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AI IN BRAIN HEALTH

# A hybrid Fully Convolutional CNN-Transformer Model for Inherently Interpretable Disease Detection from Retinal Images

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# Motivation

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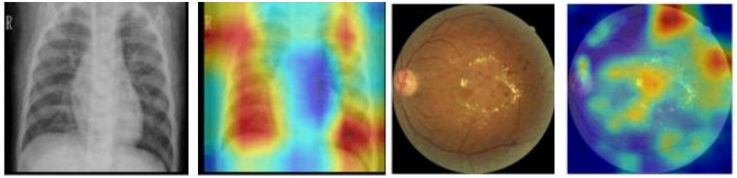
## What is interpretability?

The degree to which a human can understand the cause of a decision *(Miller, 2019)[1].*

## Why interpretable models?

- Learning tools
- Improve user trust
- Discover harmful biases
- Policy/legal considerations

## Why did the model predict this?



**Attribution maps**: highlight relevant regions ~ *Post-hoc explanation*

## Limitations of attribution maps

- Coarse-grained explanation
- Not inherently interpretable
- Poor performance on medical data
- Mostly developed for CNN-based models

# Transformers for Image Analysis

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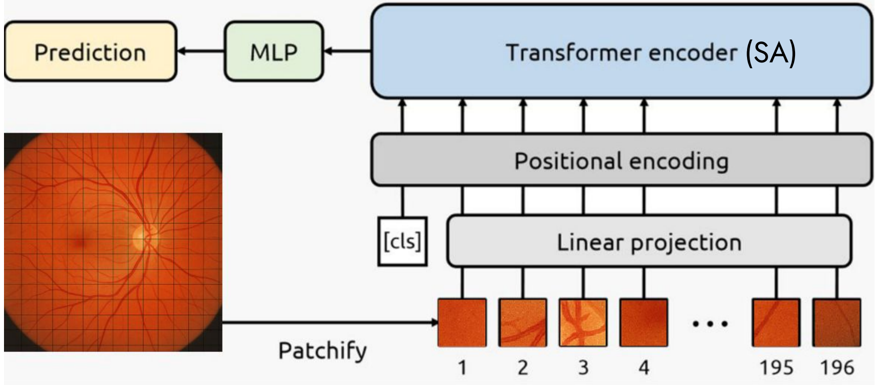
## Vision transformers

- Revolutionized computer vision
- Competitive alternative to CNNs
- Self attention long-range dependencies
- Computational intensive [2]




## Hybrid CNN-Transformers

- Balance computational cost
- CNNs + Transformer module
- Locality + global dependencies
- Interpretability remains challenging [2]

## Explaining hybrid CNN-transformers

- Post-hoc for CNNs: GradCAM [3], LRP [4], ....
- Specialized techniques tailored for ViTs
  - Attention maps [5], Rollout [6], ...
- Post-hoc vs self-explainable methods
  - Prototypes-based for ViTs [7]

# Contribution: Self-explainable CNN-Transformer

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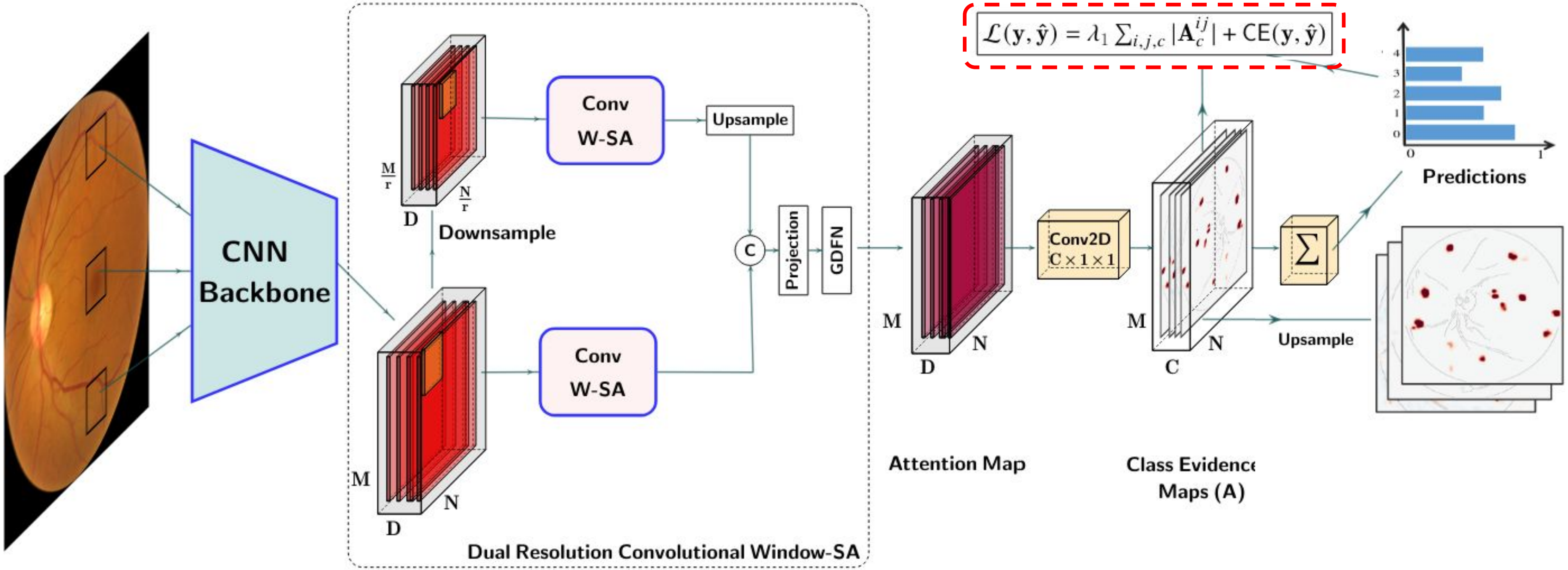


***W-SA**: Window Self Attention*

***DRSA**: Ilyas et al., MICCAI (2024);* ***Sparse Activations:** Djoumessi et al., MIDL (2023)*

# Application: Retinal disease detection

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## About DR and AMD

- Microvascular abnormalities
  - DR: Microeurysms, Hard Exudates
  - AMD: Drusen
- Can lead to vision loss
- Well-defined grading systems

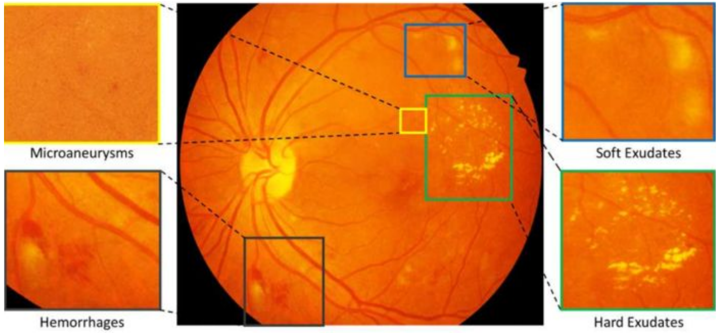
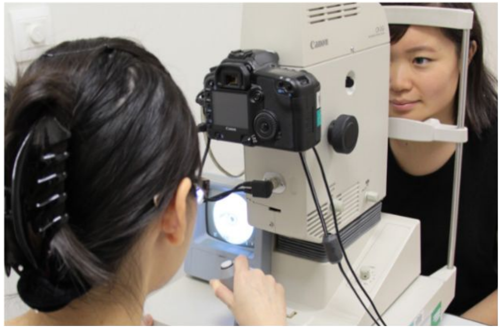



*Figure reproduced from Powal et al. (2018)*

## Managing DR and AMD

- AI-based retinal image analysis
- Predict disease stage from lesions
- Early diagnosis improves treatment
- Progression: regular follow-ups



# Classification performance

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Dataset:

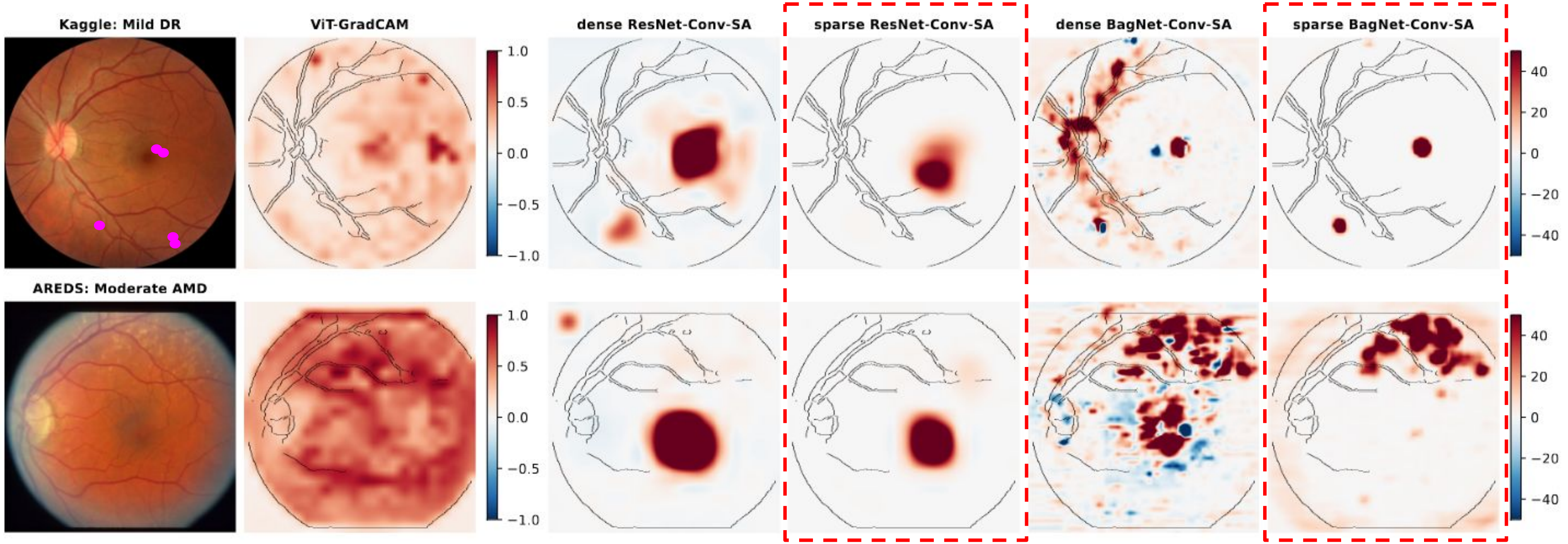
**Kaggle DR detection** (45,923; 5 classes), **AREDS AMD** (34,079; 6 classes)

| | AREDS AMD | | Kaggle DR | | Computational Cost | | |
|---|---|---|---|---|---|---|---|
| | **Acc.** | $\kappa$ | **Acc.** | $\kappa$ | **Par.** | **Mem.** | **Time** |
| ViT | $.76 \pm .03$ | $.90 \pm .02$ | $.81 \pm .02$ | $.71 \pm .04$ | 86, 094 | 341 | $09.5 \pm 0.1$ |
| Swin | $.78 \pm 0.2$ | $\mathbf{.92 \pm .02}$ | $.85 \pm .02$ | $.81 \pm .03$ | 86, 883 | 358 | $15.5 \pm 1.1$ |
| ResNet | $.78 \pm .03$ | $.89 \pm .02$ | $.85 \pm .02$ | $.81 \pm .03$ | 23, 518 | 101 | $04.2 \pm 0.5$ |
| BagNet | $.75 \pm .03$ | $.88 \pm .02$ | $.86 \pm .02$ | $.83 \pm .03$ | 16, 271 | 193 | $15.1 \pm 0.1$ |
| ResNet-FCL-SA | $.78 \pm .03$ | $.90 \pm .02$ | $.86 \pm .02$ | $.82 \pm .03$ | 69, 732 | 281 | $06.2 \pm 0.2$ |
| BagNet-FCL-SA | $.77 \pm .03$ | $.89 \pm .02$ | $.85 \pm .02$ | $.83 \pm .03$ | 62, 501 | 306 | $27.3 \pm 0.2$ |
| ResNet-Conv-SA | $.78 \pm .03$ | $.91 \pm .02$ | $.85 \pm .02$ | $.83 \pm .03$ | 69, 735 | 285 | $06.3 \pm 0.6$ |
| BagNet-Conv-SA | $.77 \pm .03$ | $.90 \pm .02$ | $\mathbf{.87 \pm .02}$ | $\mathbf{.84 \pm .02}$ | 62, 913 | 310 | $27.3 \pm 0.3$ |
| sResNet-Conv-SA | $\mathbf{.79 \pm .02}$ | $.90 \pm .02$ | $.85 \pm .02$ | $.80 \pm .03$ | 69, 735 | 285 | $06.3 \pm 0.6$ |
| sBagNet-Conv-SA | $.77 \pm .03$ | $.91 \pm .02$ | $.85 \pm .02$ | $.81 \pm .03$ | 62, 913 | 310 | $27.3 \pm 0.3$ |

***Sparsity*** *AREDS AMD. ResNet: 1e-04, BagNet: 7e-06*
*Kaggle DR. ResNet: 2e-4, BagNet: 3e-05*

***Parameter (M), Memory (Mb): Time (s)***

# Qualitative heatmap evaluation



# Quantitative Heatmap Evaluation

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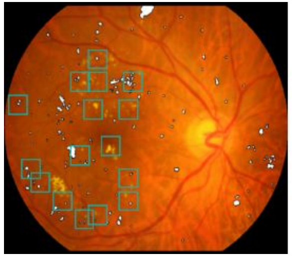
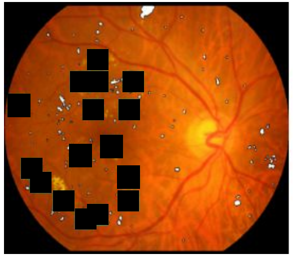
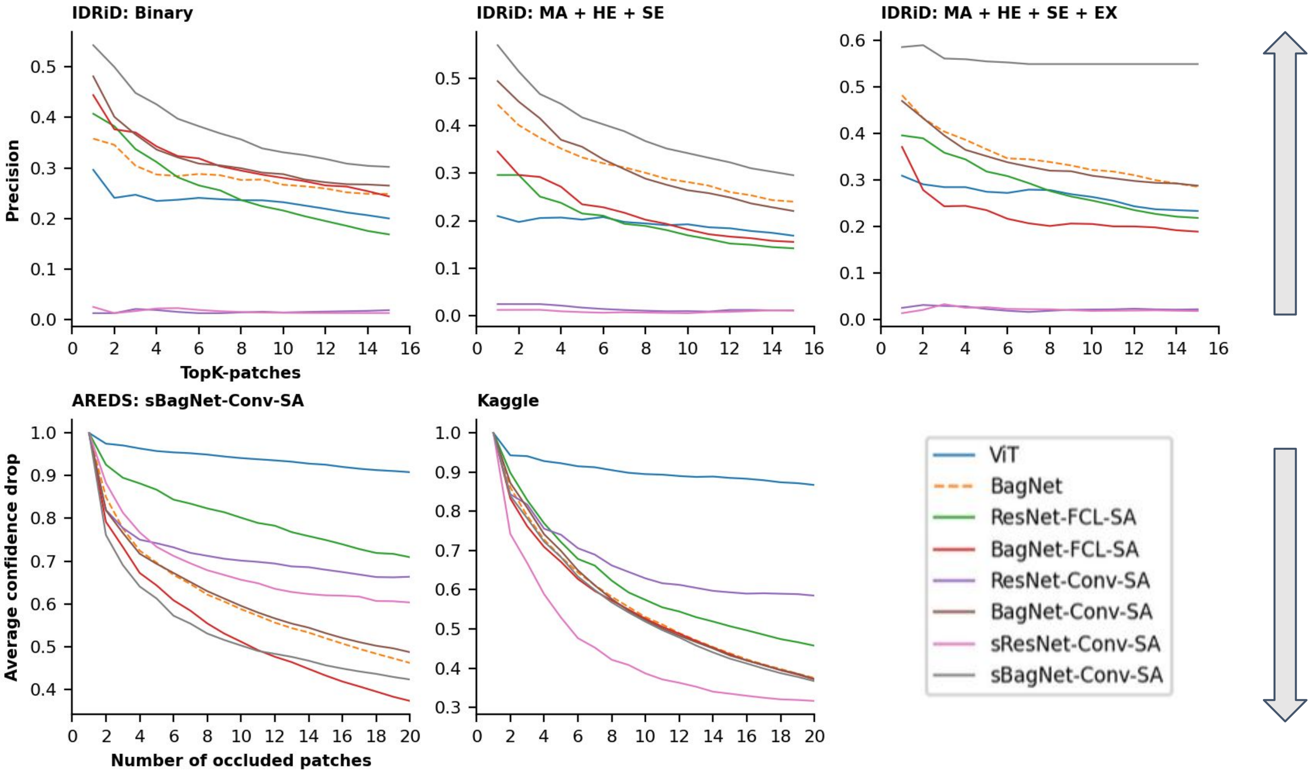
IDRiD dataset: 81 images

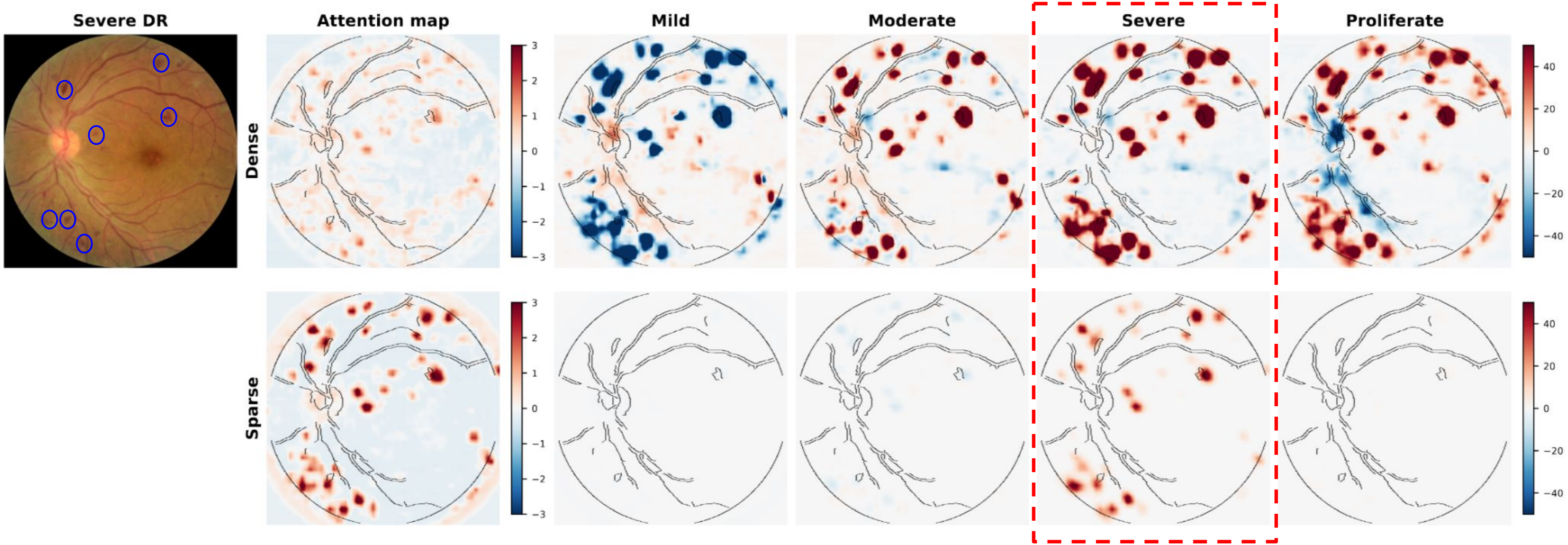
- Lesion annotations







# Interpretability for Multi-class DR Detection



# Conclusion

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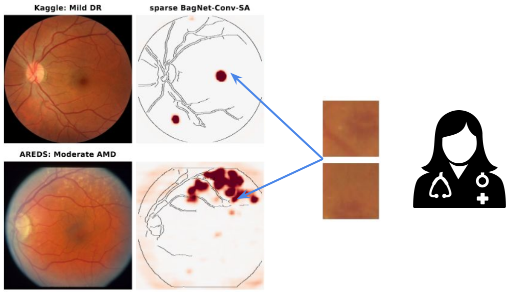
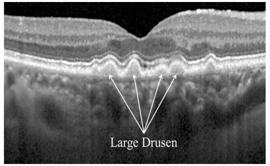
## Summary

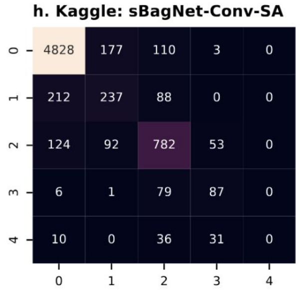
- Effectively combine prior work (DRSA, CvT, sparse explanation)
- Hybrid fully convolutional interpretable CNN-Transformer models
- CNNs: BagNet & ResNet
- Task: retinal disease detection (AMD, DR)
- Qualitative & quantitative metrics to access the interpretability

## Future work

- Clinical user validation
- Generalizability: extend to other modalities
- Improve model performance on data regime (late-stage DR)
- Aggregation techniques & extensive hyperparameters search



# Acknowledgments

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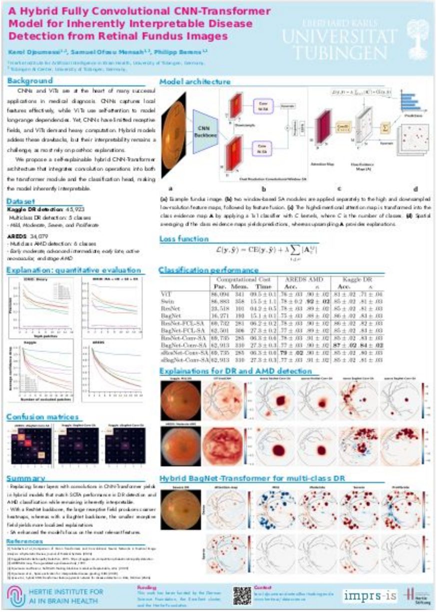
*Thank you for your attention!*


**Q & A**

# References

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*[9] Wu et al., CvT: Introducing convolutions to vision transformers (2021)*

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