Deep learning for AI-based diagnosis and treatment planning in medicine

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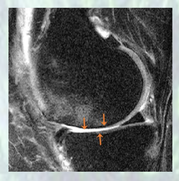
Radiomics for Knee Osteoarthritis (KOA)

Established OA scores:

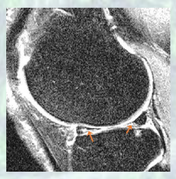
❖ WORMS, BLOKS, MOAKS ❖ Kellgren-Lawrence ❖ WOMAC

HOAKS: A novel holistic and extendable OA score for the knee:

The project will contribute to the emerging field of radiomics by identifying novel deep learning-based biomarkers from various kinds of medical image data. A novel and generalized, image-based KOA score is to be developed in a data-driven manner. Clinically applicable algorithms employing such a score will be developed for diagnostic and therapeutic decision support. The novel score may also help selecting appropriate imaging for different phases of the onset and the progression of KOA.

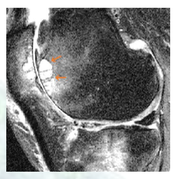


Cartilage defects

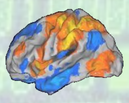


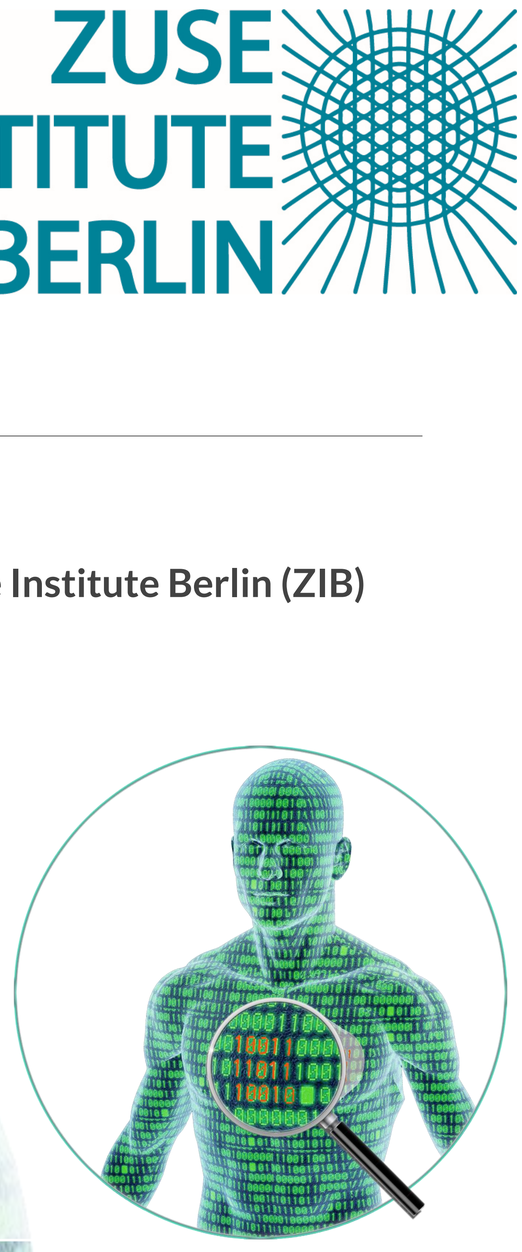
Meniscal lesions

Bone marrow lesions



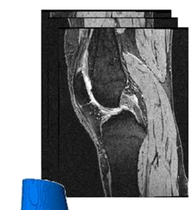
Subarticular cysts

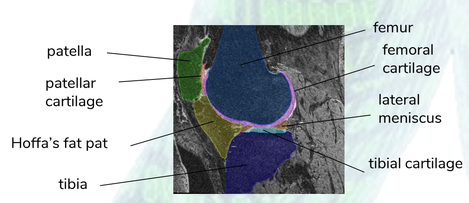


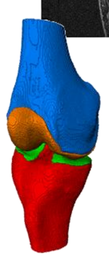


Medical Image Analysis

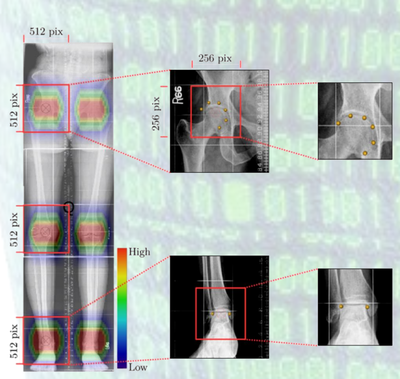
A prerequisite for the computation of quantitative image features is the segmentation of the anatomy of interest. State-of-the-art methods for segmentation of different knee structures from MRI have been developed [5]. Preliminary image-based biomarkers, i.e. mechanical leg axes (varus/valgus), meniscal tears, and meniscal extrusion [2], are being investigated.







Automated segmentation of tissue structures of the knee from MRI, such as bones and articular cartilage [1], as well as menisci [2]



Automated classification of leg alignment in X-ray using CNNs

High Performance Computing

Deep learning requires large datasets for training neural networks. We therefore investigated the suitability of different hardware systems for performing high throughput 3D segmentations ...

Segmentation of **500 MR image data sets** (384 x 384 x 160) using 100 Nodes of ZIB HLRN HPC facility **within 6 hours**

ZIB/HLRN HPC: 1872 nodes, each equipped with 2 Intel CPUs consisting of 12 cores. 120 TB of main memory

NVIDIA GeForce 1080 Ti

NVIDIA DGX-1 Deep Learning System
8x NVIDIA V100 GPU, 128 GB GPU Memory

	Training	Inference
	13 hours	8 hours
	x9 faster!	**x16 faster!**
	1.5 hours	0.5 hours

... as well as training and application of CNNs in the context of **AI radiomics**.

NVIDIA DGX-2 Deep Learning System
16x NVIDIA V100 GPU, 512 GB GPU Memory

Holistic OA Knee Score (HOAKS)

Data from large-scale longitudinal cohorts with several follow-ups will be analysed to derive hypotheses for biomarkers related to the onset and progression of KOA. Selection, annotation, and segmentation in close collaboration of radiologists at Charité and computer scientists at ZIB will lead to data ready for being trained with CNNs. Open source software packages, such as TensorFlow, PyTorch, and PyRadiomics will be employed for training image- and shape-based biomarkers. A combined correlation analysis of a wide range of biomarkers with symptoms and disease patterns will lead to a novel holistic and extendable OA score (HOAKS). This score will be evaluated on clinical patient data (BMBF Overload/PrevOP) to assess its predictive quality.
Based on such a classification, diagnosis recommendations can be derived to propose a therapy or suitable behavior for the avoidance of fast KOA progression.

Data

≤ 30.000 subjects,
2 time points,
3T MRI sequences [6]

≈ 5.000 subjects,
7 time points,
T2 map, IW TSE, 3D DESS,
T1 3D FLASH

≈ 240 subjects,
4 time points,
T2 map, IW TSE, 3D DESS,
T1 3D FLASH, T1ρ

Work Programme

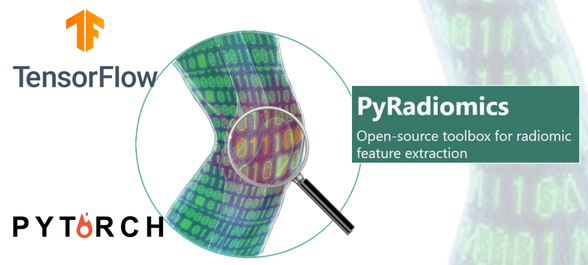
Charité

❖ Data selection
❖ Radiological annotations
❖ Evaluation of HOAKS

ZIB

❖ Data Segmentation
❖ AI Training of image- and shape-based biomarkers
❖ Development of HOAKS

HOAKS



Development of HOAKS using **Open Source Toolkits**

Publications

[1] Ambellan, Tack, Ehlke, Zachow: Automated Segmentation of Knee Bone and Cartilage combining Statistical Shape Knowledge and Convolutional Neural Networks. *Medical Image Analysis*, 52(2):109-118, 2019

[2] Tack, Mukhopadhyay, Zachow: Knee Menisci Segmentation using Convolutional Neural Networks. *Osteoarthritis and Cartilage*, 26(5):680-688, 2018

[3] Østergaard, Eshed, Althoff, Poggenborg, Diekhoff, Krabbe, Weckbach, Lambert, Pedersen, Maksymowych, Peterfy, Freeston, Bird, Conaghan, Hermann: Whole-body Magnetic Resonance Imaging in Inflammatory Arthritis: Systematic Literature Review and First Steps Toward Standardization and an OMERACT Scoring System. *Journal of Rheumatology* , 44(11):1699-1705, 2017

[4] Braum, McGonagle, Bruns, Philipp, Hermann, Aupperle, Tan, Diekhoff, Hamm, Hermann: Characterisation of hand small joints arthropathy using high-resolution MRI-limited discrimination between osteoarthritis and psoriatic arthritis. *European Radiology*, 23(6):1686-93, 2013

[5] Seim, Kainmueller, Lamecker, Bindernagel, Malinowski, Zachow: Model-based auto-segmentation of knee bones and cartilage in MRI data. *Medical Image Analysis for the Clinic*, 215-223, 2010

[6] Hoffmann, Jöckel, Kaaks, et al.: The National Cohort - A prospective epidemiologic study resource for health and disease research in Germany. https://nako.de/wp-content/uploads/2015/07/Wissenschaftliches-Konzept-der-NAKO2.pdf, 2015