RELEVANCE ANALYSIS OF MRI SEQUENCES FOR AUTOMATIC LIVER TUMOR SEGMENTATION

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MOTIVATION

Identify most important MRI sequences for liver tumor segmentation.

- Less sequences required ⇒ broader applicability
- Informed sequence selection via relevance analysis

Additionally: explain CNN decisions leading to true and false positive/negative predictions.

LIVER TUMOR SEGMENTATION MODEL

- 3D u-net, 6-channel input, 2-channel output
- 49 training, 20 test patients
- Trained on 6 MRI Sequences: T2, non contrast enhanced T1 (plain-T1), and 4 DCE T1 images acquired 20s (T1-20s), 60s (T1-60s), 120s (T1-120s), and 15min (T1-15min) after contrast agent administration (Gd-EOB-DTPA)
- Non-rigid motion correction [2]

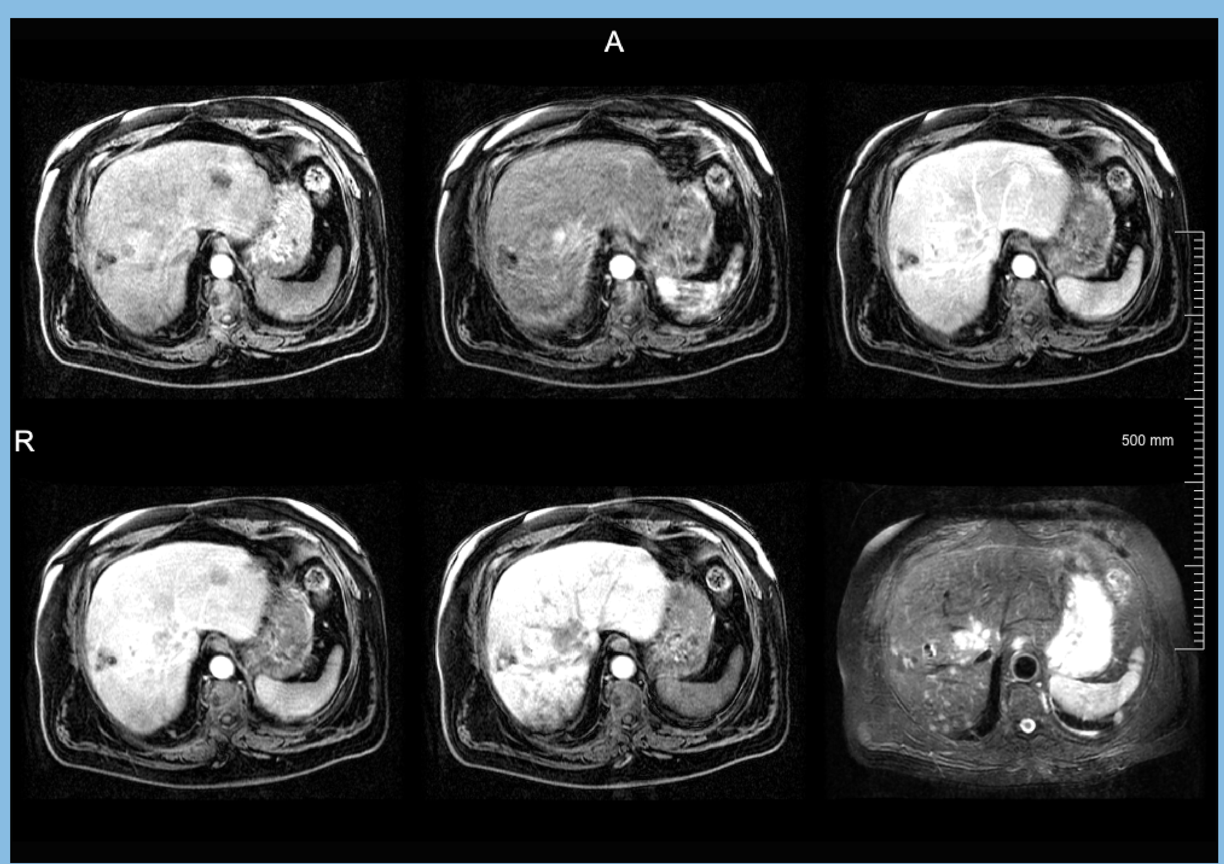

Figure: Multi-sequence MRI data: (upper row, from left) plain-T1, T1-20s, T1-60s, (lower row, from left) T1-120s, T1-15min, T2.

LAYER-WISE RELEVANCE PROPAGATION

LRP FOR IMAGE CLASSIFICATION

LRP [1] explains classification decisions for a given class i by relevance propagation from the model output y^i according to:

$$y^i = R = \ldots = \sum_{d\in L^l} R_d^{(l)} = \ldots = \sum_{d\in L^1} R_d^{(1)} = \sum M^i \qquad (1)$$

where l refers to the layer index, L^l to all neurons of layer l, and $R_d^{(l)}$ to a relevance of neuron d in layer l.

LRP FOR SEMANTIC SEGMENTATION

- Semantic segmentation ⇔ voxel-wise classification
- Compute relevance maps for each location a of a given output region A

$$M_A^i = \sum_{a\in A} \frac{M_a^i}{\sum M_a^i} \qquad (2)$$

We normalize M_a^i by its sum to ensure that each output location a equally contributes to the final relevance map M^i.

SEQUENCE RELEVANCE

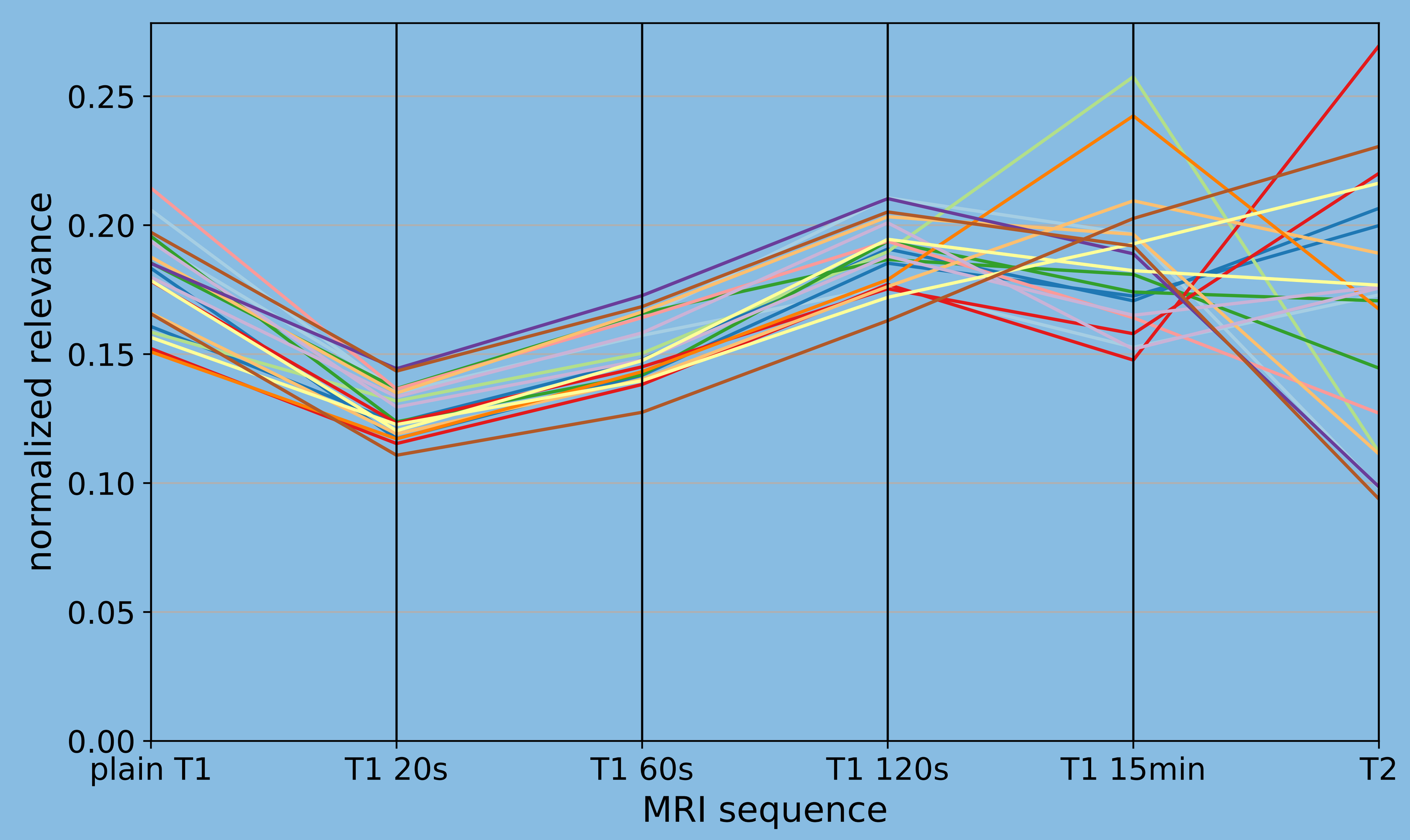

Figure: Normalized relevance distribution across input MRI sequences for 20 test patients denoted by different colors.

PIXEL-LEVEL EXPLANATIONS

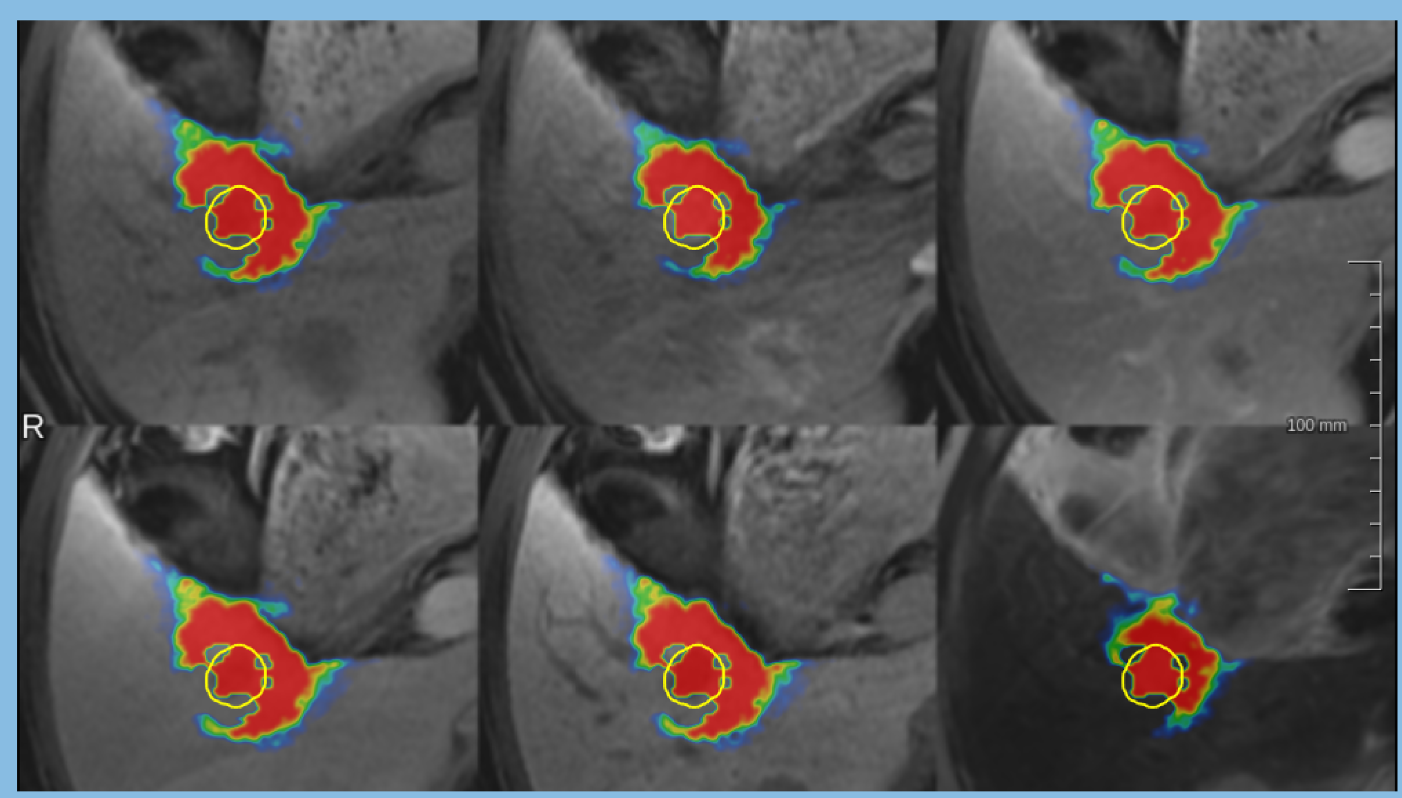

Figure: Foreground relevance maps (i=1) computed for a true positive.

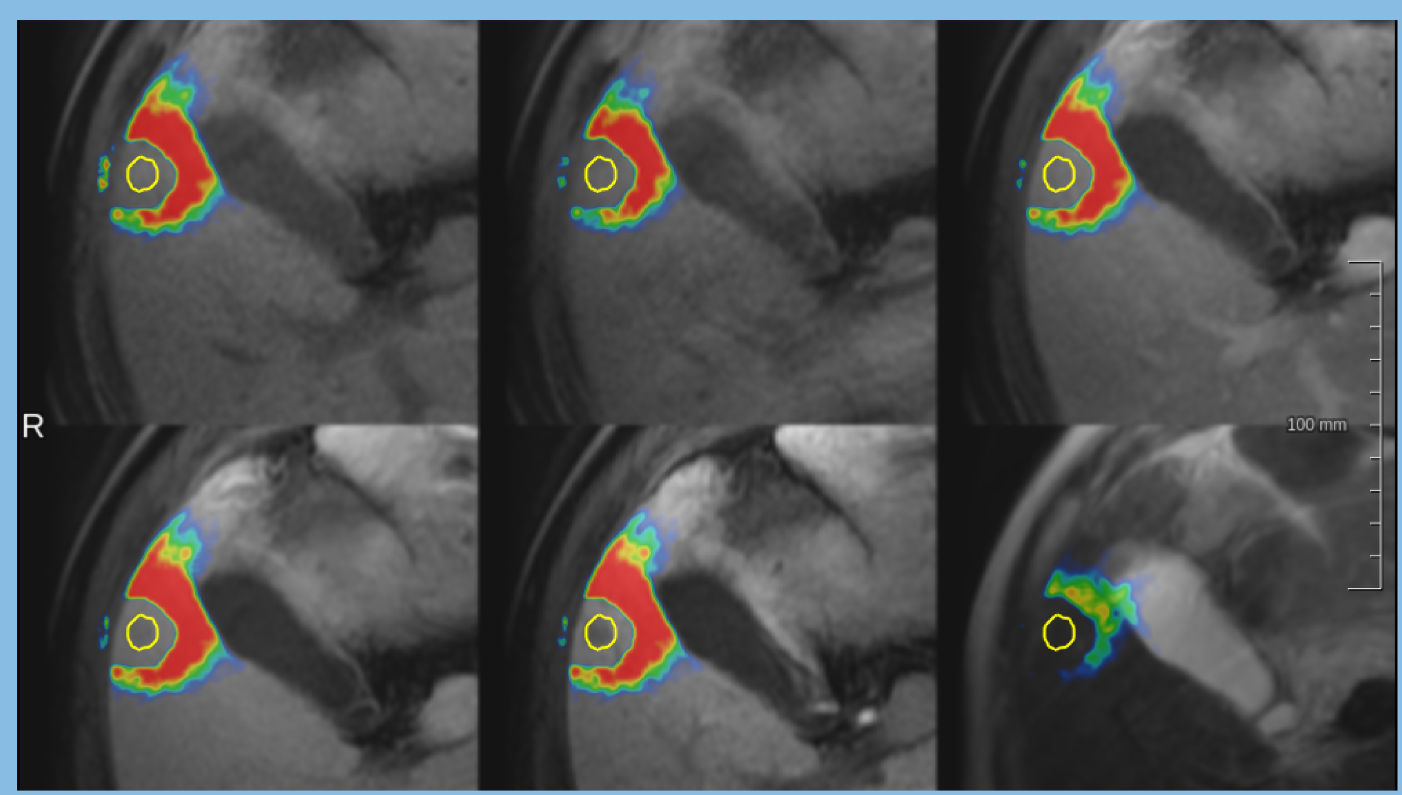

Figure: Foreground relevance maps (i=1) computed for a false negative.

CONCLUSIONS

- CNN used information from all MRI sequences
- T1-15min sequence, which was used to create training labels was not the most important one
- Similar relevance attribution for plain T1, T1-20s, T1-60s, and T1-120s
- Pixel-level explanations are hard to interpret

[1] S. Bach et al. On pixel-wise explanations for non-linear classifier decisions by layer-wise relevance propagation. *PloS ONE*, 2015.

[2] J. Strehlow et al. Landmark-based evaluation of a deformable motion correction for dce-mri of the liver. *IJCARS*, 2018.

Abstract: