MRI-based Surgical Planning for Lumbar Spine Stenosis

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Abstract

The most common reason for spinal surgery in elderly patients is **lumbar spinal stenosis (LSS)**. As treatment decisions show large variance, a standardized support system is of high value for a more objective and reproducible judgement.

In this work, we develop an automated algorithm to localize the stenosis causing the symptoms of the patient in magnetic resonance imaging (MRI). With **22 MRI features** of each of five spinal levels of 321 patients, we show it is possible to predict the location of lesion triggering the symptoms. To support this hypothesis, we conduct an automated analysis of labeled and unlabeled MRI scans extracted from 788 patients.

We confirm quantitatively the importance of radiological information and provide an algorithmic pipeline that processes **raw MRI scans**.

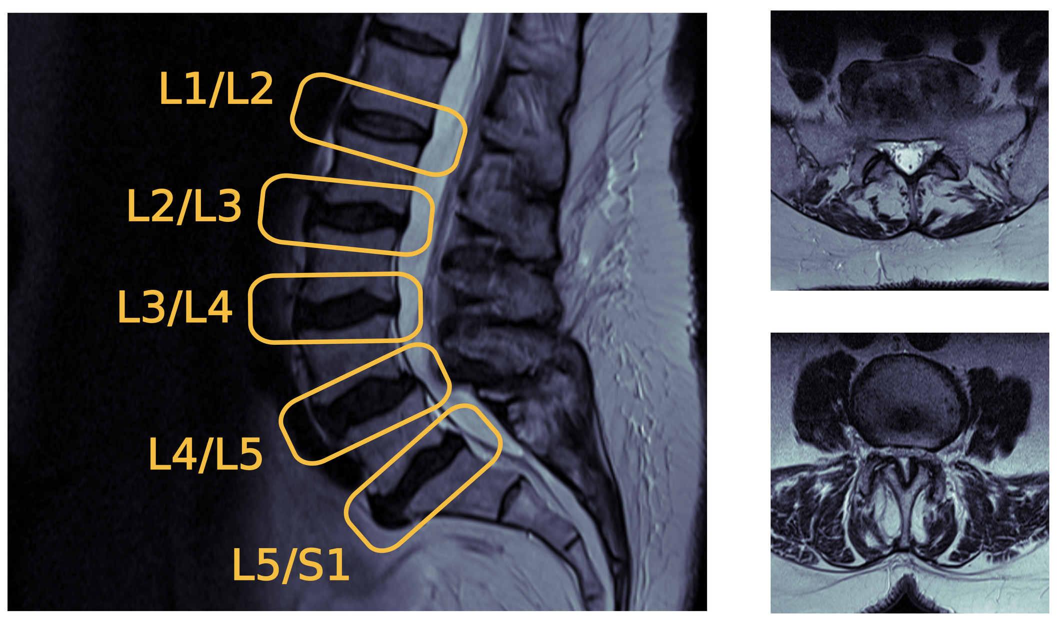

Figure 1. Left: the five segments of the lumbar spine are highlighted in yellow in a sagittal scan. Right: examples of segments affected (below) and not (above) by LSS.

Introduction

LSS is defined as "[...] **diminished space** available for the neural and vascular elements **in the lumbar spine** secondary to degenerative changes in the spinal canal [...]" and occurs in the five **levels** (**segments**) L1–L5 (figure 1).

When conservative treatments such as physiotherapy or steroid injections fail, **decompression surgery** is frequently indicated. Surgeons' decision process exhibits wide variability[1], while associations between imaging and symptoms are still not entirely clear.

Andreisek et al. [2] identified 27 radiological criteria and parameters for LSS. However, correlations between imaging procedures, clinical findings and symptoms is still unclear.

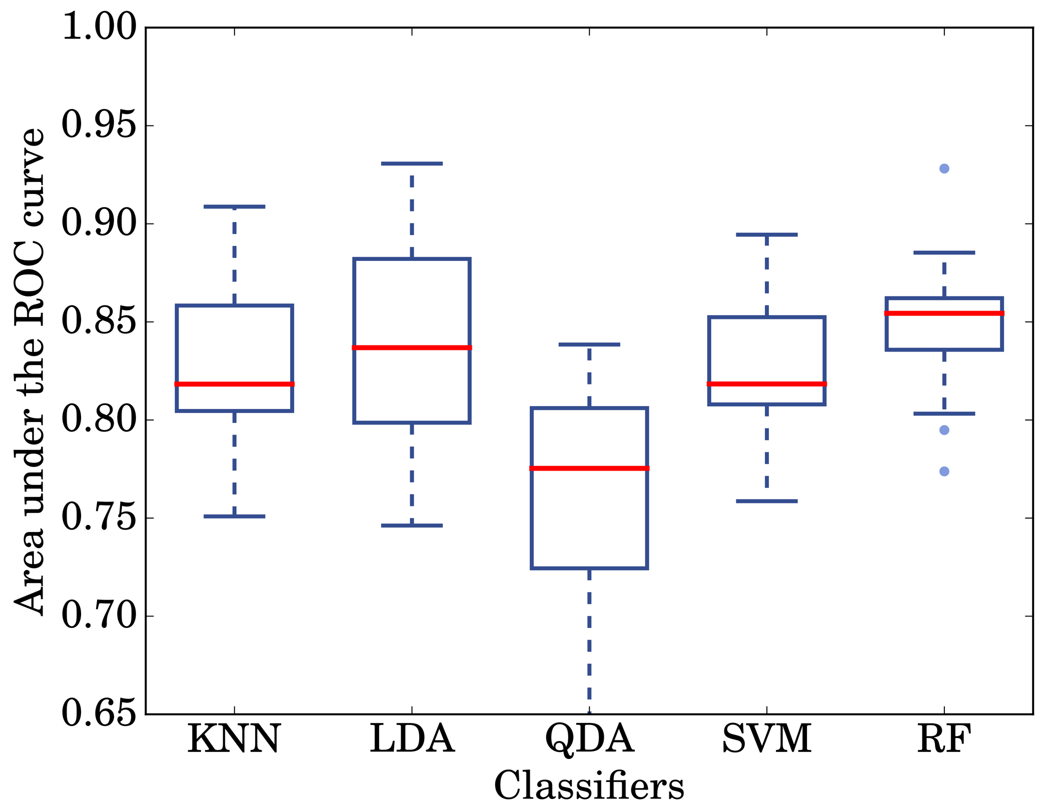

Figure 2. Box plots of the 20-fold cross validation. All classifiers show a strong signal between radiological data and surgical treatments.

The Numerical Dataset

Radiological **T1-weighted** and **T2-weighted** scans from **788 LSS patients** were collected in a multi-center study by Horten Zentrum. Radiologists manually scored 6 quantitative features and 16 qualitative features (segment-wise).

431 of the 788 patients **underwent surgery**. Among these, **321** exhibited **improvement** (assessed with NRS pain scale). The analysis focuses on these improved patients, yielding a total of **1385 segments** as data points.

We consider every segment independently as a data vector $\boldsymbol{x}$ consisting of its 22 feature values. The target is represented by a binary variable y (to operate/not to operate). The values of the area under the ROC given by 20-fold cross validation for optimized binary classifiers can be seen in figure 2.

The Image Dataset

The objective was to reproduce the classifiers results working directly with the **MRI images**.

The **T2-weighted axial scans** are preprocessed, cropped and resized to 128x128 pixels. Different **data augmentation** techniques are employed.

Two approaches were applied:

1. Direct classification through **Convolutional Neural Networks** using labeled segments
2. Dimensionality reduction through **Convolutional Autoencoders** (using all segments) followed by the previously employed binary classifiers

An **accuracy** of **~70%** was achieved.

Conclusions

While the influence of MRI scans on surgical decisions for LSS was previously unclear, we quantitatively confirm the importance of medical imaging in LSS diagnosis and treatment planning.

To the best of our knowledge these are the first and initial steps towards benchmarking LSS.

Compared to the results with the numerical dataset, the differences in accuracy (of about 15%) can be justified by the modest number of MRI scans. We are confident that further systematic efforts aimed at enlarging the image catalog could significantly improve the classification results and thus patient outcomes.

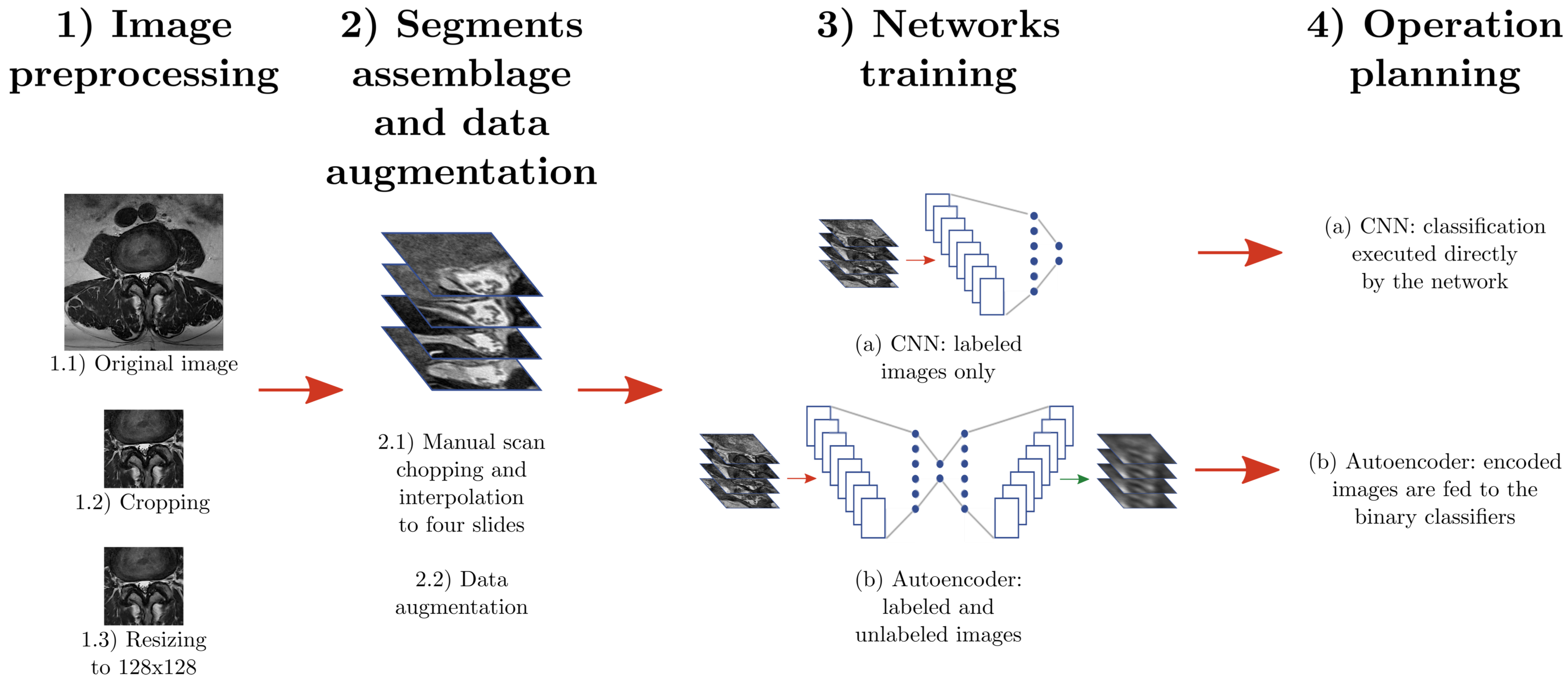

Figure 3. Pipeline of the work performed on the MRI image dataset.

Code and data are available at www.spinalstenosis-ml.ch

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References

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2. Andreisek *et al.*, Consensus conference on core radiological parameters to describe lumbar stenosis - an initiative for structured reporting, Eur. Radiol., 24, 3224–3232 (2014)