Utility of the concept bottleneck model in a CT scans analysis

Jakub Binda

University of Warsaw, Faculty of Mathematics, Informatics and Mechanics.

April 2024

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LIDC-IDRI dataset

- Lung Image Database Consortium and Image Database Resource Initiative (LIDC-IDRI)
- Publicly available database.
- Contains 1018 chest CT scans from 1010 patients.

LIDC-IDRI Dataset

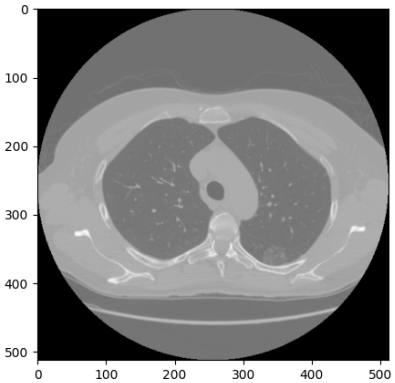

Figure: Slice of an exemplary CT scan.

LIDC-IDRI Dataset

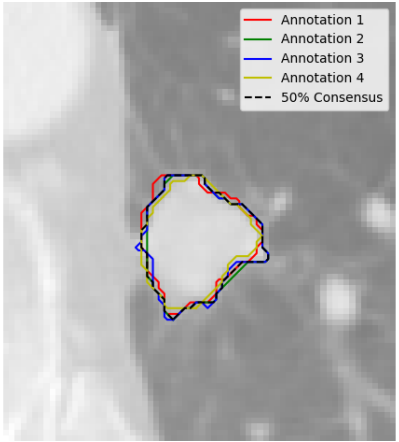

Figure: Slice of an exemplary CT scan with an annotations.

LIDC-IDRI Dataset

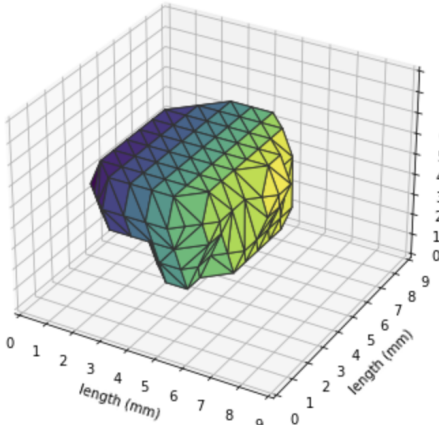

Figure: 3D visualisation of a nodule.

Dataset preparation

1. Clustering nodule's annotations with the Pylidc package.
2. Extracting small volumes around nodules.
3. Extracting nodule's features.
4. Assigning benign or malignant label.
5. In summary 854 nodules (442 benign) after preprocessing.

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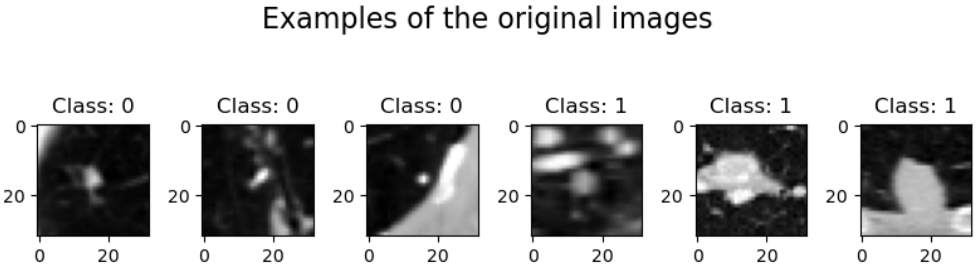

Figure: Slices of examples from prepared dataset.

Explainable models

- Why model is predicting that nodule is malignant?
- Explainability is especially important in medicine.
- Concept Bottleneck Model

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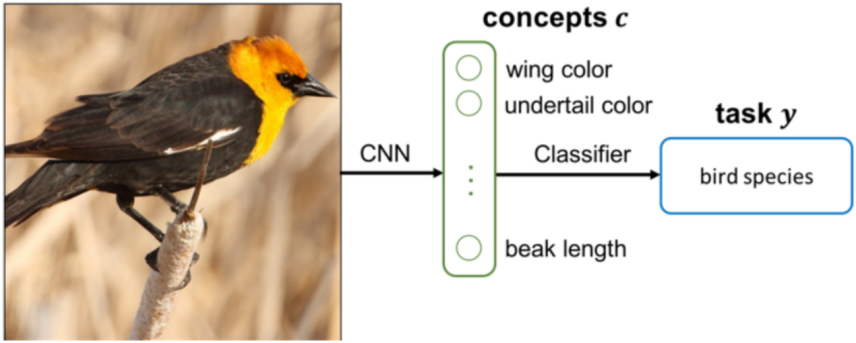
Concept Bottleneck Model



Koh et al, (2020) [2]

Concept Bottleneck Model (CBM)

Let's take a regression task as an example, then formally:

$$x \in \mathbb{R}^d$$
$$c \in \mathbb{R}^k$$
$$y \in \mathbb{R}$$

training points:

$$\left(x^{(i)}, y^{(i)}, c^{(i)}\right)_{i=1}^{n}$$

$CBM = f(g(x))$, where

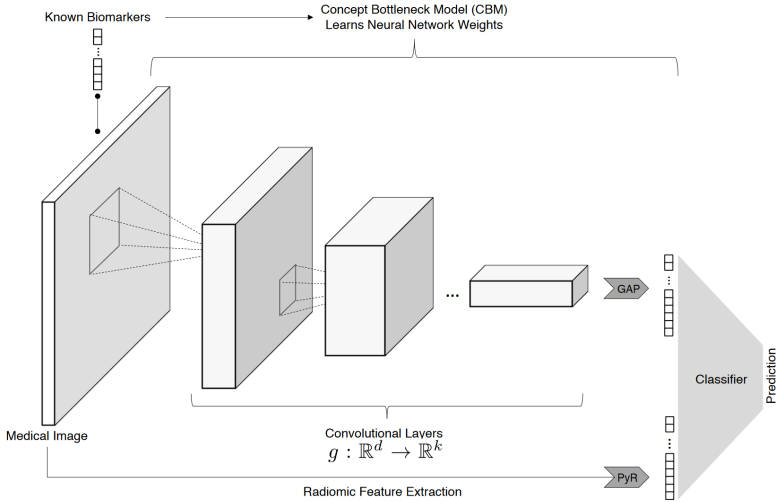
$g : \mathbb{R}^d \to \mathbb{R}^k$

$f : \mathbb{R}^k \to \mathbb{R}$

ConRad

- ConRad model is based on the Concept Bottleneck Model.
- CNN predicts biomarkers from a nodule slice. (8 biomarkers)
- Radiomics features are computed from an segmented image with PyRadiomics package. (107 features)

ConRad - general architecture



Brocki and Chung, (2023) [1]

ConRad - concept space

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ConRad - CNN biomarkers

Biomarkers which are predicted with CNN:

- subtlety
- calcification
- sphericity
- margin
- lobulation
- spiculation
- texture
- diameter

All biomarkers are numeric.

ConRad - concept space

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ConRad - final classifier

Utilized classifiers:

- Non-linear/linear SVM
- Random Forest
- Logistic Regression
- Logistic Regression with the Lasso

ConRad - results

Biomarkers and radiomics in the concept's space.

Final Layer Classifier	Recall	Precision	Accuracy
Non-linear SVM	0.886	0.899	0.897
Linear SVM	0.886	0.893	0.893
Random Forest	0.879	0.883	0.881
Logistic Regression	0.884	0.893	0.892
Logistic Regression with the Lasso	0.896	0.893	0.896

CNN - baseline

Baseline results for End2End CNN classifier.

Classifier	Accuracy
End-to-end CNN	0.891

Outcomes

- ConRad model performs as good as End2End CNN model.
- However, thanks to concept's space ConRad is much more interpretable.

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Features selection with Lasso

- Adding L1 penalty (Lasso) to Logistic regression drastically reduced number of features.
- From 107 **PyRadiomics** features only 13 have non-zero weights.
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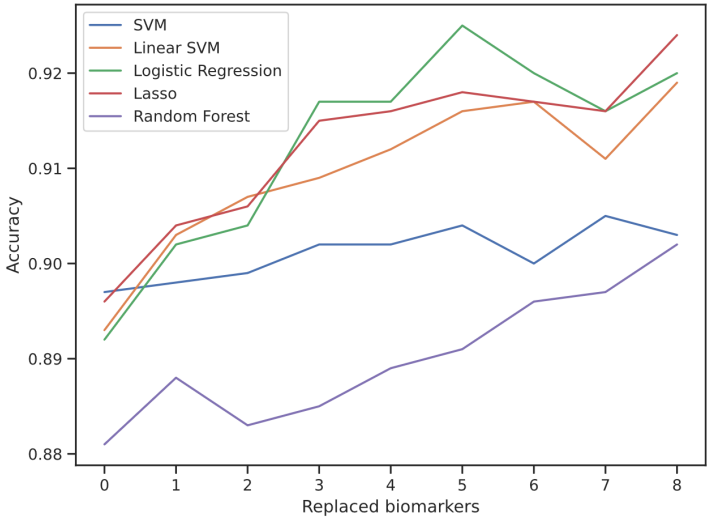
Simulation of human in the loop



Literature

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Thank you!