Medical Image Processing for Diagnostic Applications

Image Registration in Practice – Part 1

Online Course – Unit 67

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Topics

Example of 3-D/3-D Registration: Rigid Registration of the Airways

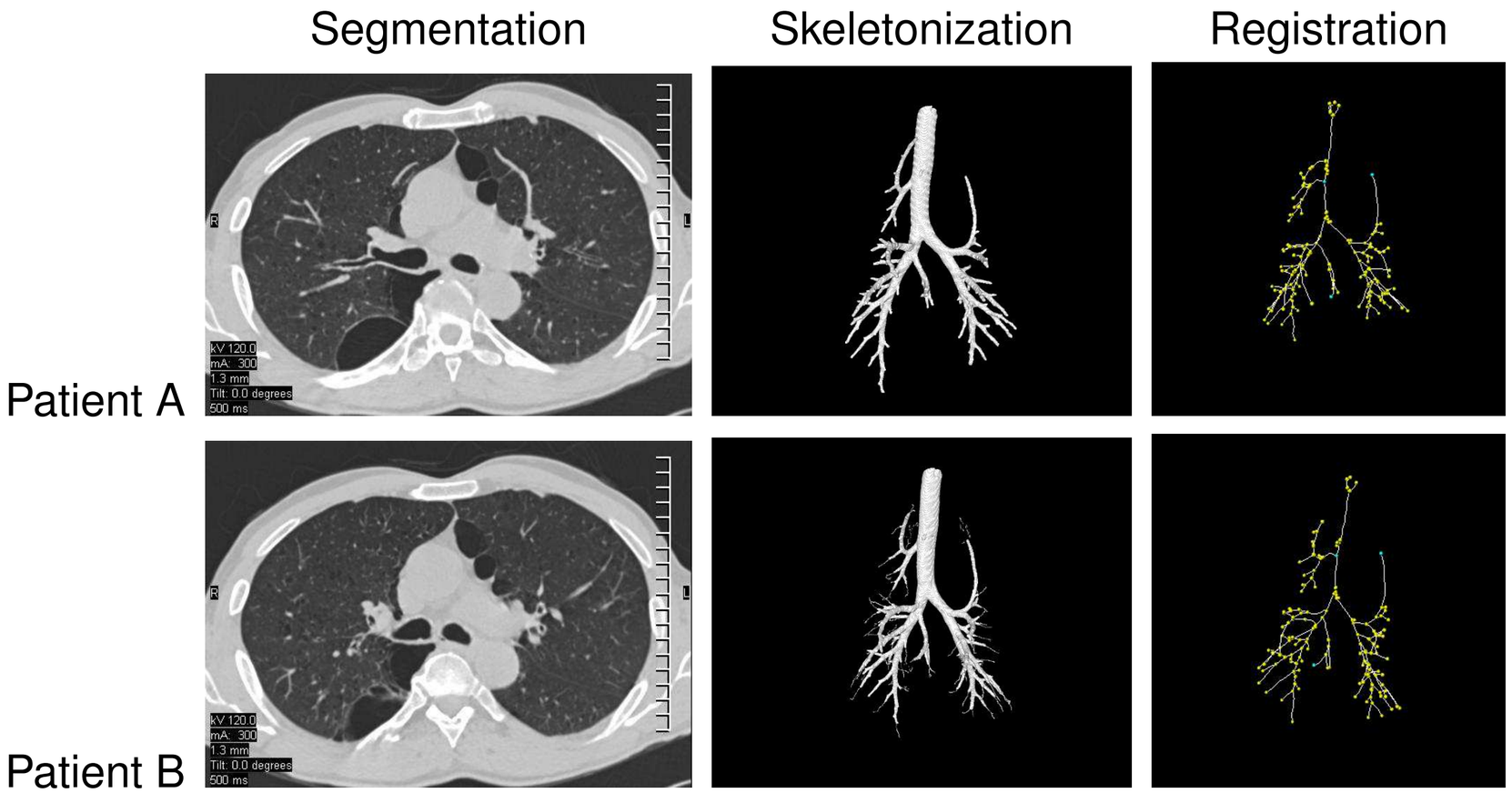

Figure 1: Rigid registration of the airways

Projections from 3-D to 2-D

Motivation: 2-D/3-D image fusion is important for applications where volume data and X-ray projections have to be registered.

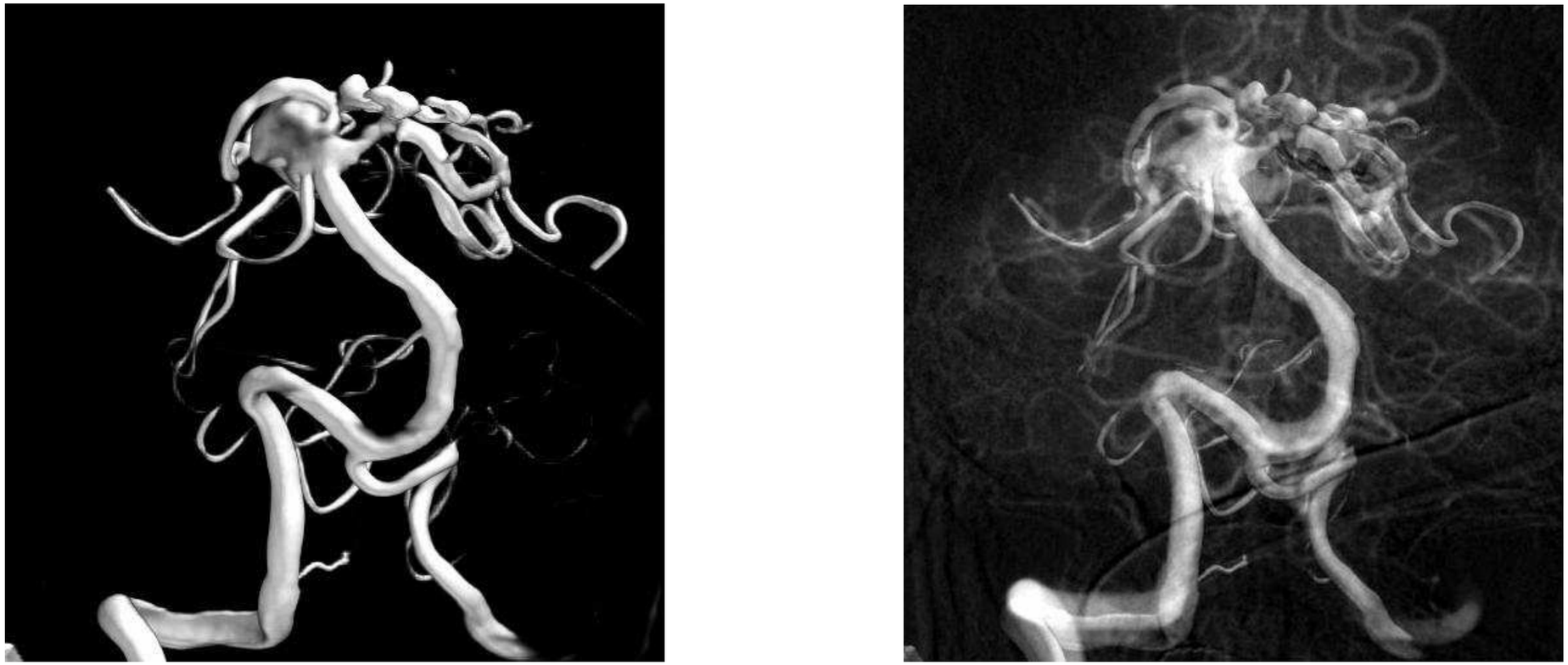

Figure 2: 2-D/3-D image fusion

Intramodal Registration

Examples for the requirement of intramodal registration are:

- digital subtraction angiography (DSA),
- dual energy X-ray and CT,
- visualization of perfusion,
- visualization of differences (therapy control),
- motion estimation (for instance, in cardiac reconstruction).

Digital Subtraction Angiography

Figure 3: Mask image (left), fill image (middle), angiogram (right)

Digital Subtraction Angiography

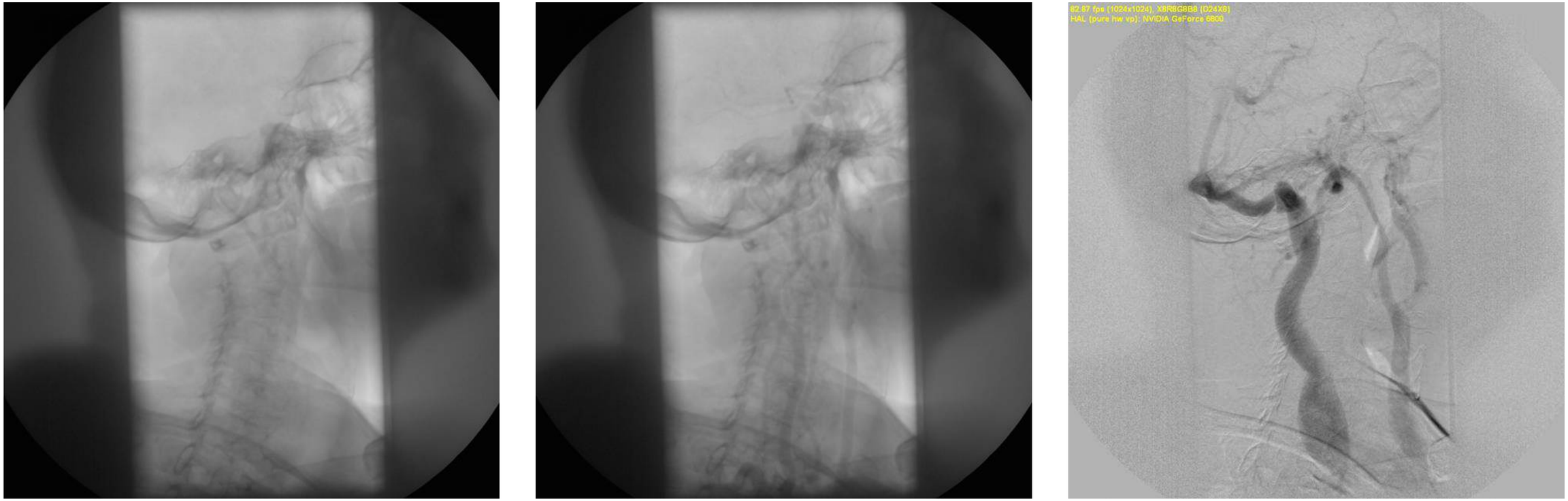

Figure 4: Mask image (left), fill image (middle), angiogram (right)

Motion Artifacts in DSA

Figure 5: Motion artifacts in DSA (Yu Deuerling-Zheng, Pattern Recognition Lab, FAU)

Motion Artifacts in DSA

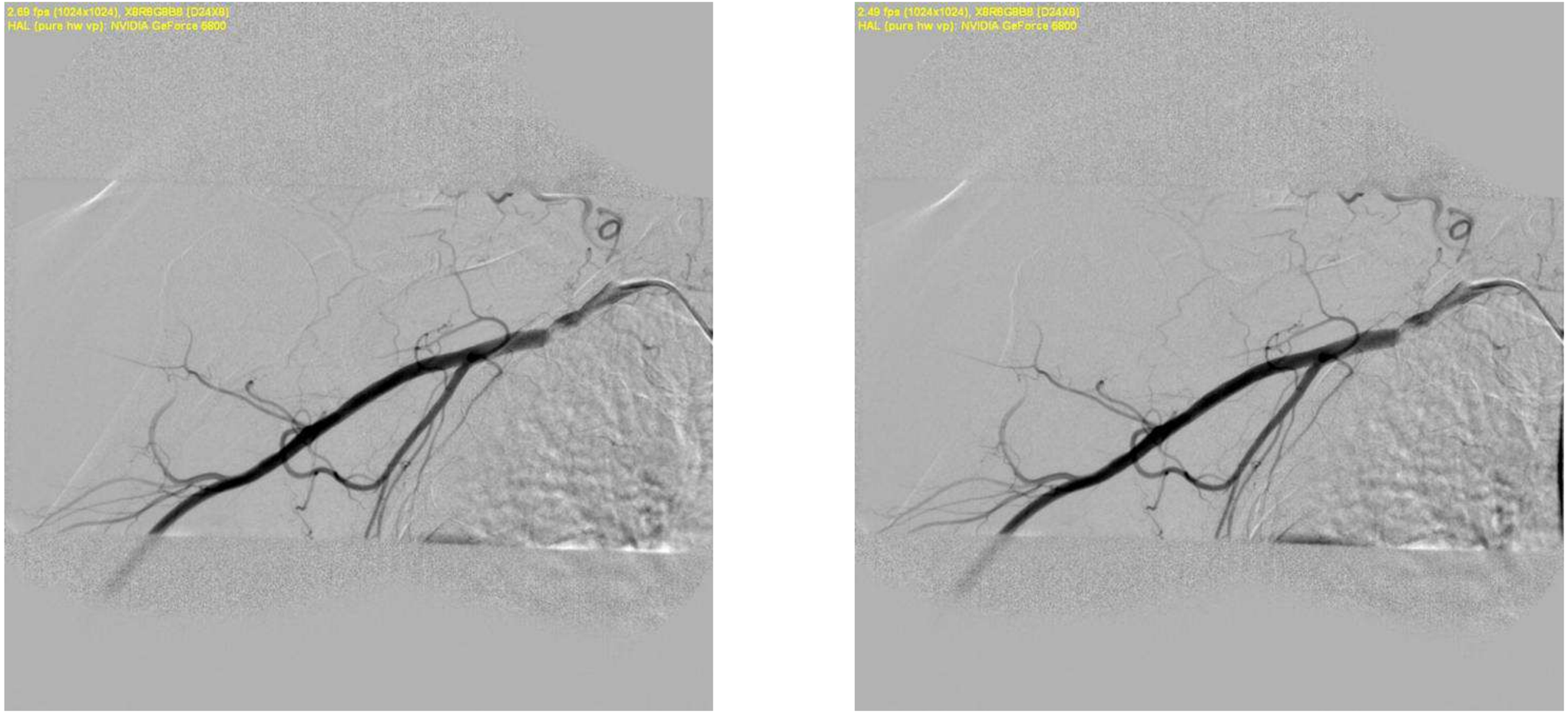

Figure 6: Motion artifacts in DSA (Yu Deuerling-Zheng, Pattern Recognition Lab, FAU)

Similarity Measures

Sum of squared differences (SSD):

$$\widehat{T} = \arg\min_{T} \sum_{i,j} \left\| f_{i,j} - T\{g_{i,j}\} \right\|^2$$

Correlation coefficient:

$$\widehat{T} = \arg\max_{T} \frac{\sum_{i,j}(f_{i,j} - \bar{f})(T\{g_{i,j}\} - \bar{g})}{\sqrt{\sum_{i,j}(f_{i,j} - \bar{f})^2 \sum_{i,j}(T\{g_{i,j}\} - \bar{g})^2}}$$

Notation:

- $[f_{i,j}]$: reference image
- $[g_{i,j}]$: image to be registered
- T: transform
- $\bar{f}$: mean intensity value of reference image
- $\bar{g}$: mean intensity value of second image

Difference Imaging in CT

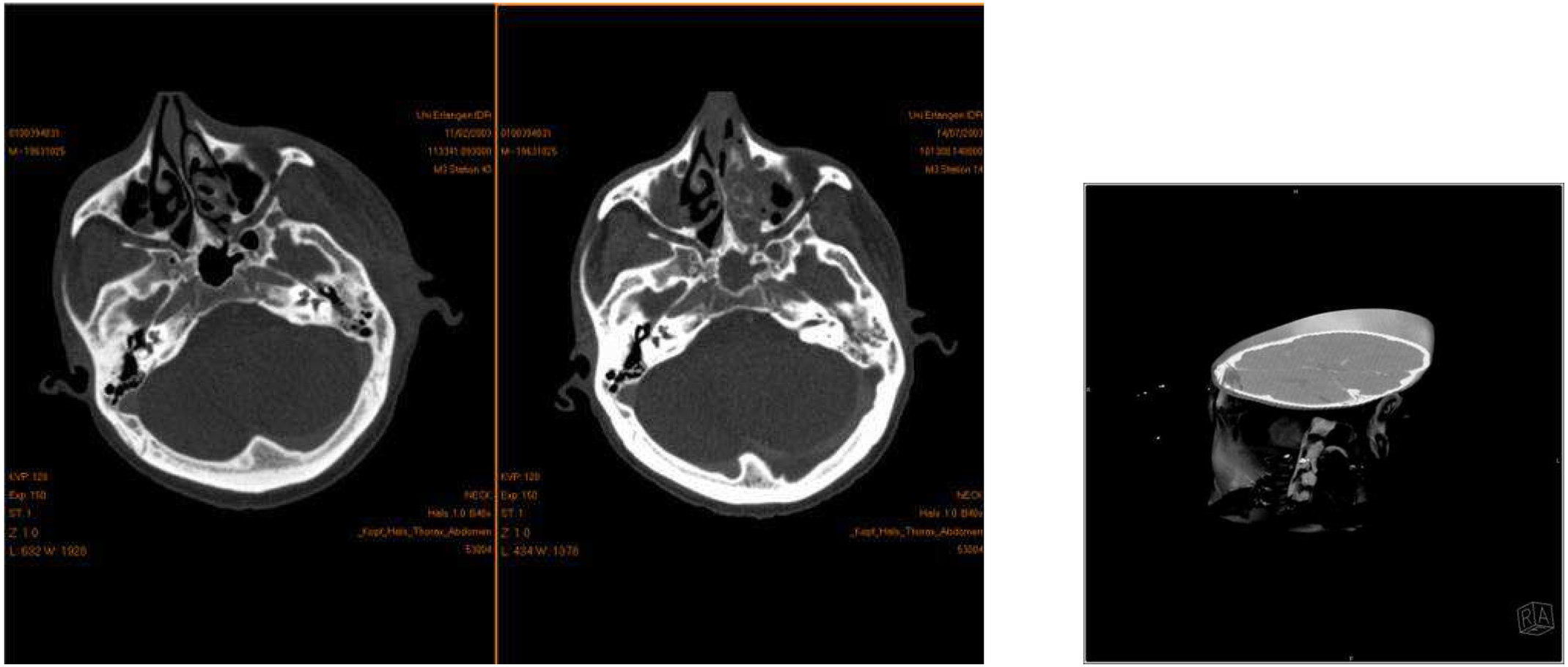

Figure 7: Difference imaging in CT (Dieter Hahn, Pattern Recognition Lab, FAU)

Registration Combined with Segmentation

Problem: Differences in images lead to a bias if all voxels are used for registration.

Solution: Apply a weighting scheme to voxels. Voxels that belong to bones are rigid and allow for a reliable estimate for the transform (high weights). Soft tissue deforms, for instance, with tumor growth and thus implies a bias (low weights).

Registration in CT using Transfer Functions

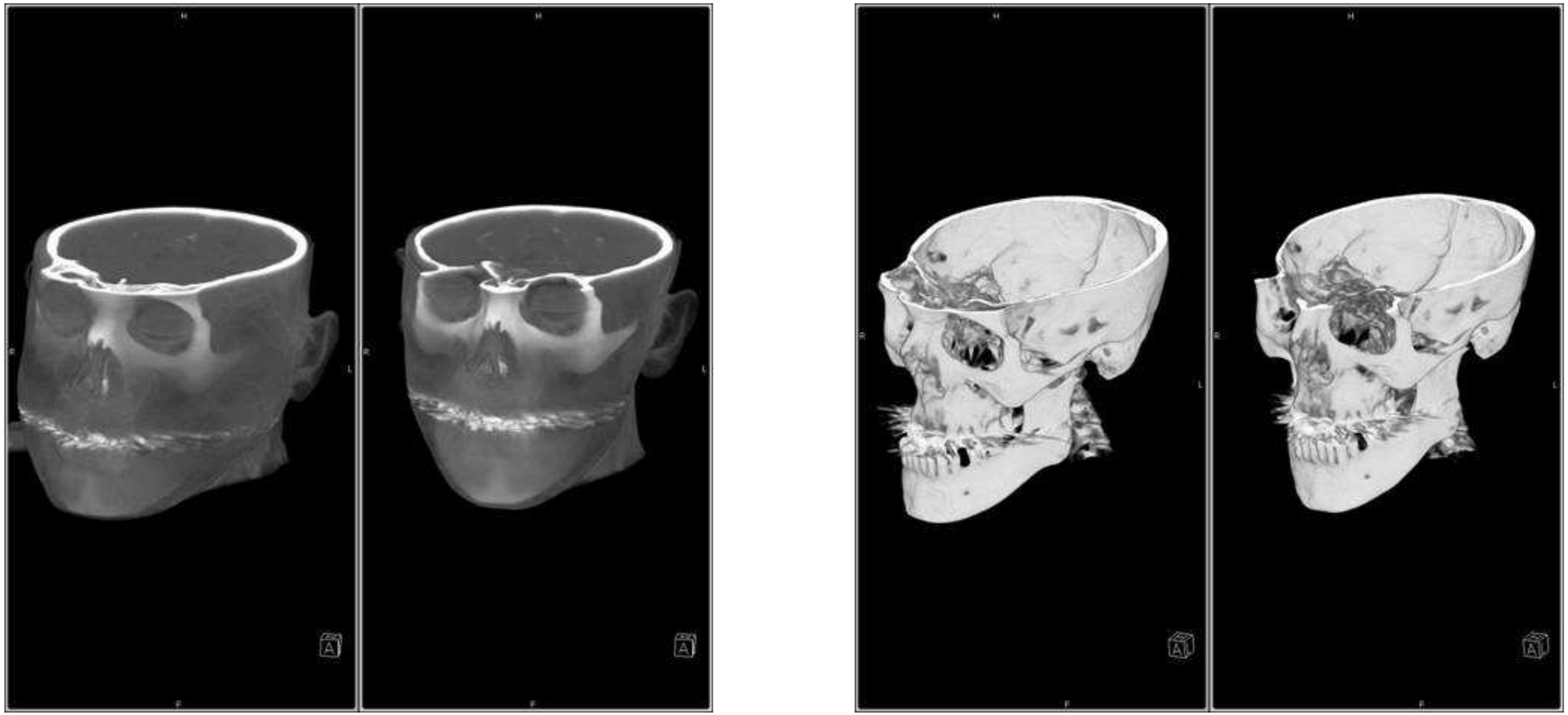

Figure 8: Difference imaging in CT: segmentation of bones (Dieter Hahn, Pattern Recognition Lab, FAU)

Registration in CT

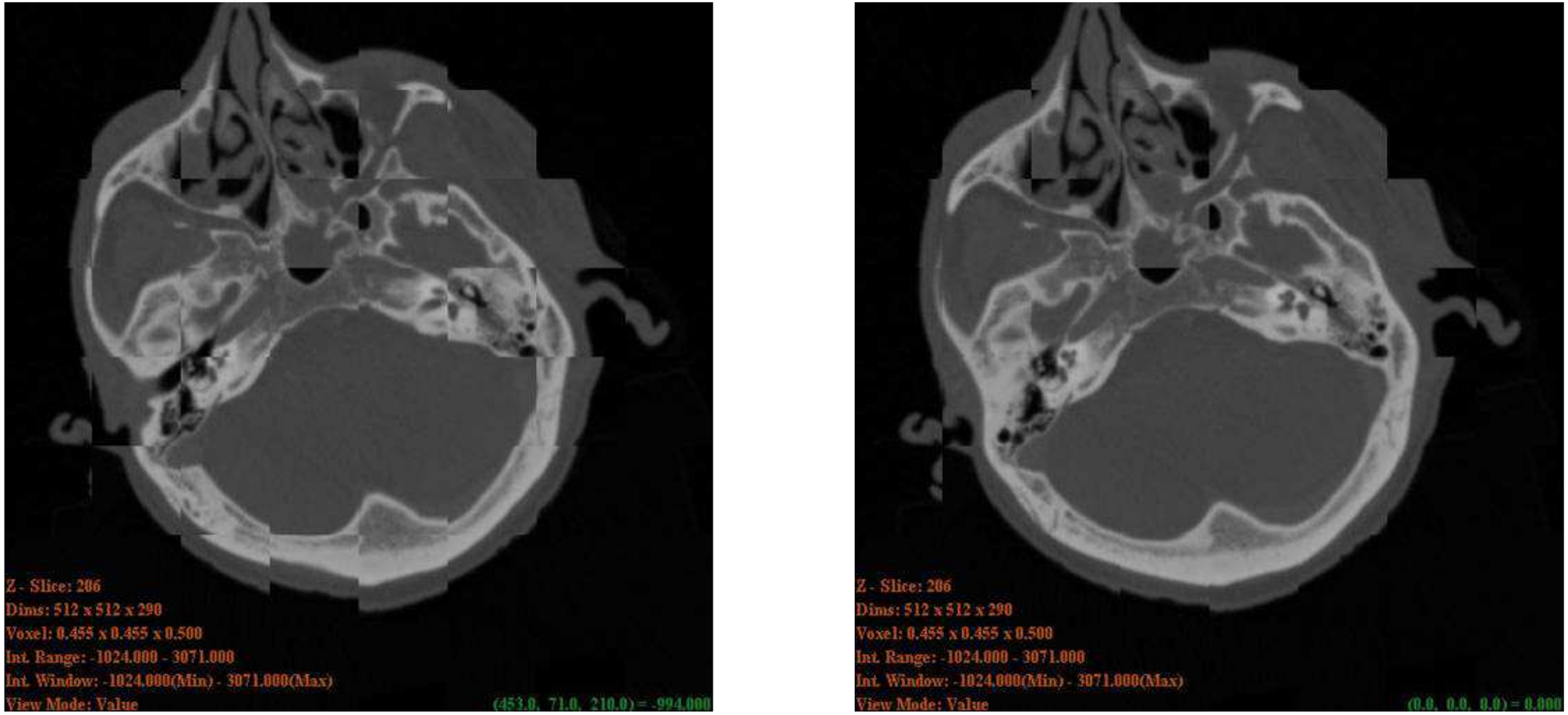

Figure 9: Checker board representation of results: no bone segmentation (left), bone segmentation (right) (Dieter Hahn, Pattern Recognition Lab, FAU)

Registration in CT

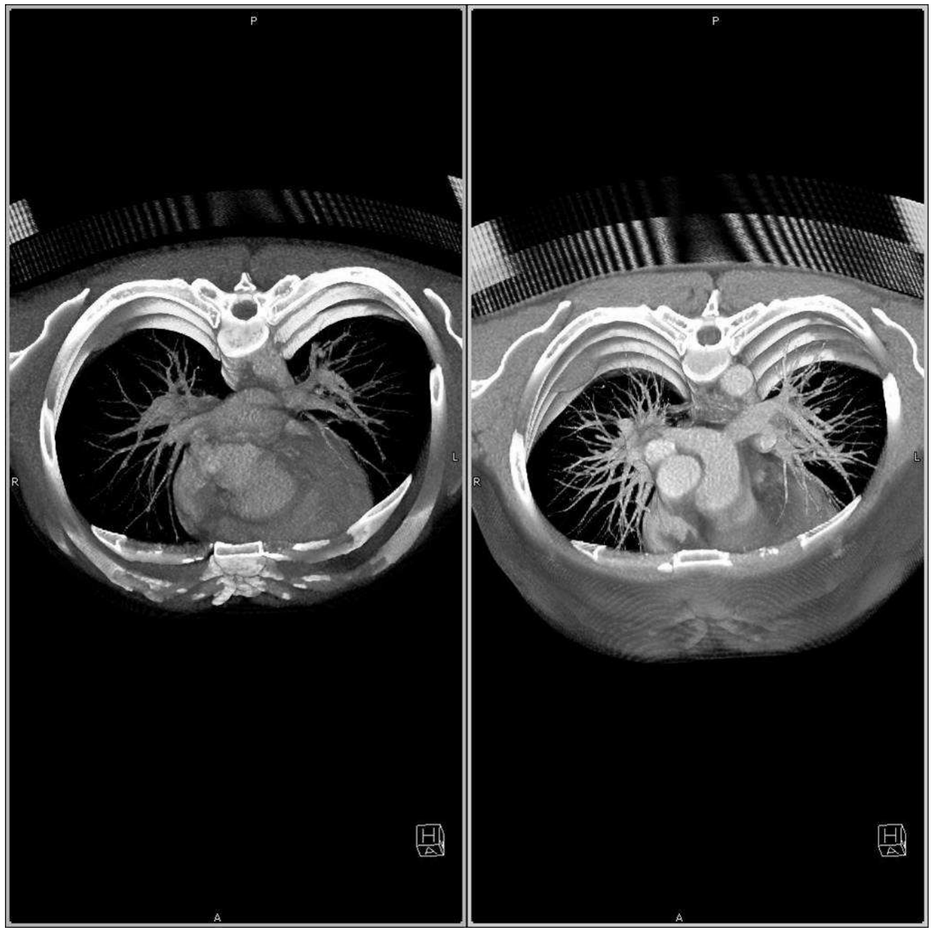

Figure 10: Thorax: tumor at two different therapy stages (Dieter Hahn, Pattern Recognition Lab, FAU)

Registration in CT

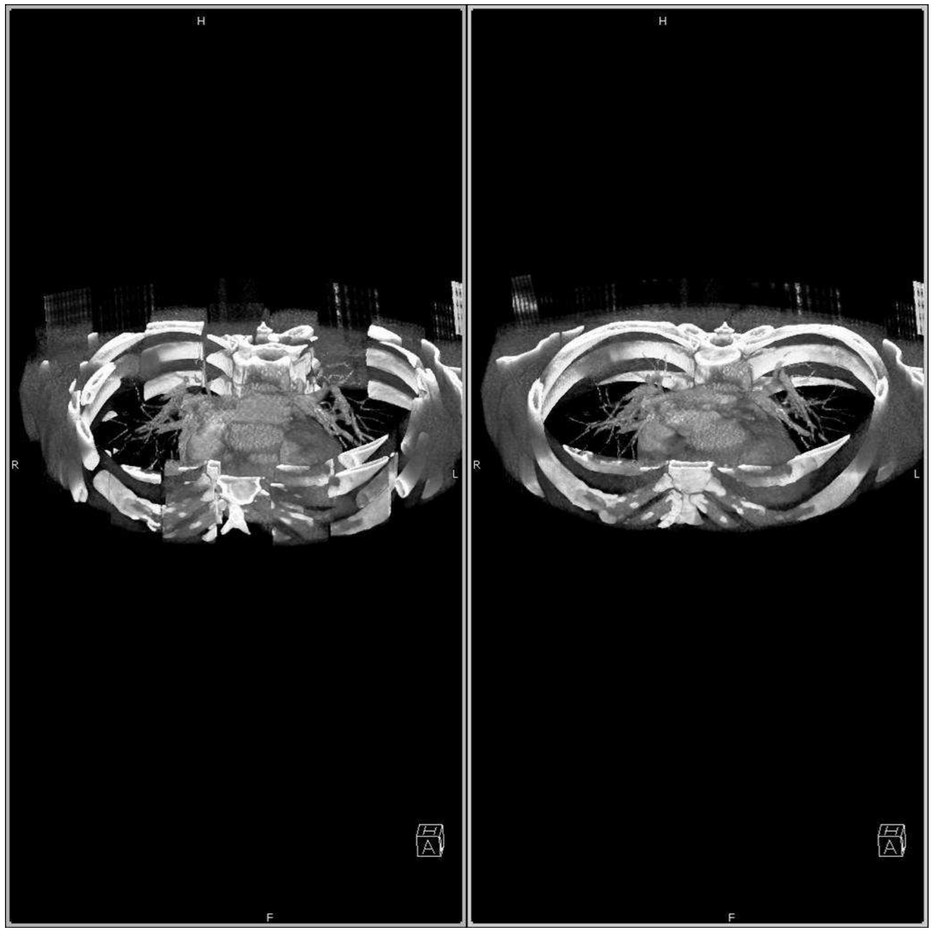

Figure 11: Checker board representation of results: no bone segmentation (left), bone segmentation (right) (Dieter Hahn, Pattern Recognition Lab, FAU)

Registration in CT

Figure 12: Difference image (Dieter Hahn, Pattern Recognition Lab, FAU)

Topics

Take Home Messages

- There is a multitude of applications of intramodal registration alone.
- It can be combined with segmentation methods, and it can be used to generate difference images.

Further Readings – Part 1

Survey papers on medical image registration:

- Derek L. G. Hill et al. “Medical Image Registration”. In: *Physics in Medicine and Biology* 46.3 (2001), R1–R45
- J. B.Antoine Maintz and Max A. Viergever. “A Survey of Medical Image Registration”. In: *Medical Image Analysis* 2.1 (1998), pp. 1–36. DOI: 10.1016/S1361-8415(01)80026-8
- L. G. Brown. “A Survey of Image Registration Techniques”. In: *ACM Computing Surveys* 24.4 (Dec. 1992), pp. 325–376. DOI: 10.1145/146370.146374
- Josien P. W. Pluim, J. B. Antoine Maintz, and Max A. Viergever. “Mutual-Information-Based Registration of Medical Images: A Survey”. In: *IEEE Transactions on Medical Imaging* 22.8 (Aug. 2003), pp. 986–1004. DOI: 10.1109/TMI.2003.815867

A paper that inspired all the sections on complex numbers, quaternions, and dual quaternions:

Konstantinos Daniilidis. “Hand-Eye Calibration Using Dual Quaternions”. In: *The International Journal of Robotics Research* 18.3 (Mar. 1999), pp. 286–298. DOI: 10.1177/02783649922066213

Further Readings – Part 2

Non-parametric mappings for image registration:

- Nonlinear registration methods applied to DSA can be found in Erik Meijering's papers.
- Jan Modersitzki. *Numerical Methods for Image Registration*. Numerical Mathematics and Scientific Computations. Oxford Scholarship Online, 2007. Oxford: Oxford University Press, 2003. DOI: 10.1093/acprof:oso/9780198528418.001.0001
- Many of Jan Modersitzki's and Bernd Fischer's papers on image registration can be found in the publication list of the Institute of Mathematics and Image Computing (Lübeck).
- The group of Martin Rumpf also published on non-parametric image registration. Details on their work can be found on the institute's webpage.