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Neural networks detect cutaneous basal cell carcinomas in histological sections

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Digital pathology

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Processing of histological information via digital slides

Goals:

- Simplification of data management
- Image quality stays the same for years
- Spacial independence of pathologists
- Possibility for discussion with specialists
- **Improvement of diagnosis**

Next step:

- Improve digital pathology with artificial intelligence

Artificial Neural Networks

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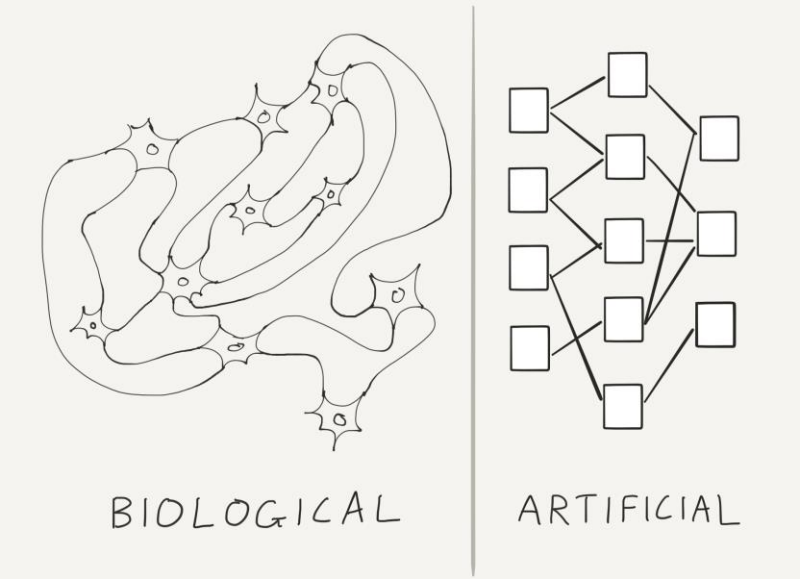
Deep neural networks are the #1 method in Machine Learning

Convolutional neural networks (CNNs) are used to detect patterns in images, state-of-the-art in

- Image recognition tasks
- Face recognition
- Self-driving cars



https://hackernoon.com/neural-networks-the-1-minute-guide-a2909507f350

LETTER

doi:10.1038/nature21056

Dermatologist-level classification of skin cancer with deep neural networks

Andre Esteva[1]*, Brett Kuprel[1]*, Roberto A. Novoa[2,3], Justin Ko[2], Susan M. Swetter[2,4], Helen M. Blau[5] & Sebastian Thrun[6]

CNN is as good at evaluation of skin lesions (photos and dermatoscopic photos) as experienced dermatologists

→ Is that also possible for histopathological images?

A. Esteva, B. Kuprel, R. A. Novoa, J. Ko, S. M. Swetter, H. M. Blau and S. Thrun, Dermatologist-level classification of skin cancer with deep neural networks, *Nature*, 2017, **542**, 115–118.

Machine learning in histopathology

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Goals:

→ Accurate predictions

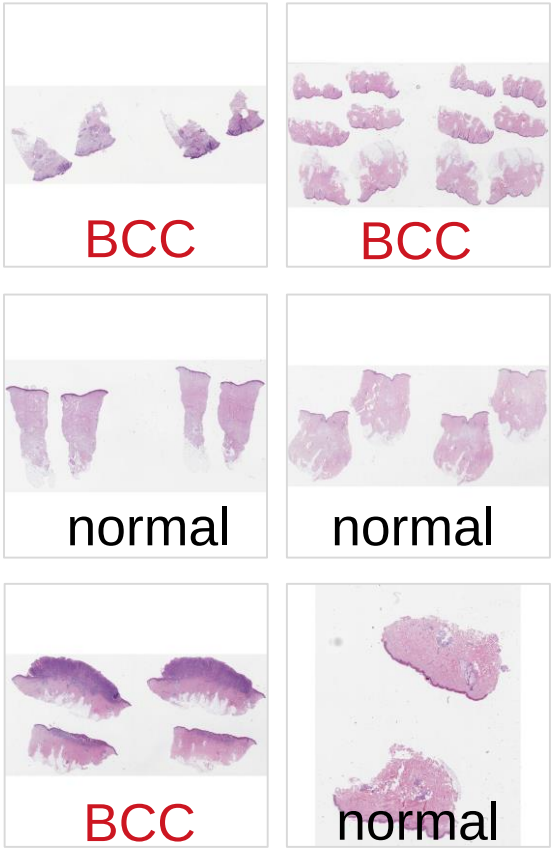
→ Interpretable methods

Proof-of-concept

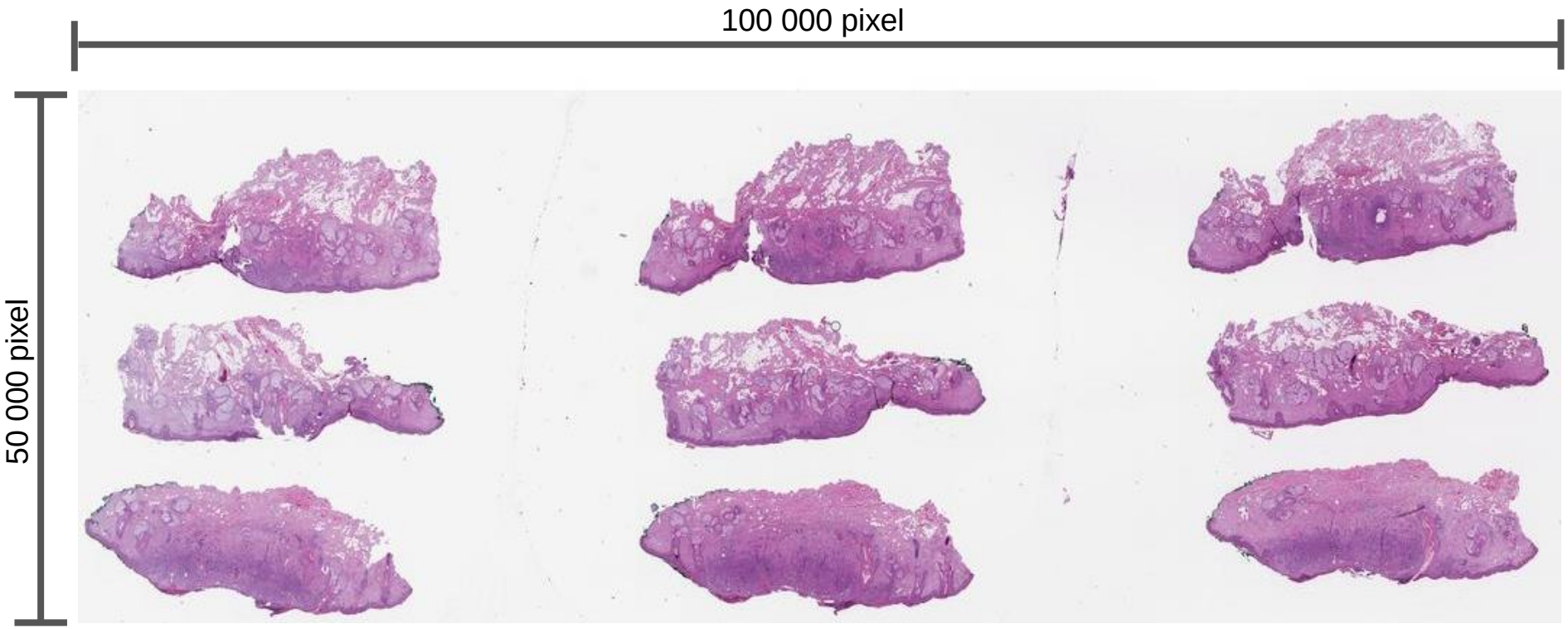
→ Easy task:
Basal cell carcinomas (BCCs) vs. normal skin

→ Classification

→ Interpretation

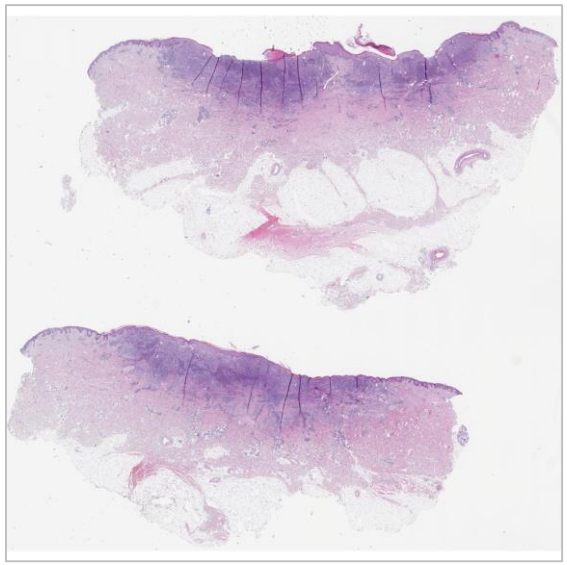


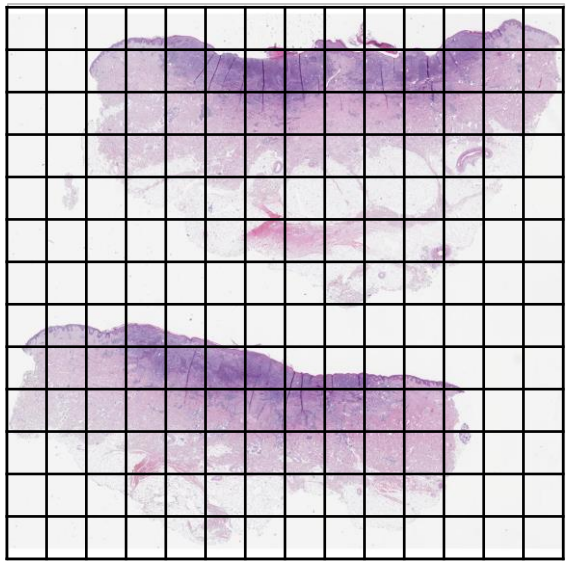
Challenges

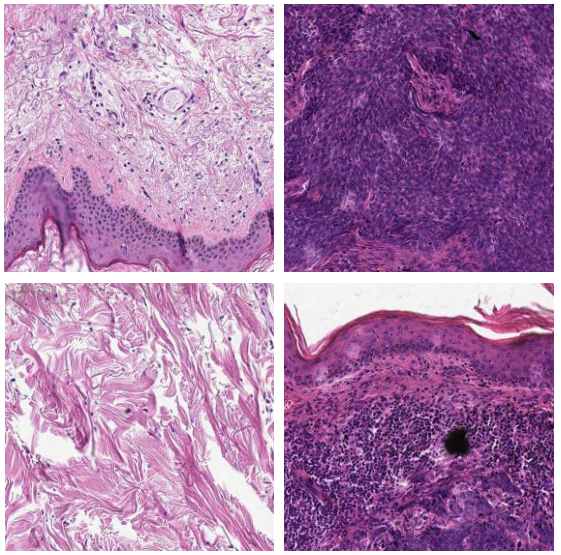


Approach

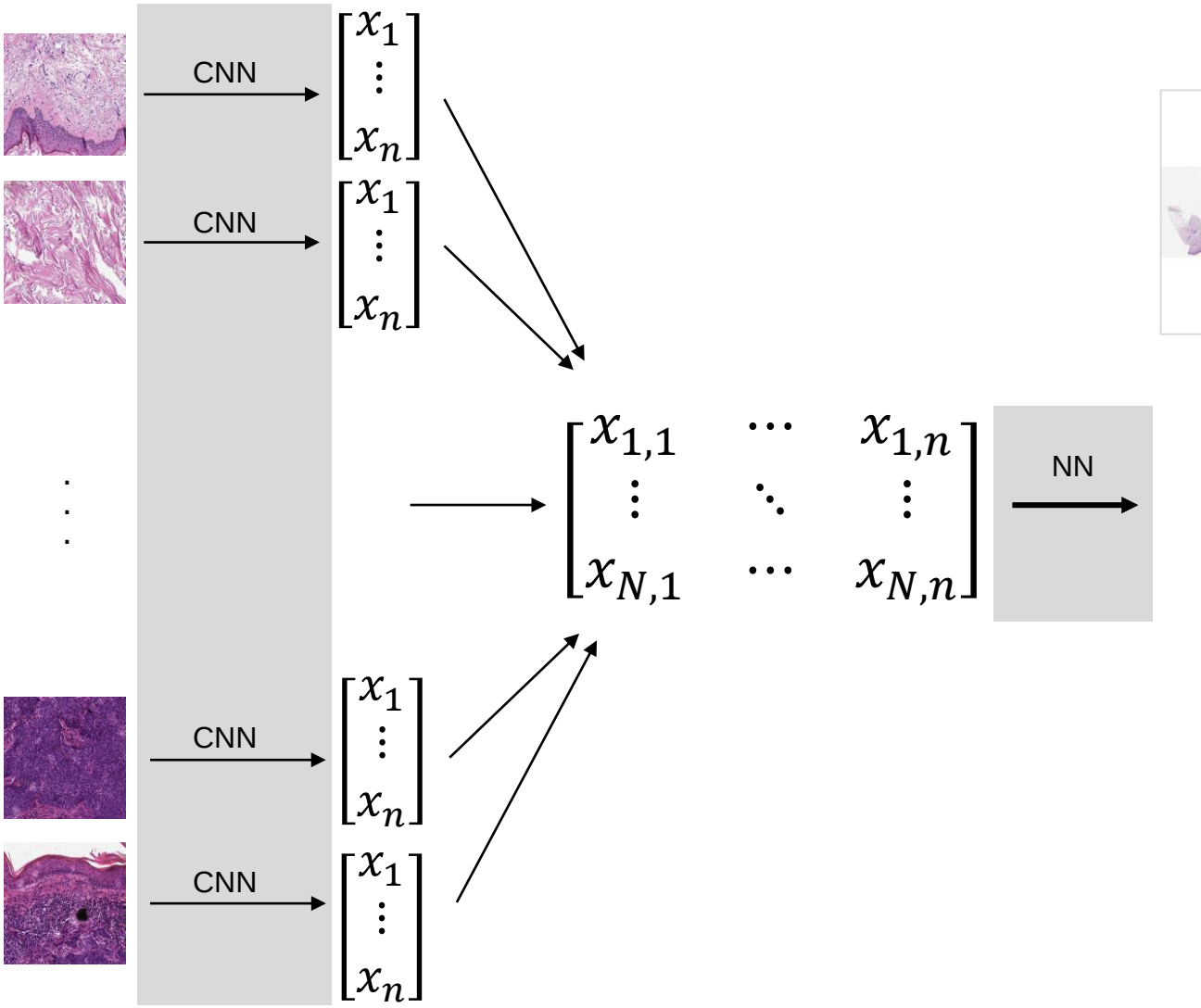
Whole slide image (WSI)	Tiling of WSI	Tiles





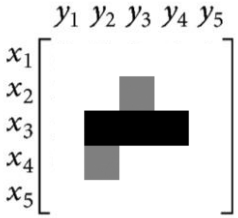


Approach



Prediction

Attention weight matrix



Results: classification

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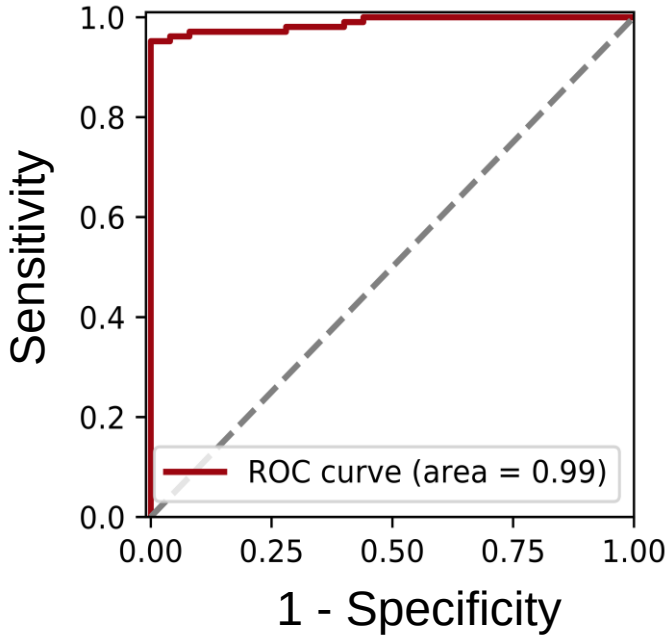
Anonymized images: **709** trainings images, **129** test images

Divided to tiles of size 244x244x3

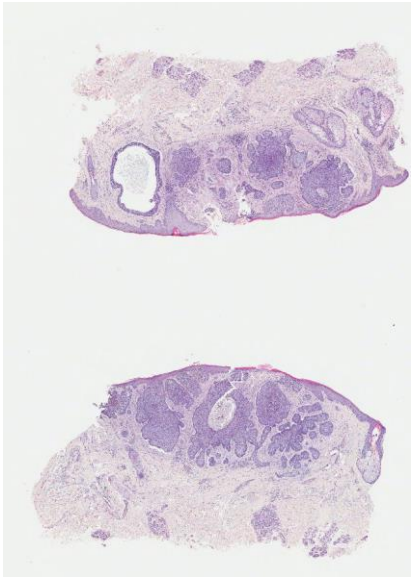
Pretrained CNN (VGG11)

Metric	Value
Accuracy (threshold = 0.5)	0.96 (0.95-0.96)
Sensitivity (threshold = 0.5)	0.97 (0.96-0.97)
Specificity (threshold = 0.5)	0.91 (0.89-0.94)
F1 score (threshold = 0.5)	0.97 (0.97-0.98)
Area under the curve (AUC of ROC curve)	**0.99** (0.99-0.99)

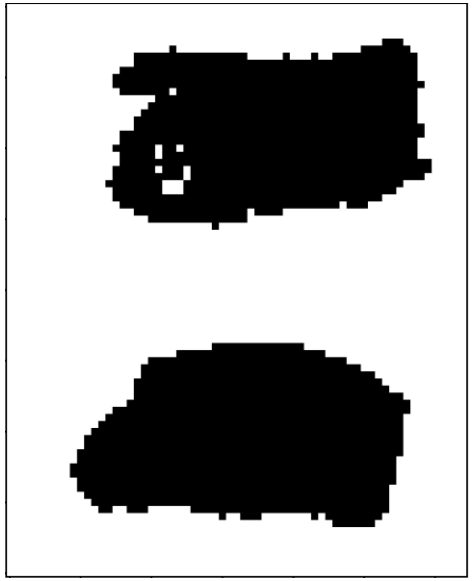


Results: interpretation of CNN

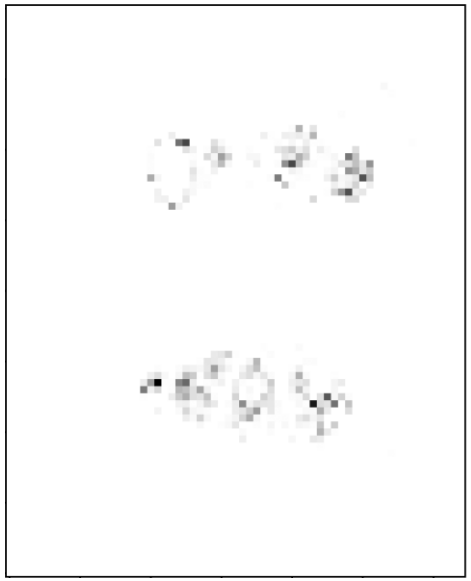
Original image

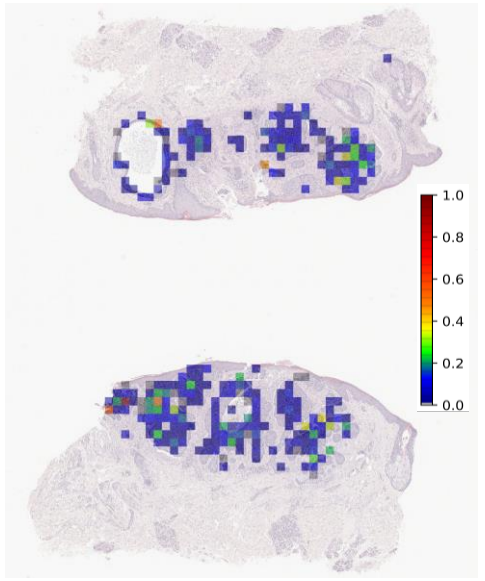


Pre-selected tiles



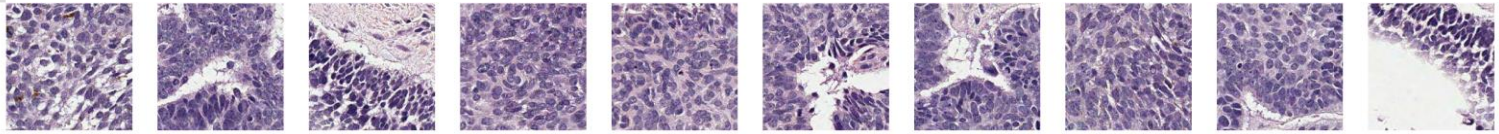
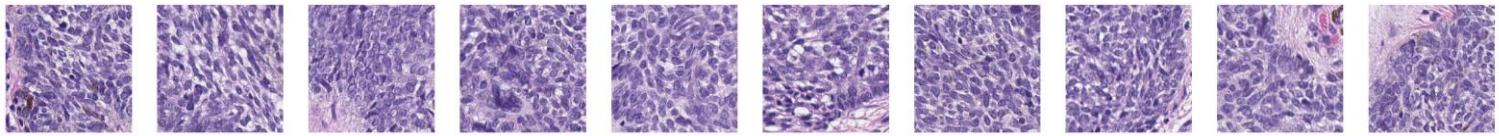
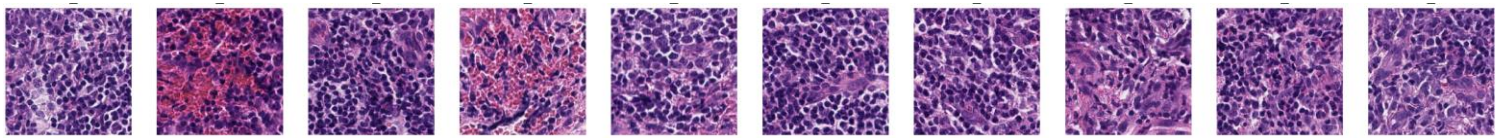
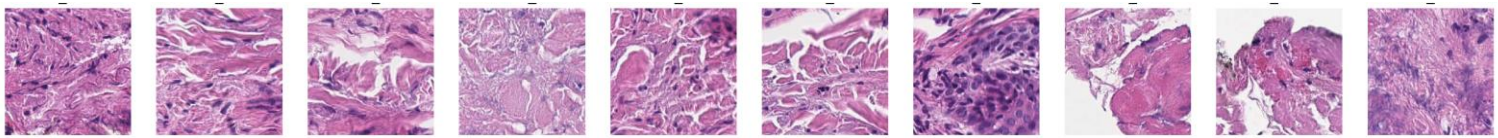
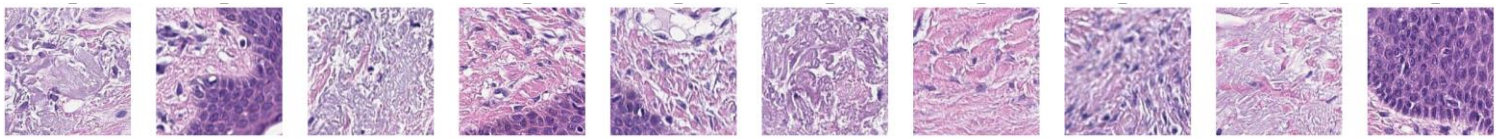
Attention weight matrix





Results: important tiles for the prediction

diagnosis

Nodular +, cystic BCC	
Superficial BCC	
Nodular + adenoid BCC	
Normal skin	
Normal skin	

Results: CNN vs. pathologist

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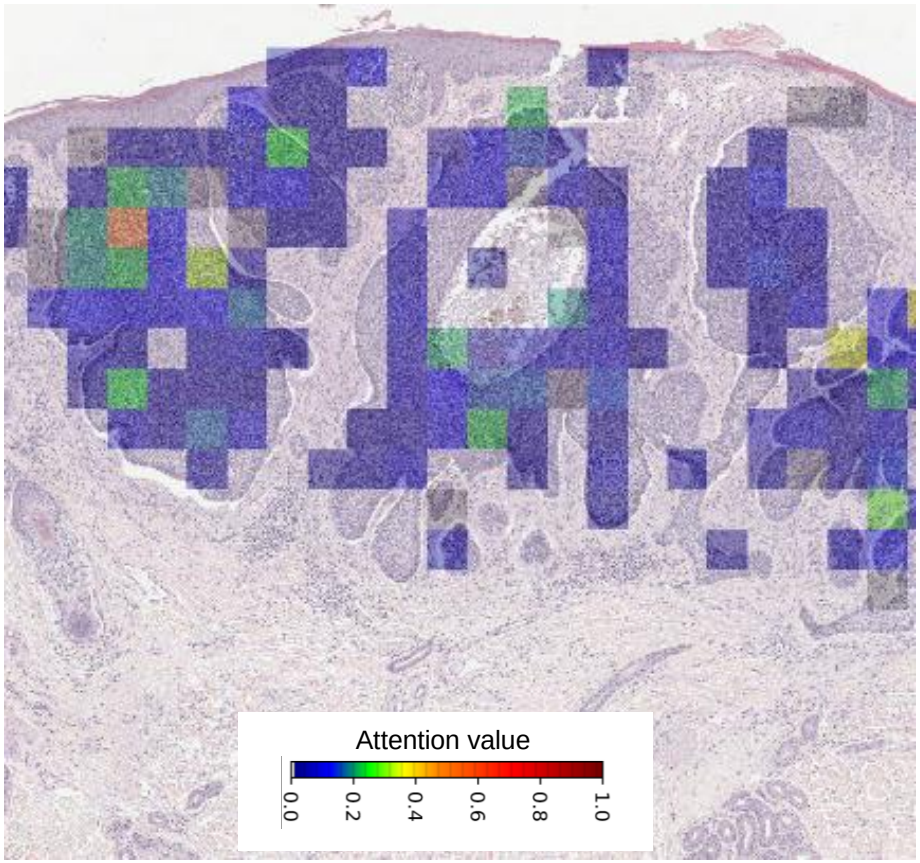
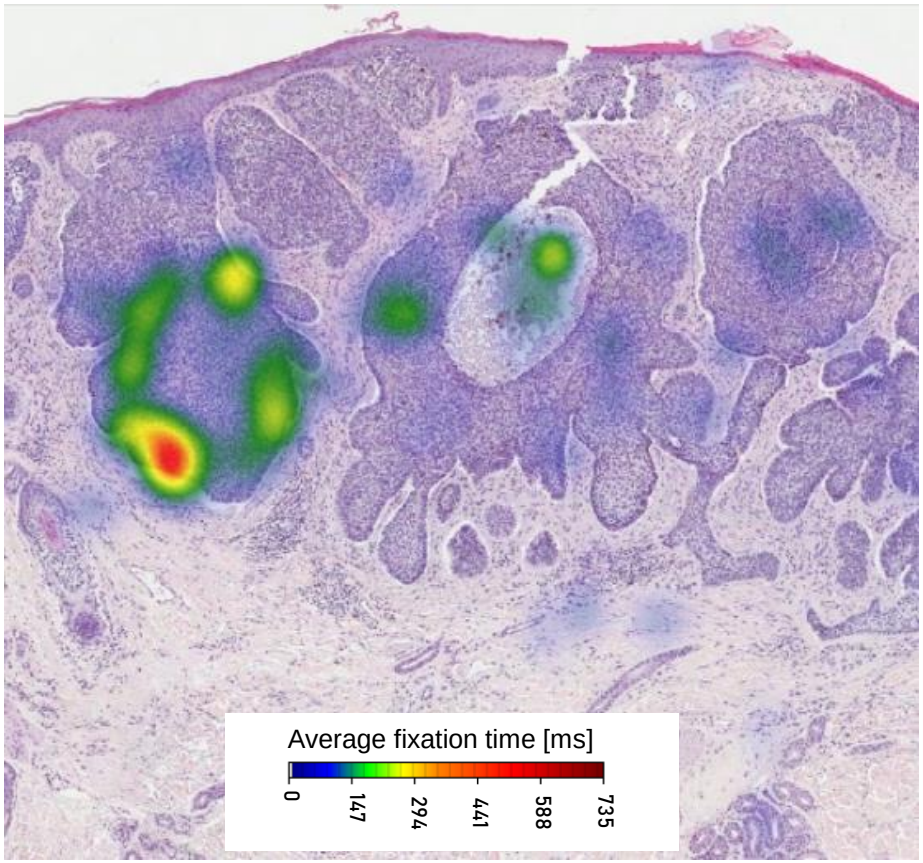
BCC example



CNN



4 board-certified pathologists

Results: CNN vs. pathologist

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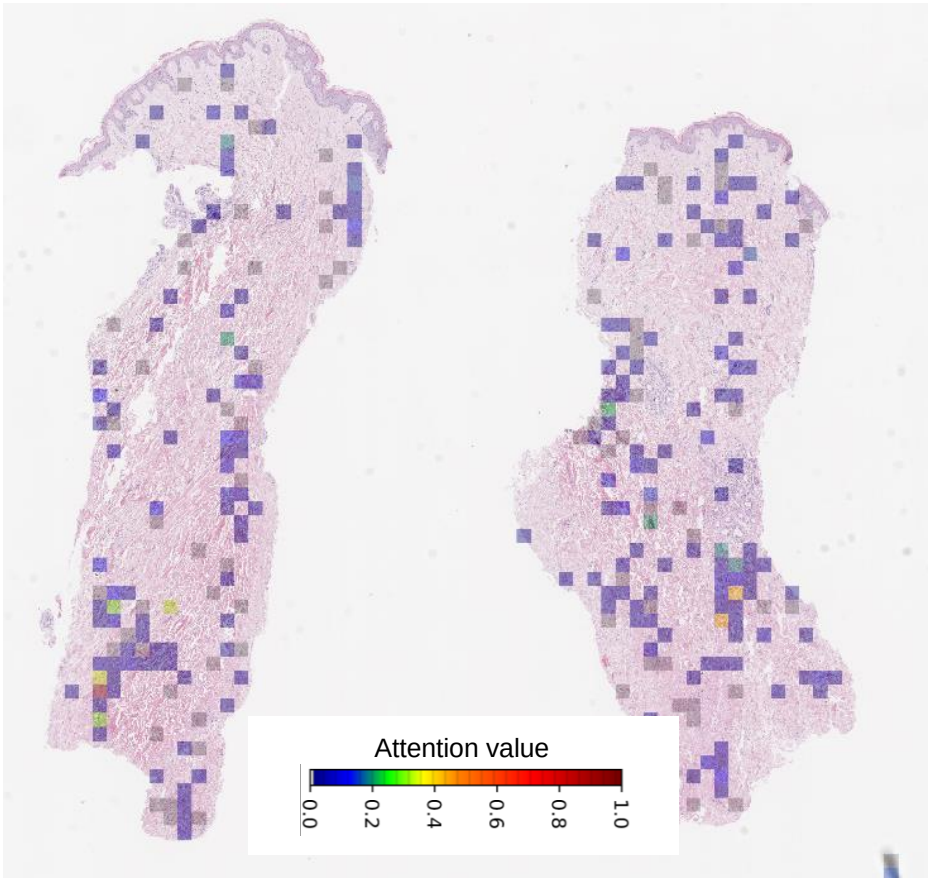
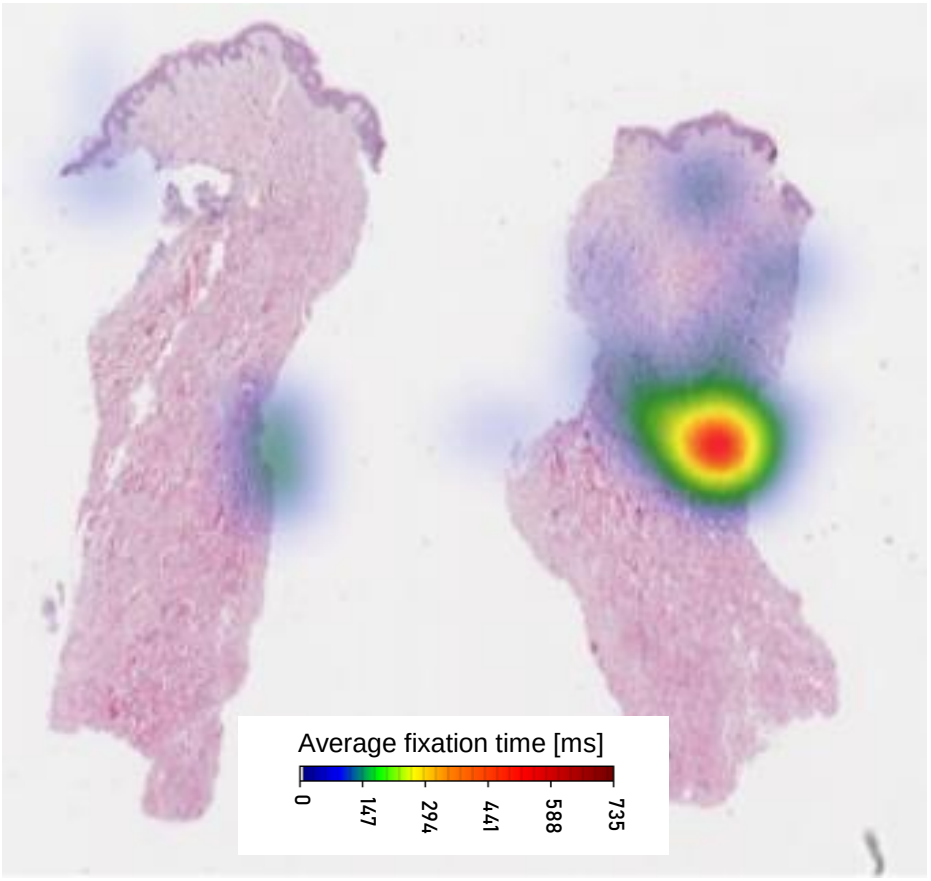
Normal skin example



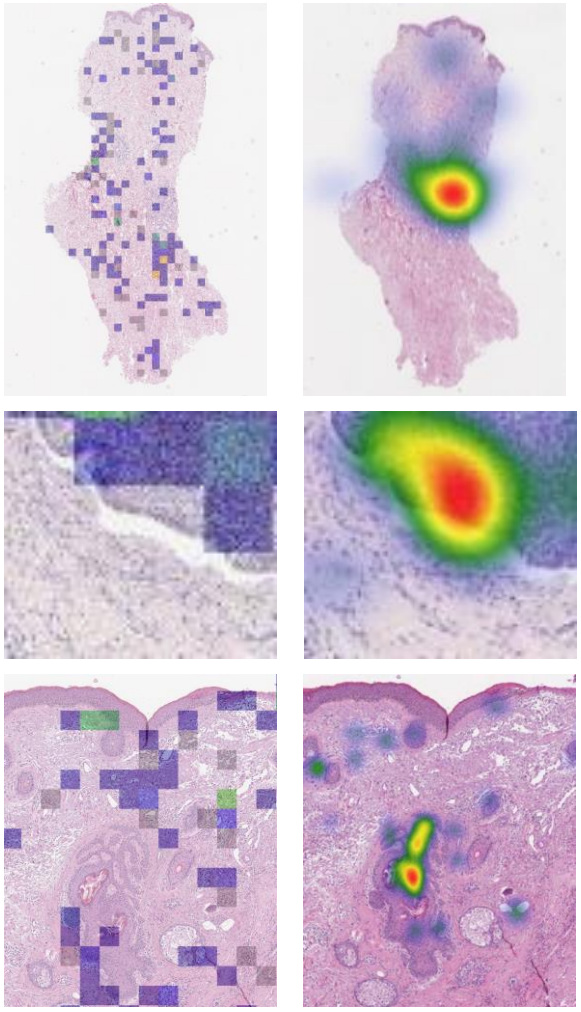
CNN



4 board-certified pathologists

Differences between CNN and pathologists

- Pathologists focus mainly at individual areas in the sections - for the NN important areas are distributed over the entire section/lesion
- Pathologists consider the artificial retraction gap as important
- Pathologists focus on the epidermis, glands and hair follicles - NN considers connective tissue



Conclusion

- CNN/attention architecture is able to distinguish between BCC and non-BCC images with a high accuracy
- CNN/attention architecture focuses on partly different patterns and structures than pathologists for diagnosis

Outlook

- Quantify differences between CNN and pathologists
- Apply similiar methods to
  - Several diseases on one slide
  - More applications (other diseases, other cancer types)
  - More images
- More targets (mutation prediction, protein expression prediction, …)

Thank you!

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