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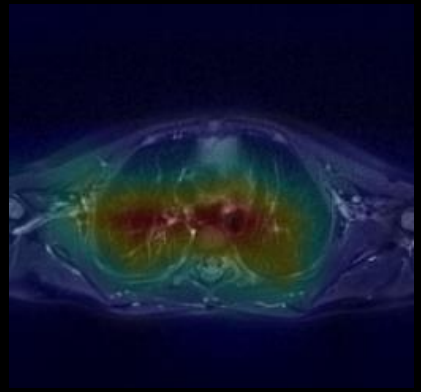

Exploring the potential of explainable artificial intelligence in deep learning for lung changes of Cystic Fibrosis patients

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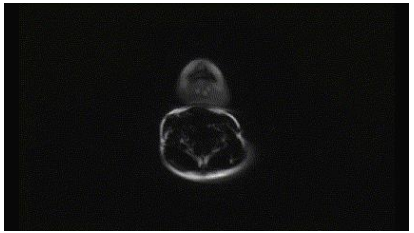
IMI Institut für Medizinische Informatik | TLRC Translational Lung Research Center Heidelberg | DZL Deutsches Zentrum für Lungenforschung | DIR Diagnostic Interventional Radiology

AIDH IMIA

Introduction



- Cystic fibrosis affects lungs[1]
- Monitoring of lung changes with morpho-functional MRI score[2]
- Deep learning supports automatic lung change detection[3]
- Explainable artificial intelligence (XAI) can increase understanding of deep-learning based classifications[4]

[1] Puderbach M, [..], Tuengerthal S; Invest Radiol. 2007
[2] Eichinger M, [..], Niemann A; Eur J Radiol. 2012
[3] Ringwald FG, in preparation
[4] van der Velden BHM, [..], Viergever MA; IEEE 2021

Objective

Apply XAI algorithms on top of an existing deep-learning based classification pipeline for perfusion defects and mucus plugging.

Methods

- Selection of suitable XAI methods
  - Suitable for medical purposes (images)
  - Pytorch[6] implementation
  - Adaptable to custom classification architecture[7]
  - Post-hoc algorithm
- Implementation and testing
- Visual evaluation and categorical classification

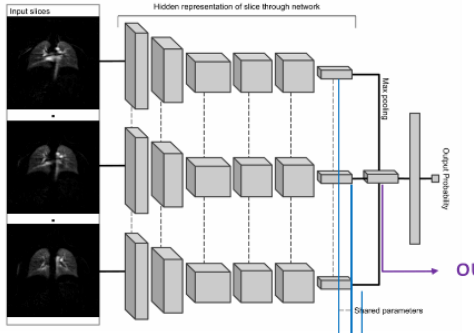
[6] Paszke A, [...], Chanan G; Adv. In Process. Syst. 2019
[7] Bien N, [...], Jones E; PLoS Med. 2018

Results

Selected XAI algorithms:

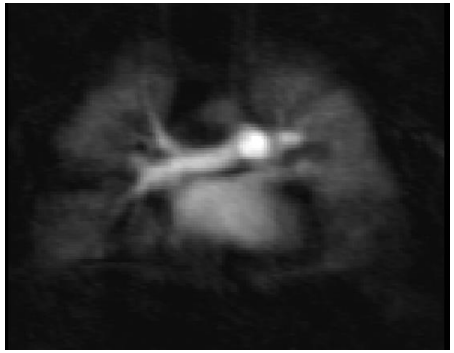
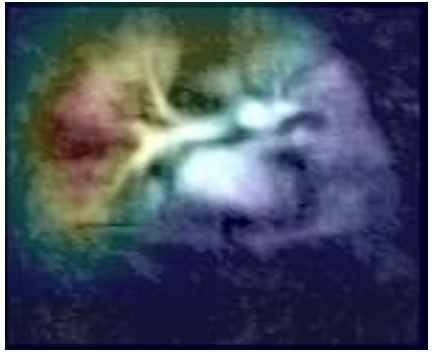
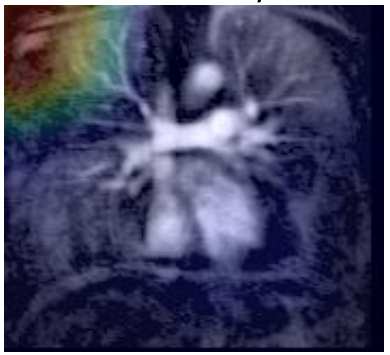
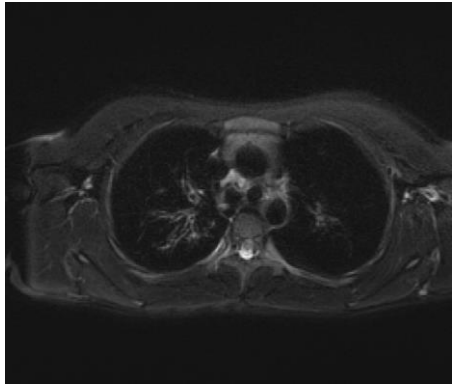
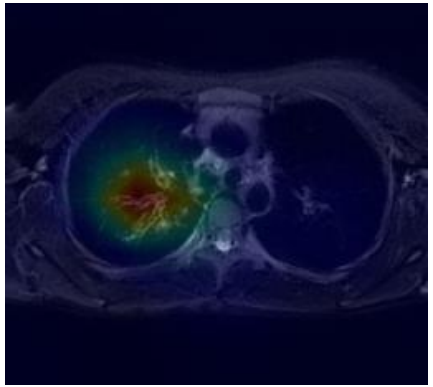
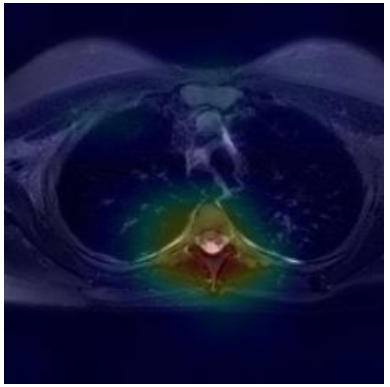
- Class activation maps (CAMs)[8]
- Grad-CAM[9]
- Integrated gradients (IG)
- Layer-wise relevance propagation (LRP)

- Acceptable calculation time under 3 seconds/MRI

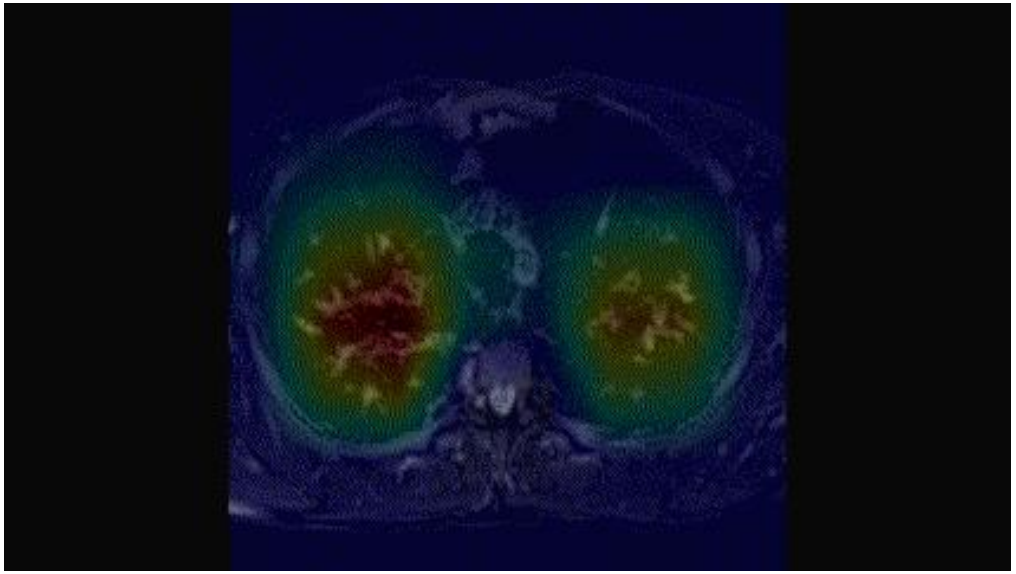


Adapted from Bien et al. [7]

[8]Zhou B, [..], Torralba A; Comp. Vis. Pat. Rec. 2015
[9] Selvaraju R.R, [..], Batra D; Int. Jour. Comp. Vis. 2016

	original	correct overlay	incorrect overlay
Perfusion defect detection (coronal)			
Mucus plugging detection (axial)			

Results



MR sequence:
BLADE (Periodically Rotated Overlapping Parallel Lines with Enhanced
Reconstruction)
Slice thickness: 5mm

Results

- CAM outperformed Grad-Cam
- Some visualizations indicating areas irrelevant for classification
- Subtraction MRI (perfusion) performing worse than BLADE

Discussion

- Grad-Cam underperformance probably related to custom classification architecture
- Image quality and blur impact on XAI algorithm performance
- Further optimization steps needed
- Importance of explainability in deep learning models
  - Increased trust and confidence in model predictions
  - Enhanced understanding of decision-making process

Conclusions

- XAI algorithms provide **additional** information for CF lung MRI classification
- Importance of relying on explainability component
- Potential for further advancements and improvements

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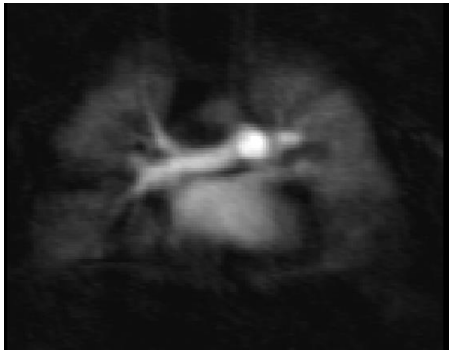
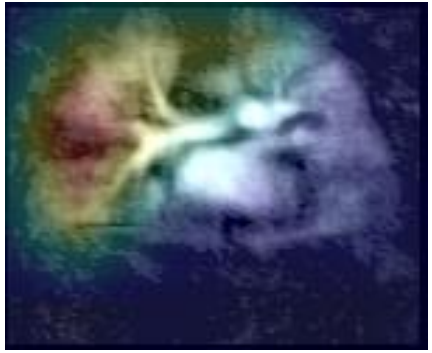
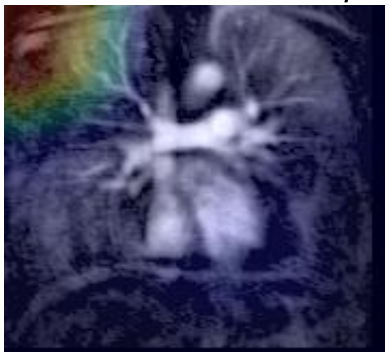
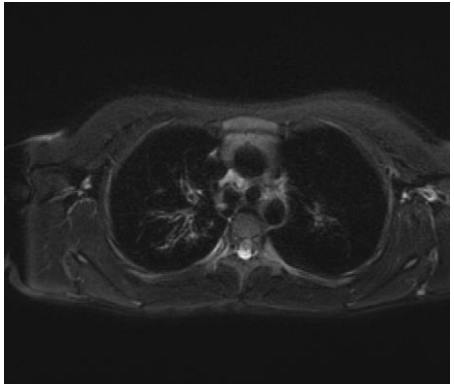
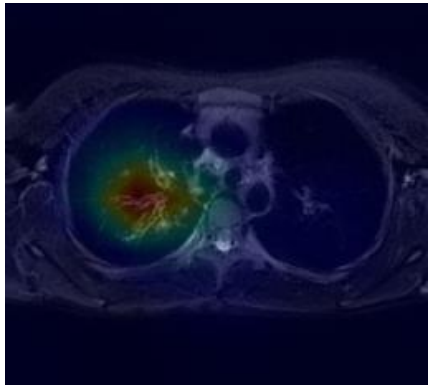
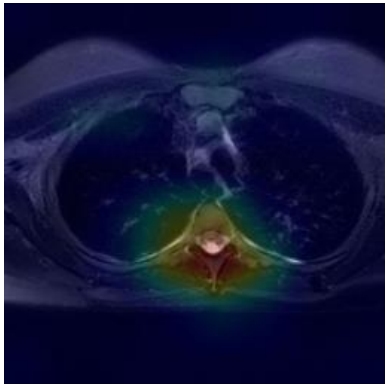
	original	correct overlay	incorrect overlay
Perfusion defect detection (coronal)			
Mucus plugging detection (axial)			

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UK HD

Categorical analysis

	Category 1	Category 2	Category 3	Category 4
CAM	20,14%	26,12%	8,20%	45,54%
Grad-CAM	-	44,03%	34,33%	21,64%

Category 1: Maximum two slices with incorrect overlays.
Category 2: At least three correct slices
Category 3: All slices with incorrect overlays or unclear overlay pixels.
Category 4: Neutral, no highlights.