

cRedAnno+: Annotation Exploitation in Self-Explanatory Lung Nodule Diagnosis

(🖱️ +)

J. Lu^{1,2}, C. Yin^{1,3}, K. Erleben¹, M. B. Nielsen², S. Darkner¹

¹ Department of Computer Science, University of Copenhagen, Denmark

² Department of Diagnostic Radiology, Rigshospitalet, Copenhagen University Hospital, Denmark

³ Department of Computer Science, Hong Kong Baptist University, China



KØBENHAVNS UNIVERSITET

(considerably) **Reducing Annotation** Need in Self-Explanatory Models for Lung Nodule Diagnosis (cRedAnno)

J. Lu^{1,2}, C. Yin^{1,3}, O. Krause¹, K. Erleben¹, M. B. Nielsen², S. Darkner¹

¹ Department of Computer Science, University of Copenhagen, Denmark

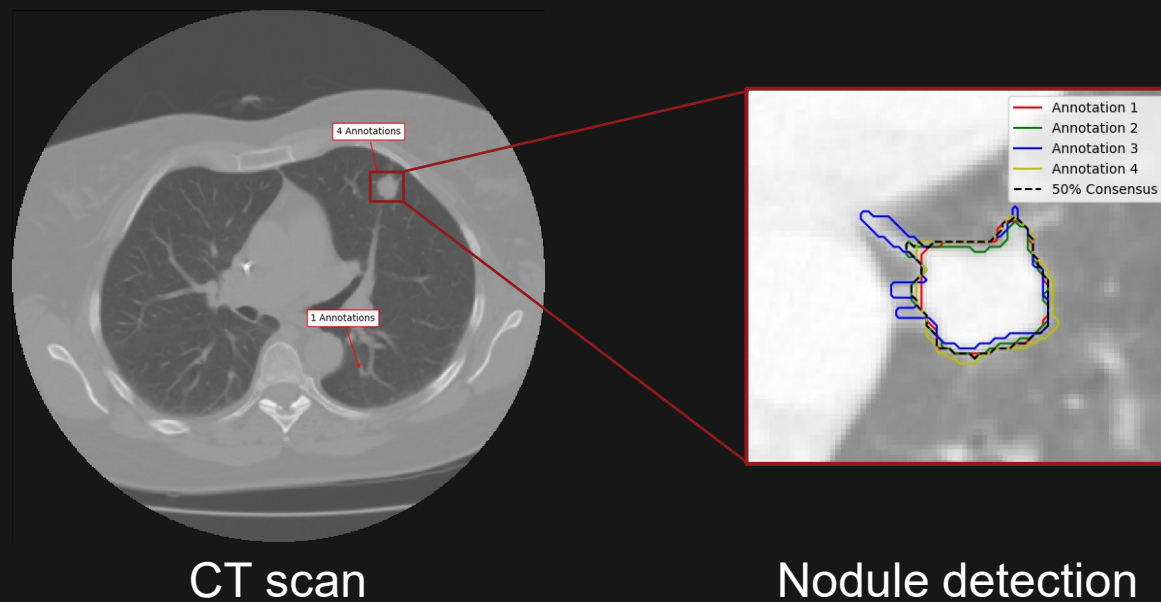
² Department of Diagnostic Radiology, Rigshospitalet, Copenhagen University Hospital, Denmark

³ Department of Computer Science, Hong Kong Baptist University, China



KØBENHAVNS UNIVERSITET

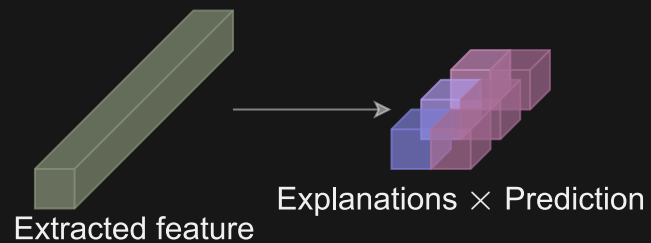
Background: Lung nodule diagnosis



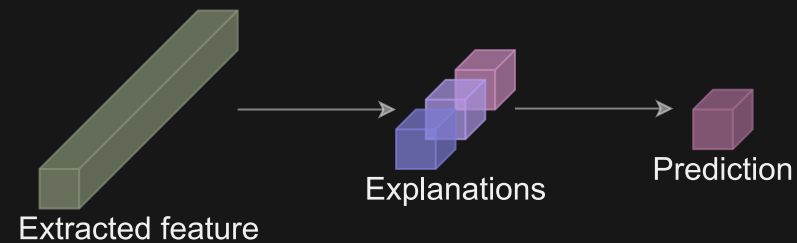
| | | |
|--------------------------|-----------------------|----------------------|
| Nodule attributes | Subtlety | Obvious |
| | InternalStructure | Soft Tissue |
| | Calcification | Non-central |
| | Sphericity | Ovoid |
| | Margin | Sharp |
| | Lobulation | Nearly No Lobulation |
| | Spiculation | Medium Spiculation |
| Texture | Solid | |
| Malignancy | Moderately Suspicious | |

Annotation info

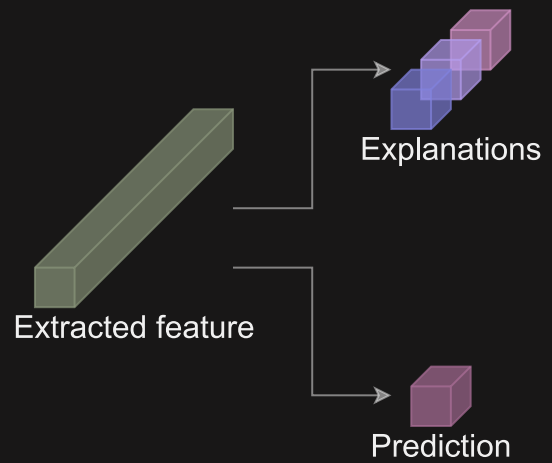
Related work: Feature-based self-explanatory models



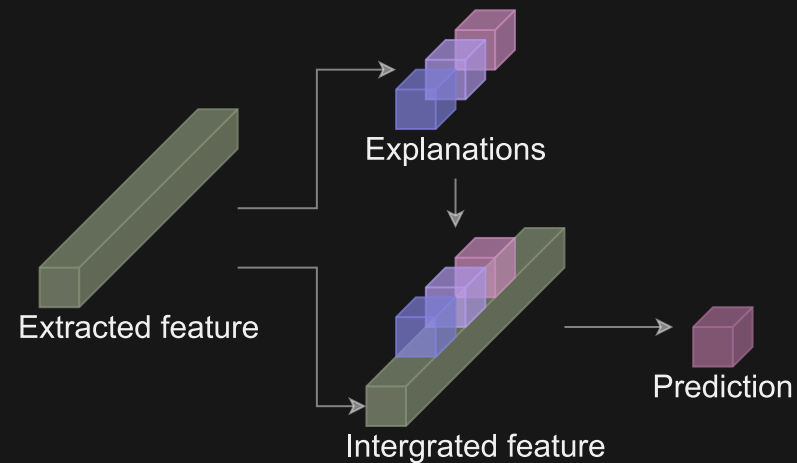
Teaching Explanation Networks



Concept Bottleneck Networks

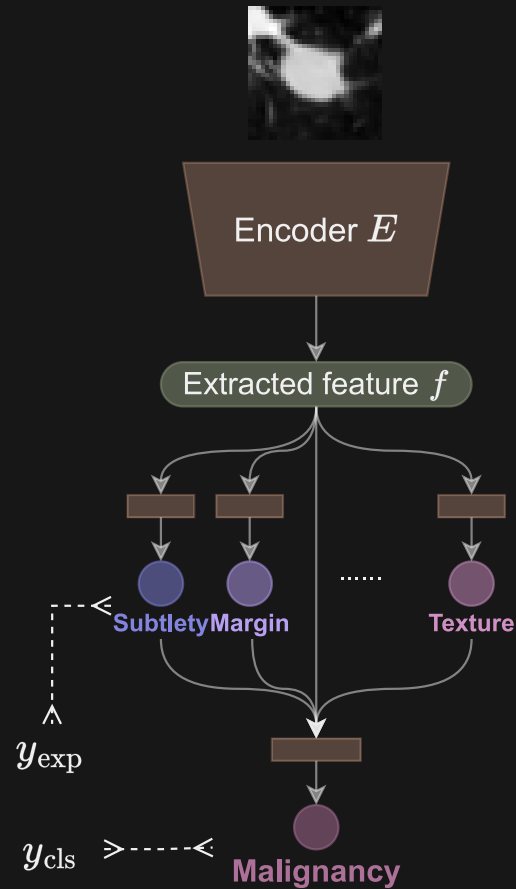


Multitask Learning Networks

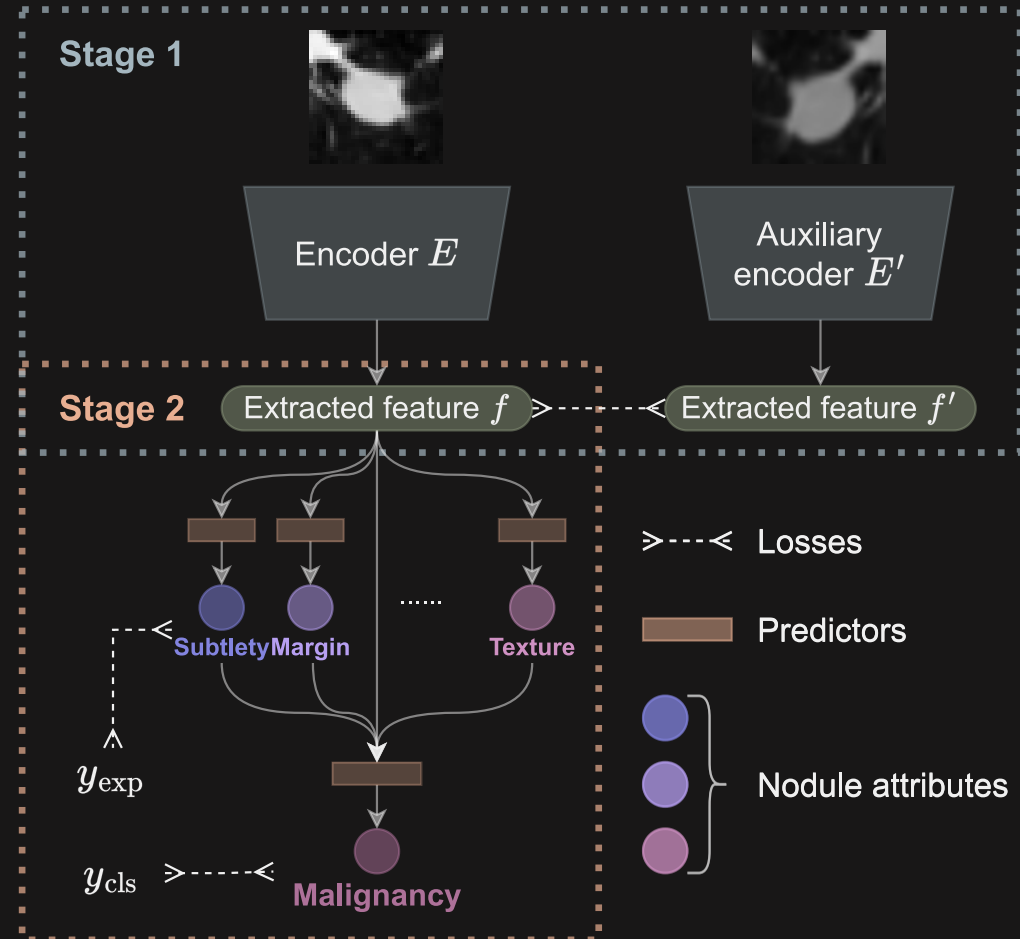


Hierarchical Networks

Method – cRedAnno : Self-supervised contrastive learning

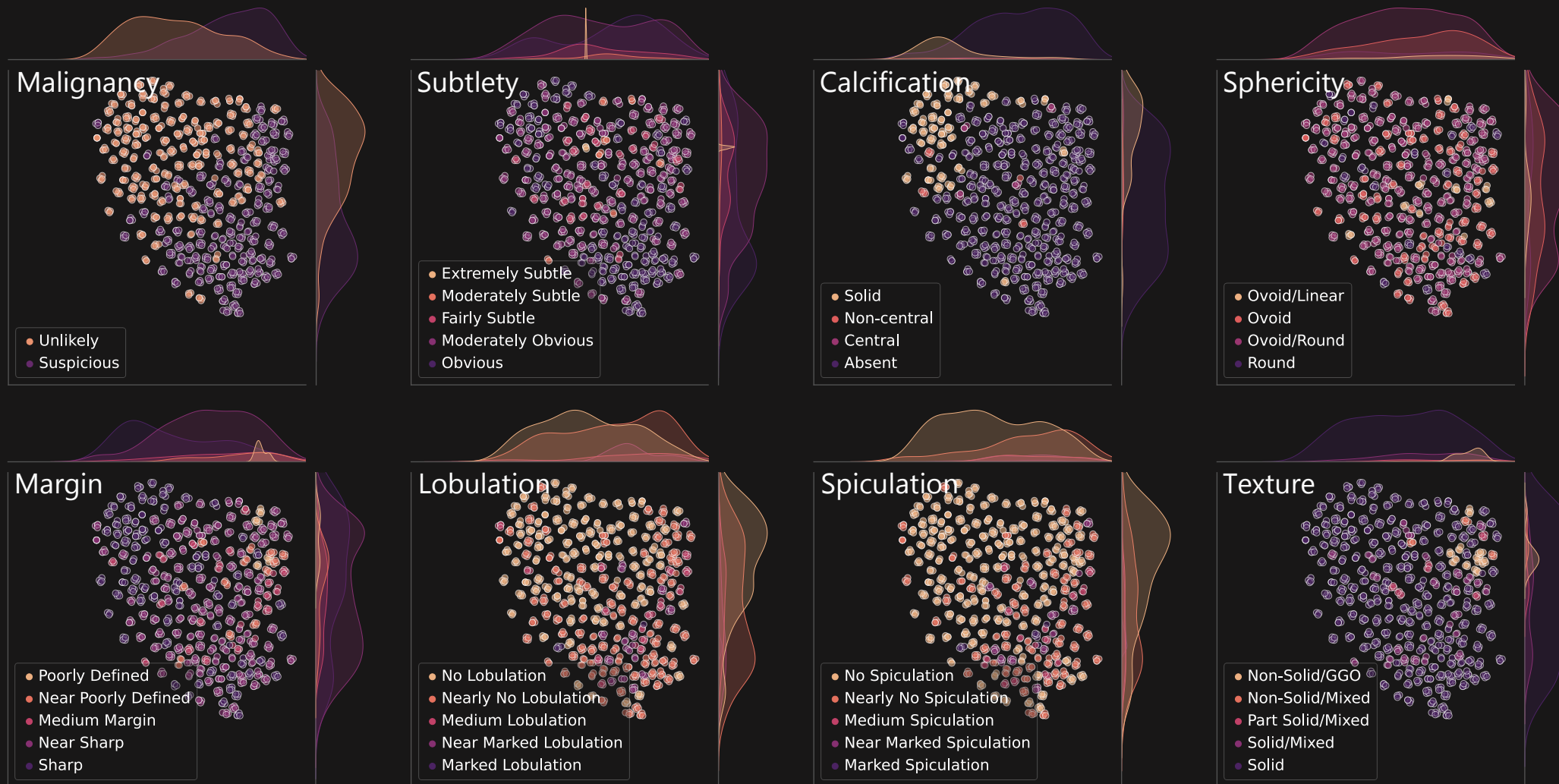


Previous methods

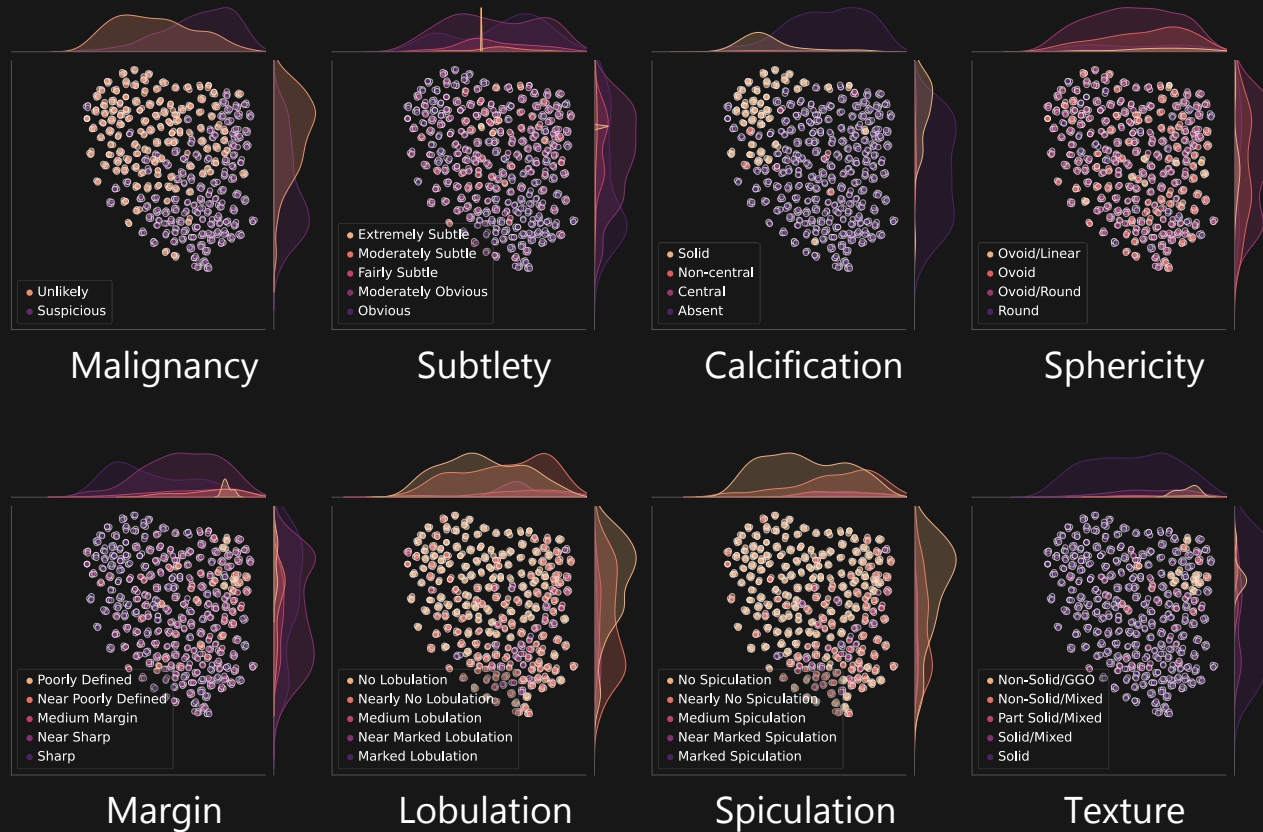
cRedAnno 

Results:

Analysis of extracted features in the learned space



Limitations of cRedAnno



- Under scarce annotation conditions
 - Unstable performance
- Randomly selected annotations are not necessarily informative enough
 - Risk of not covering enough label space
- Unlabelled data are not adequately used

cRedAnno+: Annotation Exploitation in Self-Explanatory Lung Nodule Diagnosis

(🖱️ +)

J. Lu^{1,2}, C. Yin^{1,3}, K. Erleben¹, M. B. Nielsen², S. Darkner¹

¹ Department of Computer Science, University of Copenhagen, Denmark

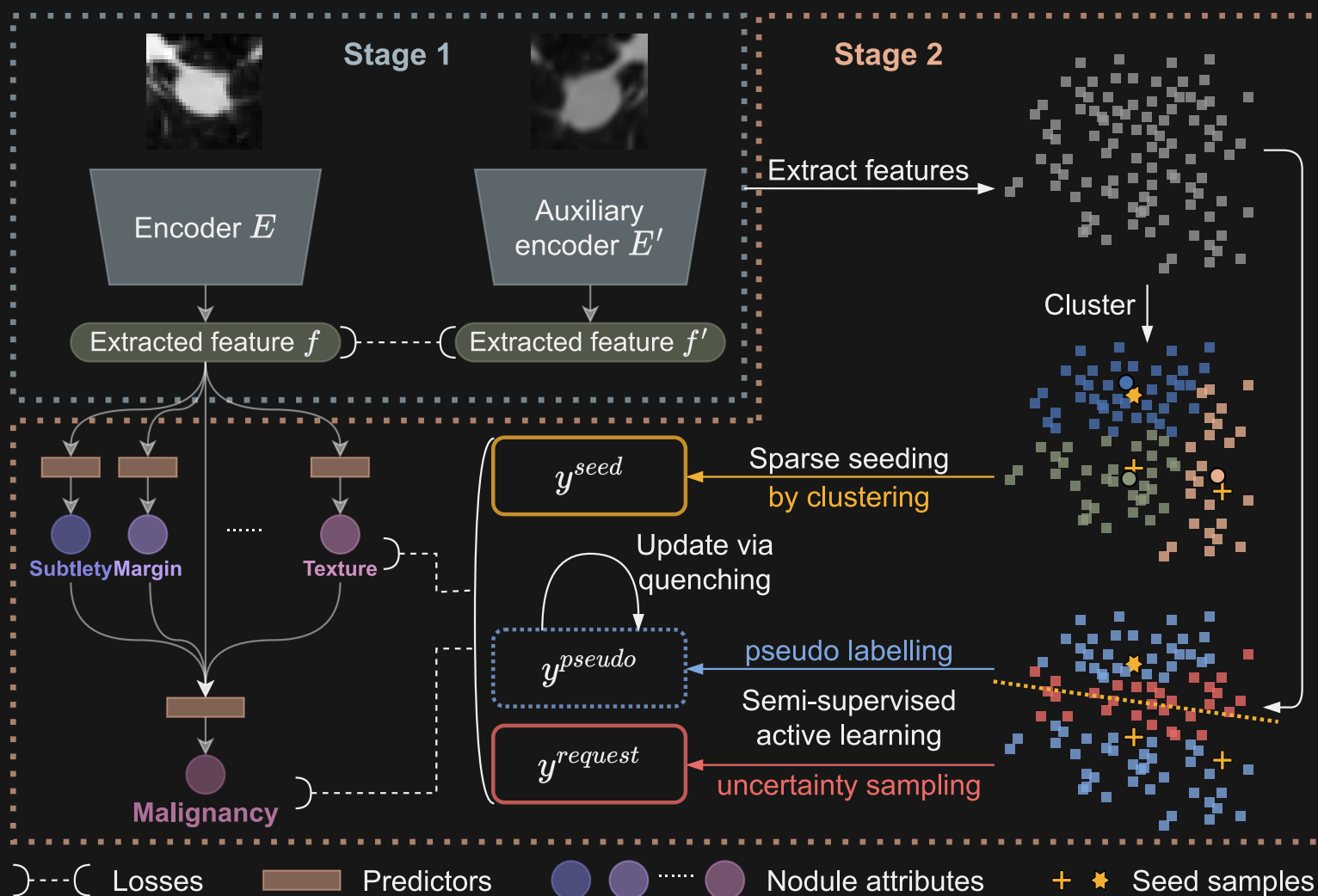
² Department of Diagnostic Radiology, Rigshospitalet, Copenhagen University Hospital, Denmark

³ Department of Computer Science, Hong Kong Baptist University, China



KØBENHAVNS UNIVERSITET






Method – cRedAnno+ + : Annotation exploitation mechanism



- Aim: jointly utilise
 - extracted features
 - annotations
 - unlabelled data
- Sparse seeding.
 - cluster centroids
- Semi-supervised active learning.
 - uncertainty sampling
 - pseudo labelling
- Quenching.
 - update pseudo labels
 - reinitialise the weights

Results:

Predicting nodule attributes and malignancy

| | Nodule attributes | | | | | | Malignancy | #nodules | Additional information | |
|--|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------|------------------------|---|
| | Sub | Cal | Sph | Mar | Lob | Spi | | | | Tex |
| Full annotation | | | | | | | | | | |
| HSCNN ^[1] | 71.90 | 90.80 | 55.20 | 72.50 | - | - | 83.40 | 84.20 | 4252 | 3D volume data |
| X-Caps ^[2] | 90.39 | - | 85.44 | 84.14 | 70.69 | 75.23 | 93.10 | 86.39 | 1149 | None |
| MSN-JCN ^[3] | 70.77 | 94.07 | 68.63 | 78.88 | 94.75 | 93.75 | 89.00 | 87.07 | 2616 | segmentation mask + ... |
| MTMR ^[4] | - | - | - | - | - | - | - | 93.50 | 1422 | all 2D slices in 3D volumes |
|  + | 96.32 ±0.61 | 95.88 ±0.15 | 97.23 ±0.20 | 96.23 ±0.23 | 93.93 ±0.87 | 94.06 ±0.60 | 97.01 ±0.26 | 87.56 ±0.61 | 730 | None |
| Partial annotation | | | | | | | | | | |
| WeakSup ^[5] (1:5) | 43.10 | 63.90 | 42.40 | 58.50 | 40.60 | 38.70 | 51.20 | 82.40 | 2558 | multi-scale 3D volume data, all malignancy annotations, 1/(1+N) on attributes |
| WeakSup ^[5] (1:3) | 66.80 | 91.50 | 66.40 | 79.60 | 74.30 | 81.40 | 82.20 | 89.10 | | |
|  (10%) | 96.06 ±2.02 | 93.76 ±0.85 | 95.97 ±0.69 | 94.37 ±0.79 | 93.06 ±0.27 | 93.15 ±0.33 | 95.49 ±0.85 | 86.65 ±1.39 | 730 | None |
|  + (10%) | 96.23 ±0.45 | 92.72 ±1.66 | 95.71 ±0.47 | 90.03 ±3.68 | 93.89 ±1.41 | 93.67 ±0.64 | 92.41 ±1.05 | 87.86 ±1.99 | | |
|  (1%) | 93.98 ±2.09 | 89.68 ±3.52 | 94.02 ±2.30 | 91.94 ±1.17 | 91.03 ±1.72 | 90.81 ±1.56 | 93.63 ±0.47 | 80.02 ±8.56 | | |
|  + (1%) | 95.84 ±0.34 | 92.67 ±1.24 | 95.97 ±0.45 | 91.03 ±4.65 | 93.54 ±0.87 | 92.72 ±1.19 | 92.67 ±1.50 | 86.22 ±2.51 | | |

[1] S. Shen *et al.*, "An interpretable deep hierarchical semantic convolutional neural network for lung nodule malignancy classification," *Expert Systems with Applications*, vol. 128, pp. 84–95, Aug. 2019.

[2] R. LaLonde *et al.*, "Encoding Visual Attributes in Capsules for Explainable Medical Diagnoses," in *Medical Image Computing and Computer Assisted Intervention – MICCAI 2020*, Cham, 2020, pp. 294–304.

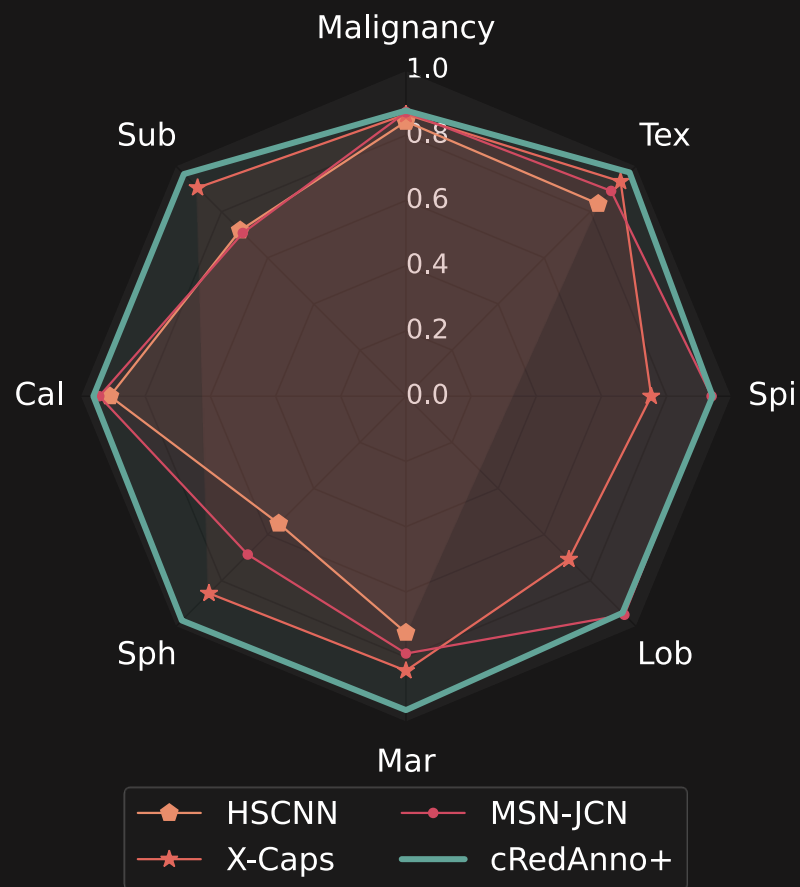
[3] W. Chen *et al.*, "End-to-End Multi-Task Learning for Lung Nodule Segmentation and Diagnosis," in *2020 25th International Conference on Pattern Recognition (ICPR)*, Milan, Italy, 2021, pp. 6710–6717.

[4] L. Liu *et al.*, "Multi-Task Deep Model With Margin Ranking Loss for Lung Nodule Analysis," *IEEE Trans. Med. Imaging*, vol. 39, no. 3, pp. 718–728, Mar. 2020.

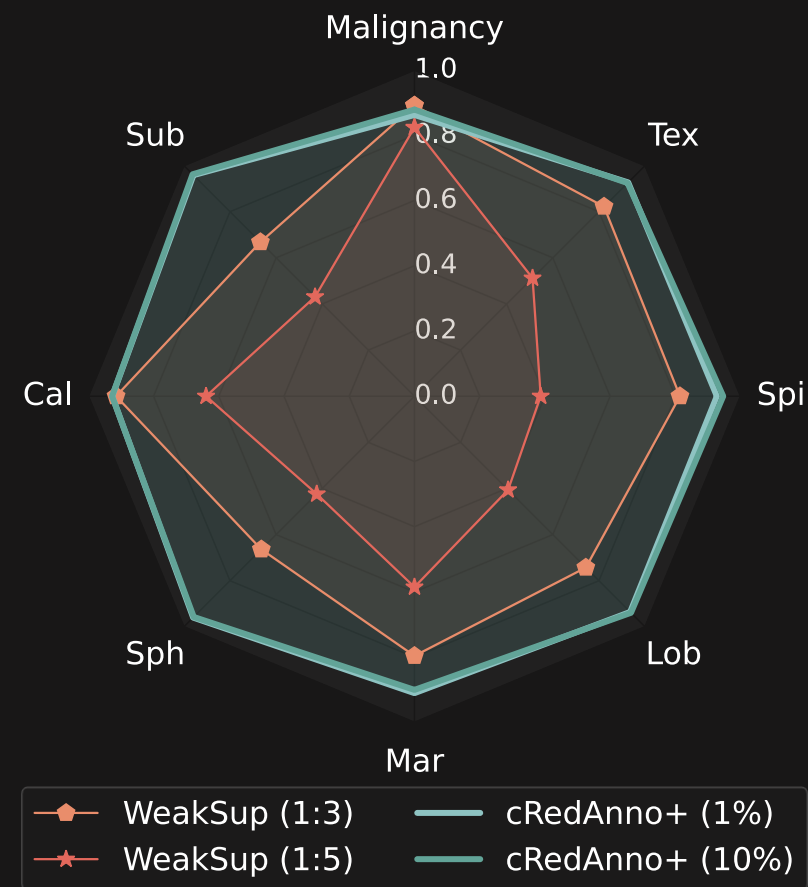
[5] A. Joshi *et al.*, "Lung nodule malignancy classification with weakly supervised explanation generation," *J. Med. Imag.*, vol. 8, no. 04, Aug. 2021.

Results:

Predicting nodule attributes and malignancy



Full annotation

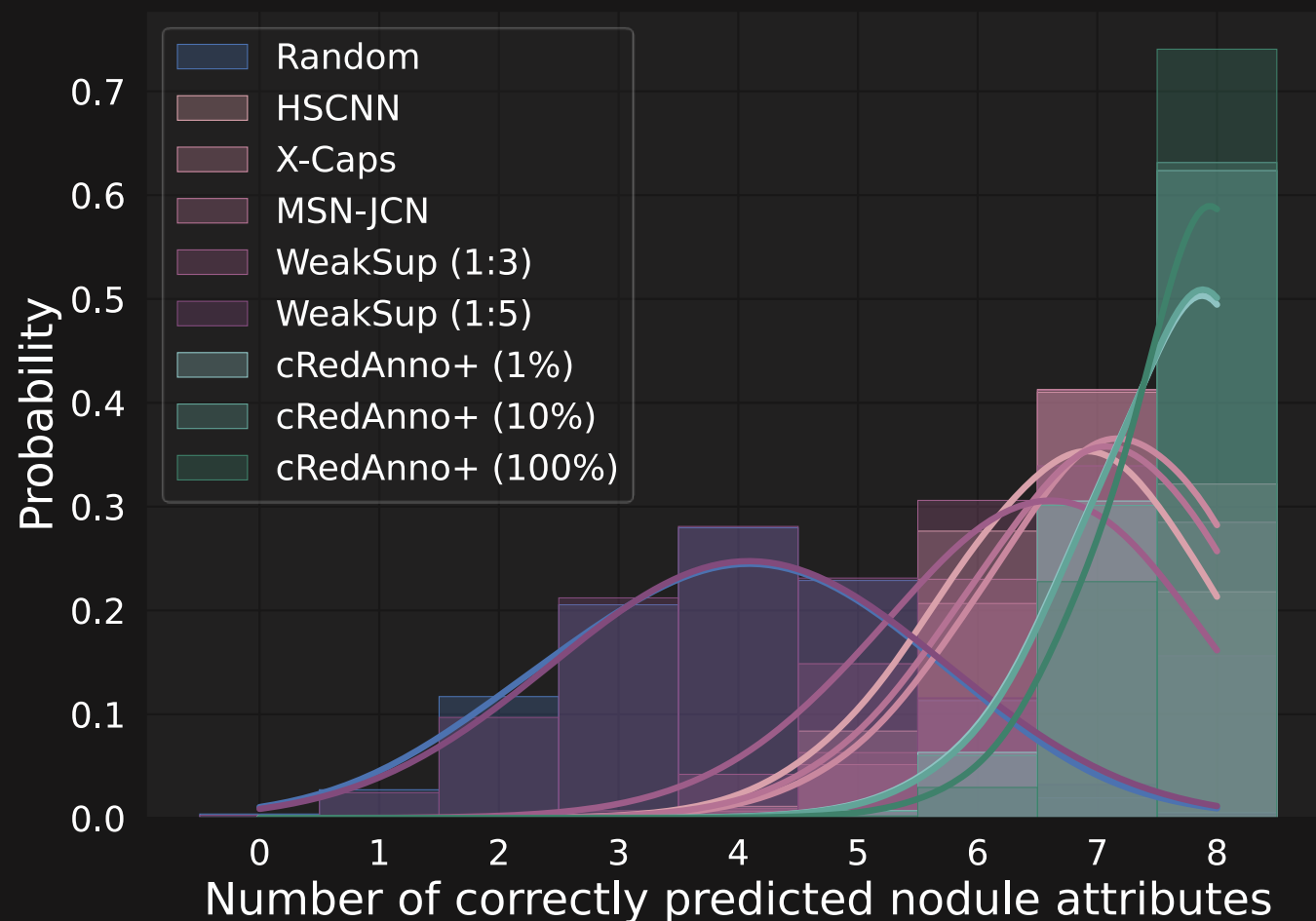


Partial annotation

Simultaneously high accuracy in predicting malignancy and all nodule attributes.

Results:

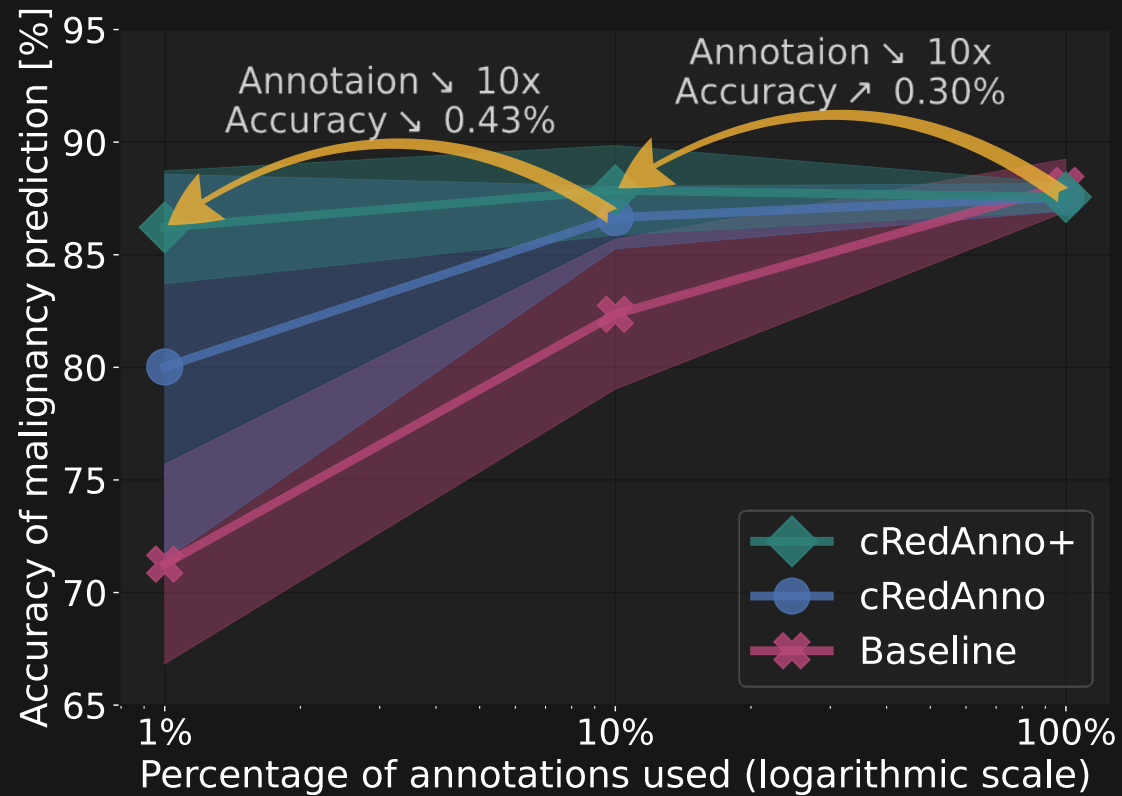
Predicting nodule attributes for a given sample



- cRedAnno+ shows a significantly larger probability of simultaneously predicting all 8 nodule attributes correctly.
- >90% nodules have at least 7 attributes correctly predicted, even under the extreme 1% annotation condition.

Results

Comparison with cRedAnno



Ablation study

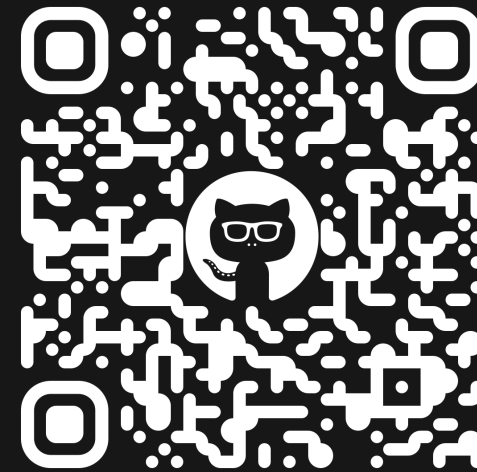
| Seed sample selection | Annotation acquisition strategy | Pseudo labelling | Quenching | Malignancy accuracy | |
|-----------------------|---------------------------------|------------------|-----------|---------------------|--------------------|
| | | | | (10%) | (1%)* |
| random | × | × | × | 86.65 ±1.39 | 80.02 ±8.56 |
| random | malignancy confidence | dynamic | ✓ | 82.71 ±7.47 | 79.50 ±11.10 |
| sparse | integrated entropy | dynamic | ✓ | 86.52 ±0.99 | 86.22 ±2.51 |
| sparse | malignancy confidence | static | × | 85.91 ±1.66 | 85.35 ±1.93 |
| sparse | malignancy confidence | dynamic | ✓ | 87.86 ±1.99 | 86.22 ±2.51 |

* Does not contain requested annotations.

Conclusion

- A data-/annotation-efficient self-explanatory approach for lung nodule diagnosis
 - Contrastive learning (👉)
 - learn semantically meaningful reasoning space
 - Annotation exploitation mechanism (👉 +)
 - jointly utilise the extracted features, annotations, and unlabelled data
- Comparing with SOTA:
 - 1% annotation, fewer samples
 - competitive in malignancy prediction
 - significantly better in predicting all nodule attributes as explanations

- Open-source code



github.com/diku-dk/credanno

- Implementation
- Sample selection
- Pre-processing
- Experiments
- Plots

Considerably Reducing Annotation Need in Self-Explanatory Models for Lung Nodule Diagnosis (cRedAnno 🖱️) and (cRedAnno+ 🖱️ +)



github.com/diku-dk/credanno

Background

| | |
|-------------------|------------------------------|
| Subtlety | Obvious |
| InternalStructure | Soft Tissue |
| Calcification | Non-central |
| Sphericity | Ovoid |
| Margin | Sharp |
| Lobulation | Nearly No Lobulation |
| Spiculation | Medium Spiculation |
| Texture | Solid |
| Malignancy | Moderately Suspicious |

