Retrieval of 4D Dual Energy CT for Pulmonary Embolism Diagnosis

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Overview

- Motivation: pulmonary embolism and Dual-Energy CT Imaging
- Methods: 4D texture analysis and retrieval
- Results
- Conclusions and future work

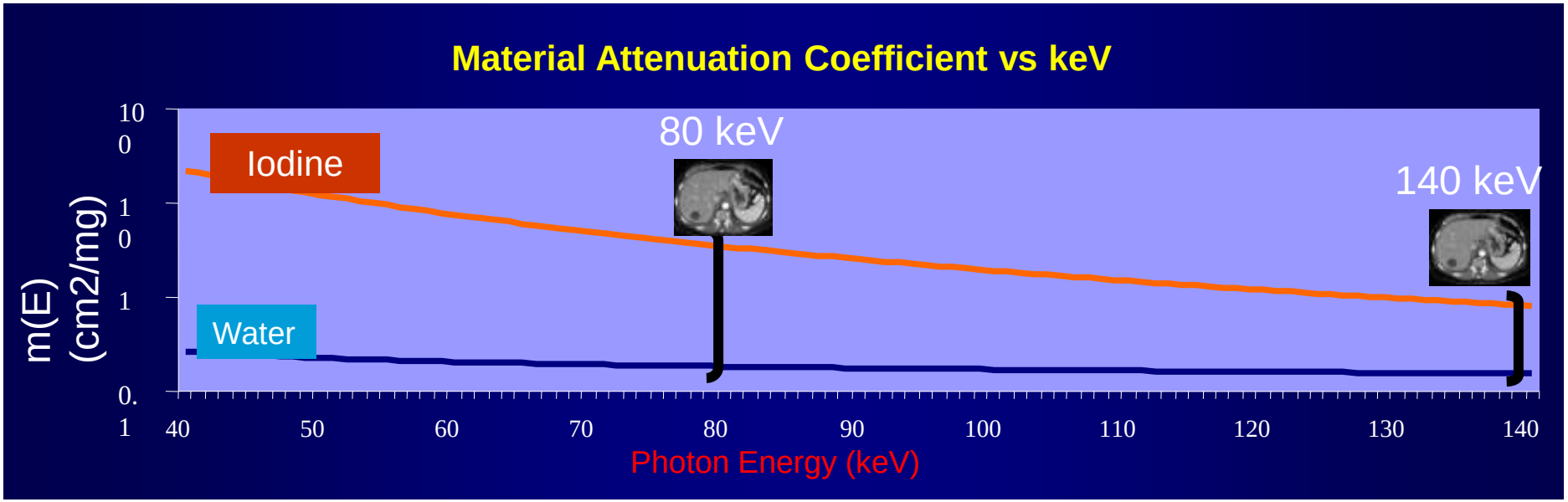
Introduction to Pulmonary Embolism

- Acute Pulmonary Embolism has high mortality rates
  - 30% deaths 3 years after hospital discharge
  - 75% of deaths occur during initial hospital admission
- Avoidable cause of death if treated immediately
  - Delays in diagnosis increase risk of death
- CT appearance of the embolized lung parenchyma
  - Wedge-shaped regions
  - Simple 3D Texture

Can Dual Energy CT add extra information?

Features of Dual Energy CT

- Dual Energy CT contains 4D data
  - 3 spatial coordinates: x, y, z and 1 energy coordinates: e
- At varying energy levels, attenuation curves behave differently for different materials



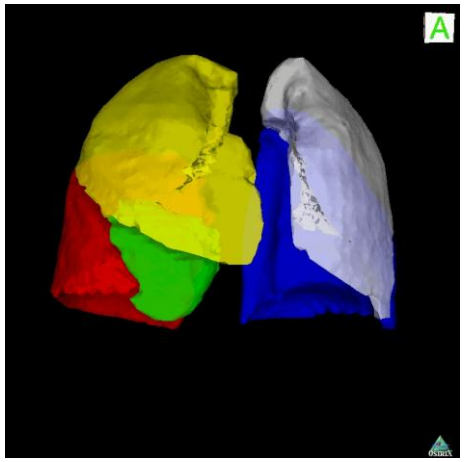
- E.g., allows for isolating iodine components

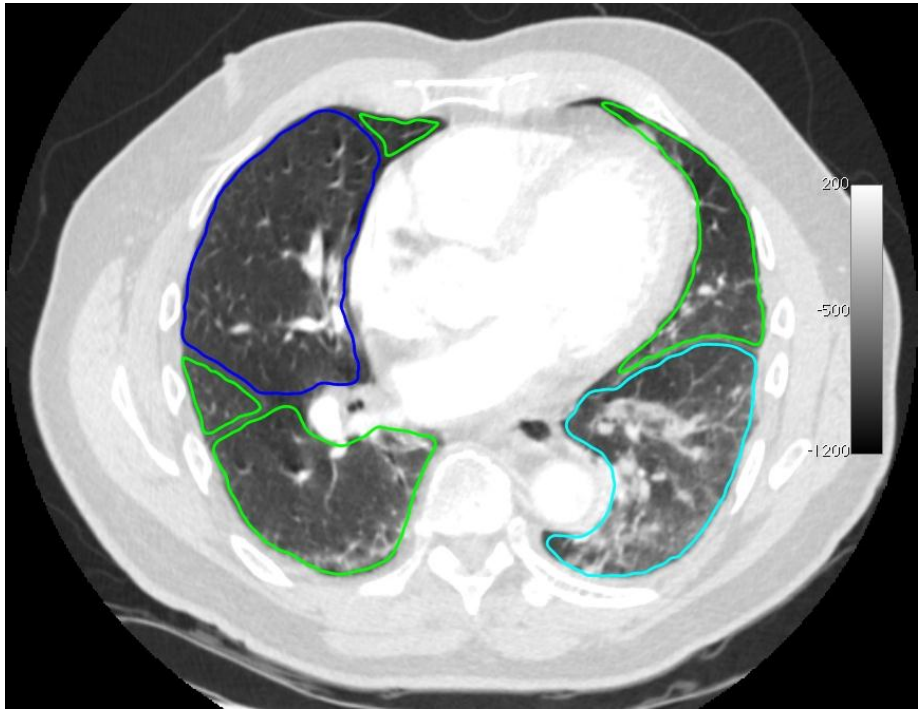
Motivation

- Dual Energy CT is currently underused
  - Lack of a clear clinical application
  - Limitations of displaying dimensions larger than 3 for human inspection
- Computerized 4D texture analysis
  - Comprehensive data analysis
  - Clinical benefits and opportunities
    - Quantitative comparisons of the parenchyma between healthy and embolism
    - Visualization of ischemia
    - Content-based retrieval of cases with similar Dual Energy CT patterns as diagnosis aid

Methods: Dataset and Ground Truth

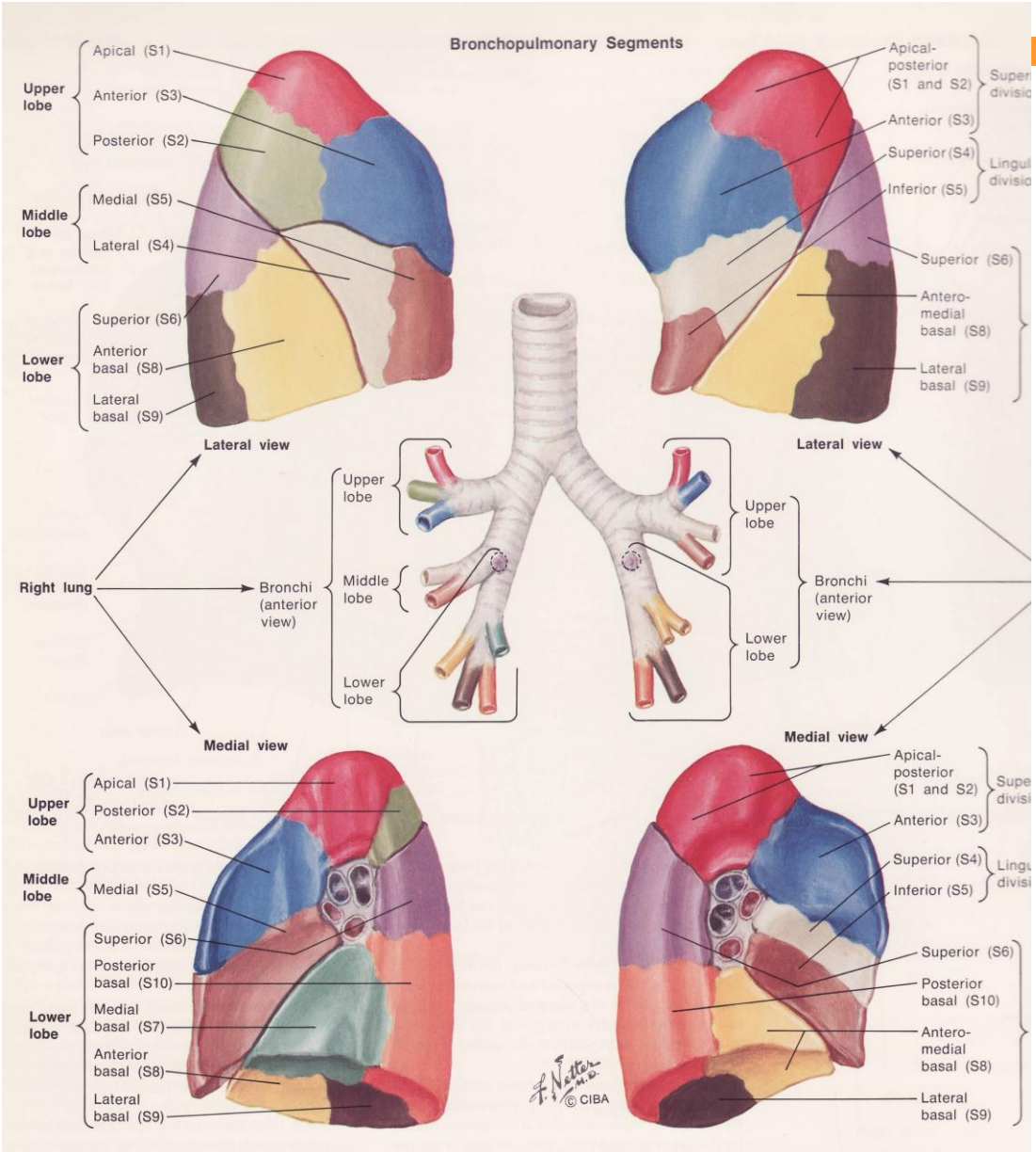
- Dataset:
  - 13 patients
  - Image resolution
    - 0.83mm/voxel (axial plane)
    - 1mm inter-slice distance
    - 1.25mm slice thickness
    - 11 energy levels
- Ground truth
  - Lobes manually segmented
  - Qanadli index per lobe





Methods: Qanadli index

- Severity of pulmonary embolism
- Computation depends on artery occlusion level
  - +0: no occlusion
  - +1: partial
  - +2 : complete occlusion

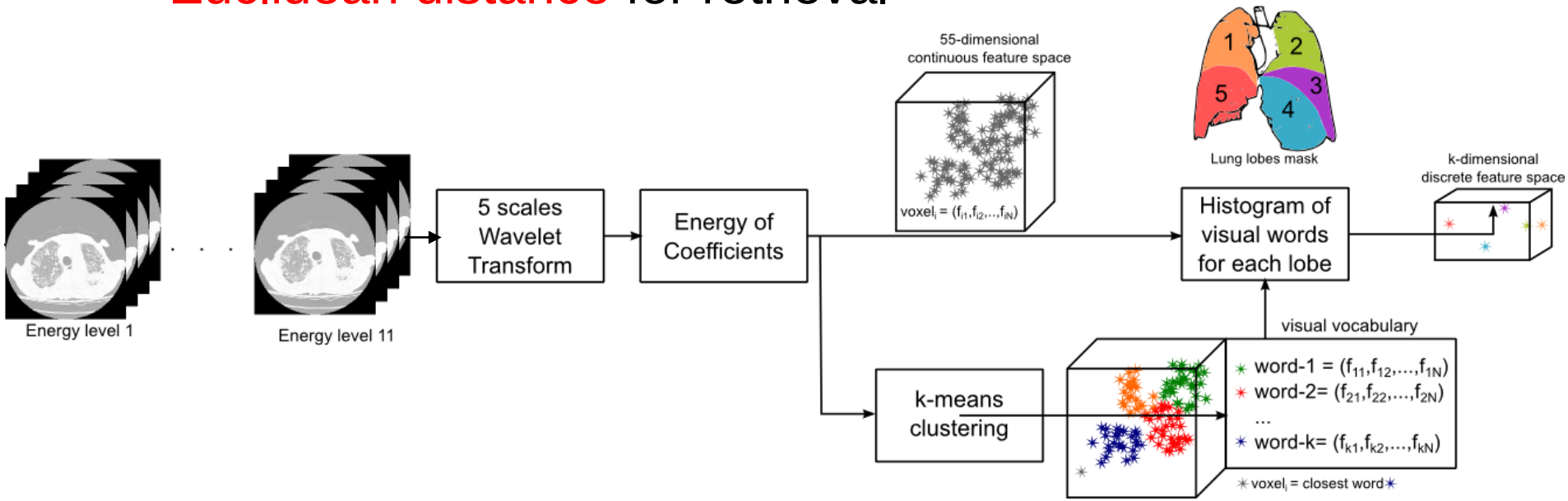


Methods: 4D Texture analysis

- One 3D volume is obtained per energy level
- 3D low level features are computed for each volume:
  - 3D difference of Gaussians wavelet coefficients
  - 1 to 5 scales in dyadic progression
  - Energy of coefficients in a 6x6x6 neighborhood (overlapping)
- High level features are computed in a Leave One Patient Out cross-validation

Methods: 4D Texture analysis

- High-level features: Bags of visual words
  - Leaving one patient out, the low level features are clustered into a varying number of visual words
  - The remaining patient is then described by the histogram of visual words for each lobe
  - Euclidean distance for retrieval



Experimental setup

PARAMETERS

- Data Sources
  - All 11 energy levels
  - Only 70 KeV energy level
- Visual Words
  - 50, 100, 150
- Wavelet scales
  - 1, 2, 3, 5 scales

EVALUATION

- Retrieval of similar lobes
  - Healthy: Qanadli = 0 (21)
  - Embolism: Qanadli > 0 (44)
- Precision measured
  - P@1
  - P@5
  - P@10

Results: 3D Data (70 KeV)

Scales	Visual Words	P@1(%)	P@5(%)	P@10(%)
1	50	60	56	**56**
	100	57	57	55
	150	58	56	54
2	50	55	57	55
	100	58	57	**56**
	150	**63**	**60**	54
3	50	51	55	53
	100	49	53	55
	150	55	55	55
5	50	45	50	52
	100	51	49	52
	150	51	52	53
Mean		54.42	54.75	54.17
Standard Deviation		4.92	3.06	1.34

Results: 4D Data (all energy levels)

Scales	Visual Words	P@1(%)	P@5(%)	P@10(%)
1	50	55	56	56
	100	58	55	57
	150	58	56	56
2	50	62	58	55
	100	62	**62**	**60**
	150	**63**	**62**	**60**
3	50	58	54	55
	100	60	59	58
	150	57	**62**	58
5	50	45	52	51
	100	57	52	51
	150	58	52	52
Mean		57.75	56.67	55.75
Standard Deviation		4.47	3.75	3.00

Results: Comparison 3D (70KeV) and 4D

Scales	Visual Words	P@1(%)	P@5(%)	P@10(%)
1	50	-5	0	0
	100	1	-2	2
	150	0	0	2
2	50	7	1	0
	100	4	5	4
	150	0	2	6
3	50	7	-1	2
	100	11	6	3
	150	2	7	3
5	50	0	2	-1
	100	6	3	-1
	150	7	0	-1

22 out of 36	Experiments where 4D performs better than 3D
6 out of 36	Experiments where 3D performs better than 4D

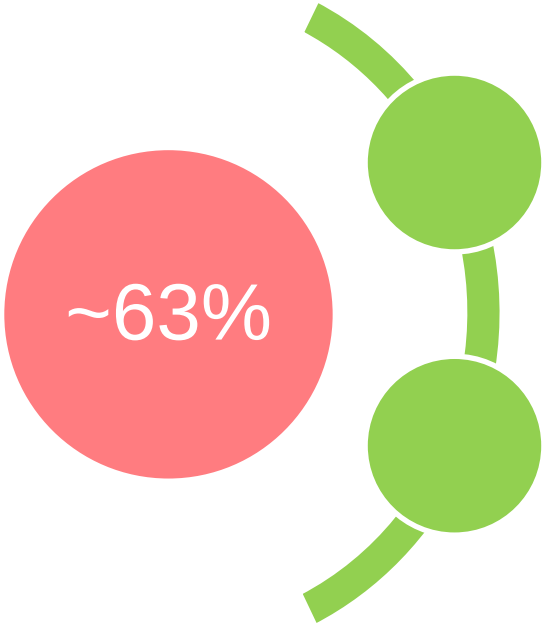
Best configurations (P@1)

4D Data. 2 scales, 150 VW

	Healthy	Embolism
Healthy	47.6%	52.4%
Embolism	29.5%	70.5%

3D Data. 2 scales, 150 VW

	Healthy	Embolism
Healthy	52.4%	47.6%
Embolism	31.8%	68.2%



Same configuration: 2 scales, 150 VW

Different data source

Best configurations (P@5)

4D Data. 2 scales, 100 VW

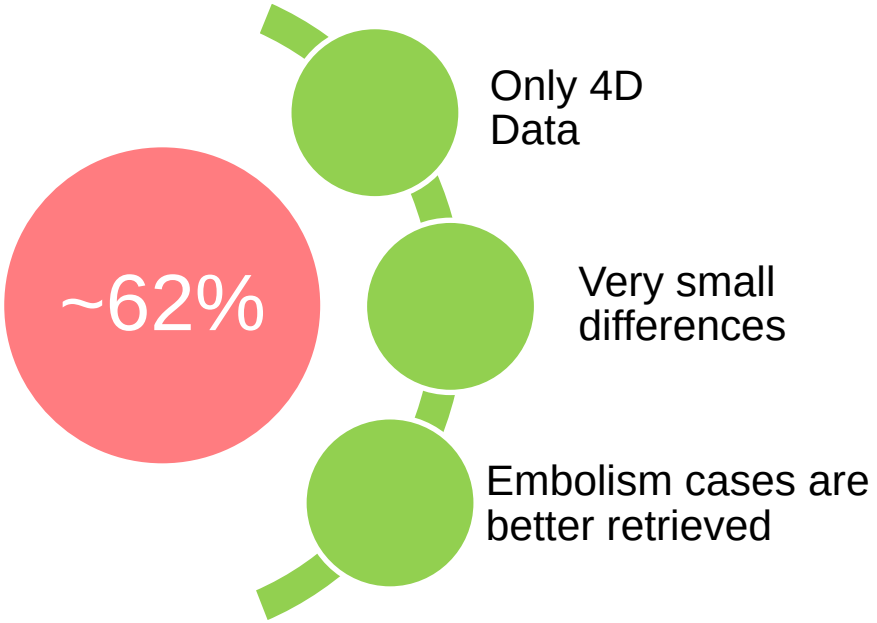
	Healthy	Embolism
Healthy	43.8%	56.2%
Embolism	29.5%	70.5%

4D Data. 2 scales, 150 VW

	Healthy	Embolism
Healthy	43.8%	56.2%
Embolism	29.9%	70.1%

4D Data. 3 scales, 150 VW

	Healthy	Embolism
Healthy	44.8%	55.2%
Embolism	29.1%	70.9%



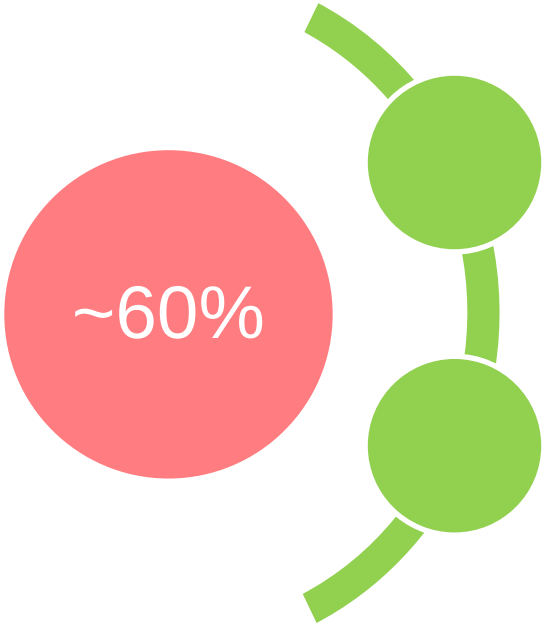
Best configurations (P@10)

4D Data. 2 scales, 100 VW

	Healthy	Embolism
Healthy	42.4%	57.6%
Embolism	31.1%	68.9%

4D Data. 2 scales, 150 VW

	Healthy	Embolism
Healthy	40%	60%
Embolism	31.8%	68.9%



Only 4D Data

Embolism cases are better retrieved

Conclusions & Future Work

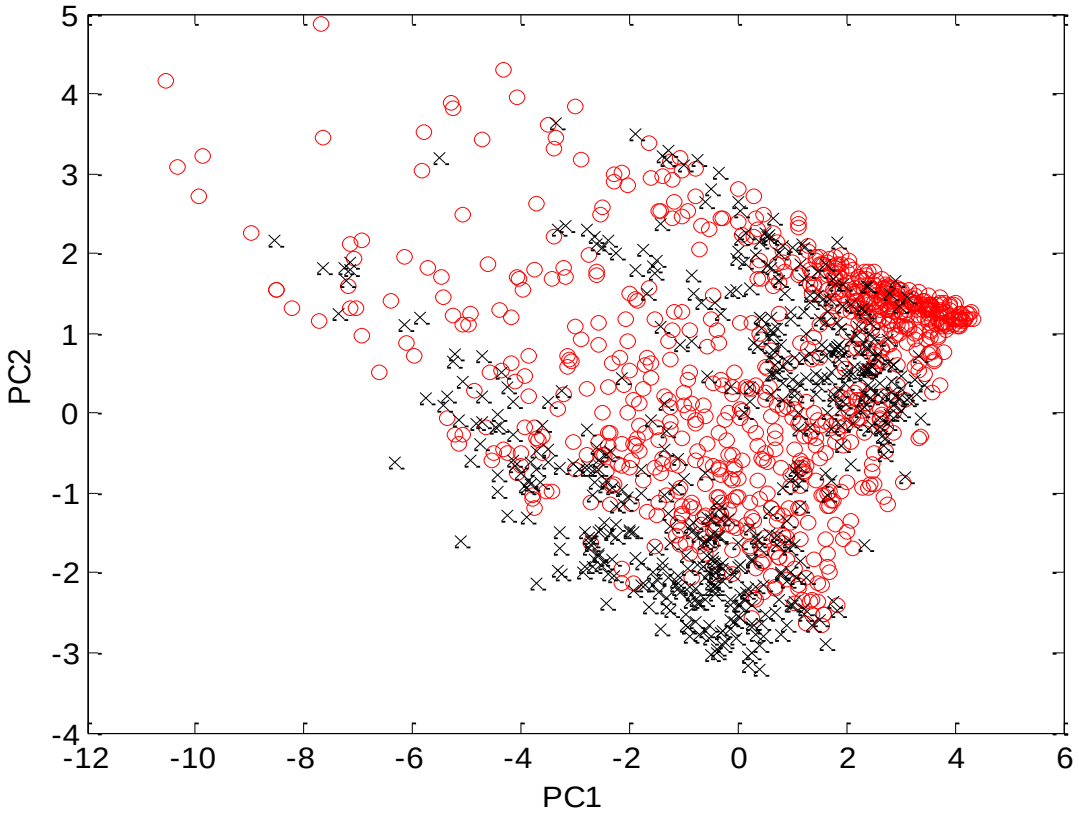
- 4D texture analysis of Dual Energy is relevant for the characterization pulmonary embolism
- Best performing configurations suggest
  - 4D data
  - 2 wavelet scales
  - 150 visual words, but more can lead to better results
- Future work
  - Complete the dataset with more control patients
    - New dataset with 19 patients with embolism and 8 control already available

Conclusions & Future Work

- Investigate other low-level features
  - Grey-level histograms in Hounsfield Units
  - Non-isotropic wavelets
  - 2 first principal components:

x healthy

o embolism



Thank you for your attention!

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