Automated evaluation of hand radiographs in patients with rheumatoid arthritis

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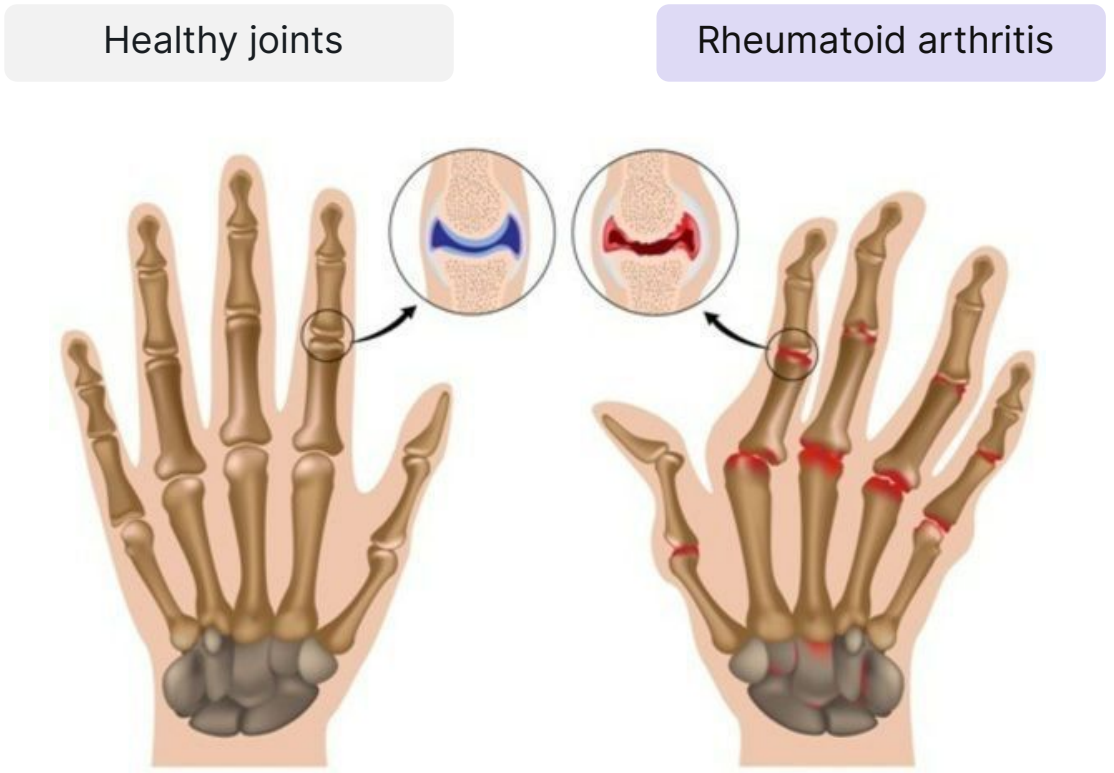
Rheumatoid arthritis

Chronic inflammatory autoimmune connective tissue disease **leading to disability**

It is characterized by **joint damage** and damage to internal organs.



Rheumatoid arthritis. Statistics

Prevalence

0.5-2%

New cases per year

27/ 100 000

Men : Women

Peak incidence

40-55 y.o.

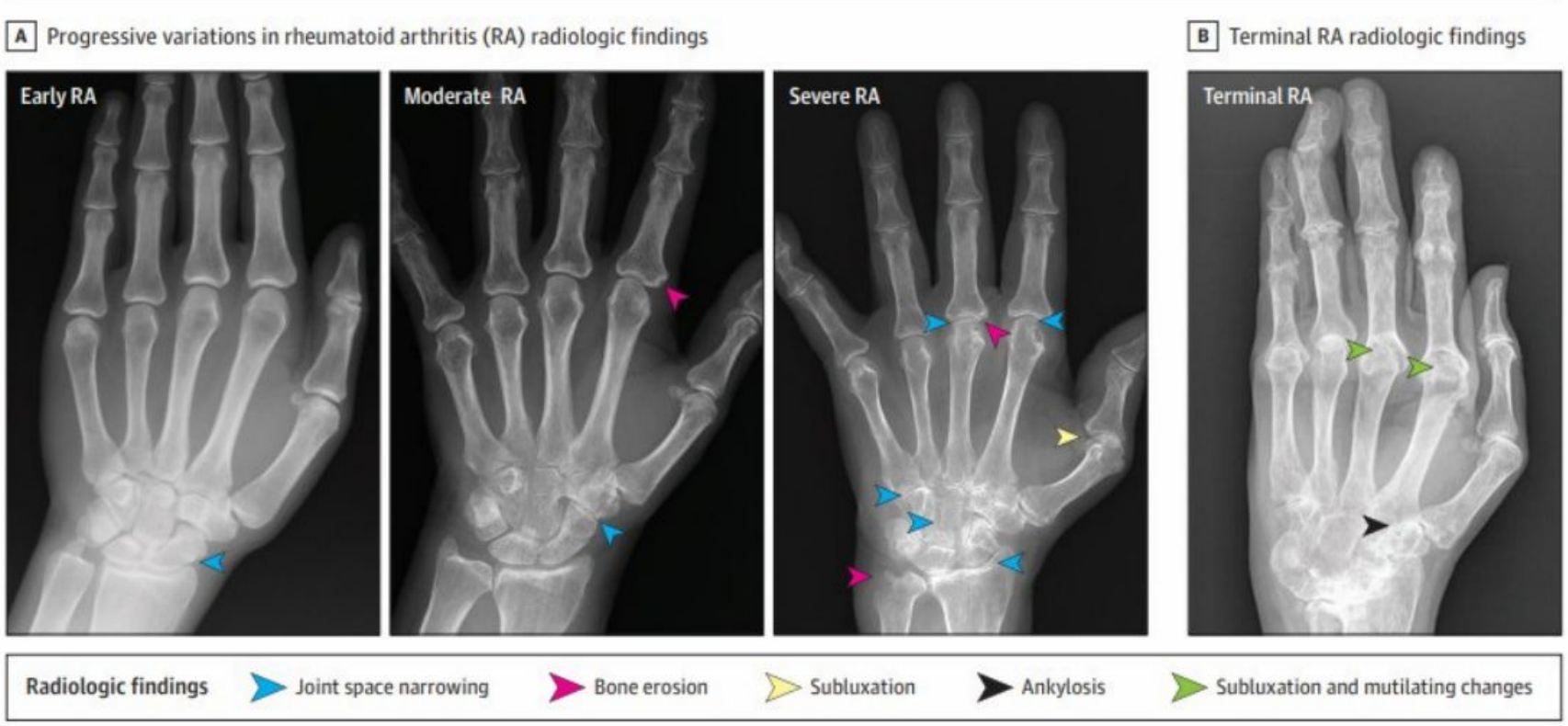
Years before disability

3-5

Rheumatoid arthritis. Diagnostics

RA is a progressive disease

It is important to monitor the dynamics of the disease during treatment



Aletaha, Daniel, and Josef S. Smolen. "Diagnosis and management of rheumatoid arthritis: a review." Jama 320.13 (2018): 1360-1372.

Rheumatoid arthritis. Diagnostics

Sharpe van der Heide method

Assessment for each joint of the hands and feet

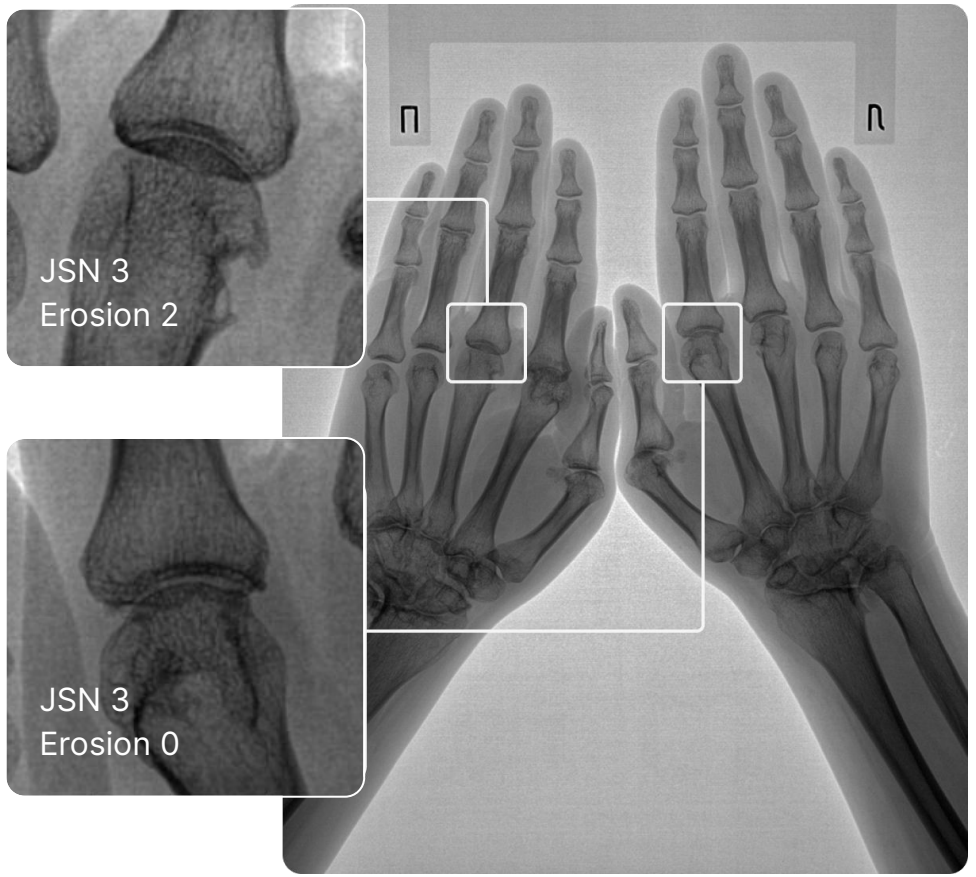
- Joint space narrowing (JSN): 0-4
- Joint erosion: 0-5

Problem

Takes a lot of time

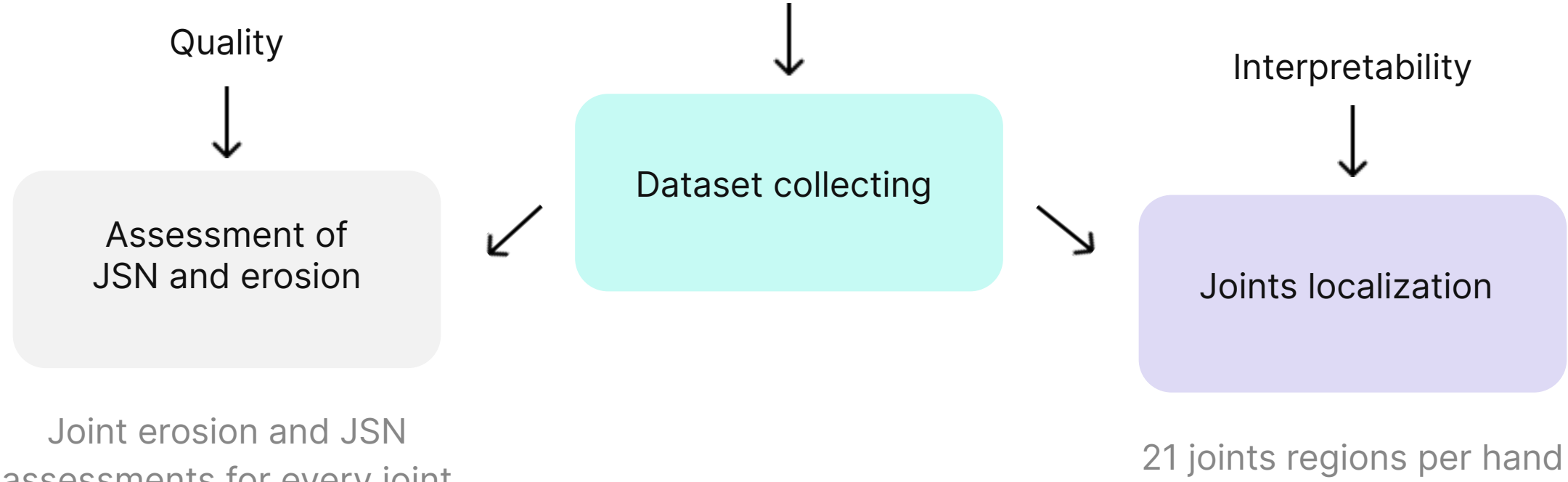
Task

Automation of the assessment of the degree of JSN and joint erosion.



Dataset

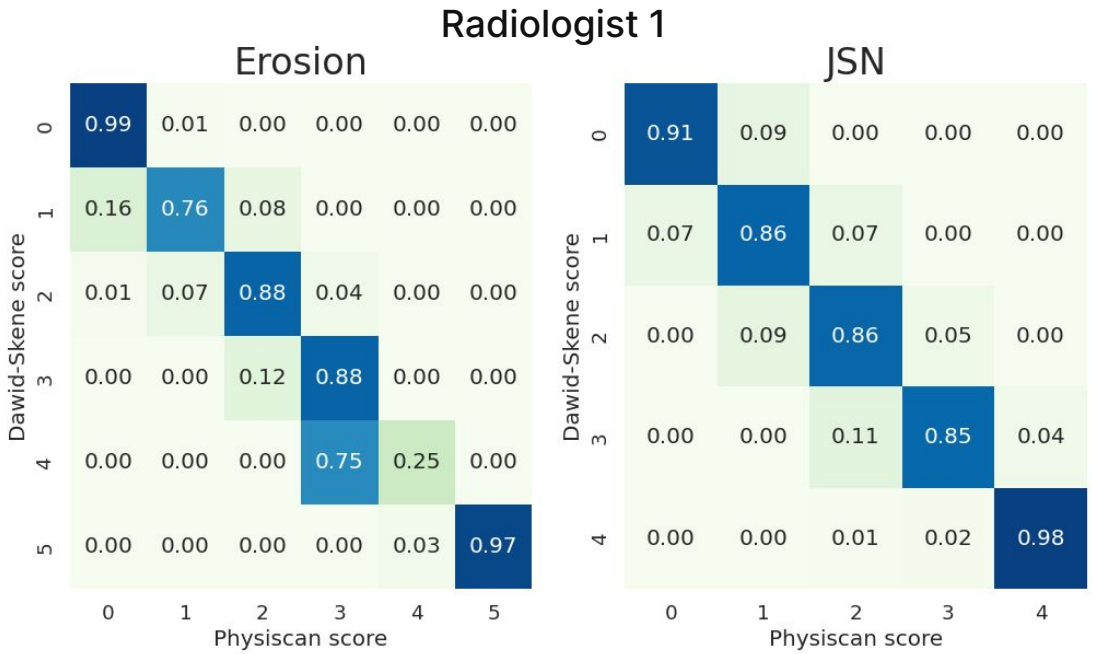
There are **no open datasets** with joint markings

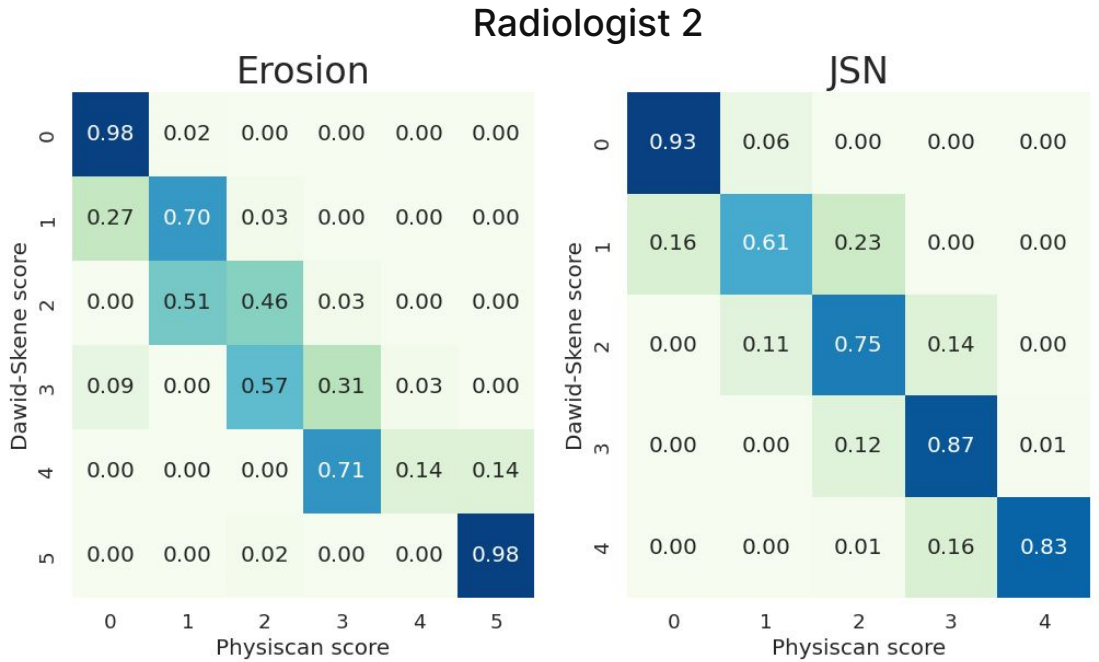


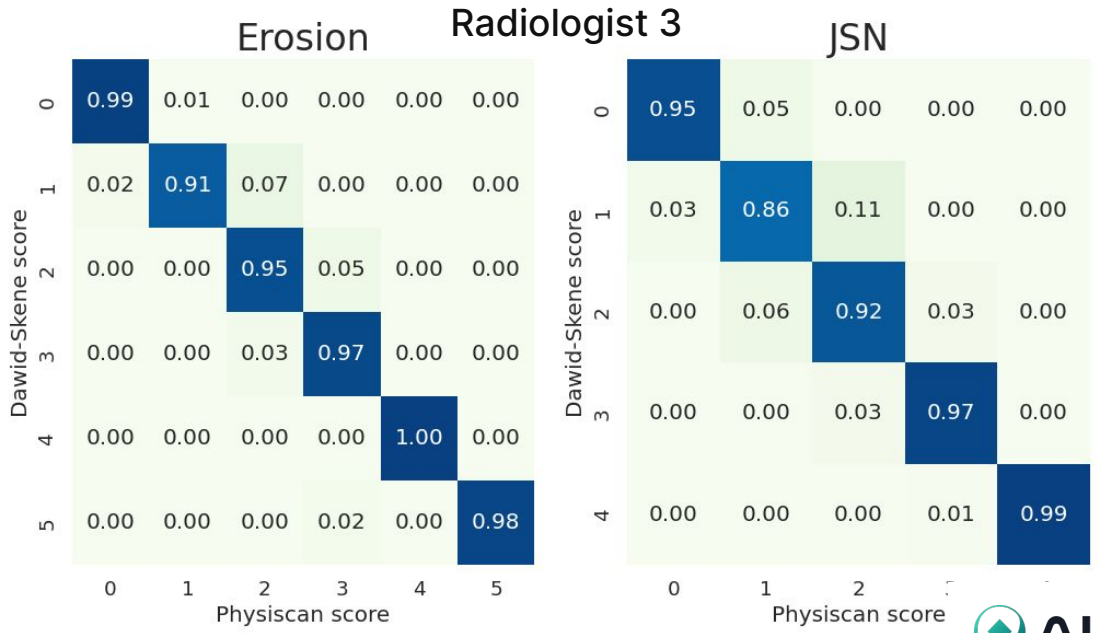
Dataset. Analysis

Confusion matrices between 3 radiologists and target labels which are selected by **Dawid-Skene** algorithm

The assessment of the joints is not fully agreed





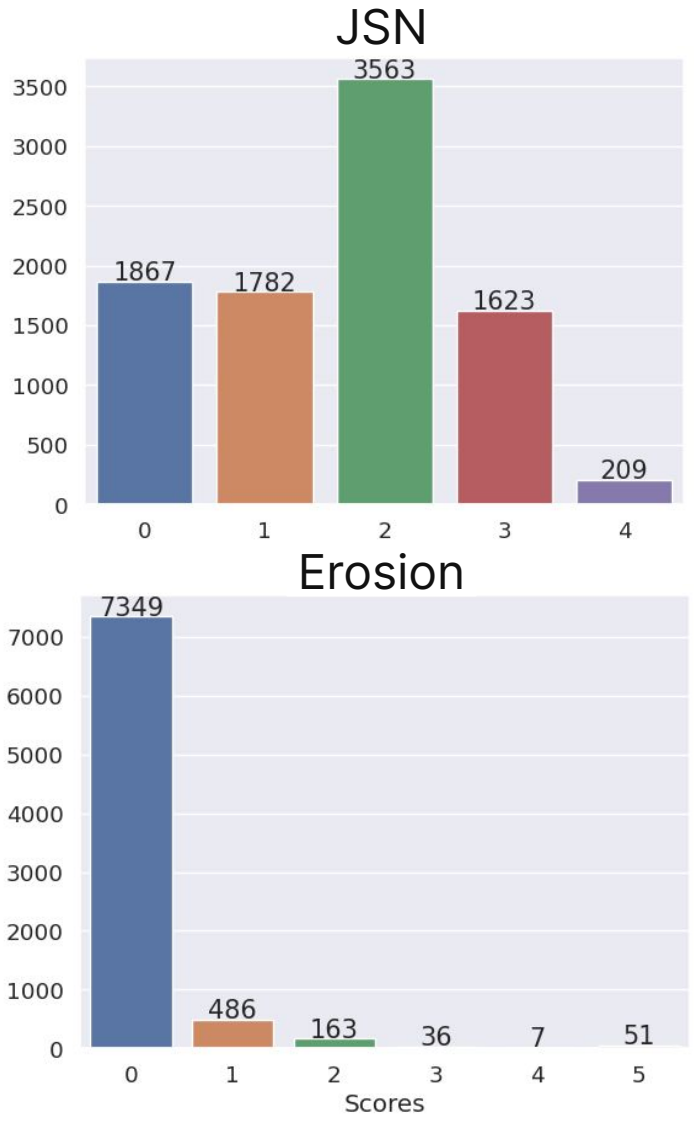


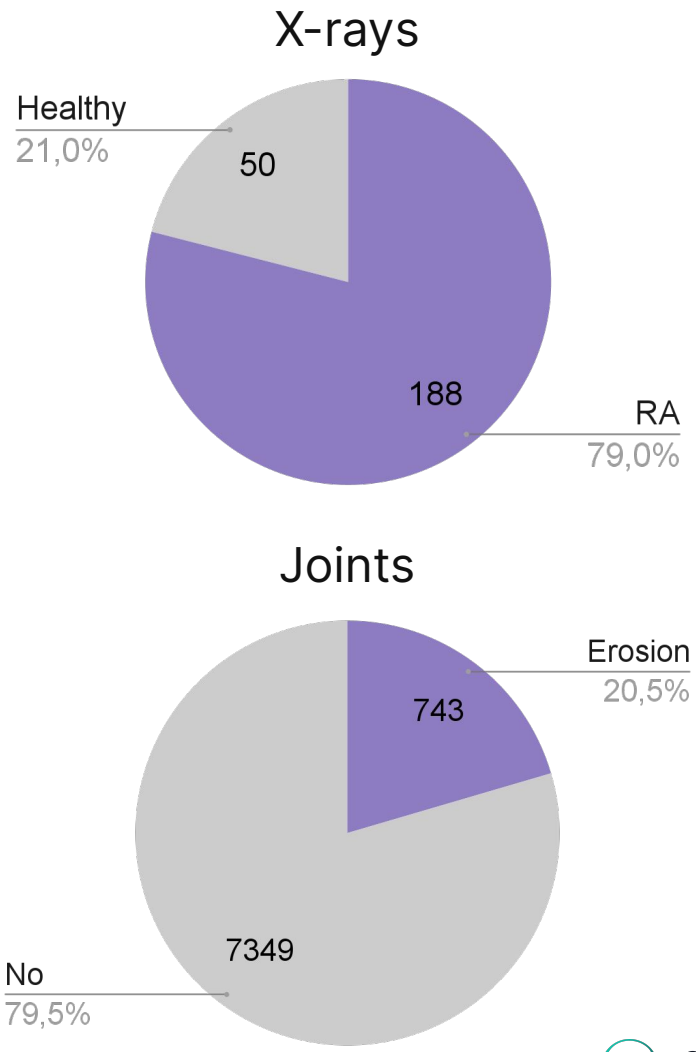
Dataset. Statistics

350
patients (in total)

268
for joints localization

236
for joints assessment





Previous works. Two stages approach

→ Joints localization as
- regression task (1)
  easier and more intuitive
- detection task (2)

→ Assessment for every joint as
- one model for erosion and JSN
- two models for erosion and JSN (1, 3)
  works better

\+ Interpretability

\+ Increase dataset in 21 times for joints assessments

* Two or more models

\− Receptive field includes only one joint

1) A multistage deep learning method for scoring radiographic hand and foot joint damage in rheumatoid arthritis
2) Deep Learning-Based Computer-Aided Diagnosis of Rheumatoid Arthritis with Hand X-ray Images Conforming to Modified Total Sharp/van der Heijde Score
3) 2020 Hongyang Li and Yuanfang Guan for RA2 Rheumatoid Arthritis Image DREAM Challenge (1st place for narrowing prediction)

Previous works. One stage approach

→ RetinaNet with 3 heads to predict boxes, erosion and JSN classes

Adaptive IoU Thresholding for Improving Small Object Detection: A Proof-of-Concept Study of Hand Erosions Classification of Patients with Rheumatic Arthritis on X-ray Images (2023)

→ U-Net with localization, erosion and JSN channels

Adaptive IoU Thresholding for Improving Small Object Detection: A Proof-of-Concept Study of Hand Erosions Classification of Patients with Rheumatic Arthritis on X-ray Images (2022)

\+ Only one model

\+ Receptive field includes all joints

− Needs full images →needs more data

− Difficult to interpret

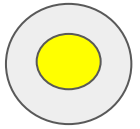
One-stage segmentation model. The architecture is U-Net with localization, erosion and JSN heads.

- Dataset generation: 1)Segmentation masks were obtained from the centres of boxes with circles of radius r, those pixels, the distance to the nearest centre from which is greater than R, were taken as background mask, the rest of them were ignored.
  2) Local label smoothing. We move probability mass to neighboring classes with probability p.

- Input to the model: image + 2 channels, as coordinate grids by x and y coordinates.

- Model: U-Net, encoder - Efficcinet Net B5, decoder - upsampling layers. The last decoder layer is the input for 3 pixel classifiers.

- Model output: 1) prediction of joint class or background 2) narrowing class 3) erosion class. In this case the target is formed as circles around the joints. In this case between the joint circle and the background, there is an area in which the loss does not count.



Stage 1/2. Joints localization

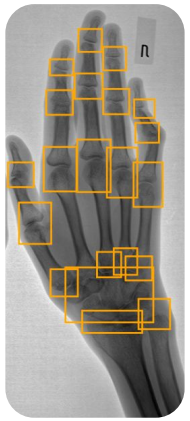
Localization as regression task

- Find the seam
- Split image
- Flip left image

EfficientNet-V2-L

Training tricks:
-Use pretrained model
-DioU Loss

Bounding Boxes

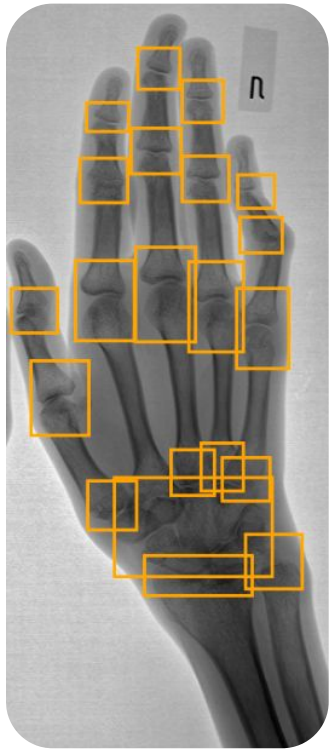


Results on test data: accuracy* = 0.98%

* TP if center of predicted bbox is not far from center of target and predicted bbox size are close to target

Stage 2/2. Joints assessment

Assessment as classification task



Preprocessing

Image processing takes place independently

Independent models

VGG16 → **Erosion** + JSN assessments for every joint

SWIN S → **JSN** assessments for every joint

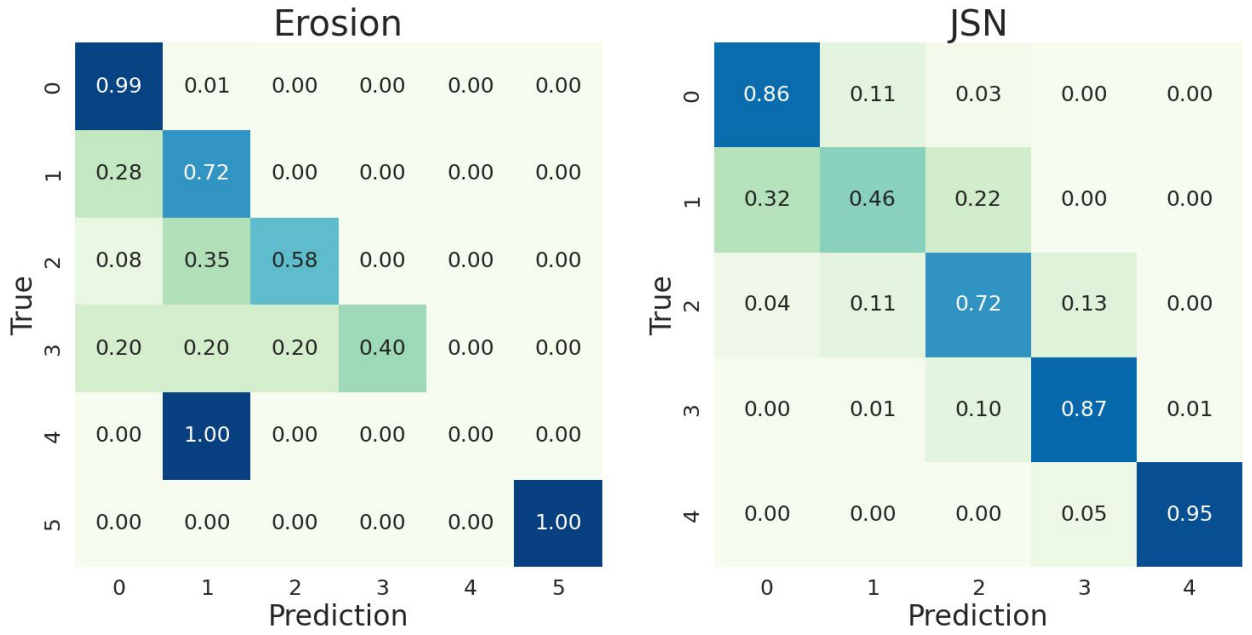
Training tricks
- Pretrain on big dataset with hands xrays
- Use small models – larger models overfits
- Smooth CE loss for classes of close scores
- Extended bboxes
- Aggressive augmentations

Classification Results

Model	Weighted Accuracy	Approx. Accuracy
Erosion	0.70	0.82
JSN	0.69	0.96

Radiologists	Weighted Accuracy	Approx. Accuracy
Erosion	0.76	0.98
JSN	0.75	0.99

Joints assessment. Confusion matrices



Conclusions: the model is close to the most experienced experts

Web prototype demonstration

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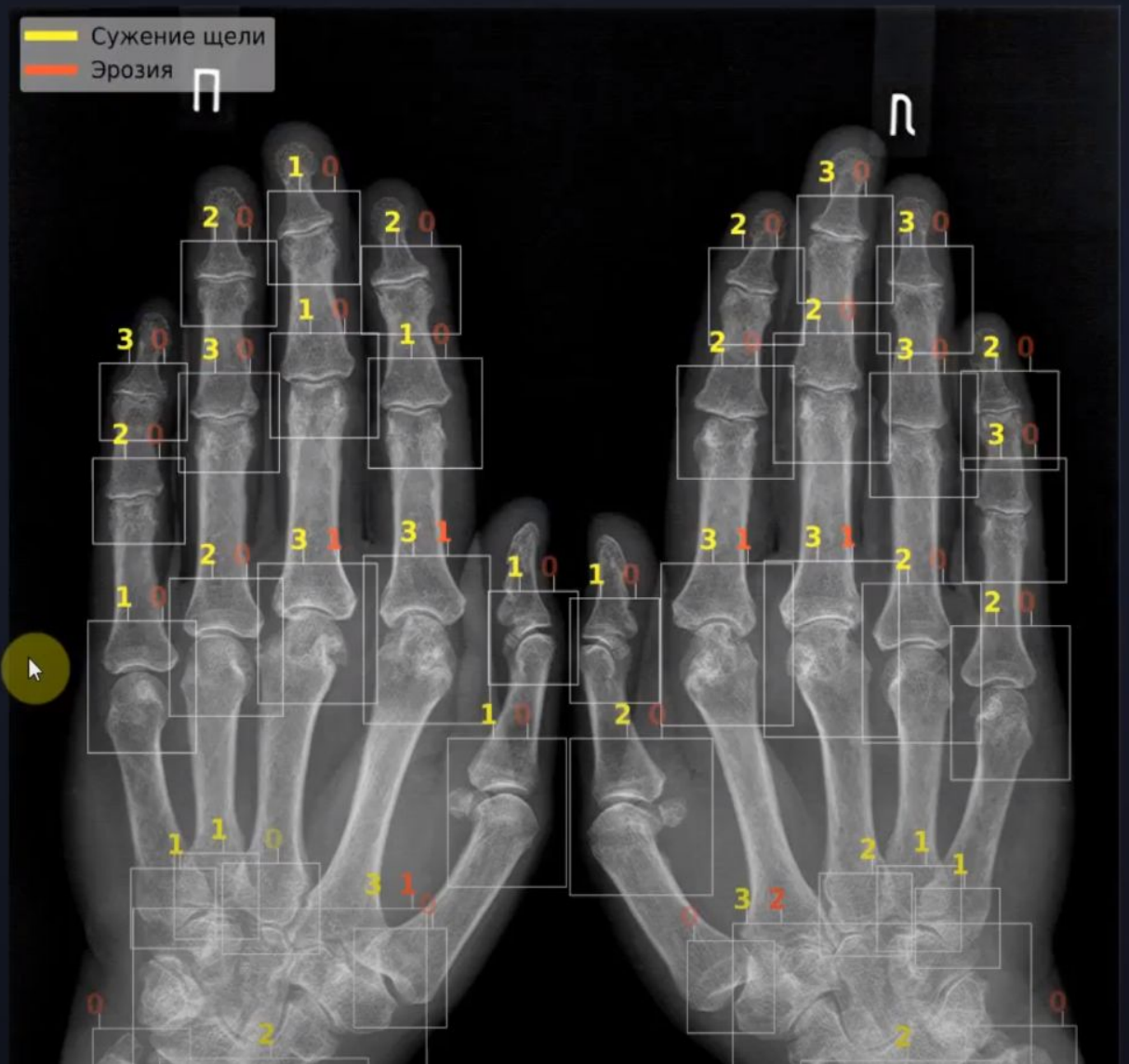
Только для исследовательских целей

К исходным значениям

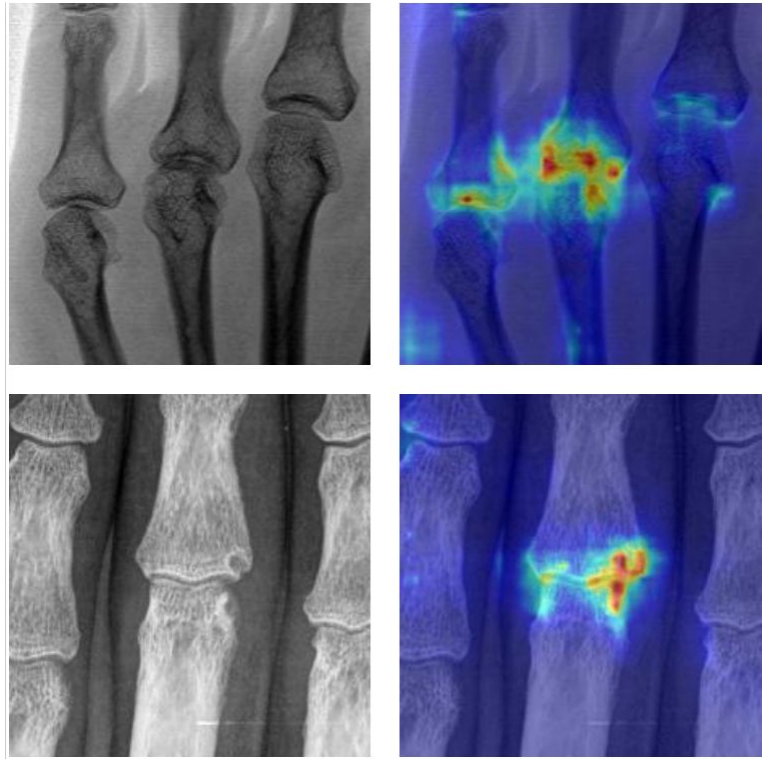
Скачать:

Сустав	Справа		Слева	
	Эрозии	Сужение щелей	Эрозии	Сужение щелей
1-й МФ	0	1	0	1
Дистальные межфаланговые (ДМФ) суставы				
2	0	2	0	2
3	0	1	0	3
4	0	2	0	3
5	0	3	0	2
Проксимальные межфаланговые (ПМФ) суставы				
2	0	1	0	2
3	0	1	0	2
4	0	3	0	3
5	0	2	0	3
Пястно-фаланговые (ПЯФ) суставы				
1	0	1	0	2
2	1	3	1	3
3	1	3	1	3
4	0	2	0	2
5	0	1	0	2
1-й ЗП сустав	0	X	0	X

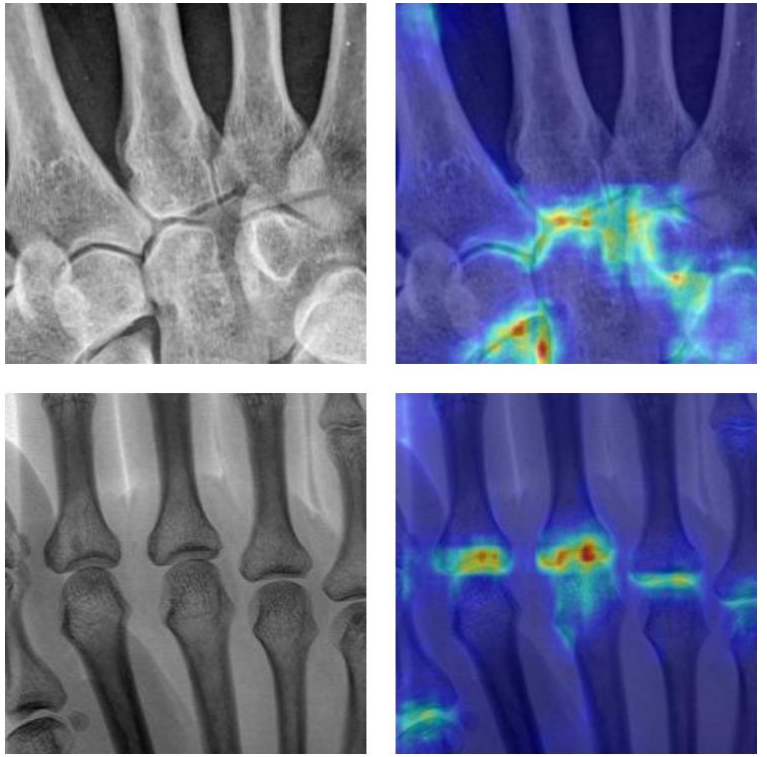


Interpretability

Erosion



JSN



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Future work

- Add more assessments for hands x-rays.
- Add feet x-rays and update model.
- Try several methods of interpretation, adjusting them to our models

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- Article - MICCAI (Q1)