Oral Presentation at IPCAI 2020, Munich, Germany

Precise Proximal Femur Fracture Classification for Interactive Training and Surgical Planning

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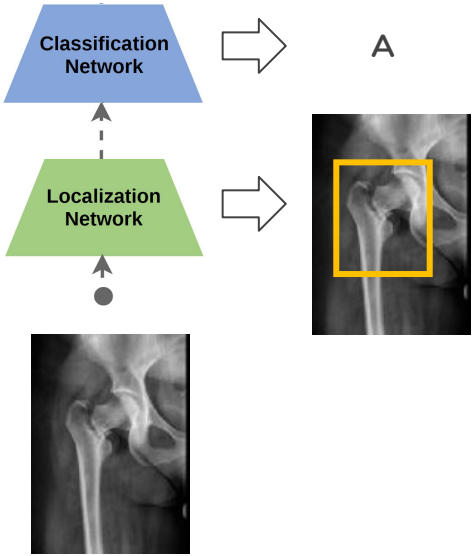
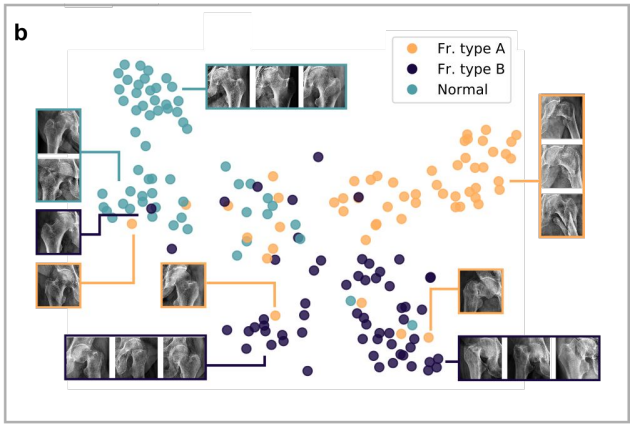
Jiménez-Sánchez, A., Kazi, A., Albarqouni, S., Kirchhoff, C., Biberthaler, P., Navab, N., Kirchhoff, S. & Mateus, D. (2020).
Precise proximal femur fracture classification for interactive training and surgical planning. International Journal of Computer Assisted Radiology and Surgery.

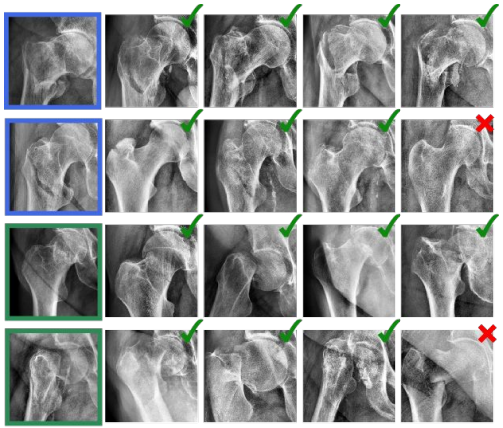
Precise proximal femur fracture classification for interactive training and surgical planning

Computer-aided diagnosis (CAD): localizes and classifies fractures.

How to effectively **integrate** such tool into the **clinical routine**? Several strategies are presented: e.g. **image retrieval as a clinical use case**.







Introduction

Clinical Motivation

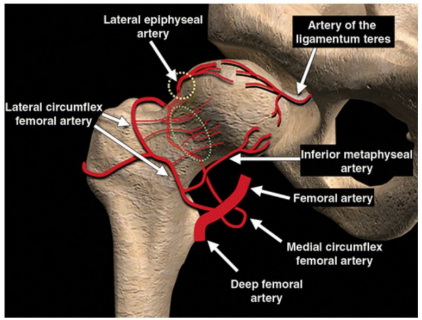
- **X-ray** imaging: standard diagnosis procedure to detect and classify proximal femur fractures.

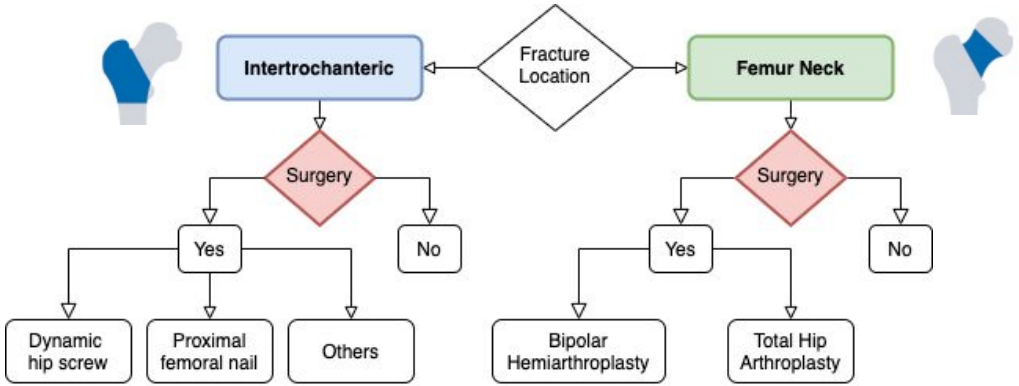
- Most common in elderly population, **risk** of suffering a **fracture increases exponentially** above the age of 65.

Clinical Motivation

- The gold standard to treat proximal femur fractures is a **surgical** procedure. [1]

[2]



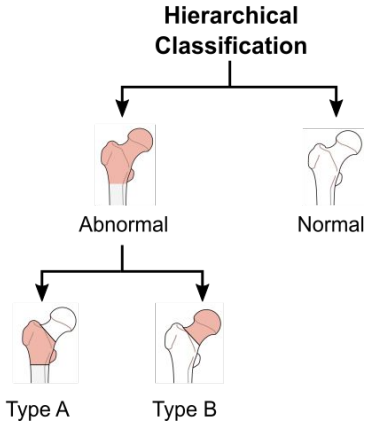


- **Early detection and classification** are **essential** for the indication of the adequate treatment.

[1] Tan, L. T. J., Wong, S. J., & Kwek, E. B. K. (2017). Inpatient cost for hip fracture patients managed with an orthogeriatric care model in Singapore. Singapore medical journal, 58(3), 139.
[2] Sheehan, S. E., Shyu, J. Y., Weaver, M. J., Sodickson, A. D., & Khurana, B. (2015). Proximal femoral fractures: what the orthopedic surgeon wants to know. Radiographics, 35(5), 1563-1584.

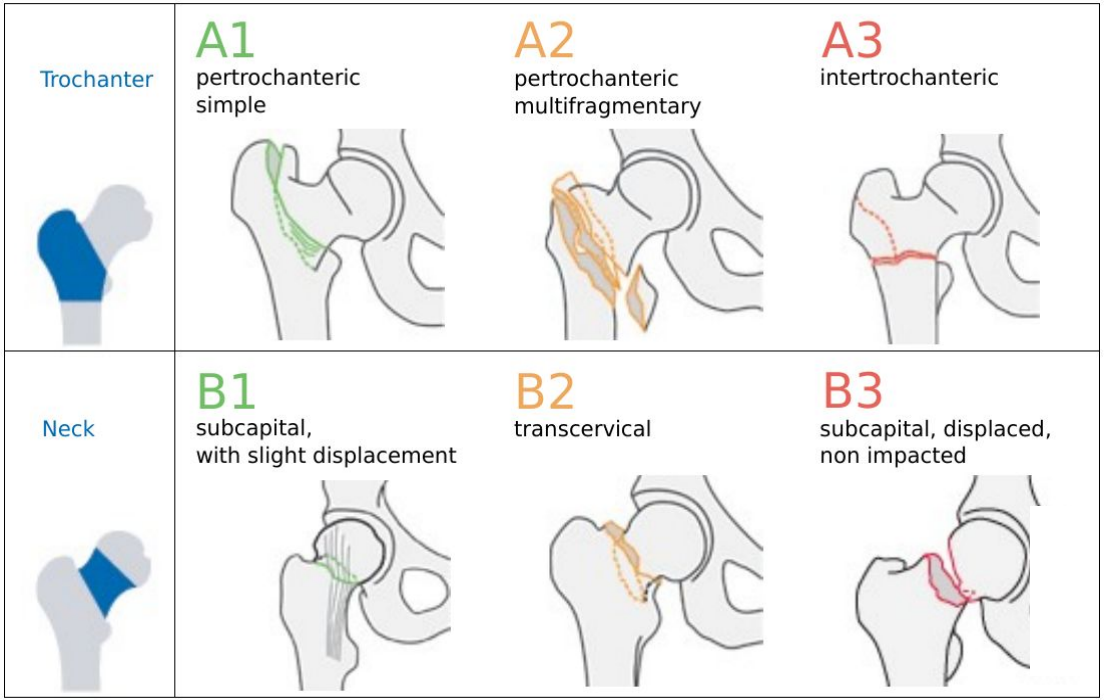
AO Classification

- **Classification** according to the Arbeitsgemeinschaft für Osteosynthese **(AO) Standard**. [3]
- Classification system for **fractures** of all **bones** in the skeleton based on **radiographs**, including the proximal femur.
- AO classification system is of **hierarchical** character.



[3] Kellam, J., Meinberg, E., Agel, J., Karam, M., Roberts, C. (2018). Introduction: Fracture and Dislocation Classification Compendium-2018: International Comprehensive Classification of Fractures and Dislocations Committee. Journal of Orthopaedic Trauma. 32 Suppl 1. S1-S10.

AO Classification: Proximal Femur Fractures



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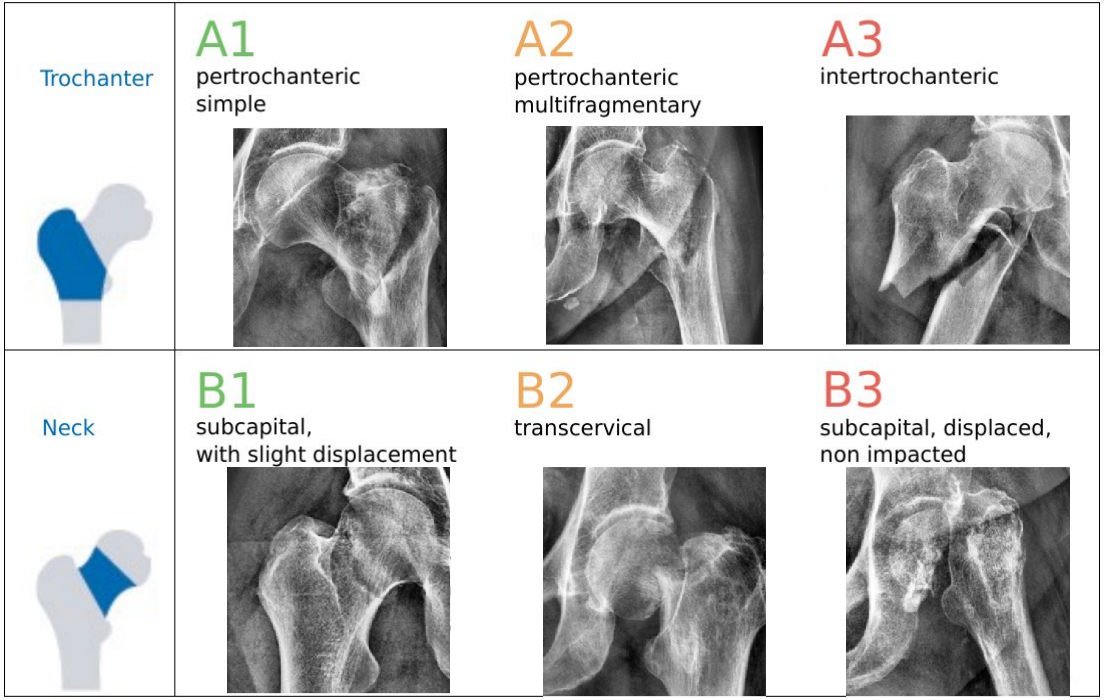

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AO Classification Challenges

- Required **years of experience** for reliable classification: **(5-10 years)**.

- **Variability:** Inter-expert agreement on subclasses: **68%** kappa correlation (66% residents, 71% experts). [4]

[4] Embden, Daphne van et al. “The comparison of two classifications for trochanteric femur fractures: the AO/ASIF classification and the Jensen classification.” Injury 41 4 (2010): 377-81 .

Computer-aided Diagnosis (CAD)

- Convolutional Neural Networks (CNNs) to develop a CAD system that supports the **detection and classification (A- and B-type)** of proximal femur fractures.

- We propose the **localization** of a **region of interest** (ROI) around the fracture area, which further improves the classification results.

- How to effectively **integrate** such **tool** into the **clinical routine?**
  - We perform a **sensitivity analysis** of the size of the localized ROI,
  - investigate the potential of **retrieval** for the training of young trauma surgeons.

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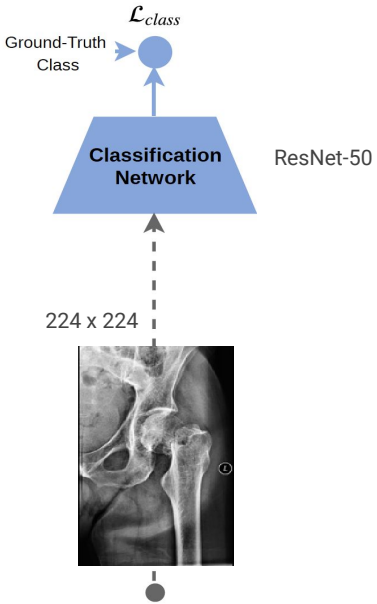
Method

Classification on full radiographs

Full radiographs

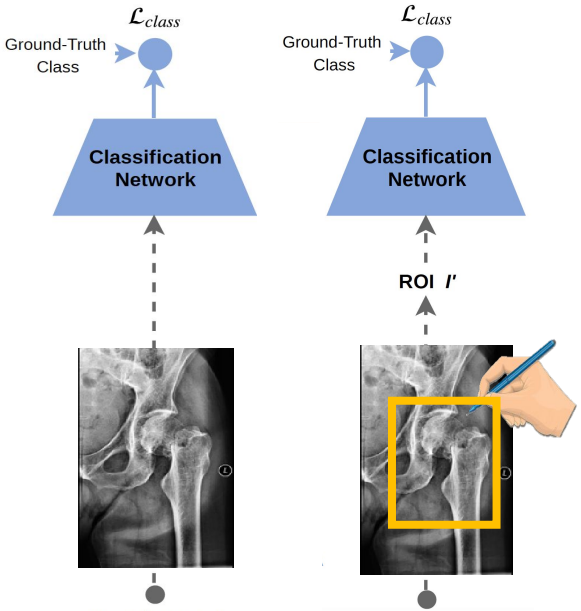


Cross-entropy

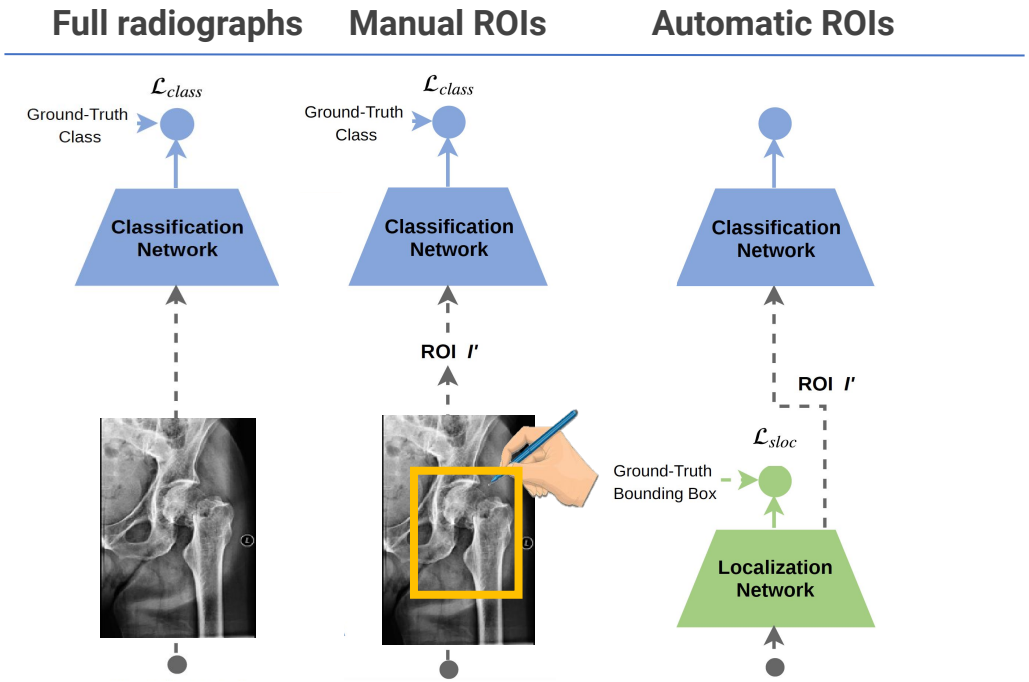
$$\mathcal{L} = -\sum_{x} g_l(x) log(p_l(x))$$

Classification on manual ROIs

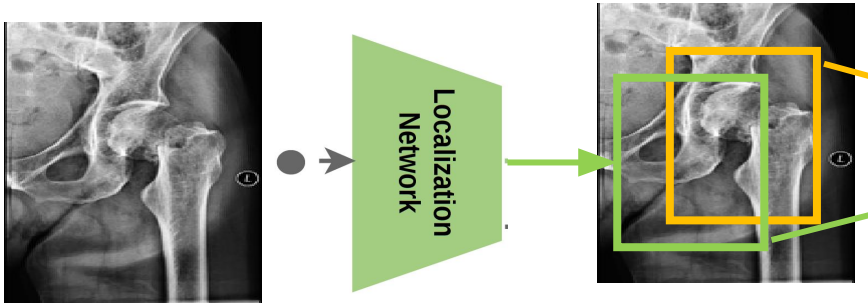
Full radiographs **Manual ROIs**



Classification on automatic ROIs



ROI localization



AlexNet

L_{loc}: regression loss, L2 norm

$$\mathcal{L} = \sum_{x} (bbox_{gt}(x) - bbox_{pred}(x))^2$$

Bounding box parameterized as:
- center
- scale

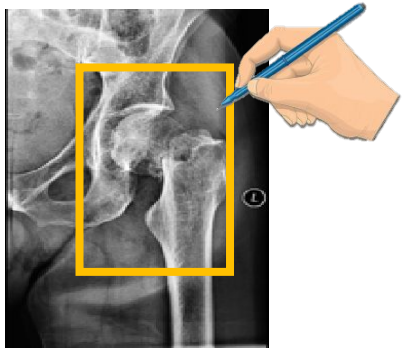
Results

Experimental Validation

- **Clinical dataset**

  ~1300 X-ray images,
  from 780 patients.

Full radiograph



Manual ROI

Experimental Validation

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  - 70% - training
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  3 classes: **A (24%)**, **B (34%)**, **Normal (42%)**

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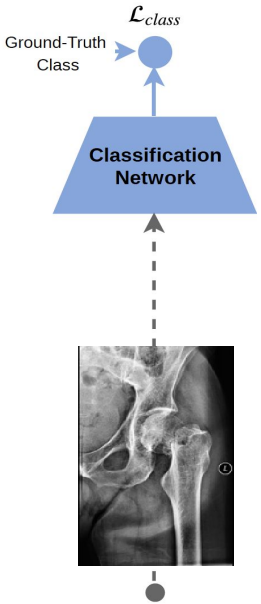
- **Evaluation metric for classification**

  F1-score
  AUC: Area Under the Receiver Operating Characteristic Curve (ROC)

Classification on full radiographs

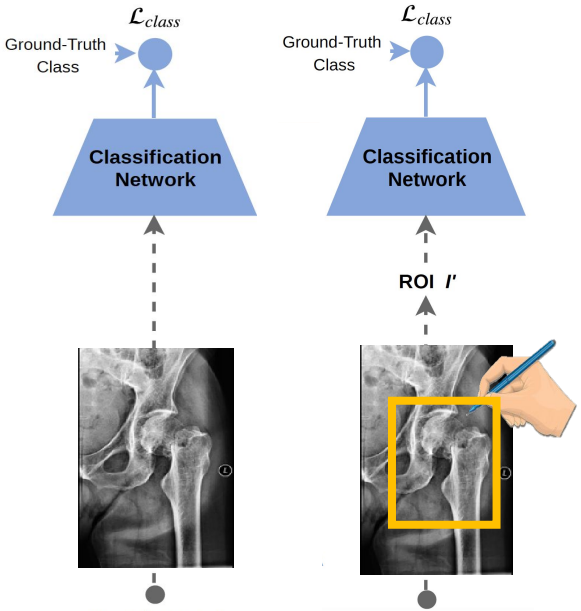
Full radiographs



F1-score	2 classes	3 classes
Full radiographs	0.84	0.83

Classification on manual ROIs

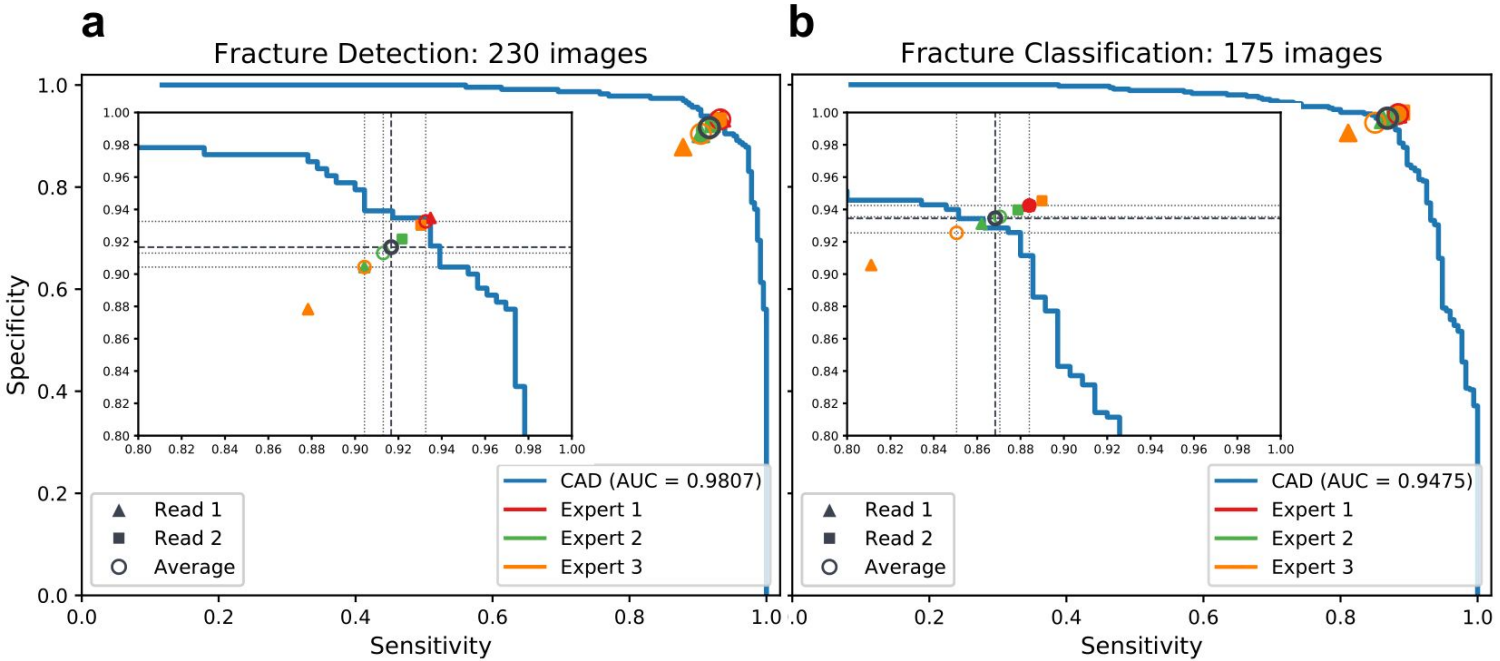
Full radiographs **Manual ROIs**



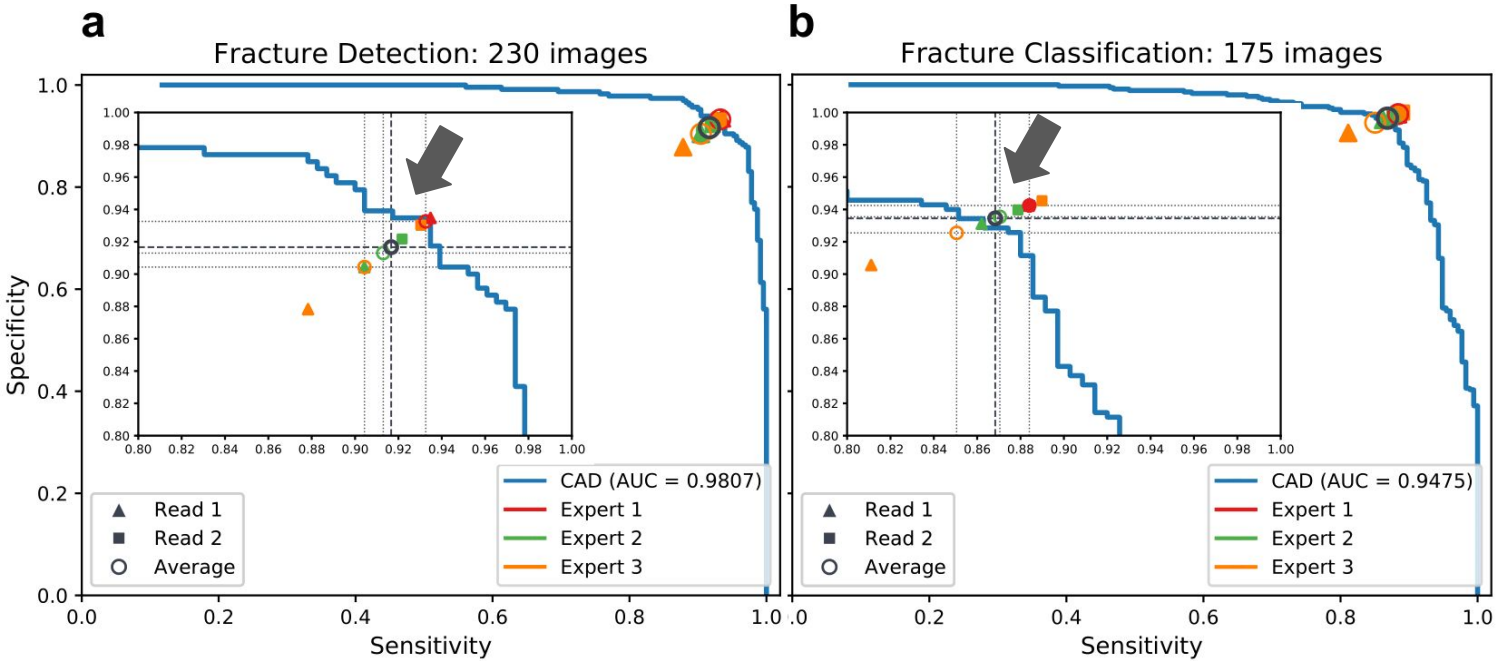
F1-score	2 classes	3 classes
Full radiographs	0.84	0.83
Manual ROIs	**0.94**	**0.87**

ROI localization helps!

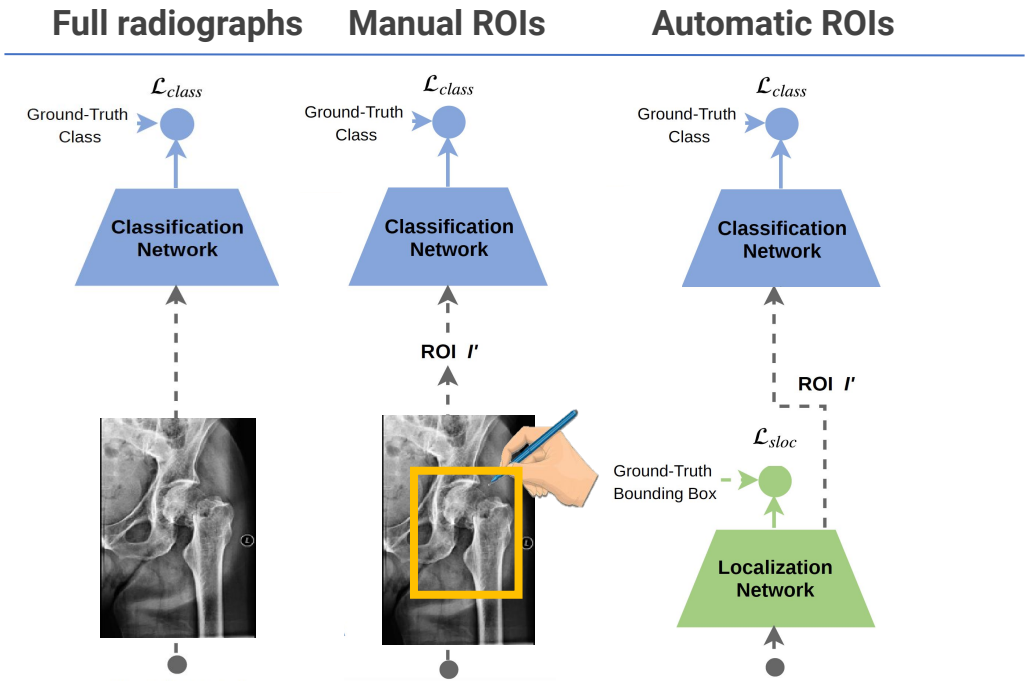
Expert-level performance



Expert-level performance



Classification on automatic ROIs



F1-score	2 classes	3 classes
Full radiographs	0.84	0.83
Manual ROIs	**0.94**	**0.87**
Automatic ROIs	0.93	0.85

Automatic ROIs (supervised localization) comparable to manual ROI

Supervised ROI localization

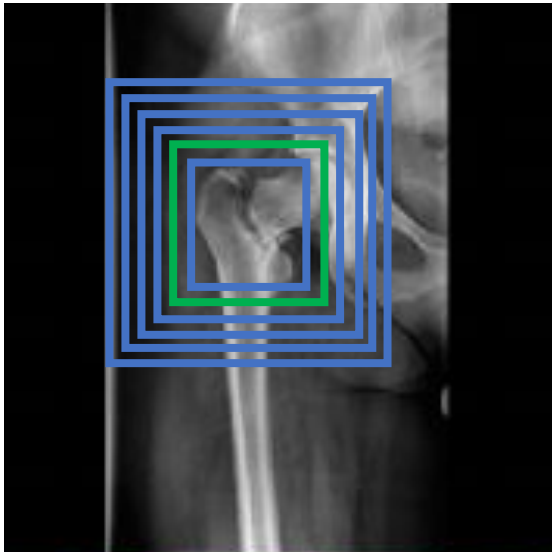
Green: ground truth bounding box
Blue: predicted bounding box

100% of the predicted **centers** of the ROI
were **contained** in the **original bounding box.**

ROI scale sensitiveness analysis

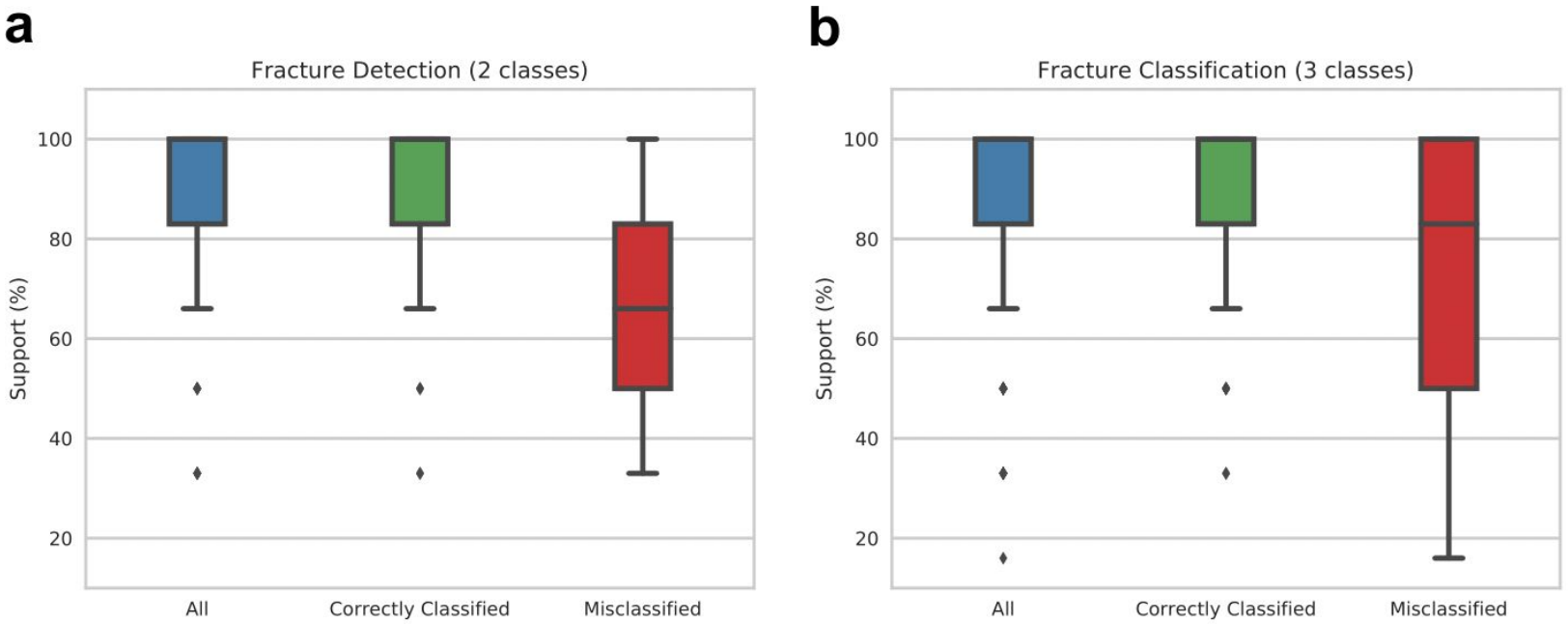
- The predicted bounding boxes were scaled by the following values: [0.75, 1.00, 1.25, 1.50, 1.75, 2.00]

ROI scale sensitiveness analysis



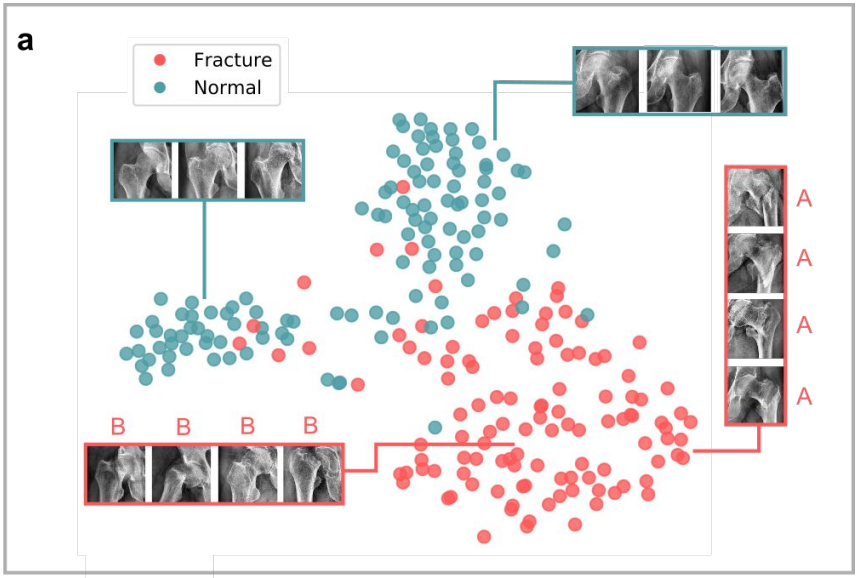
- The predicted bounding boxes were scaled by the following values: [**0.75**, **1.00**, **1.25, 1.50, 1.75, 2.00**]
- Obtain class prediction at each scale.
- Quantify the percentage of correct predictions across scales (Support %).

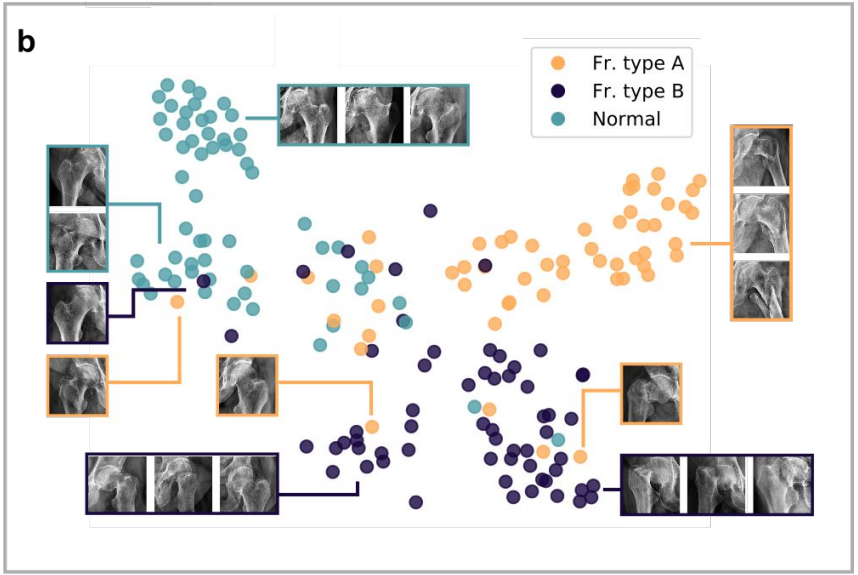
ROI scale sensitiveness analysis



Informative disagreement!

Clinical use case: image retrieval

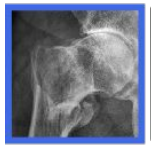


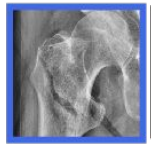


Dimensionality reduction: t-SNE embedding

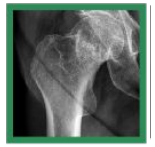
Clinical use case: image retrieval

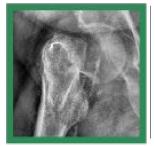
Type A





Type B





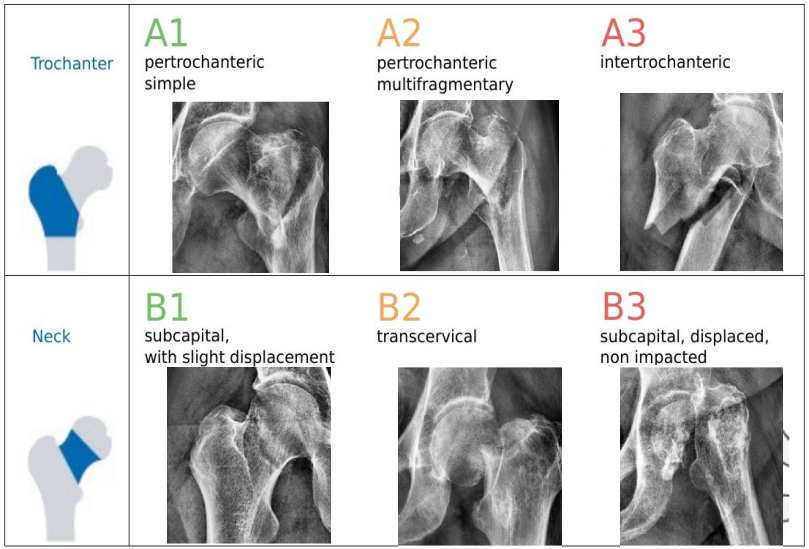
Clinical use case: image retrieval

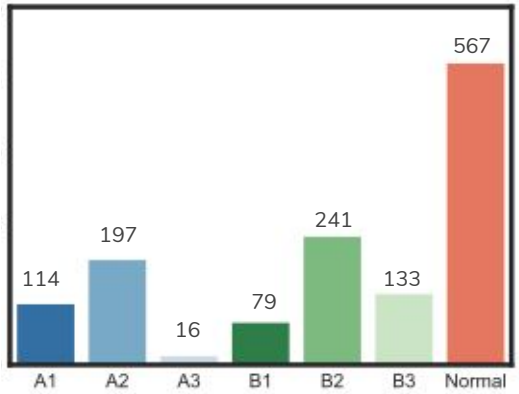
On average, 9/10 retrieved images are relevant.

Discussion

Technical limitations & future work

- Our **dataset** suffers from a **high imbalance** in the distribution of the classes when considering the **subtypes of A- and B-fractures**.





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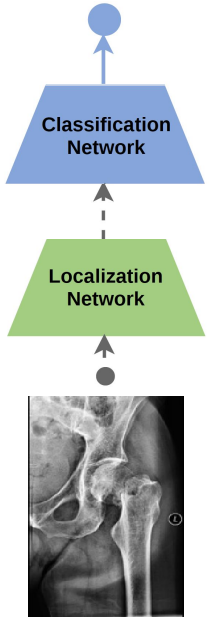
LE-15

“Hierarchical Deep Curriculum Learning for the Classification of Proximal Femur Fractures”

Conclusions

Precise proximal femur fracture classification for interactive training and surgical planning

- **CAD** scheme for the **detection** and further **classification** of **proximal femur fractures.**



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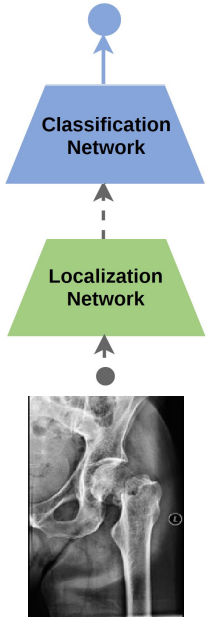
- **CAD** scheme for the **detection** and further **classification** of **proximal femur fractures.**
- The classification of A- and B-fractures is crucial for **planning the treatment** either **conservatively** or **surgically**, and if so, to choose the adequate surgical implant.



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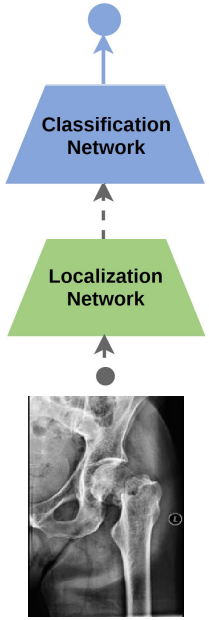

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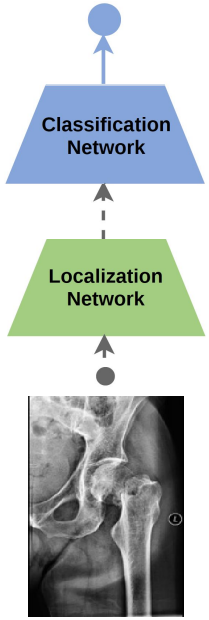
- **In-depth evaluation** of an automatic system according to the **AO system**.
- Several strategies are discussed to favor the **adoption** of our CAD tool into the **daily clinical routine**.



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website

Thank you for your attention!

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