Robust Registration of Longitudinal Spine CT

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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

Registration Procedure

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

Prior-based Registration Objective
Incorporating priors into optimization problem

\[ \psi(I, J, P_i, P_j, T) = \rho(T(I), J) + \frac{1}{|V_{ij}|} \sum_{v \in V_{ij}} \phi(T(P_i(v)), P_j(v)) \]

Quantitative Evaluation
Baselines for Comparison
- 'Centers of Mass': pre-aligns centers of intensity masses
- '1D Exhaustive': exhaustive search along the main anatomical axis

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

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

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