

# Vertebrae Localization in Pathological Spine CT via Dense Classification from Sparse Annotation

Ben Glocker<sup>1</sup>, Darko Zikic<sup>1</sup>, Ender Konukoglu<sup>2</sup>, David R. Haynor<sup>3</sup>, Antonio Criminisi<sup>1</sup>

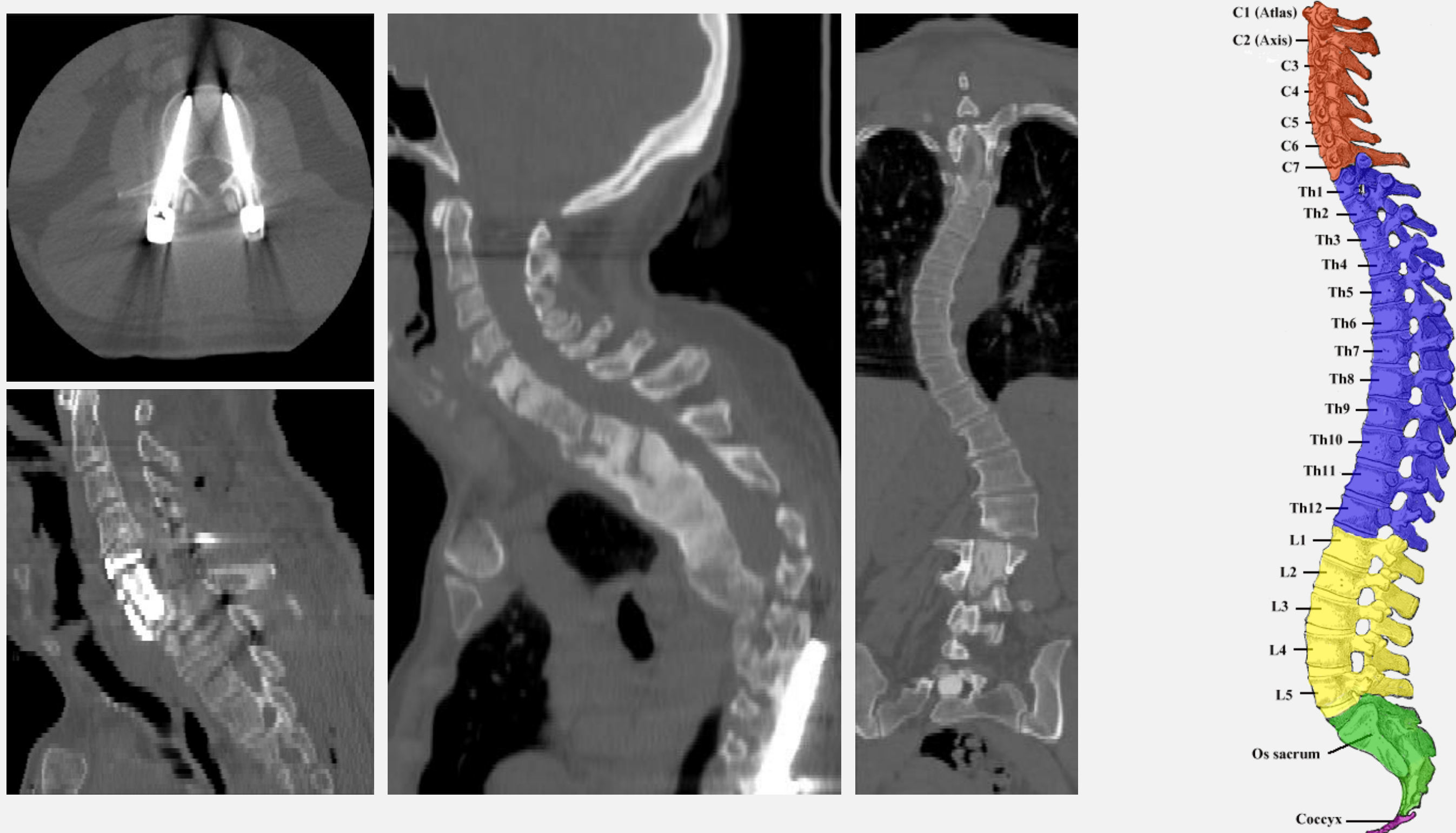
<sup>1</sup>Microsoft Research Cambridge, UK

<sup>2</sup>Martinos Center, MGH, Harvard Medical School, USA

<sup>3</sup>University of Washington, Seattle, USA

Microsoft  
Research

## Task: Locate and Name Vertebrae

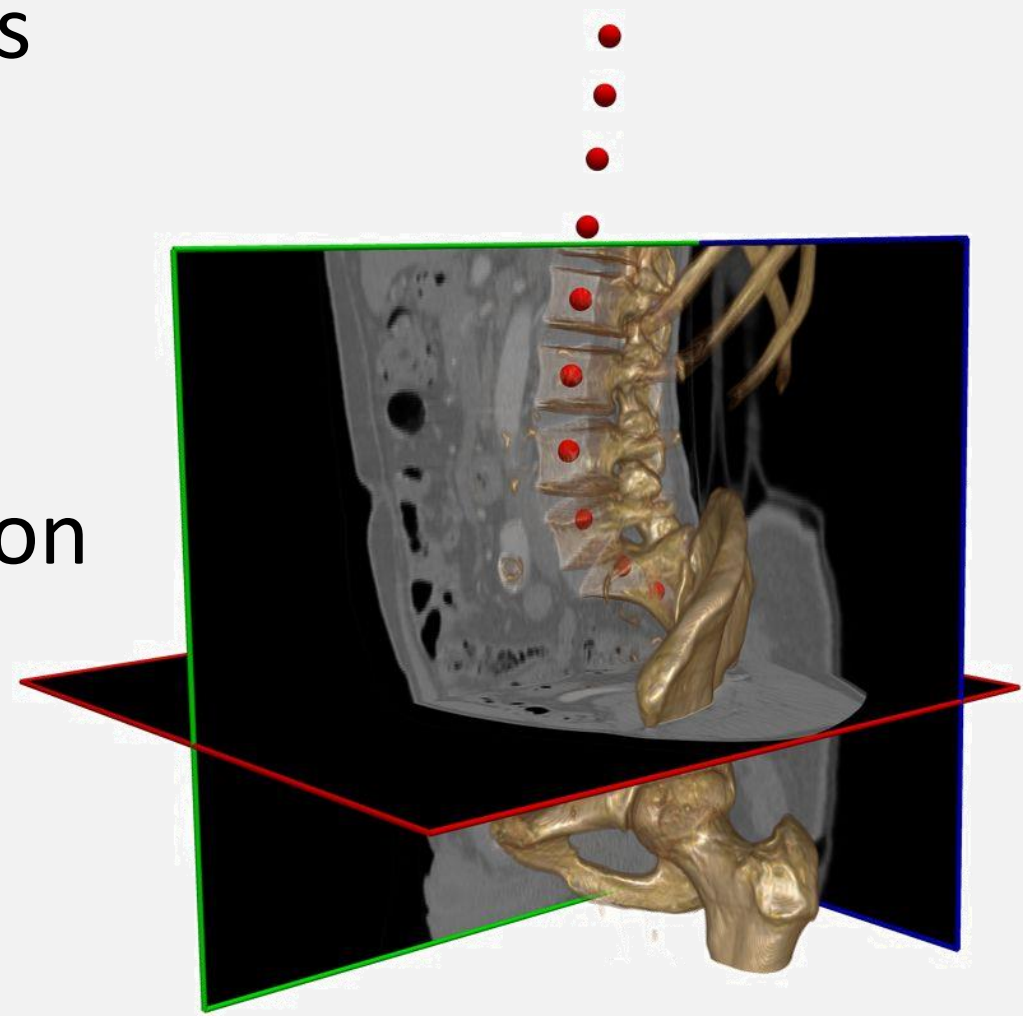


### Motivation: Patient-specific coordinate system

- longitudinal registration of pre- and post-operative scans
- initializing vertebral body segmentation methods
- image-guided assessment of surgical outcomes
- shape & population analysis

### Challenges

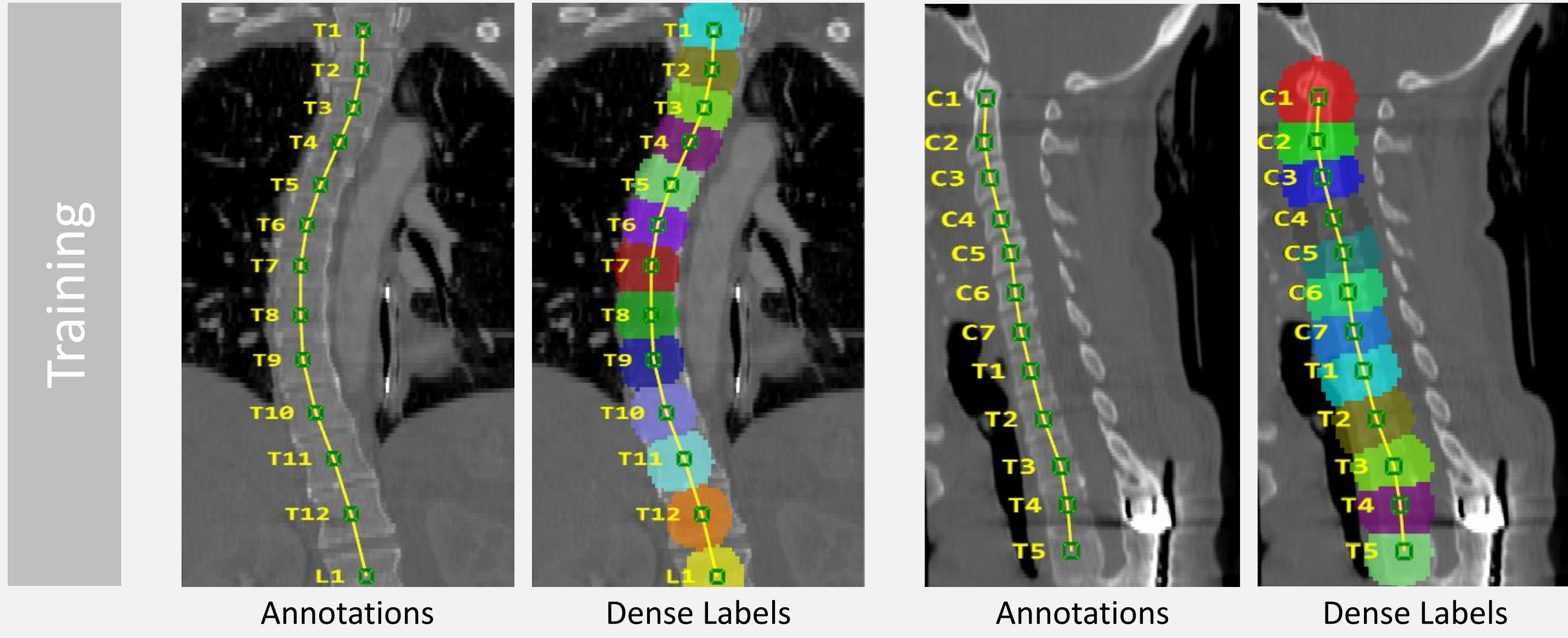
- small field-of-view, lack of contextual information
- low resolution, image noise
- presence of pathologies
- image artifacts due to surgical implants



## Localization via Dense Classification

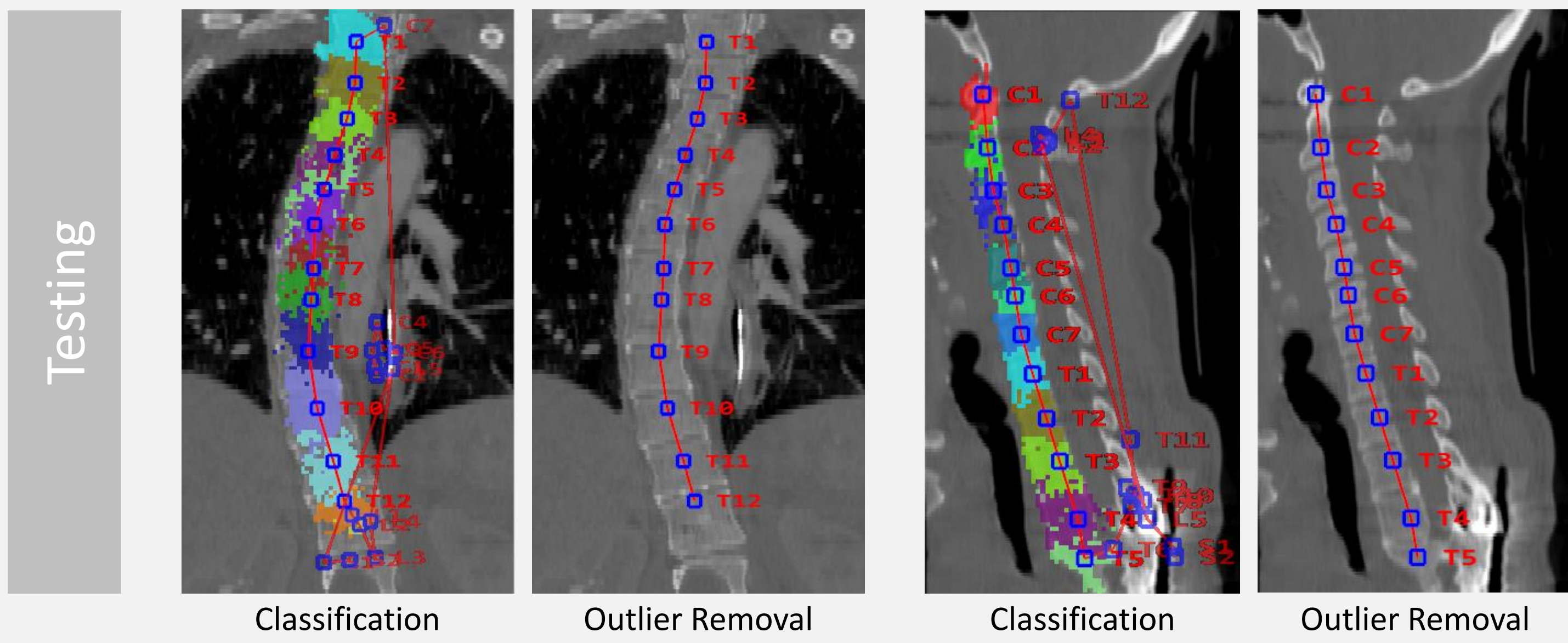
### › Dense Labels from Sparse Annotations

Generate training data for learning a dense classifier



### › Centroid Estimation from Dense Classification

Voxel-wise classification, mean shift, and outlier removal



## Quantitative Evaluation

### Two Clinical Datasets

#### Normal CT

- **200 CT scans**, mostly trauma patients
- slice distances between [0.5, 6.5]mm
- number of slices between [51, 2058]
- from only 4 vertebrae up to whole-body scans

#### Spine CT

- **224 CT scans**, spine patients
- pre- and post-operative scans
- limited view, 5-15 visible vertebrae
- include high-grade scoliosis, kyphosis, fractures, implants

### Localization Errors & Identification Rates

Method		Regression Forests + HMM [Glocker et al. 2011]				Proposed Approach			
Data	Region	Median	Mean	Std	Id.Rates	Median	Mean	Std	Id.Rates
Normal CT	All	5.4	9.7	11.2	80%	7.6	11.5	14.1	76%
	Cervical	6.5	8.2	6.1	73%	6.3	7.7	4.4	78%
	Thoracic	5.5	9.9	10.8	77%	8.7	12.4	11.6	67%
	Lumbar	5.3	9.4	12.0	86%	6.6	10.6	16.9	86%
Spine CT	All	14.8	20.9	20.0	51%	8.8	12.4	11.2	70%
	Cervical	11.5	17.0	17.7	54%	5.9	7.0	4.7	80%
	Thoracic	12.7	19.0	20.5	56%	9.8	13.8	11.8	62%
	Lumbar	23.2	26.6	19.7	42%	10.2	14.3	12.3	75%

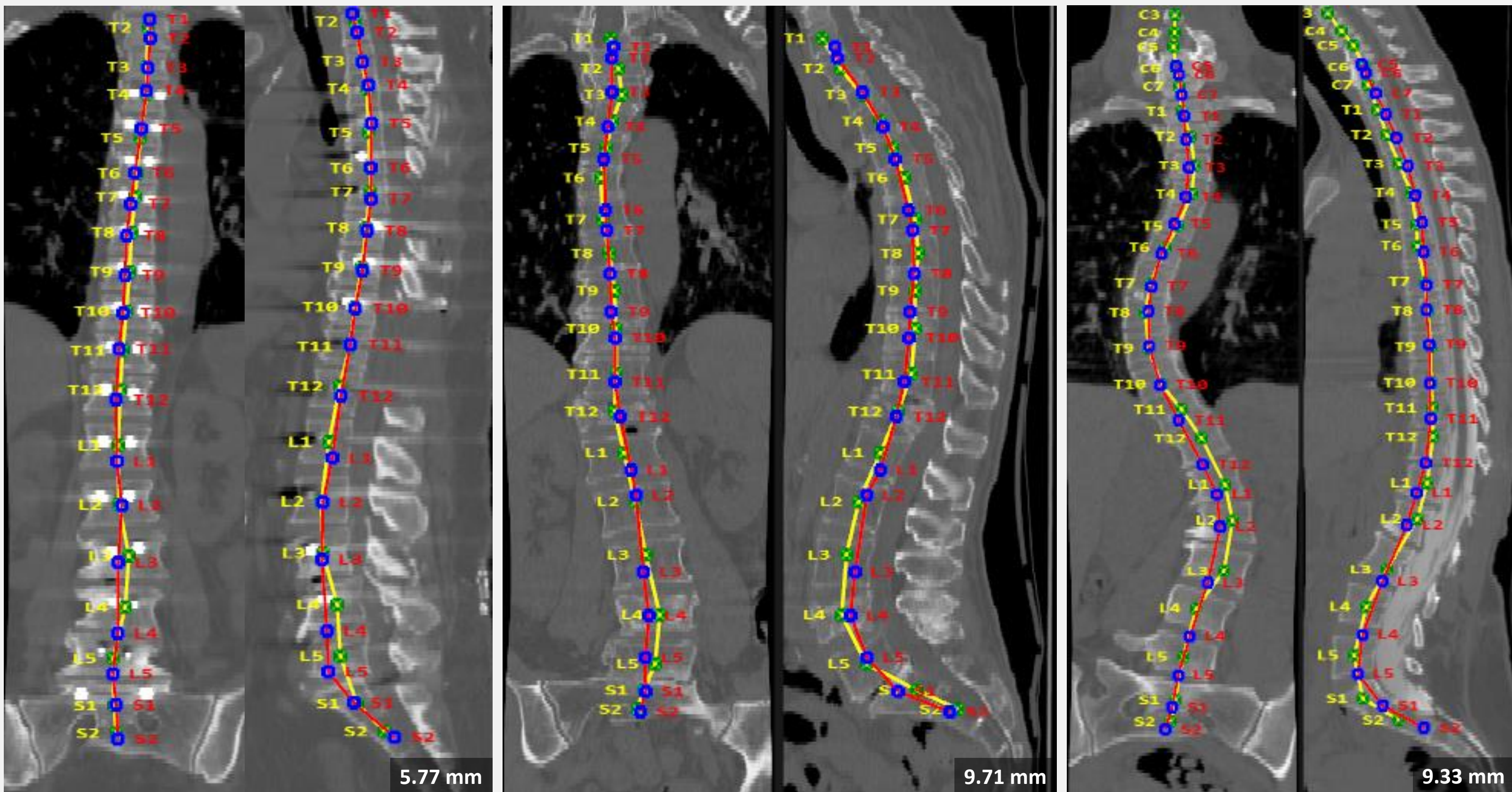
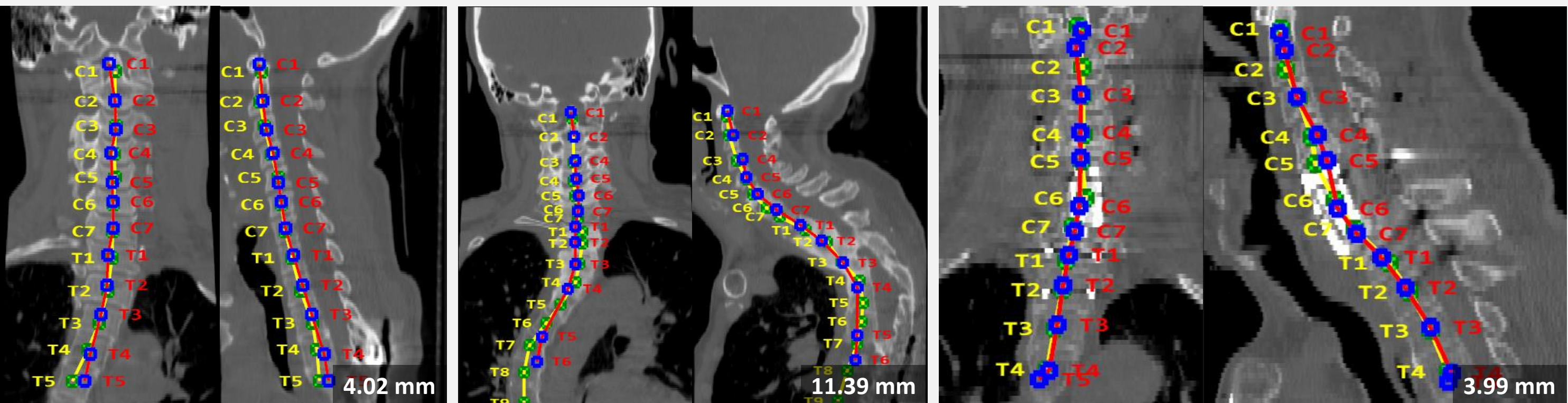
### Experimental Setup

- 2-fold cross-validation (50/50% train-test split)
- 20 trees, depth 24, minimum 8 examples
- 2000 random features with 200 features tested per node
- include only image points in the HU range of spinal structures

### Computational Efficiency

- Intel Xeon 2.27GHz, 12 GB RAM, C# implementation
- **Localization of all vertebrae in 512<sup>2</sup>x200 images takes 1 minute**

### Visual Examples



Spine CT dataset available on  
<http://research.microsoft.com/medimaging>