Robust Registration of Longitudinal Spine CT

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BioMedIA

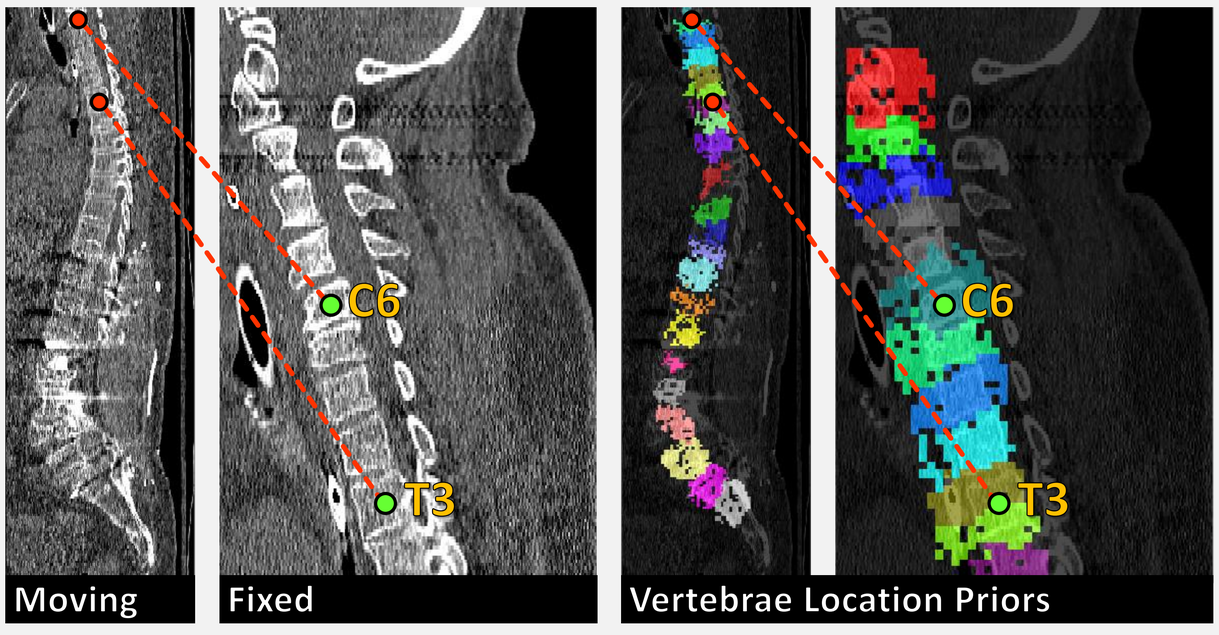
Longitudinal Registration

Challenge: Fully automatic, robust initialization

- Robust initialization is a major challenge for automatic methods
- Pre- and post-operative scans can vary significantly, e.g. small overlap
- Shape differences after treatment of deformities, e.g. scoliosis
- Appearance differences due to surgical implants, e.g. metal screws

Solution: Use of location priors during registration

- Learning-based extraction of semantic information from images
- Location priors provide patient-specific coordinate system
- Priors are used to initialize the registration and guide the optimization
- Integrating priors significantly reduces the number of failure cases

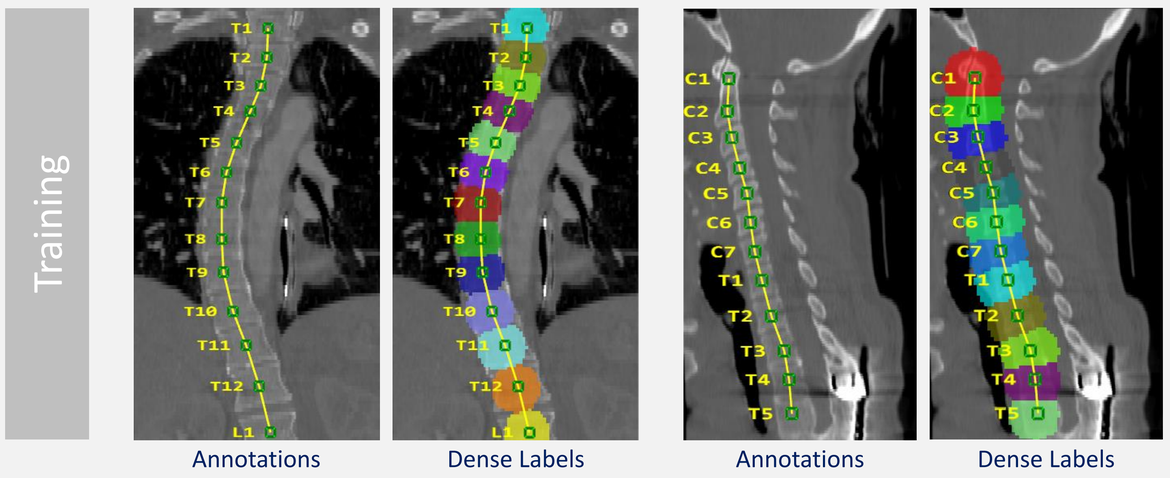


Localization Priors via Classification

Glocker et al. "Vertebrae Localization in Pathological Spine CT via Dense Classification from Sparse Annotations". MICCAI 2013

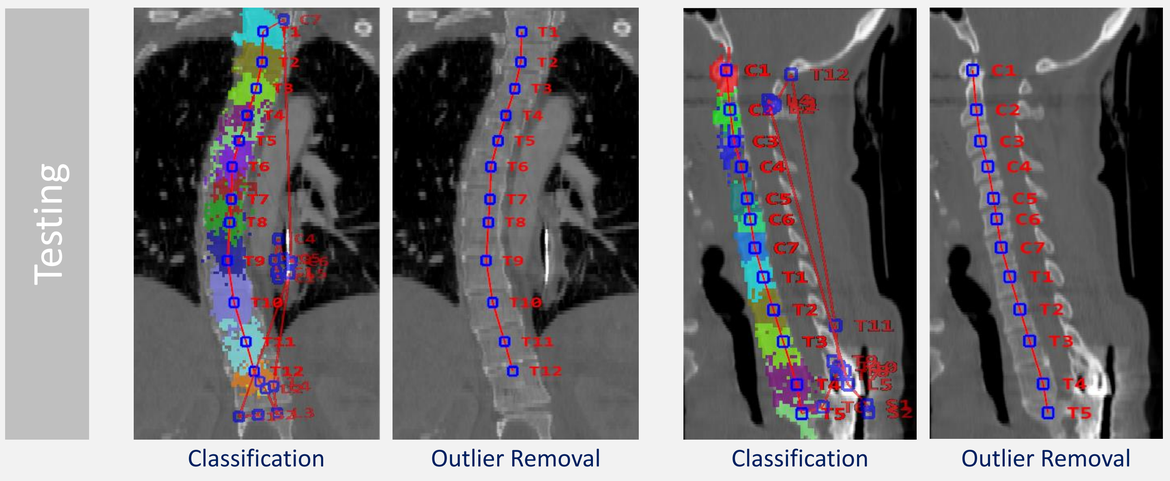
› Dense Labels from Sparse Annotations

Generate training data for learning a dense classifier



› Centroid Estimation from Dense Classification

Voxel-wise classification, mean shift, and outlier removal



Registration Procedure

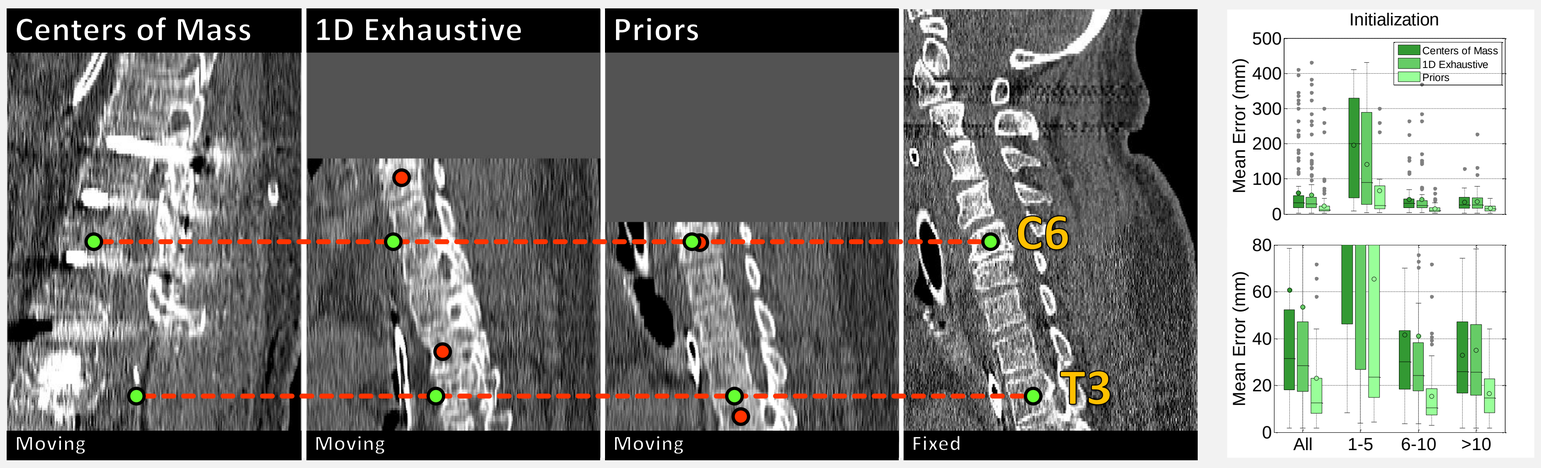
1. Prior-based Initialization
2. Rigid Registration
3. FFD-based Non-rigid Registration

Prior-based Registration Objective

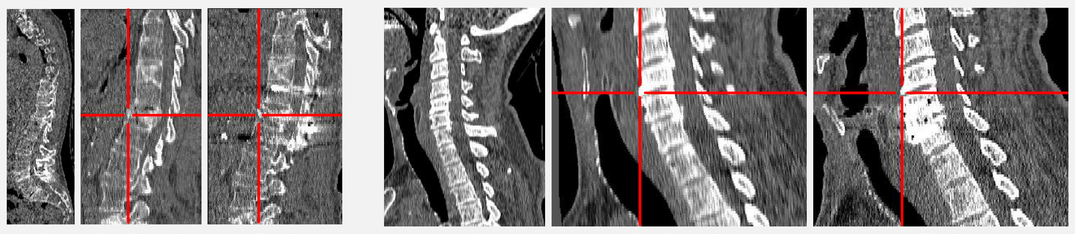
Incorporating priors into optimization problem

$$\psi\big(\underbrace{I,J}_{\text{Images}},\underbrace{P_I,P_J}_{\text{Prior Maps}},T\big)=\underbrace{\rho(T(I),J)}_{\text{Intensity-based objective}}+\frac{1}{\underbrace{|\mathcal{V}_{IJ}|}_{\text{Detected Vertebrae}}}\sum_{v\in\mathcal{V}_{IJ}}\underbrace{\phi\left(T\big(P_I(v,\cdot)\big),P_J(v,\cdot)\right)}_{\text{Prior-based objective}}$$

Initialization with different methods



Visual registration examples

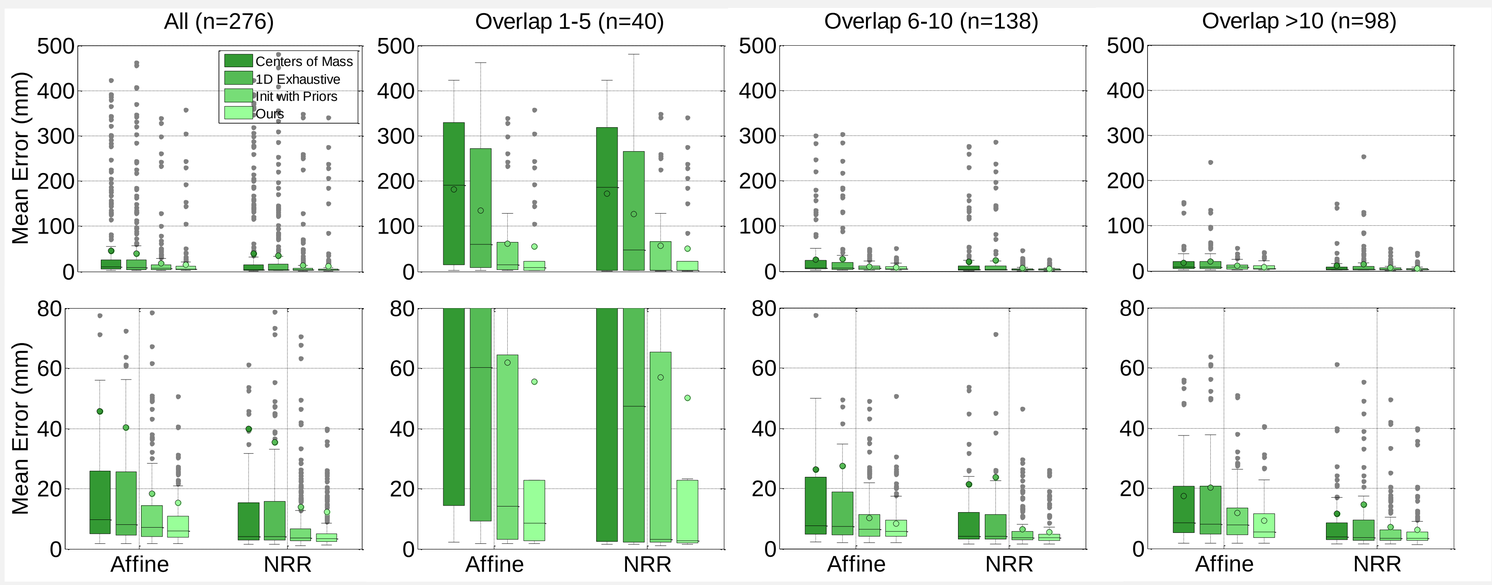


Quantitative Evaluation

Baselines for Comparison

- '**Centers of Mass**': pre-aligns centers of intensity masses
- '**1D Exhaustive**': exhaustive search along the main anatomical axis

Statistics of registration errors for different methods



Computational Efficiency

- Intel Xeon 3.5GHz, C# implementation
- **Registration including prior computation takes 2 min**

Clinical Spine CT Dataset*

*available on http://research.microsoft.com/spine

- **CT scans from 93 patients**
- **A total of 276 registrations**
- pre- and post-operative scans
- limited view, 5-15 visible vertebrae
- include high-grade scoliosis, kyphosis, fractures, implants
- manual annotations of all vertebrae centroids available

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