Vertebra Segmentation using Deep Learning

DTU Compute
Visual Computing
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Background

- 25 methods for labelling and segmentation of vertebra were benchmarked in the MICCAI 2019/2020 challenges on the VerSe dataset
- Most approaches are purely deep-learning based and perform better than other hybrid approaches* (using statistical shape models)
- Top performing aproaches all use 3D U-Nets in their segmentation algorithms
- The Dice-coefficient (a measure of the overlap of predicted and true class) of the segmentations can be seen in Figure 3

these are marked in purple in Figure 3.

My PhD project is part of **SOLID**, which is an **ESS Lighthouse**. I will also be collaborating with the Department of Forensic Medicine at Copenhagen University.

The VerSe dataset

- 374 multi-detector CT spine scans
- Ground truth vertebral centers and full segmentations
- 4505 individual vertebra, segmented at voxel-level
- Largest publicly available spine dataset

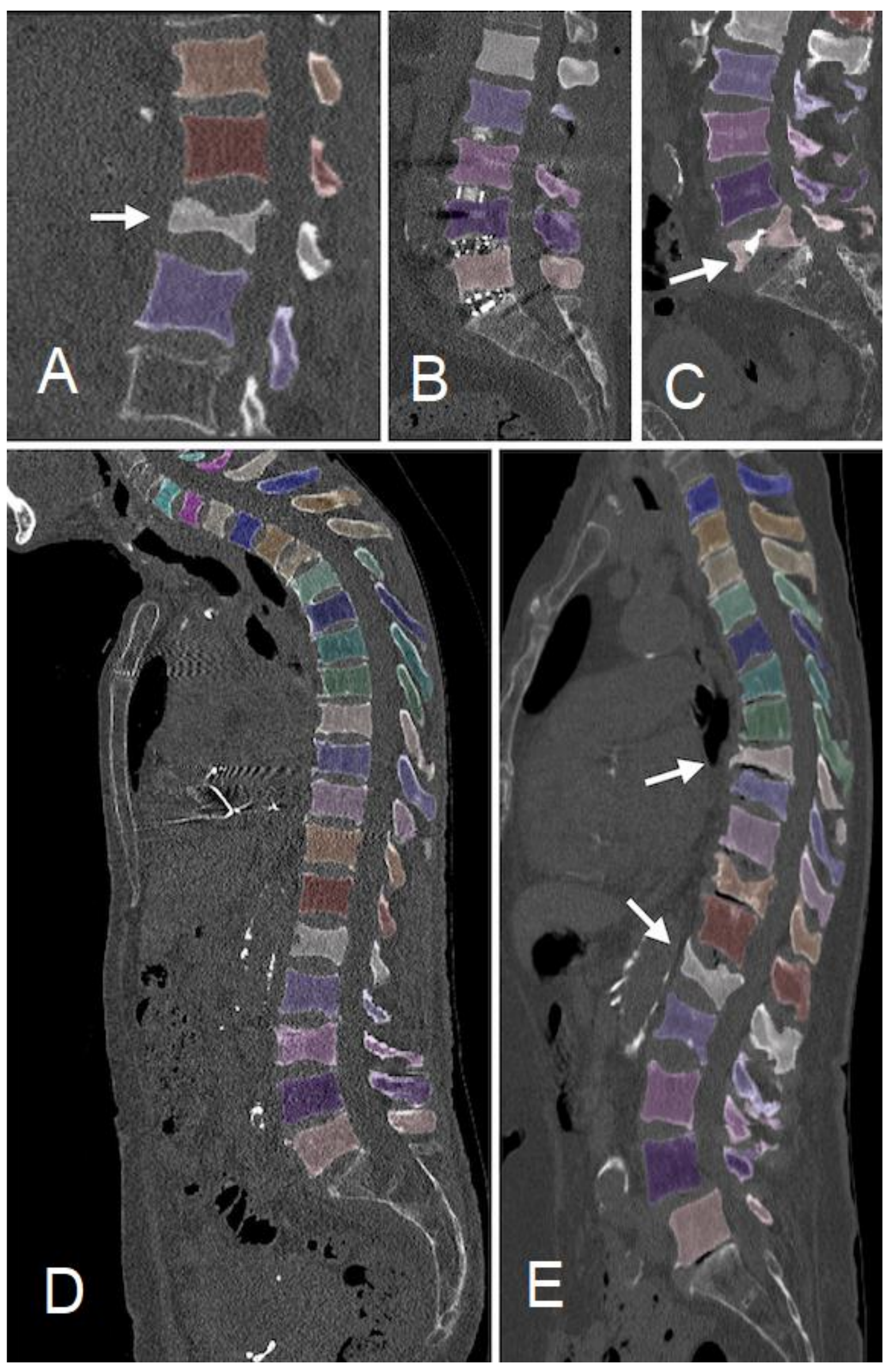

Figure 1. Anomalies: Fractured vertebra (A, E), metal insertions (B), cemented vertebra (C) and a noisy scan (D).

Figure adapted from [1]

Research questions

- What is the best way to do segmentation of vertebra?
- How can we utilize the full volume of the obtained scans and avoid downsampling?
- How can we quantify the structure of the bone in order to predict e.g. bone density and investigate osteoporosis cases?
- How can we best automate the process of obtaining valuable knowledge from spine scans?

Efficient and early detection of diseases

Osteoporosis is a severe condition, that increases the risk of death 8-fold. Information about size and shape of the vertebra as well as information about bone density enables improvement of diagnostics and treatment of this and other bone conditions such as fractures, scoliosis, kyphosis, etc.

Robust algorithms

Anatomical variations and pathologies that might be present in medical CT-scans of spines, such as vertebral fractures (Fig. 1 A+E), transitional vertebra, cemented vertebra (Fig. 1 C), metal implants (Fig. 1 B), etc. can complicate the segmentation and labelling process. It is important to take these cases into account when designing the algorithm.

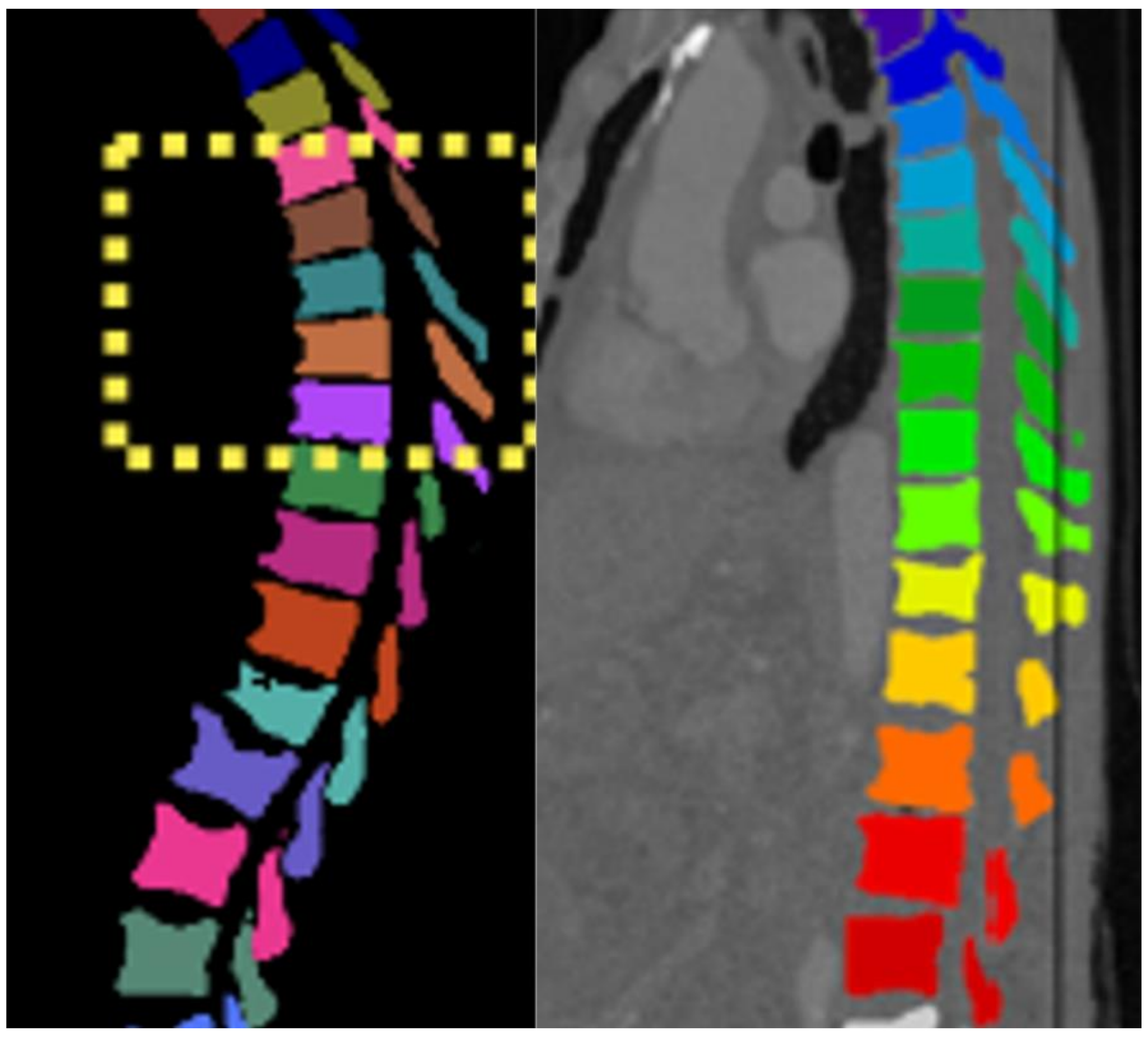

Figure 2. Segmentation from the Payer C. algorithm (left) and the ground truth multi-label segmentation map (right) used by [1] to benchmark the proposed methods. The map was obtained using a human-machine hybrid approach.

Figure adapted from [1]

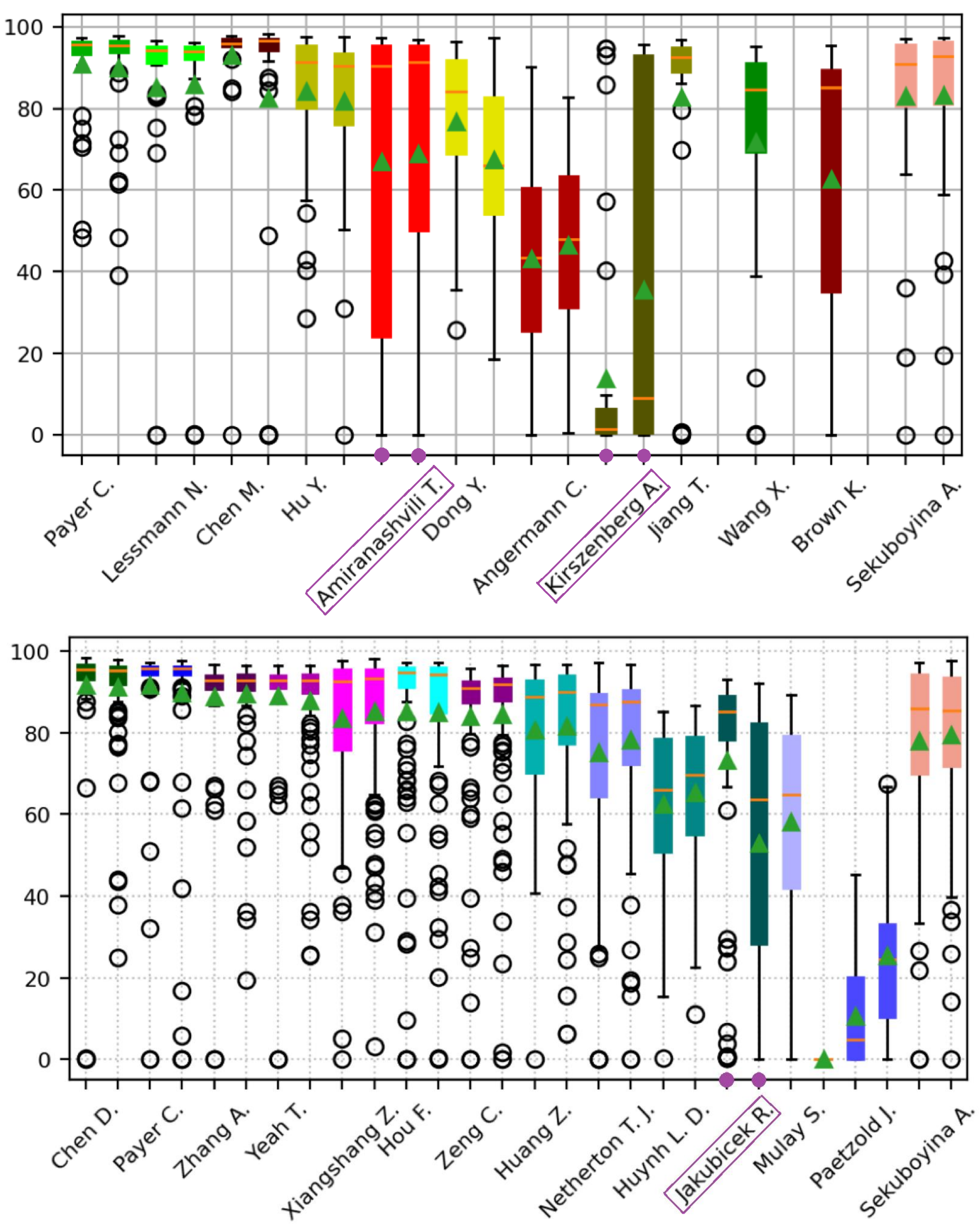

Figure 3. The Dice-coefficient of the benchmarked algorithms on the VerSe'19 (top) and VerSe'20 (bottom) data. Non-fully deep-learning approaches marked in purple.

Figure adapted from [1]

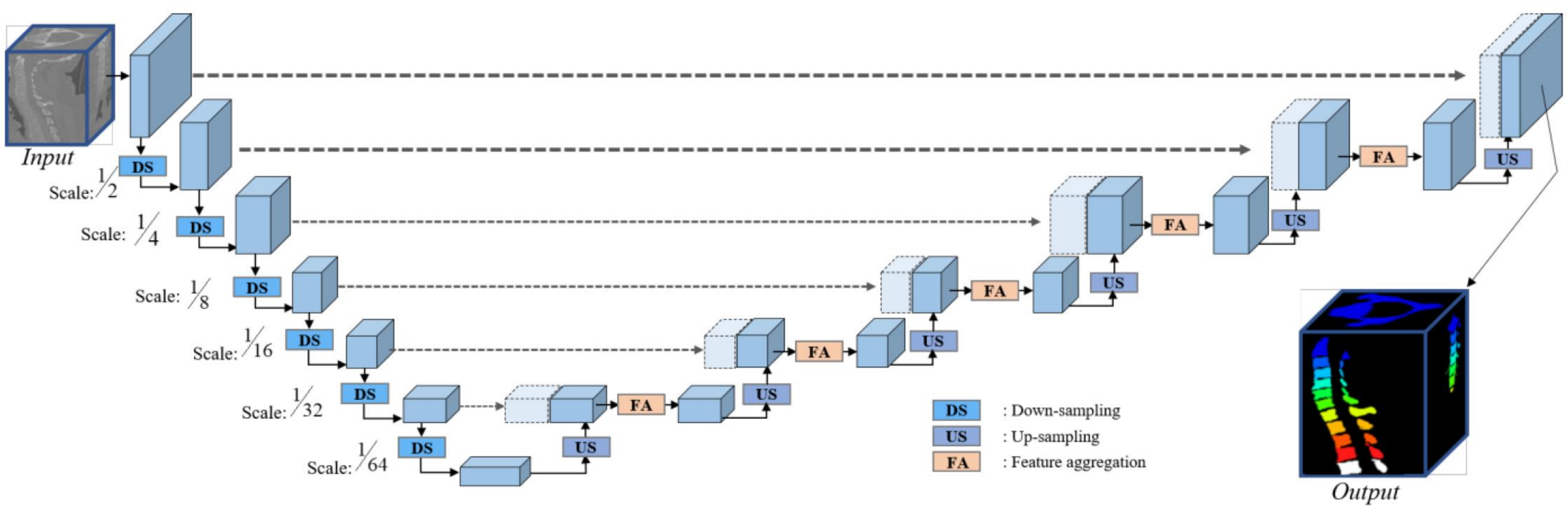

Figure 4. Example of a 3D U-Net used in one of the benchmarked methods.

Figure adapted from [1]

References

[1] Sekuboyina et al., VerSe: A Vertebrae Labelling and Segmentation Benchmark for Multi-detector CT Images, Medical Image Analysis, Volume 73, 2021