Employing Acoustic Features to Aid Neural Networks Towards Platform Agnostic Learning in Lung Ultrasound Imaging

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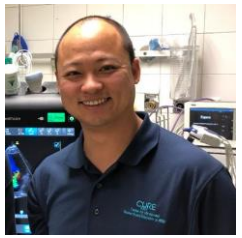

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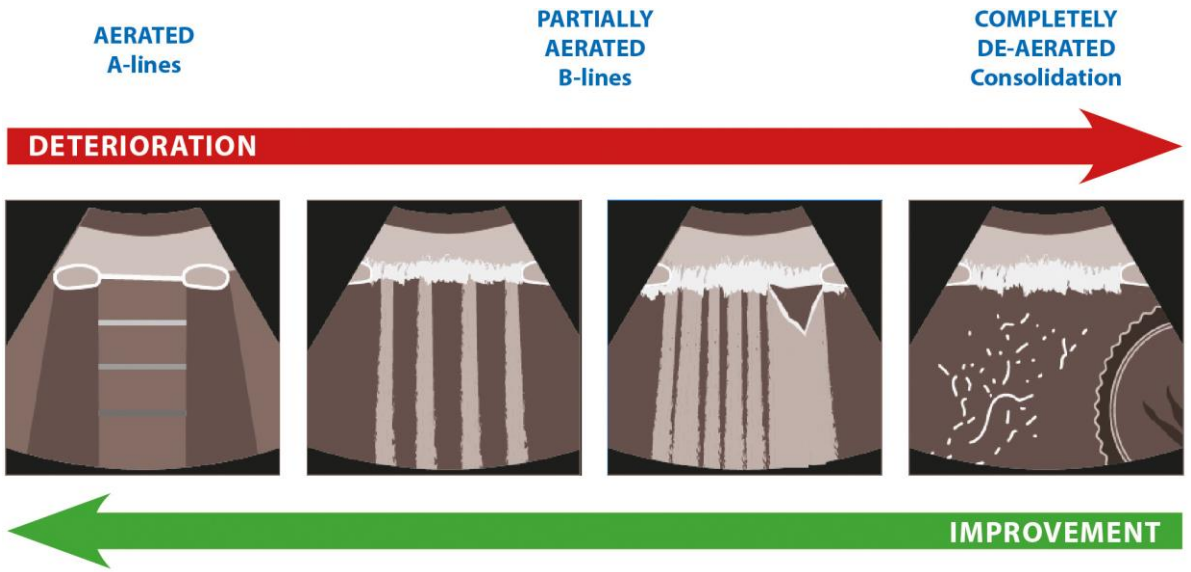
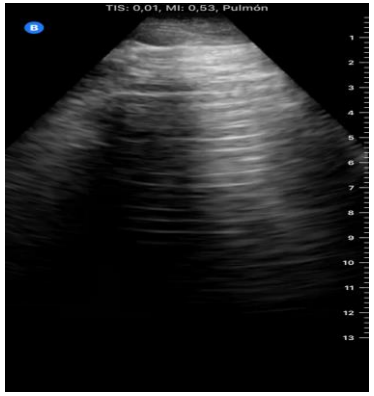
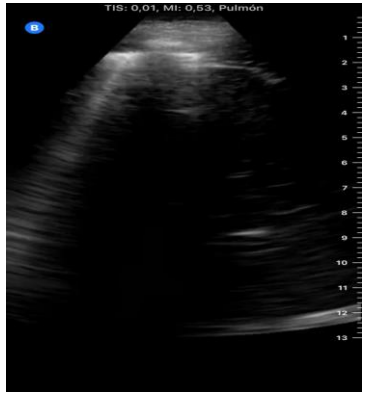
Mr. Madhavanunni A N
(Research Scholar, Electrical Engineering, IIT Palakkad)

How Ultrasound Sees COVID19 Infection







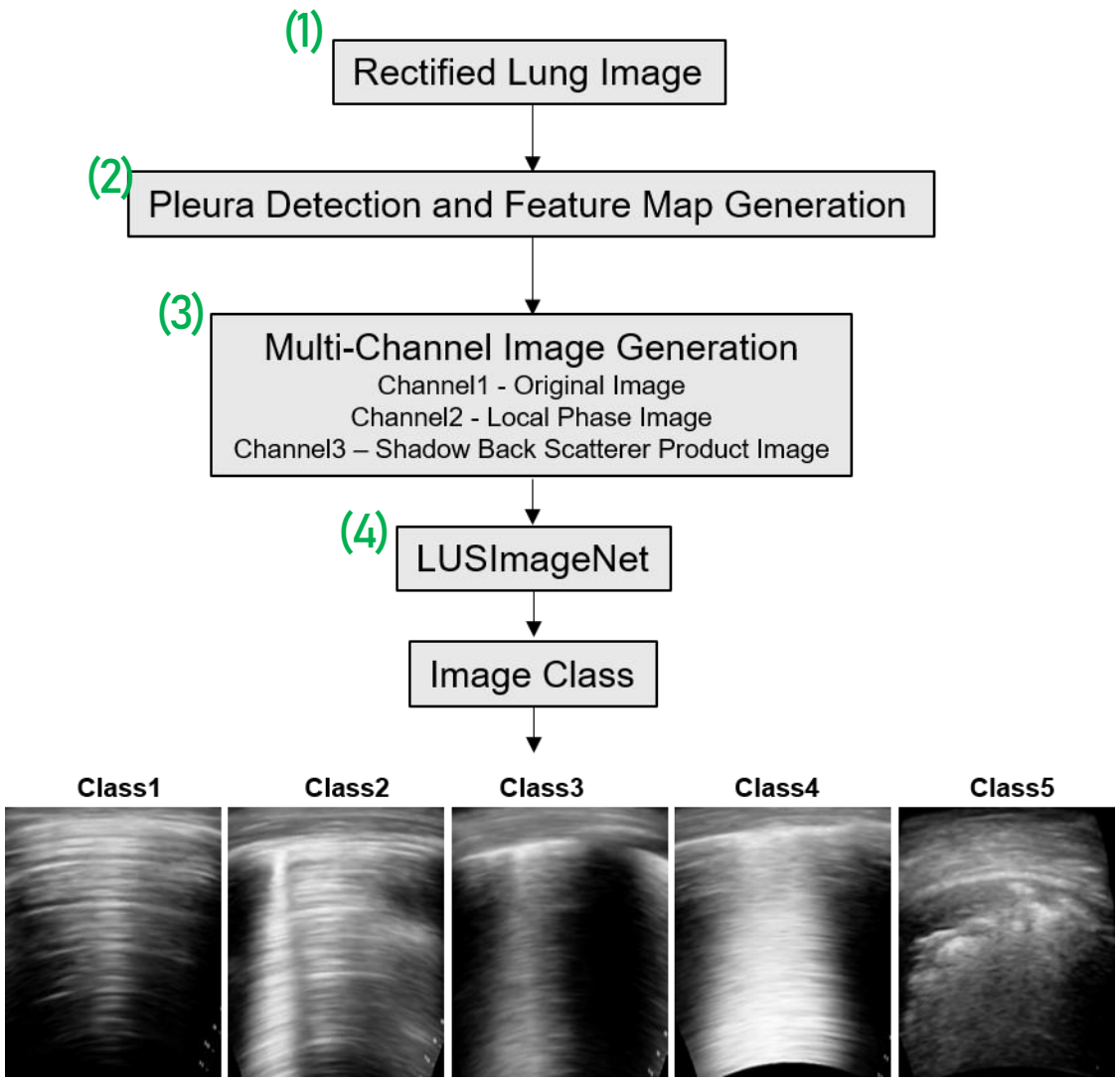
Insights from the Physics of Lung Ultrasound:

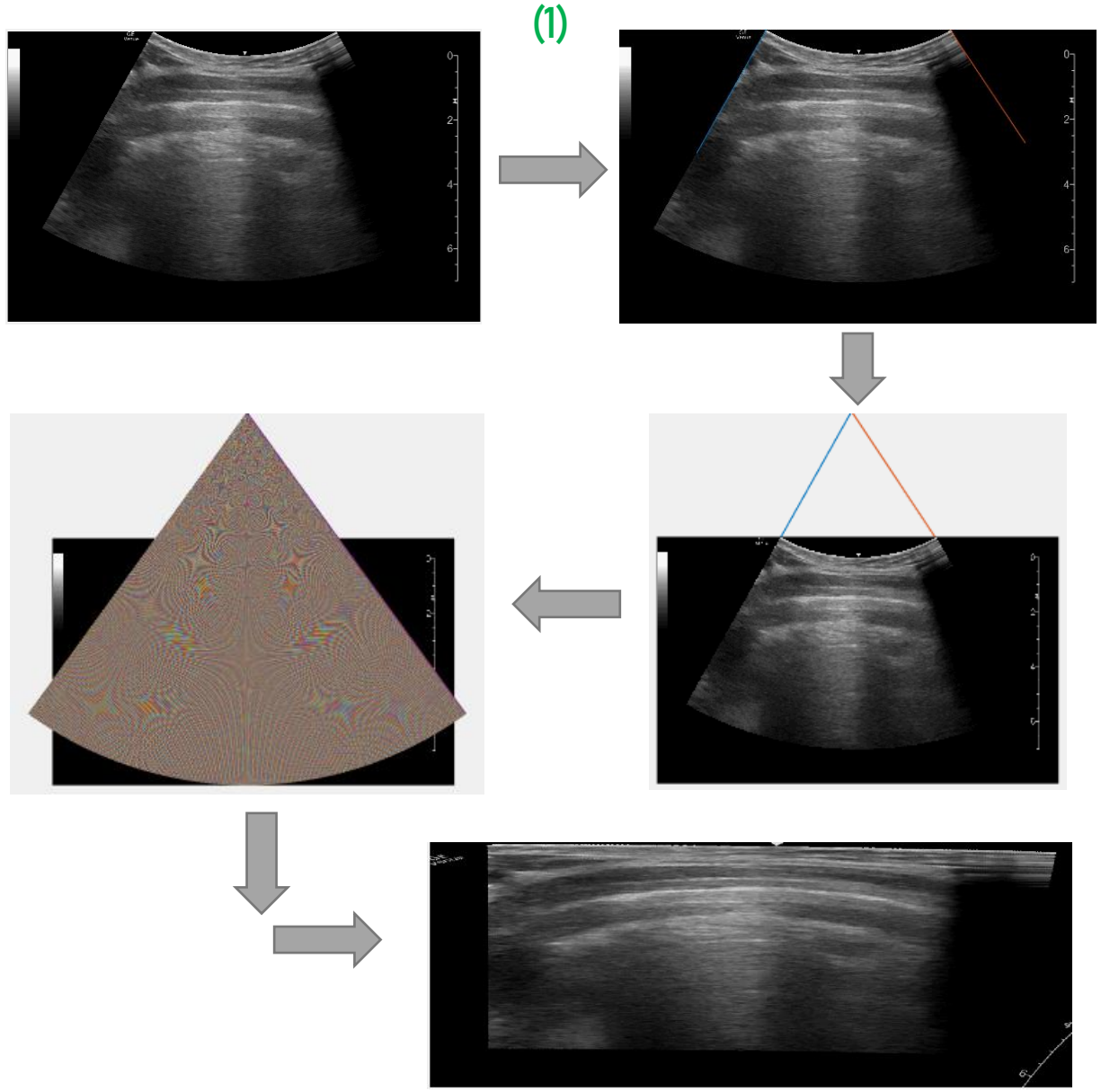
- Pleura (combination of parietal pleura and visceral pleura) behaves like a specular reflector (intensity ridge)
  - Results in phase asymmetry in images
  - Results in multiple reflections (healthy lung) or acoustic shadows (unhealthy lung)

- The signatures for COVID19 are essentially horizontal (A lines) and vertical lines (B lines) (or profiles)
  - Results in significance of local phase in images

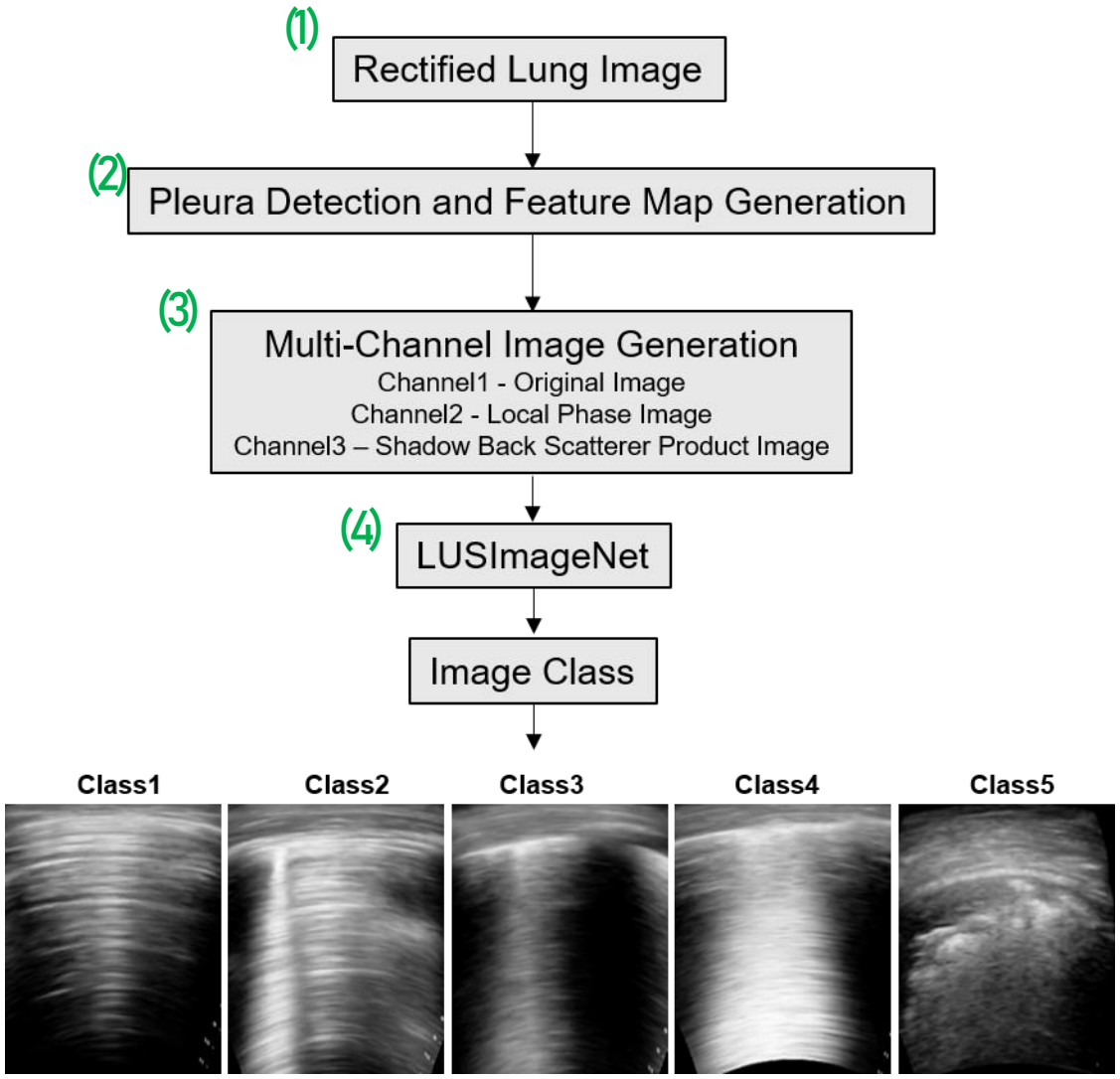
Smith, M. J., S. A. Hayward, S. M. Innes, and A. S. C. Miller. "Point-of-care lung ultrasound in patients with COVID-19–a narrative review." *Anaesthesia* (2020).

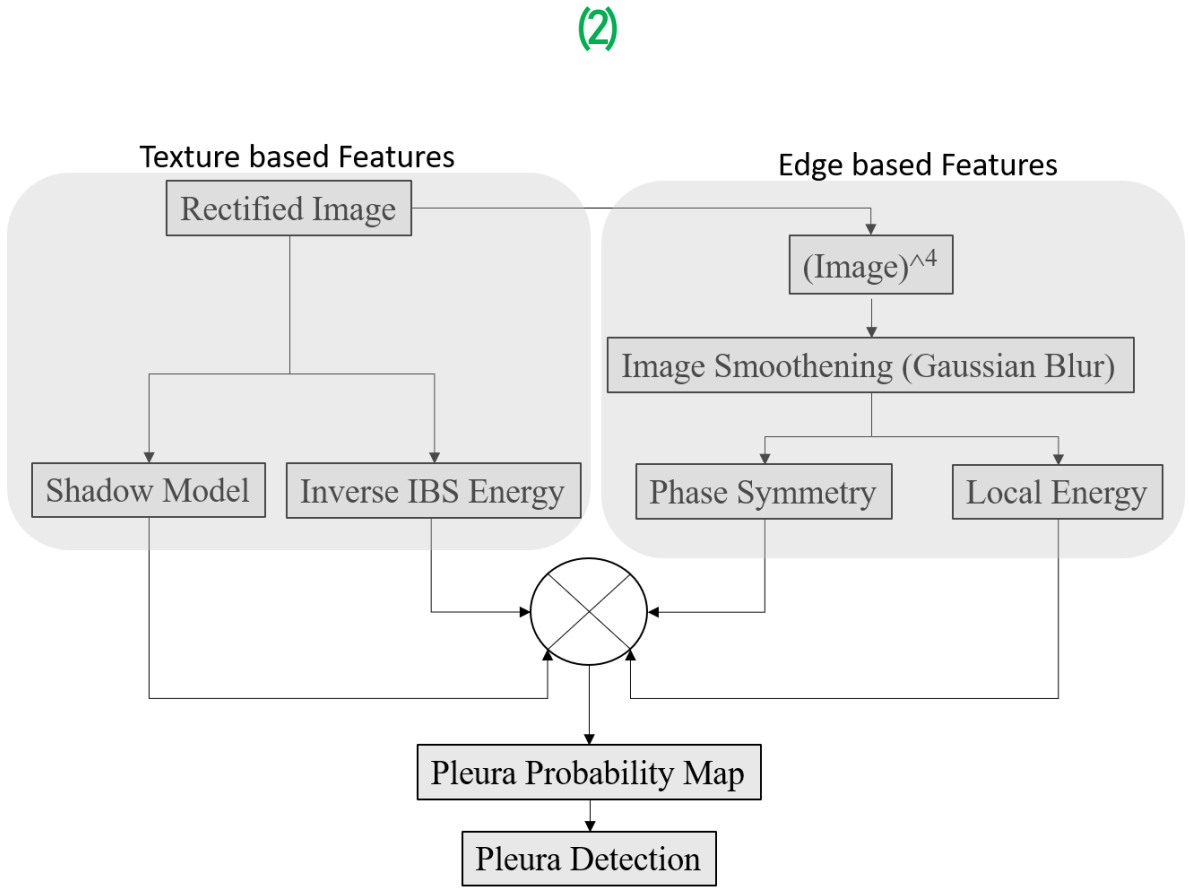
LUS – Severity Classification - Rectification





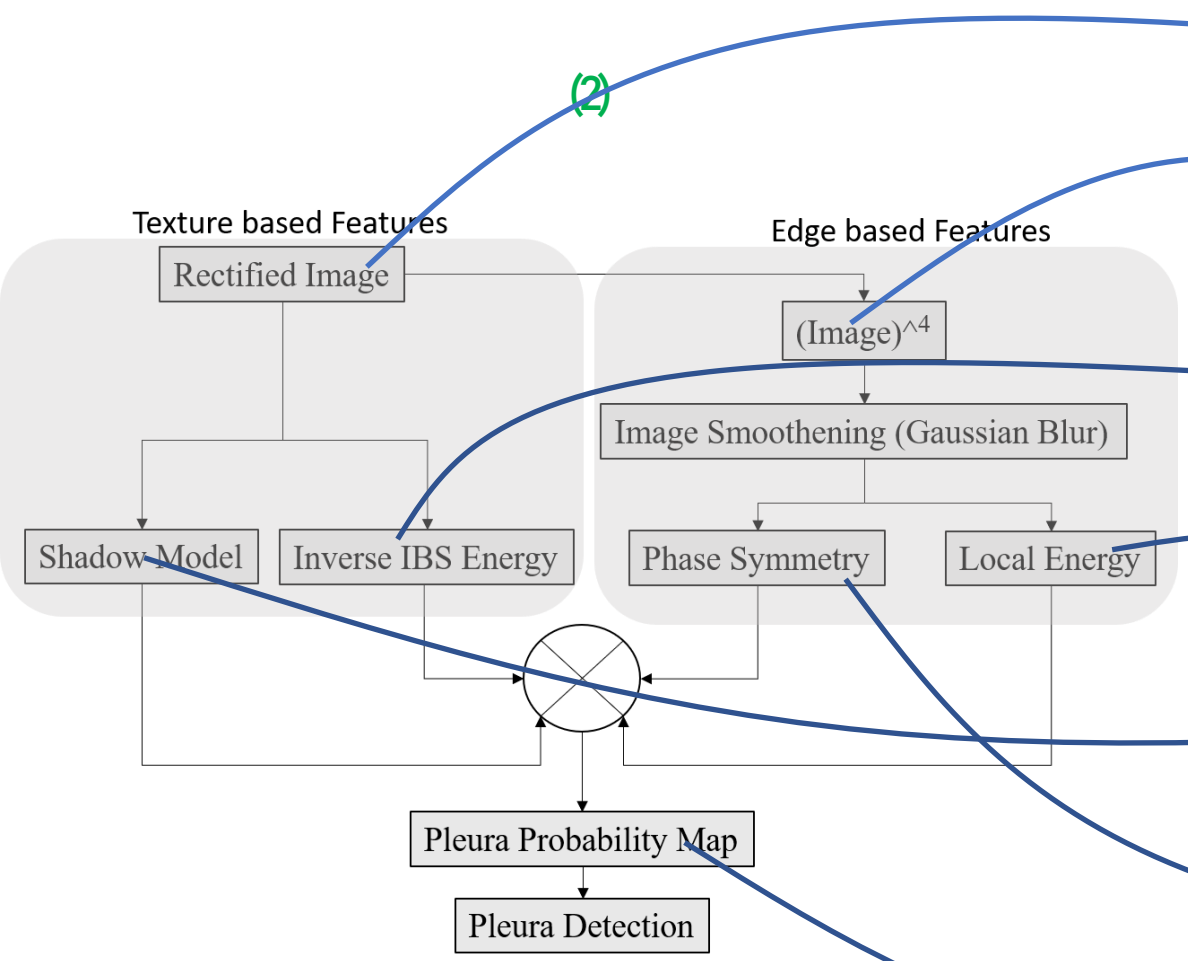
LUS – Severity Classification – Pleura Detection

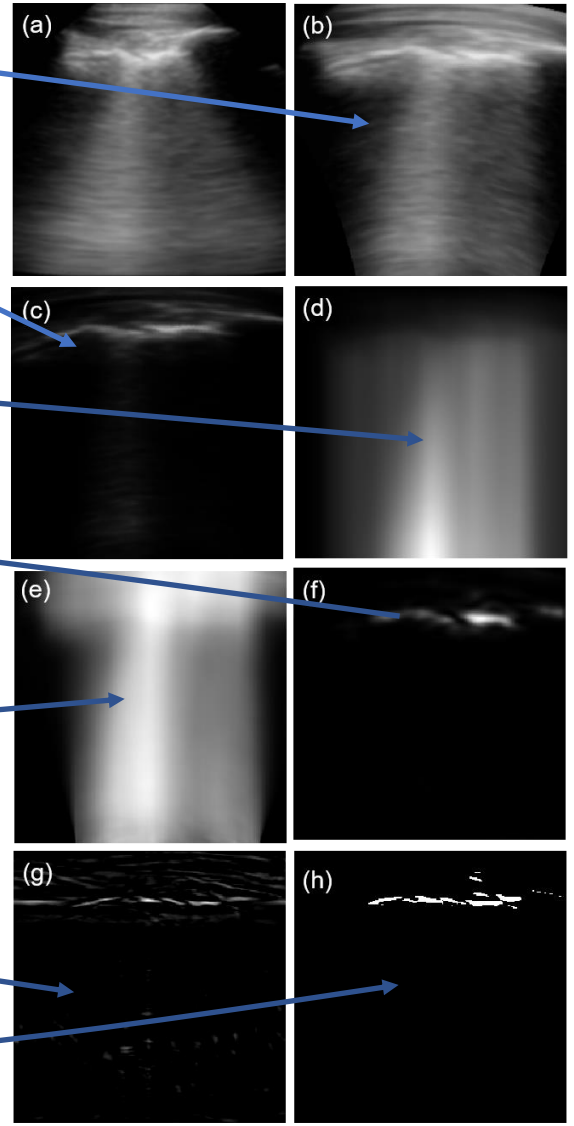




Jia, Rui et. al., "Automatic bone segmentation in ultrasound images using local phase features and dynamic programming." in Proc. of IEEE 13th international symposium on biomedical imaging (ISBI), pp. 1005-1008, 2016.

LUS – Severity Classification – Pleura Detection





$$IBS(i,j) = \sum_{k=1}^{i} I^2(k,j)$$

$$\text{Shadow}(i,j) = \frac{\sum_{k=i}^{R} G(k-i)I(i,j)}{\sum_{k=i}^{R} G(k-i)}$$

LUS – Severity Classification – Multichannel Image Generation

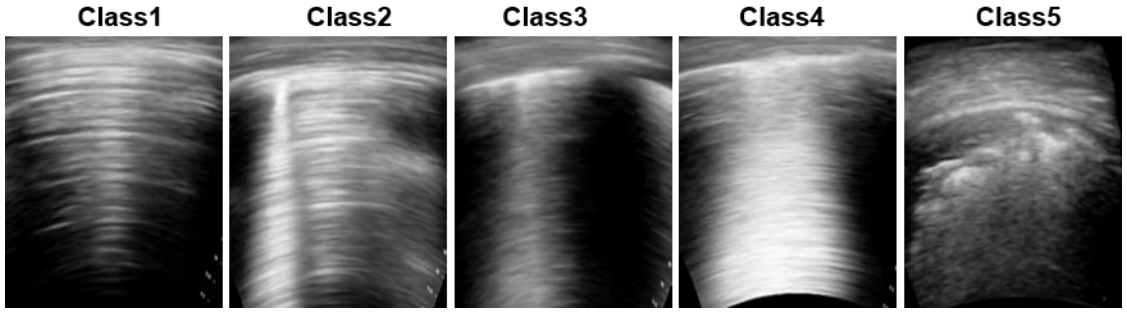
(1) Rectified Lung Image

(2) Pleura Detection and Feature Map Generation

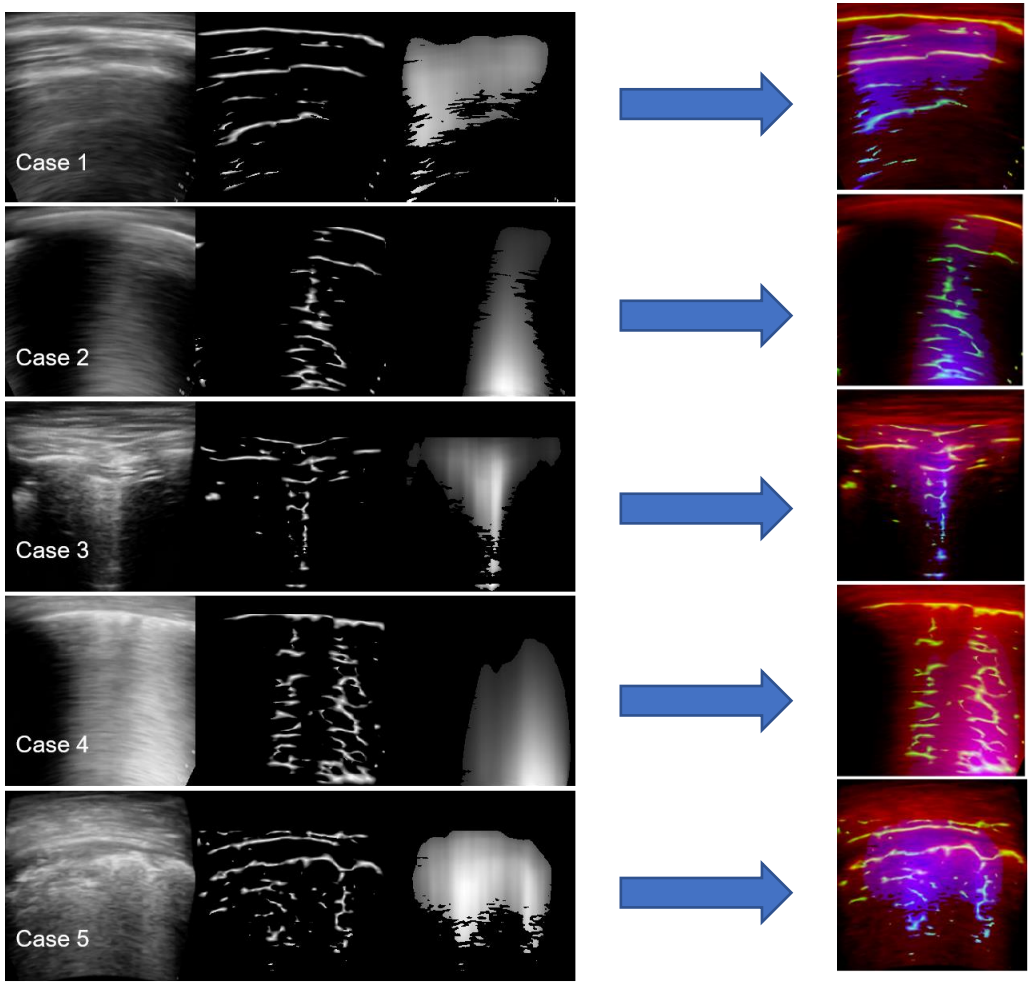
(3) Multi-Channel Image Generation
Channel1 - Original Image
Channel2 - Local Phase Image
Channel3 – Shadow Back Scatterer Product Image

(4) LUSImageNet

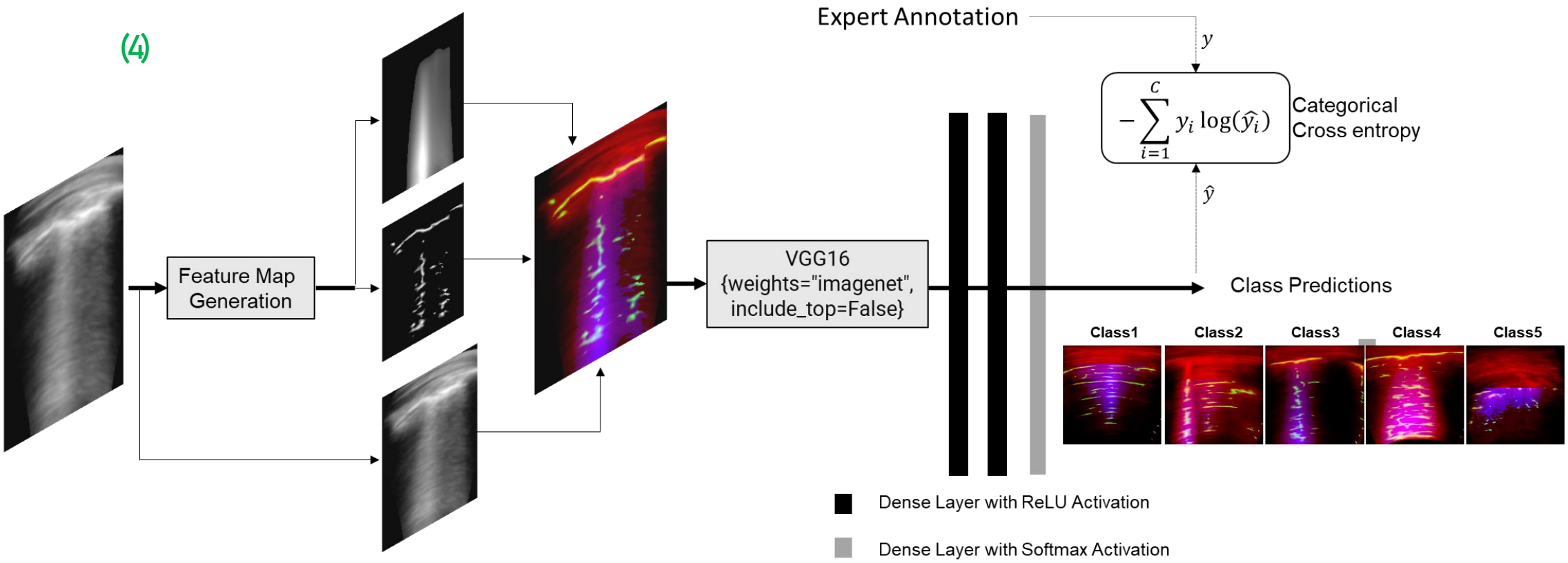
Image Class



(3)



LUS – Severity Classification – Physics Driven Neural Network



Simonyan, Karen, and Andrew Zisserman. "Very deep convolutional networks for large-scale image recognition." arXiv preprint arXiv:1409.1556, 2014.

LUS – Severity Classification – Results

Table I Class wise performance comparison of proposed approach with gray scale images and multi-channel images for **validation dataset**

Input	Class	Accuracy	Sensitivity	Specificity
Images	1	0.98	0.98	0.99
	2	0.96	0.78	0.98
	3	0.96	0.91	0.97
	4	0.97	0.86	0.98
	5	0.99	0.99	0.99
Multi-Channel	1	0.99	0.98	0.99
	2	0.96	0.80	0.98
	3	0.96	0.93	0.98
	4	0.97	0.88	0.98
	5	0.99	1.00	0.99

Table II Class wise performance comparison of proposed approach with gray scale images and multi-channel images for an **unseen data acquisition (test dataset)**

Input	Class	Accuracy	Sensitivity	Specificity
Images	1	0.73	0.56	0.79
	2	0.83	0.40	0.97
	3	0.81	0.51	0.92
	4	0.80	0.41	0.85
	5	0.83	0.67	0.85
Multi-Channel	1	0.89	0.61	0.98
	2	0.86	0.86	0.86
	3	0.90	0.90	0.98
	4	0.97	0.97	0.98
	5	0.86	0.86	0.87