CENTER FOR BIOTECH DATA SCIENCE, CENTRE FOR LANGUAGE AND LEARNING

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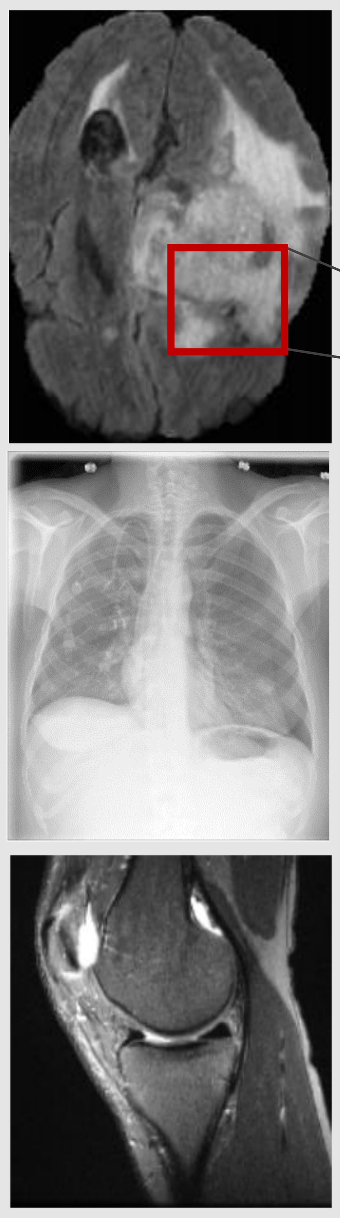
DEEP LEARNING-ASSISTED MEDICAL IMAGE ANALYSIS

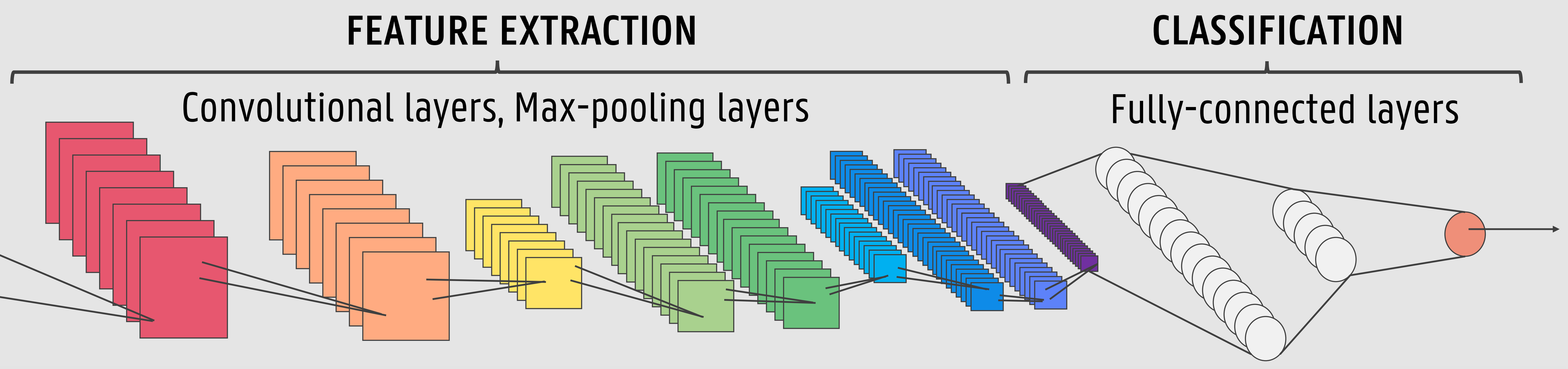
Medical image analysis investigates data produced by various imaging techniques and by different modalities to gather useful information for diagnosing abnormalities. Deep learning can be used to improve the computational efficiency and accuracy of medical image analysis by automatically processing and analyzing vast amounts of images. This interdisciplinary approach between data science and medical science allows for precise problem solving, for instance assisting pathologists with performing diagnoses.

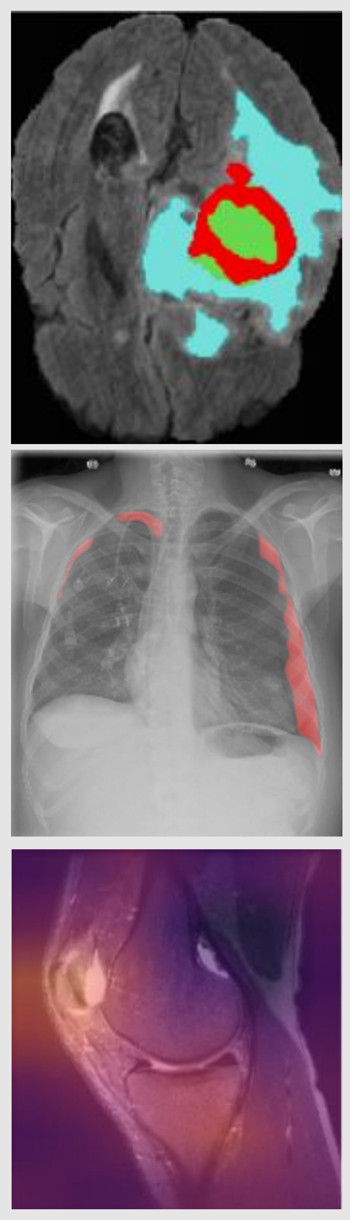
GLOBAL OVERVIEW OF CONVOLUTIONAL NEURAL NETWORKS

INPUT

MRI / X-RAY







OUTPUT

Localization of abnormalities

Image Pre-processing

- Transformation of input images before feeding them to an algorithm
- Data cleaning (outlier removal) , data transformation (normalization and aggregation), data reduction (volume reduction)
- Division of input images into smaller images and isolation of tissues of interest

Network Architecture

- Design neural network models, as a combination of convolutional, pooling, and fully-connected layers

Model Training

- Feed training data to different models in order to improve their predictive ability via an iterative evaluation process
- Select a model by tuning parameters and through validation using external data
- Goal: improve accuracy and minimize total loss (by updating weights and biases)

Model Prediction

- Use the selected model to generate an answer (prediction) for new input images

USE CASES OF DEEP LEARNING-ASSISTED MEDICAL IMAGE ANALYSIS

LUNG PNEUMOTHORAX DETECTION

Fully Convolutional Neural Network Model (Gooben et al., 2019)

Image Pre-processing

- Images are rescaled to 480 x 480 pixels and cropped into patches of 448 x 448

Network Architecture

- Use of U-Net, with both a contracting and an expanding path

Model Training

- Use of 871 images with pixel-level ground truth annotations for 400 epochs
- Use of patient stratified cross-validation, together with data augmentation

Model Prediction

- Semantic segmentation and localization of the pathology
- Generation of pixel-level probabilities of pneumothorax

KNEE ABNORMALITY DETECTION

MRNet Model (Bien et al., 2018)

Image Pre-processing

- Histogram-based intensity standardization, rescaling to 256 x 256 pixels

Network Architecture

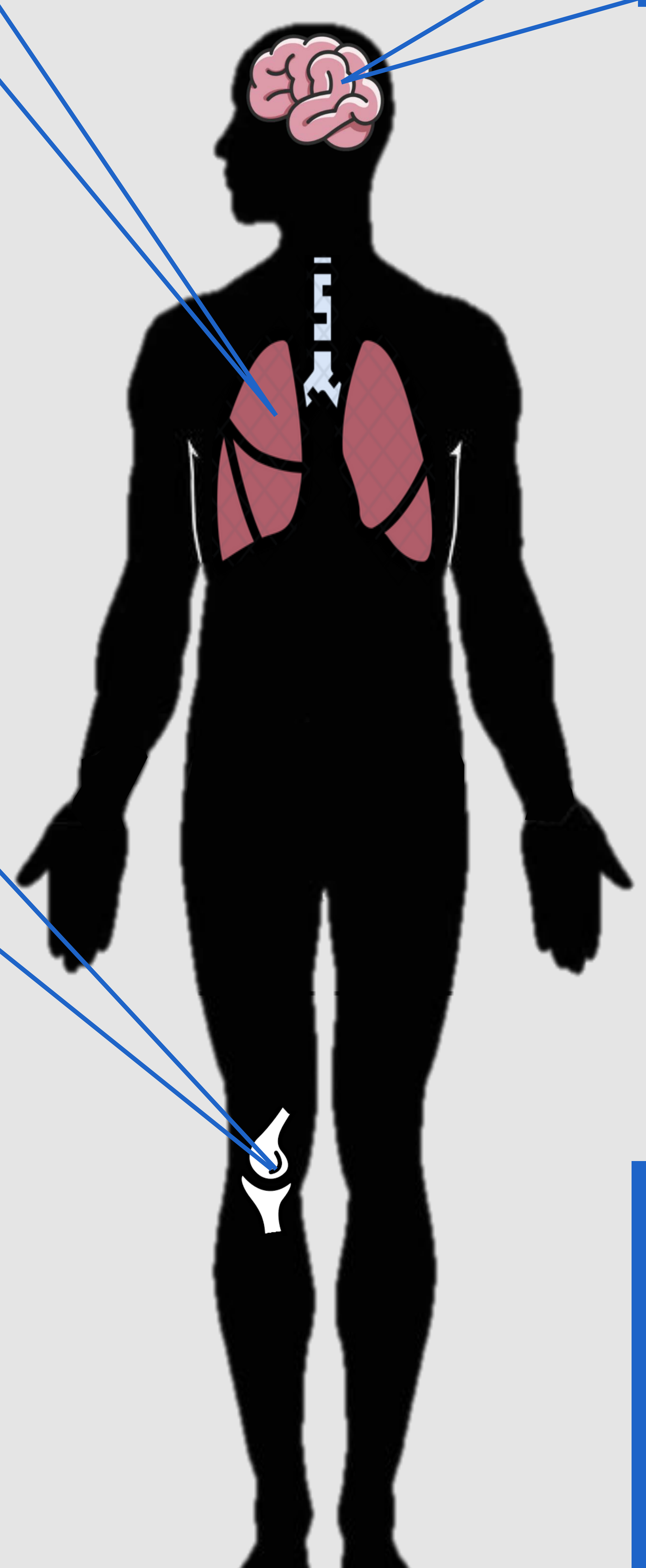
- Use of AlexNet, global normalization pooling layers, max-pooling layers, and fully-connected layers for mapping 3-D MRI series to a single probability prediction

Model Training

- Use of 1,370 knee MRI examinations manually retrieved from clinical reports

Model Prediction

- Localization of abnormalities and single output prediction of the most weighted importance for each of the saggittal T2, coronal T1, and axial PD plane series



BRAIN TUMOR SEGMENTATION

3-D U-Net Model (Weninger et al., 2019)

Image Pre-processing

- Image normalization based on standard deviation of intensity
- Use of a contrast agent to increase the visibility of body structures/fluids
- Cuboid bounding box for cropping non-brain regions

Network Architecture

- Padding in every convolutional layer to equalize the input and output size
- Use of an Adam-optimizer, ReLU activation functions, and instance-norm layers

Model Training

- Use of complete brain images from the BraTS dataset (cropped to brain mask)
- Dimensionality reduction via unpadded convolutional layers
- Use of training patches consisting of three tumor classes: *eritumoral edema*, *necrotic tumour*, or *GD- enhancing core*

Model Prediction

- Prediction of patient survival rate considering age and the distance between the centroids of tumor and brain
- Localization of brain tumors, using different colors to grade severity

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CHALLENGES AND OPPORTUNITIES

- Neural network models can be used to **avoid unnecessary examinations and surgeries** by providing rapid preliminary diagnoses and prioritizing patients.
- **Designing neural network models is an art**, not a science, and the models created are best used to **support the decision-making processes of medical experts.**
- The **black box nature of neural network models** hampers the understanding of predictions made, and makes debugging almost impossible when predictions fail.
- **Interdisciplinary interaction** between machine learning specialists and medical experts will be **key to the successful deployment of A.I.-based medical diagnosis systems.**

Gooben A., Deshpande H., Harder T., Schwab E., Baltruschat I., Mabotuwana T., Cross N. & Saalbach A. (2019). Pneumothorax Detection and Localization in Chest Radiographs: A Comparison of Deep Learning Approaches. *MIDL 2019 Conference Abstract Submission.*

Bien, N., Rajpurkar, P., Ball, R. L., Irvin, J., Park, A., Jones, E., Lungren, M. P. (2018). Deep Learning-Assisted Diagnosis for Knee Magnetic Resonance Imaging: Development and Retrospective Validation of MRNet. *PLOS Medicine,15*(11). doi:10.1371/journal.pmed.1002699

Weninger, L., Rippel, O., Koppers, S. & Merhof D. (2019), Segmentation of Brain Tumors and Patient Survival Prediction: Methods for the BraTS 2018 Challenge. *Brainlesion: Glioma, Multiple Sclerosis, Stroke and Traumatic Brain Injuries Lecture Notes in Computer Science*, pp. 3-12, https://doi.org/10.1007/978-3-030-11726-9_1

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