

Spine-GAN: Semantic segmentation of multiple spinal structures

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Objective: this work is to automatically generate unified reports of lumbar spinal MRIs in the field of radiology, i.e., given an MRI of a lumbar spine, directly generate a radiologist-level report to support clinical decision making.

Challenges:

- High variety and variability of spinal structures in MR images
- Multiple targets: average 21 spinal structures per MRI require automated analysis
- Weak spatial correlations and subtle differences between normal and abnormal structures generate dynamic complexity and indeterminacy

Highlights:

- For the first time, automated report generation in spine radiology is achieved
- Propose a weakly supervised framework using object level annotations without requiring radiologist-level report annotations to generate unified reports
- Overcome four inevitable tasks: semantic segmentation, radiological classification, positional labeling, and structural captioning
- Contribute to relevant time savings and expedites the initiation of many specific therapies

Recurrent Generative Adversarial Network

- A generator for generating pixel-level predicted maps
- A discriminator for correcting predicted errors and global contiguity
- A Local-LSTM module for spatial dynamic modeling

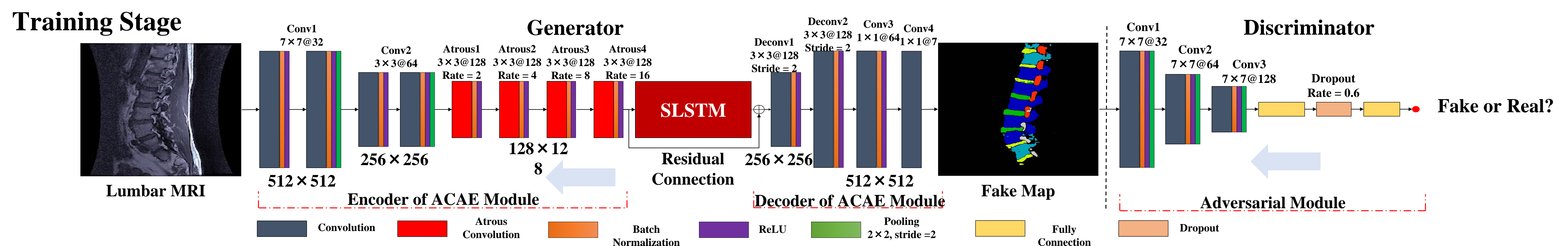
Prior Knowledge-Based Symbolic Program Synthesis

Unsupervised Labeling

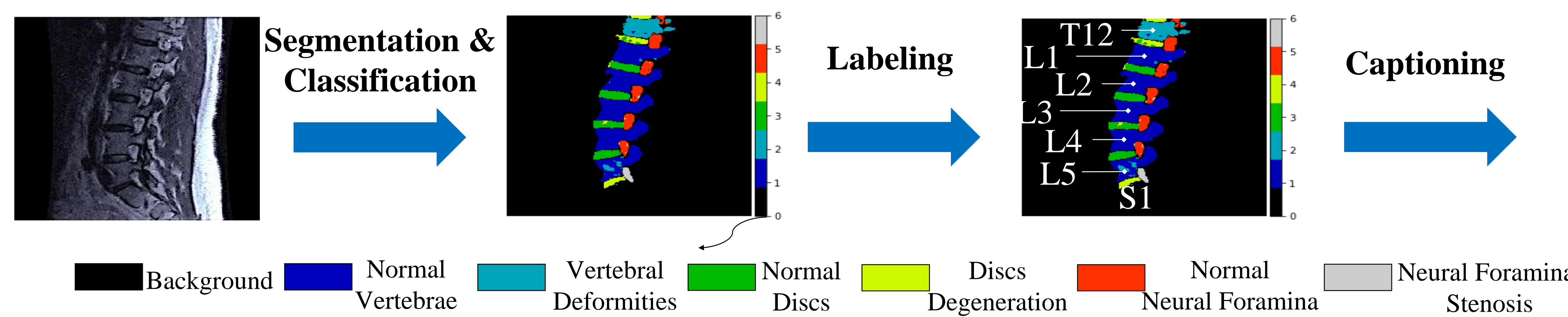
The input of the unsupervised labeling process is the predicted maps, and the output is three dictionaries comprised of locations and normalities of three spinal structures.

Template-Based Captioning

The input of this captioning process is three dictionaries and the output is a fully structural radiological report.



Testing Stage

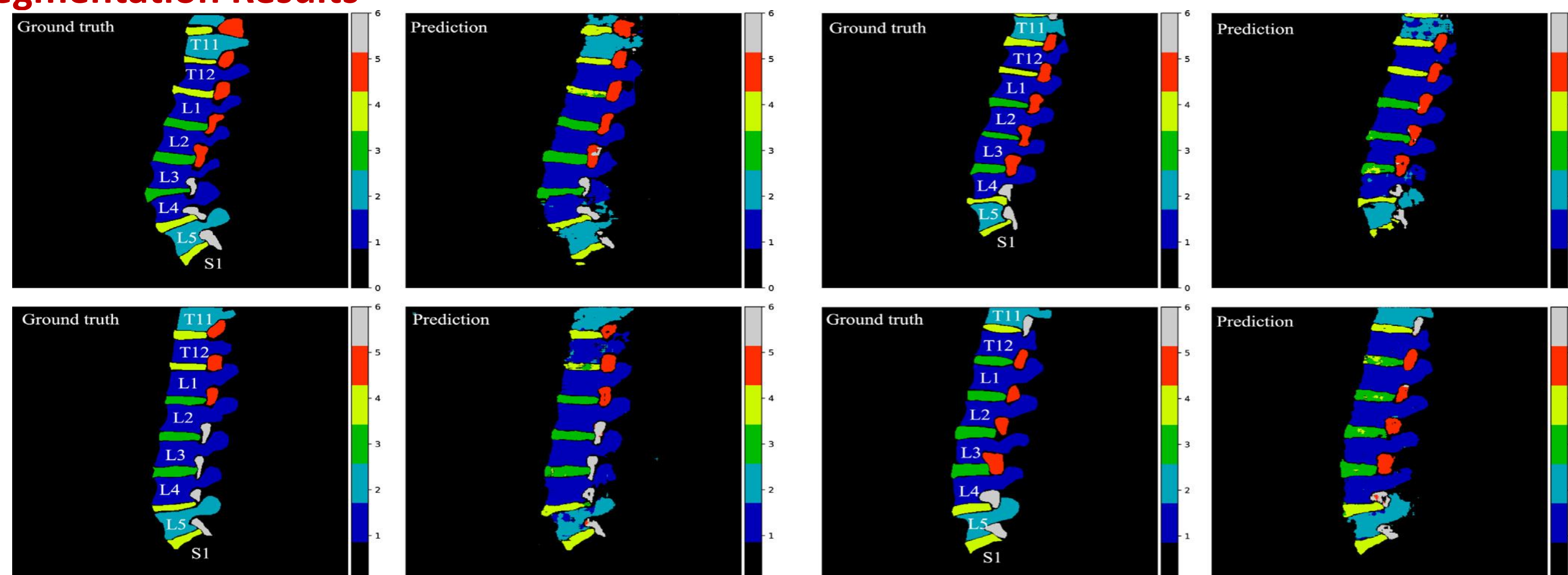


Radiological Report
Findings:
At T12-L1, the intervertebral disc has degenerative changes...
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At L5-S1, disc degenerative changes are associated with neural foraminal stenosis. The above vertebra does not have deformative changes.

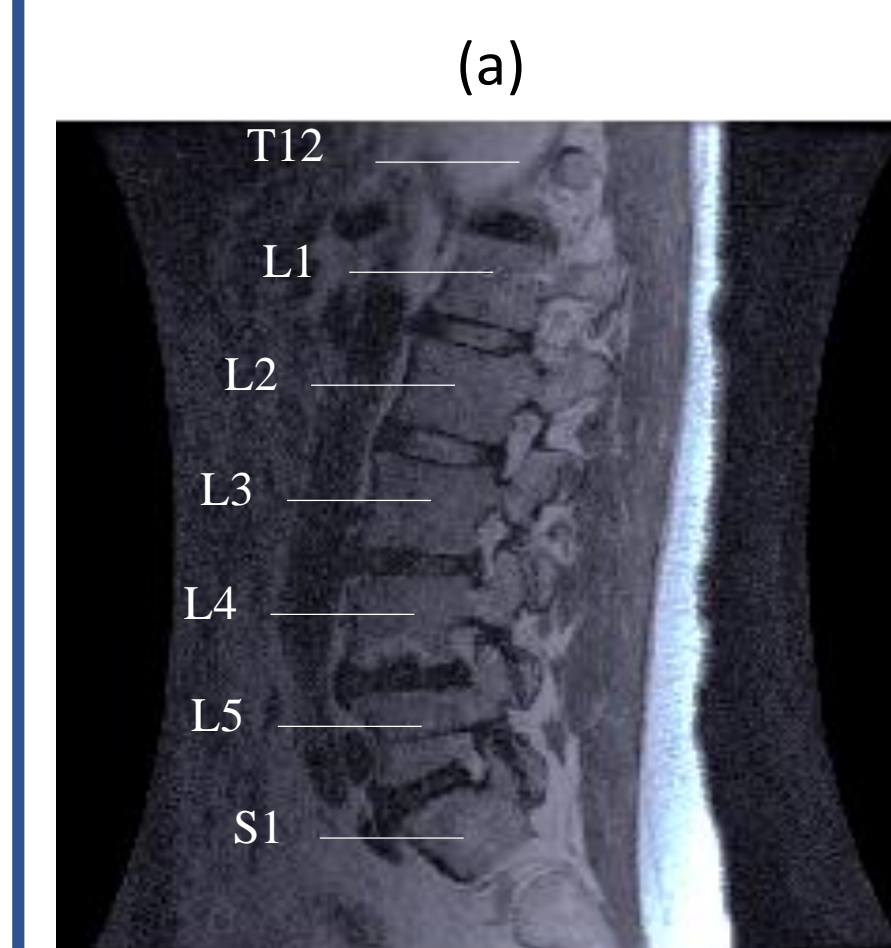
Dataset

- Data: mid-slice sagittal T1/T2-weighted spinal MR images, 253 images from 253 subjects, 147 females and 106 males
- Age: [15, 89] yrs, average: 58.9 yrs
- Repetition time: from 380 ms to 4,000 ms with mean of 1,529 ms
- Echo time: from 8.144 ms to 151 ms with mean of 38.35
- Slice thickness: from 0.879 mm to 4 mm with mean of 3.14 mm

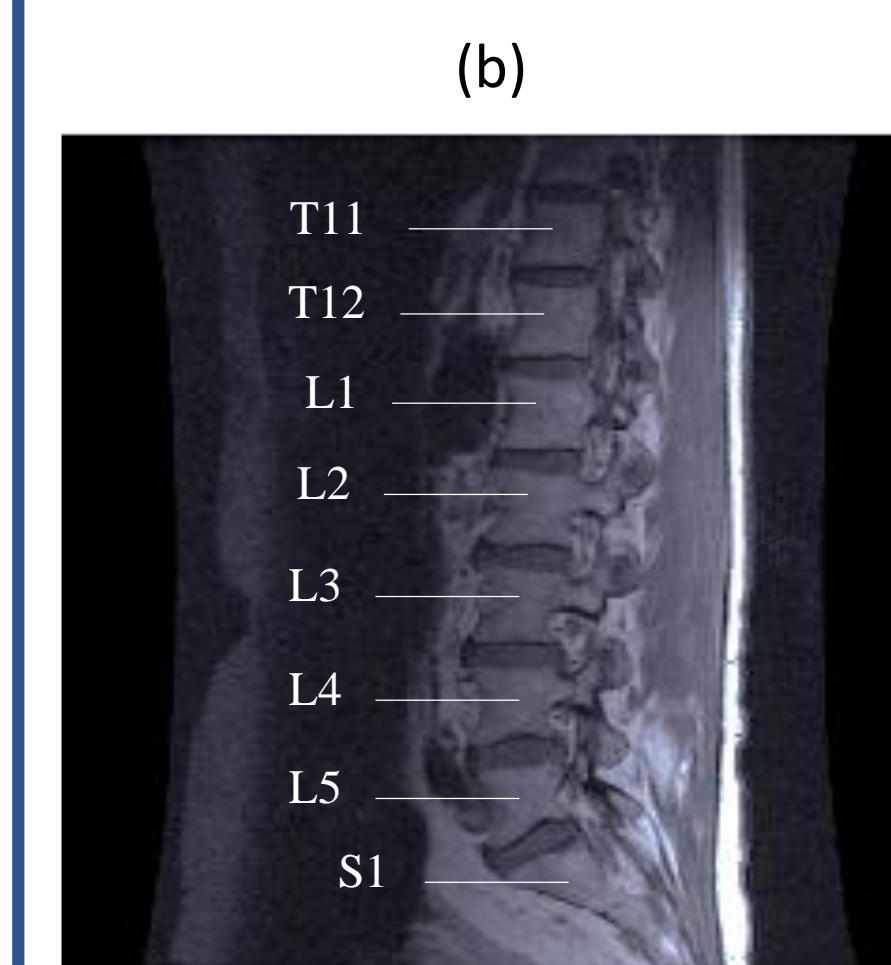
Segmentation Results



Generated Radiological Reports



(a) Radiological Report
At T12-L1, the intervertebral disc has obvious degenerative changes. The neural foramen does not have stenosis.
At L1-L2, the above vertebra has deformative changes. The intervertebral disc does not have obvious degenerative changes. The neural foramen does not have obvious stenosis.
At L2-L3, the neural foramen has obvious stenosis. The intervertebral disc does not have obvious degenerative changes. The above vertebra does not have deformative changes.
At L3-L4, disc degenerative changes are associated with neural foraminal stenosis.
At L4-L5, disc degenerative changes are associated with neural foraminal stenosis.
At L5-S1, the intervertebral disc has obvious degenerative changes. The above vertebra also has deformative changes. They lead to the neural foraminal stenosis.



(b) Radiological Report
At T12-L1, the intervertebral disc has obvious degenerative changes. The neural foramen does not have stenosis.
At L1-L2, the above vertebra does not have deformative changes. The intervertebral disc does not have degenerative changes. The neural foramen also does not have stenosis.
At L2-L3, the above vertebra does not have deformative changes. The intervertebral disc does not have degenerative changes. The neural foramen also does not have stenosis.
At L3-L4, the neural foramen has obvious stenosis. The intervertebral disc does not have obvious degenerative changes. The above vertebra does not have deformative changes.
At L4-L5, disc degenerative changes are associated with neural foraminal stenosis.
At L5-S1, the intervertebral disc has obvious degenerative changes. The above vertebra also has deformative changes. They lead to neural foraminal stenosis to a certain extent.