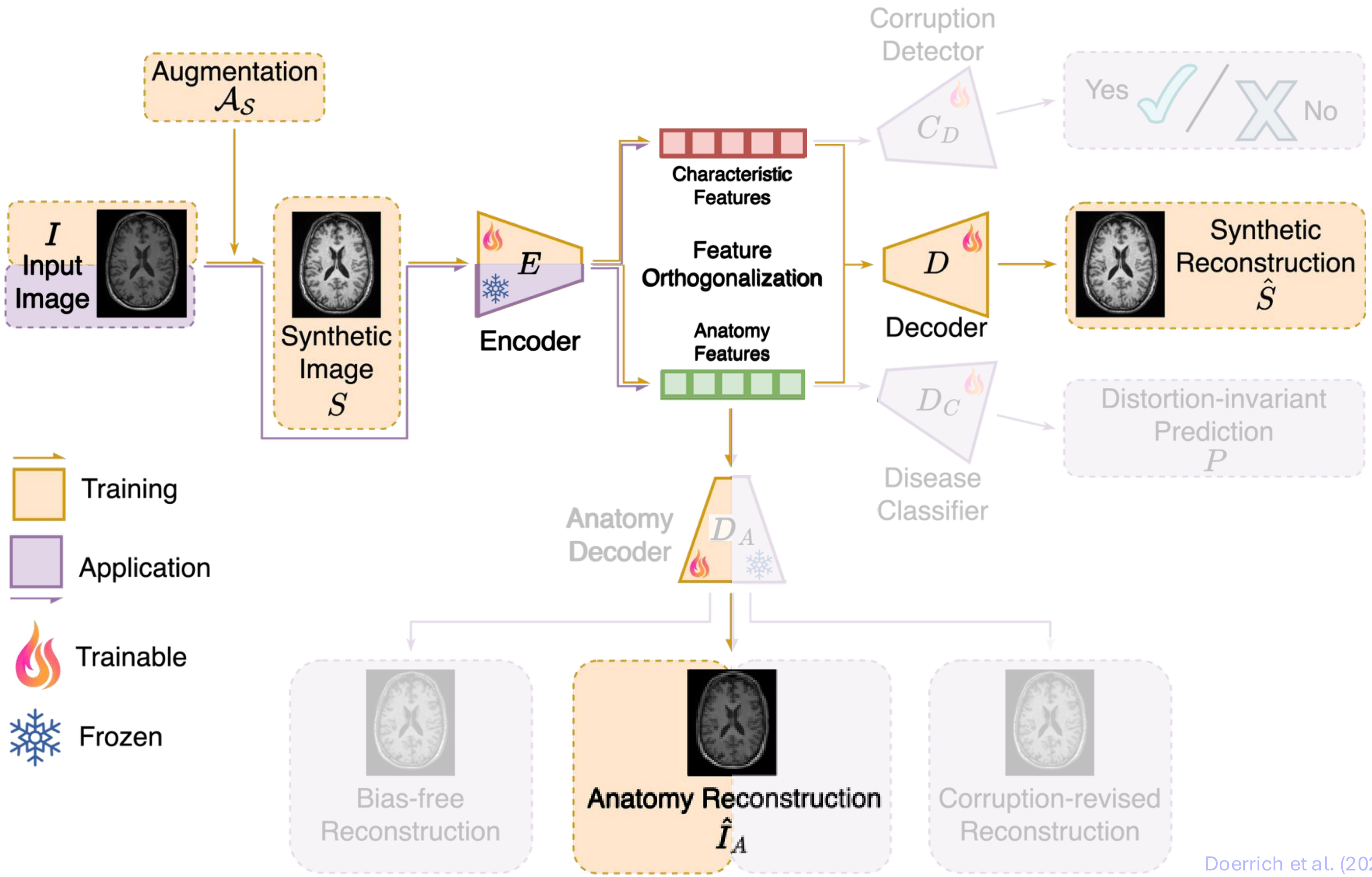
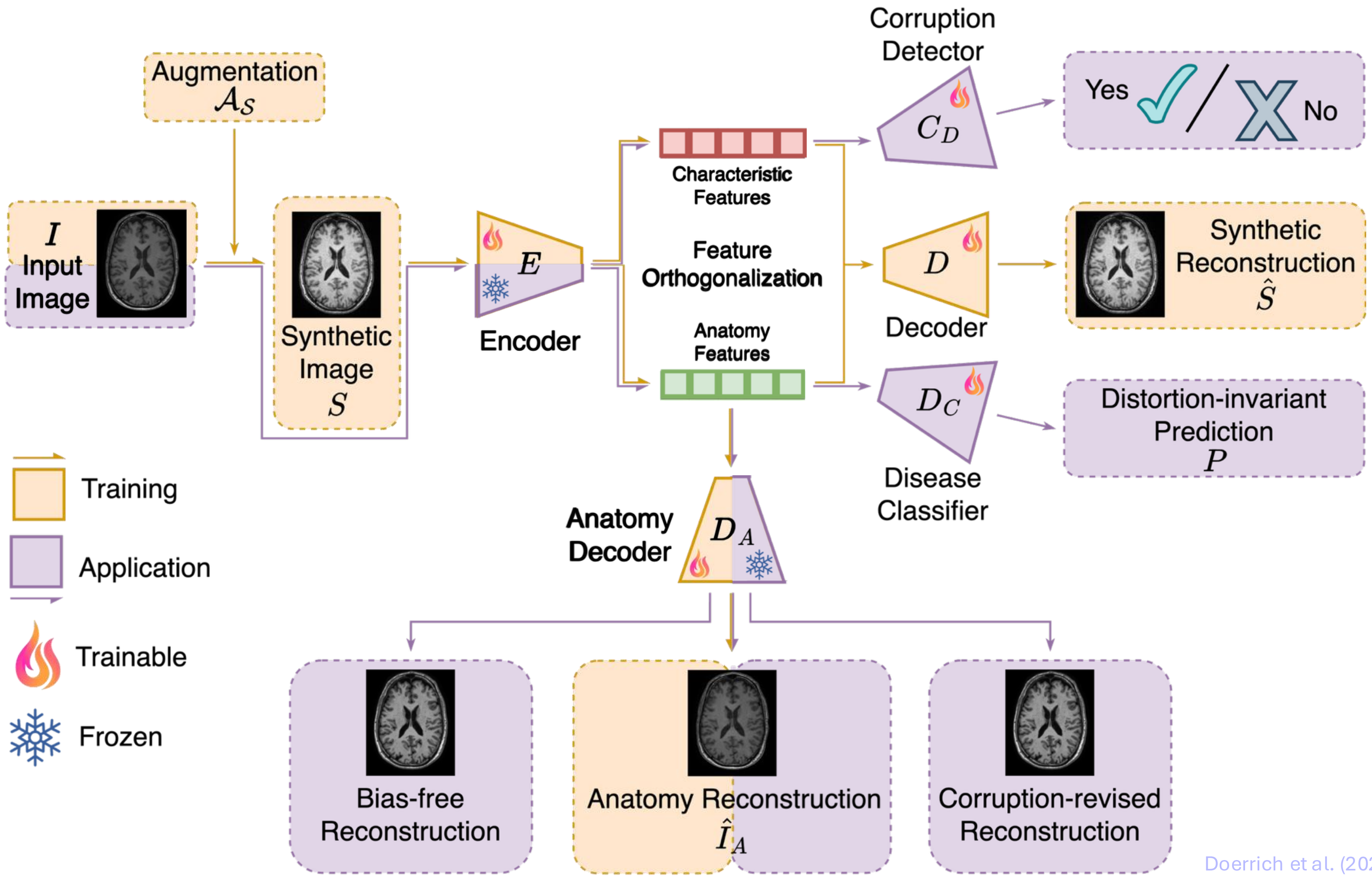
Possibilities



Doerrich et al. (2023) *RROW @ BMVC*

Possibilities



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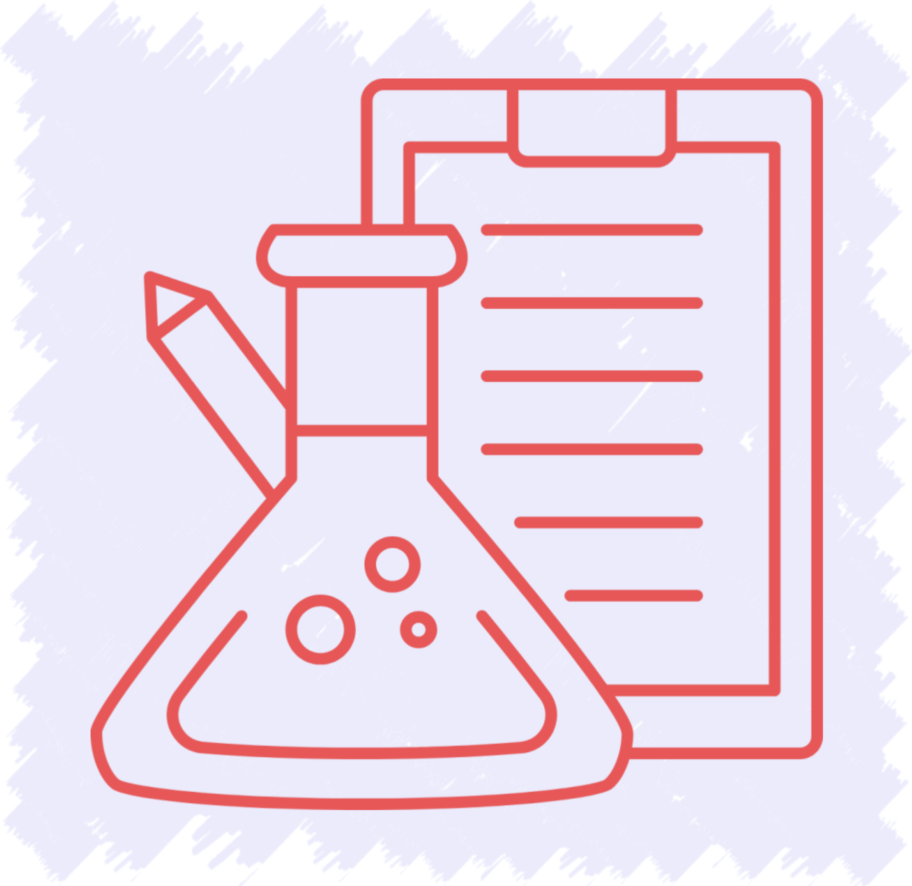
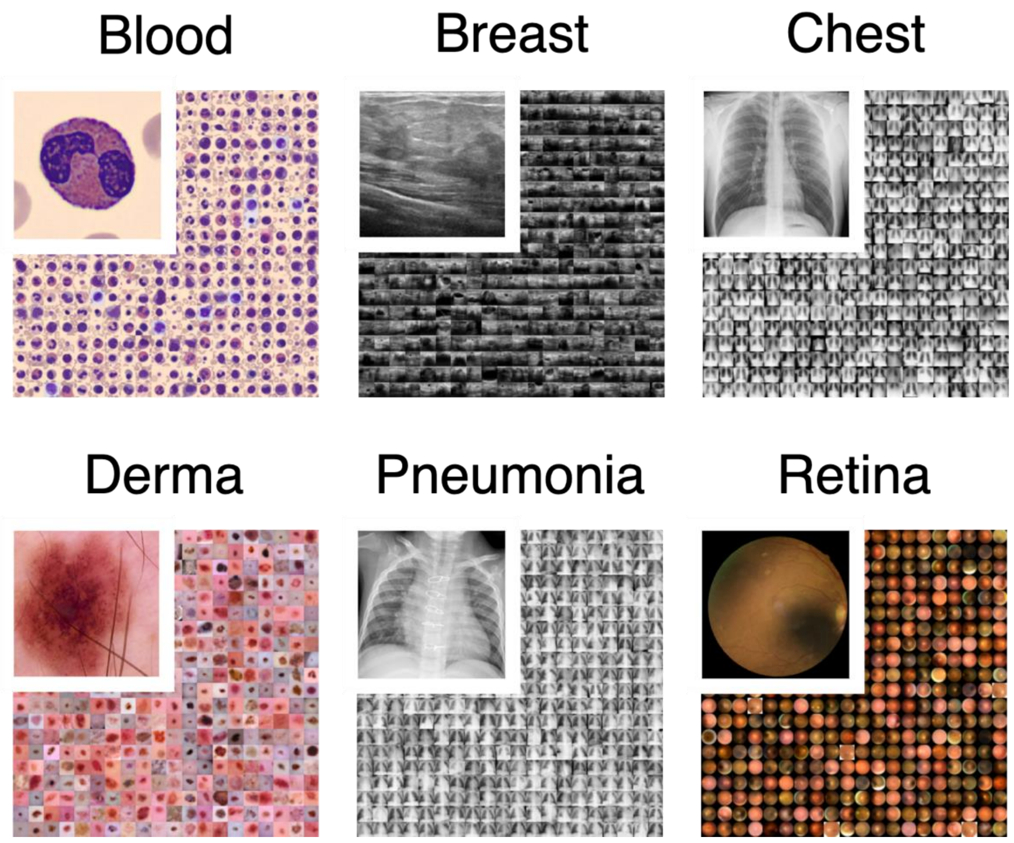
Experiments & Results



Datasets

- 6 diverse datasets from the MedMNIST+ dataset collection
  (blood, breast, ..., retina)
- 5 different modalities
  (cell microscopy, ..., fundus camera)
- 2 distinct image resolutions
  (28 x 28 and 224 x 224 pixels)
- Disparate dataset scales
  (546 up to 78,468 samples)
- Various classification tasks
  (from 2 up to 8 classes)
- Grayscale and RGB images



Doerrich et al. (2023) *RROW @ BMVC*

Reconstruction and Corruption Revision

Peak Signal-to-Noise Ratio → PSNR

Structural Similarity Index → SSIM

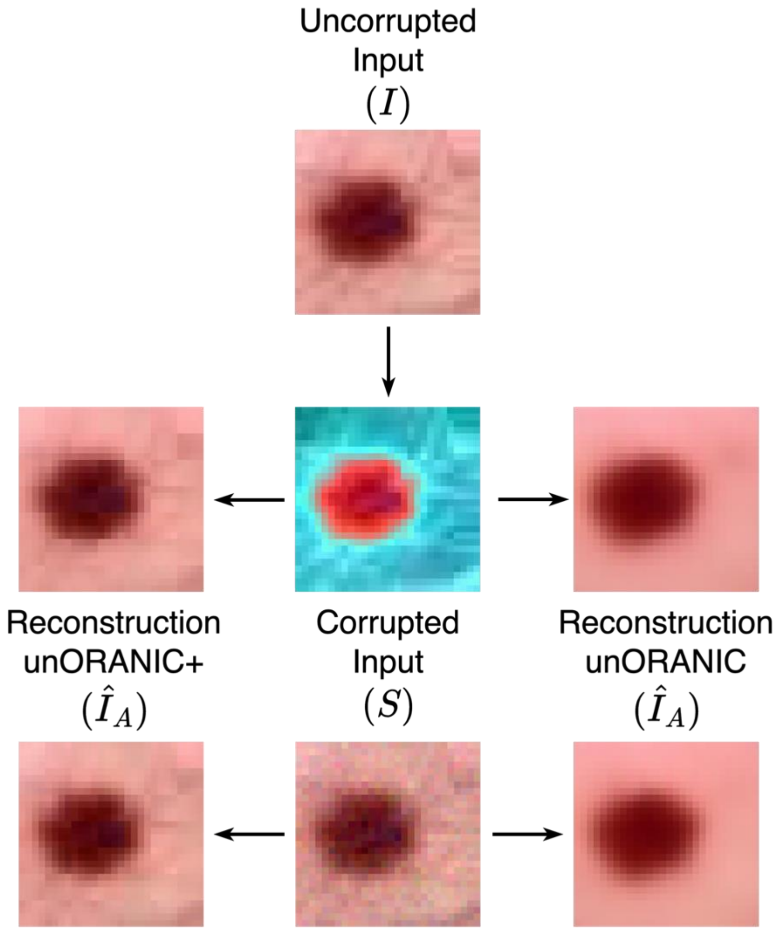
Dataset	PSNR unORANIC $\hat{I}_A$	PSNR unORANIC $\hat{I}$	PSNR unORANIC+ $\hat{I}_A$	PSNR unORANIC+ $\hat{I}$	SSIM unORANIC $\hat{I}_A$	SSIM unORANIC $\hat{I}$	SSIM unORANIC+ $\hat{I}_A$	SSIM unORANIC+ $\hat{I}$
Blood	27.06	31.70	**35.88**	**49.15**	0.877	0.943	**0.987**	**0.999**
Breast	19.48	29.39	**26.21**	**33.55**	0.526	0.816	**0.889**	**0.957**
Chest	27.93	33.73	**35.30**	**56.02**	0.956	0.983	**0.995**	**0.999**
Derma	23.73	38.57	**30.07**	**45.09**	0.864	0.970	**0.971**	**0.995**
Pneumonia	24.00	36.04	**28.96**	**44.80**	0.901	0.977	**0.977**	**0.997**
Retina	27.50	36.31	**30.39**	**37.71**	0.888	0.954	**0.936**	**0.978**

28 x 28

Anatomical Reconstructions ($\hat{I}_A$) *Input Reconstructions* ($\hat{I}$)

	Input Reconstruction ($\hat{I}$) [PSNR]						Anatomical Reconstruction ($\hat{I}_A$) [PSNR]					
	Blood	Breast	Chest	Derma	Pneumonia	Retina	Blood	Breast	Chest	Derma	Pneumonia	Retina
unORANIC	26.66	20.28	28.33	27.55	27.[illegible]1	31.25	24.5[illegible]	17.62	26.02	23.10	21.61	25.64
unORANIC+	**44.63**	**27.80**	**42.23**	**33.22**	**34.[illegible]7**	**35.37**	**38.[illegible]**	**24.94**	**32.35**	**26.91**	**26.86**	**31.41**

224 x 224



Reconstruction and Corruption Revision

Peak Signal-to-Noise Ratio

Structural Similarity Index

Dataset	PSNR				SSIM			
	unORANIC		unORANIC+		unORANIC		unORANIC+	
	$\hat{I}_A$	$\hat{I}$	$\hat{I}_A$	$\hat{I}$	$\hat{I}_A$	$\hat{I}$	$\hat{I}_A$	$\hat{I}$
Blood	27.06	31.70	**35.88**	**49.15**	0.877	0.943	**0.987**	**0.999**
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28 x 28

Anatomical Reconstructions

Input Reconstructions

	Input Reconstruction $(\hat{I})$ [PSNR]						Anatomical Reconstruction $(\hat{I}_A)$ [PSNR]					
	Blood	Breast	Chest	Derma	Pneumonia	Retina	Blood	Breast	Chest	Derma	Pneumonia	Retina
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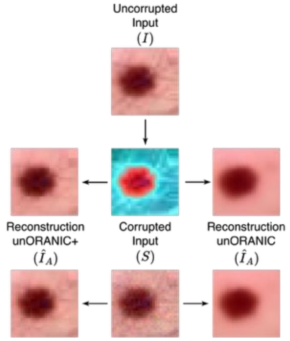
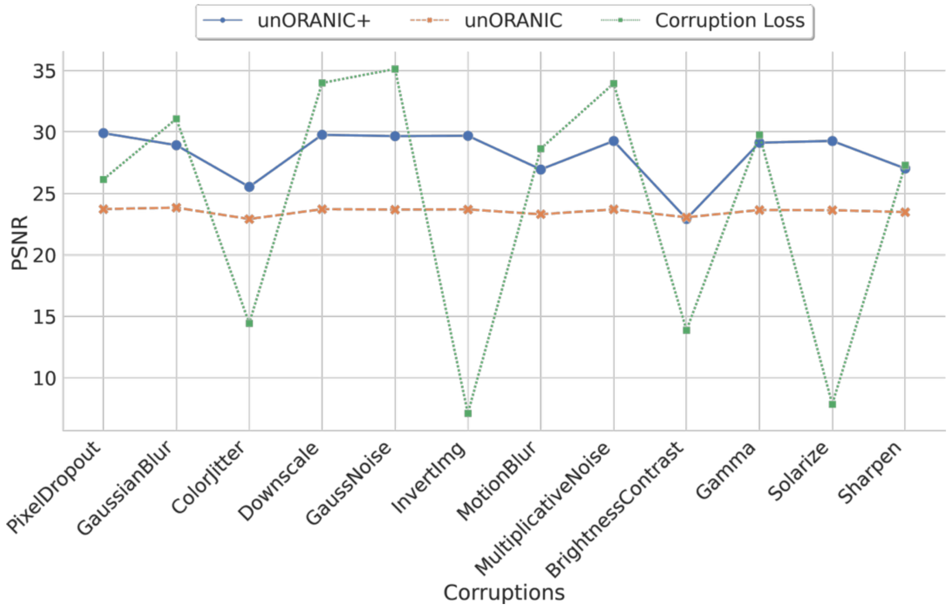
unORANIC+	**44.63**	**27.80**	**42.23**	**33.22**	**34.87**	**35.37**	[illegible]	**24.94**	**32.35**	**26.91**	**26.86**	**31.41**

224 x 224





Disease Classification and Corruption Detection

Accuracy

Area Under the ROC Curve

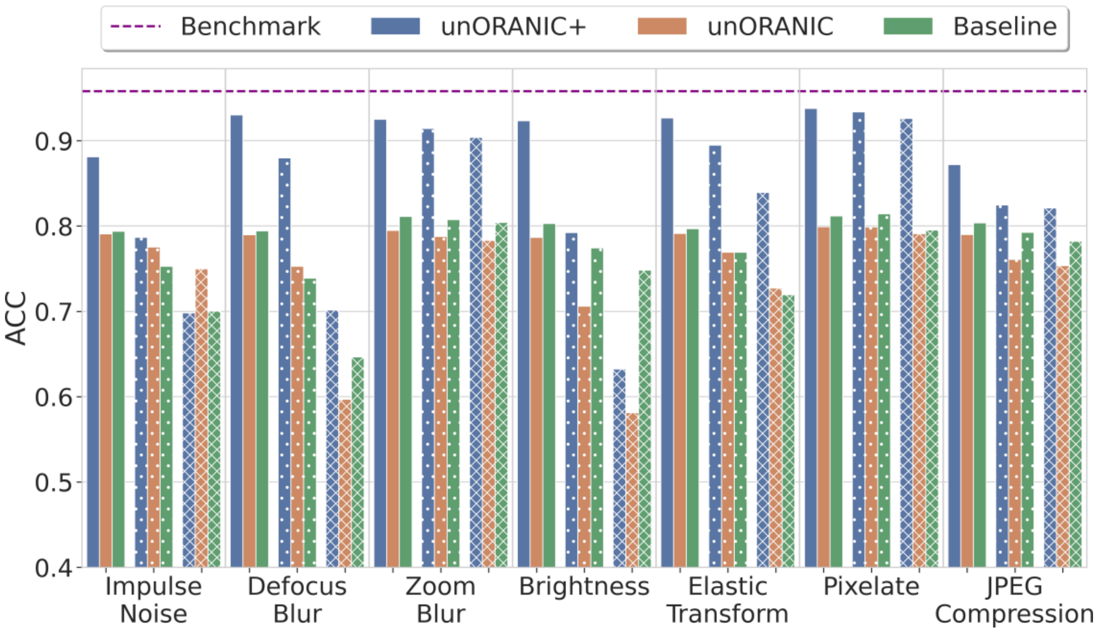
Methods	Disease Classification ACC	Disease Classification AUC	Corruption Detection ACC	Corruption Detection AUC
ResNet-18†	0.958	0.998	0.973	0.998
ViT†	0.930	0.992	0.914	0.926
unORANIC	0.800	0.952	0.962	0.976
unORANIC+	**0.935**	**0.994**	**0.970**	**0.980**

28 x 28

Fully supervised model trained end-to-end

	Disease Classification [AUC]						Corruption Detection [AUC]					
	Blood	Breast	Chest	Derma	Pneumon[illegible]a	Retina	[illegible]	Breast	Chest	Derma	Pneumonia	Retina
ResNet-18†	0.840	0.794	0.518	0.608	0.9[illegible]7	0.684	0.9[illegible]1	0.833	0.876	0.842	0.867	0.869
ViT†	0.891	0.580	0.535	0.501	0.8[illegible]0	0.647	0.79[illegible]	0.663	0.820	0.660	0.639	0.700
unORANIC	0.930	0.774	0.528	0.717	0.9[illegible]3	0.681	0.7[illegible]4	0.586	0.635	0.625	0.639	0.644
unORANIC+	**0.997**	0.757	**0.563**	0.563	**0.9[illegible]5**	0.675	**[illegible]54**	**0.616**	**0.892**	**0.690**	**0.694**	**0.783**

224 x 224



Resilience to unseen corruptions during training

Take-Home Message

Take-Home Message

Self-supervised ***orthogonalization of*** *anatomical and image-characteristic* ***information*** *in images* ***enables*** *the generation of* ***robust*** *latent* ***representations*** *even* ***in*** *the* ***presence*** *of* ***data inhomogeneities*** *and* ***domain shifts***.

Thank you for your attention!

Paper

Code

References

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