EPOSTM
Electronic Presentation Online System

Patient motion correction in low dose tomographic (3D +Time) fluoroscopy

Poster No.: C-1960
Congress: ECR 2013
Type: Scientific Exhibit
Authors: B. Flach[1], M. Brehm[1], J. Kuntz[2], S. H. Bartling[2], M. Kachelrieß[1]; [1]Erlangen/DE, [2]Heidelberg/DE
Keywords: Interventional vascular, CT-Angiography, Fluoroscopy, Physics
DOI: 10.1594/ecr2013/C-1960

Purpose

4D (=3D+time) interventional image guidance (see Fig. 1 on page 2) requires tomographic data acquisition during the whole intervention. However, the method, which is also called tomographic fluoroscopy or CT fluoroscopy, will be routinely accepted only if the patient dose level can be kept as low as in 2D+time fluoroscopic guidance, which is the standard image guidance technique in today's interventions.

To achieve this goal of enabling tomographic fluoroscopy at the same dose as projective fluoroscopy the update volumes have to be reconstructed from data with very sparse angular sampling at a very low dose. To guarantee high quality of the update volumes during intervention a high quality prior volume acquired before intervention is necessary [1,2].

Depending on the type and duration of an intervention patient motion can lead to non-applicability of the static prior volume. Consequently, the prior volume needs to be continuously updated.

Images for this section:

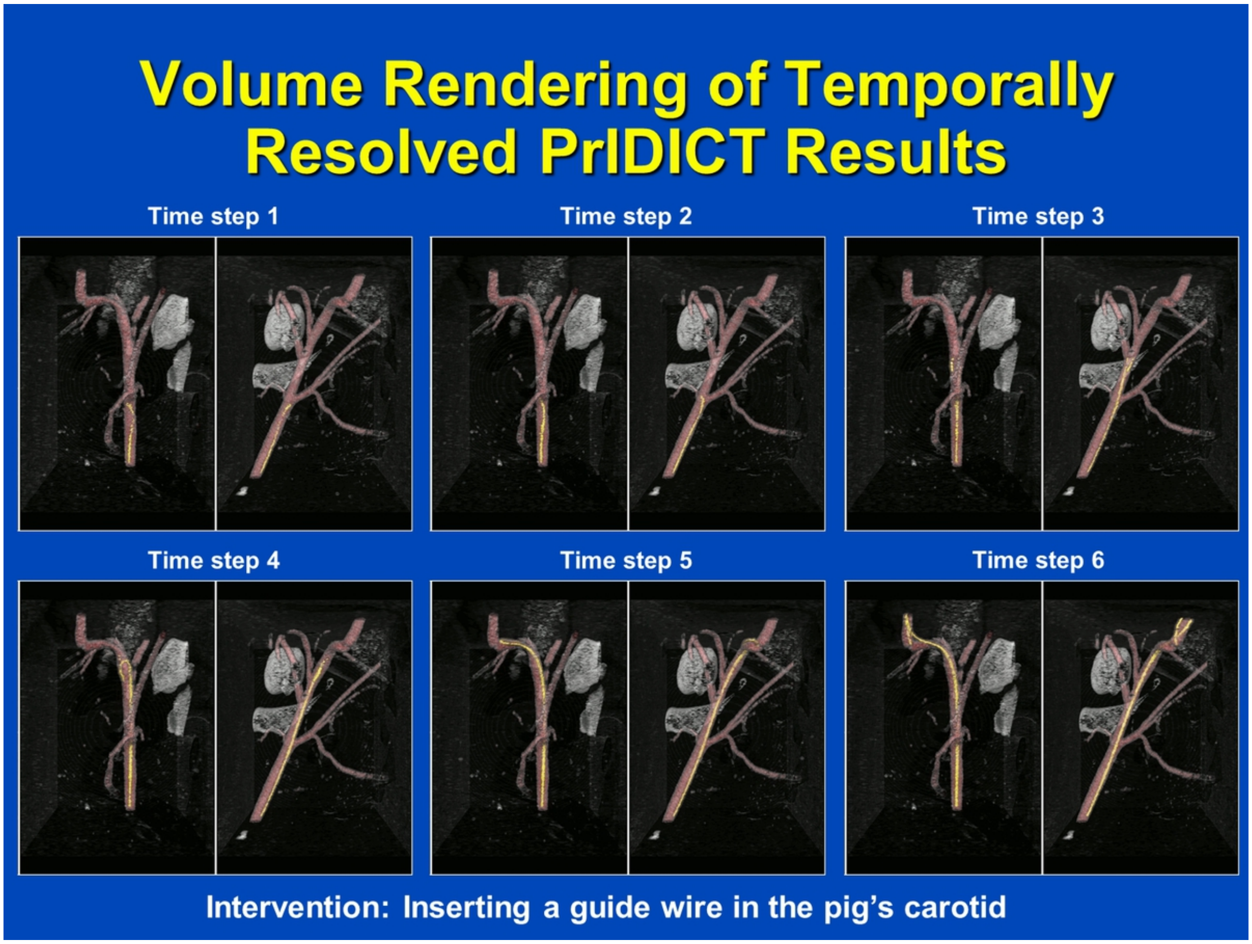

Fig. 1: 4D intervention guidance

Methods and Materials

Reconstruction using prior data

We realize low dose tomographic fluoroscopy using continuous CT scans with very few projections per rotation. Due to dose restrictions only N_U=15 projections are used for each temporal update. To obtain high quality images the information from a fully sampled (N_P=600 projections) prior scan is used. Ideally (in case of no motion) the difference of the forward projected prior and the rawdata for the temporal update shows only interventional material and noise. Because of the very sparse sampling the image quality of the reconstruction of the difference is disturbed by streak artifacts. To reduce these artifacts the L_0-norm is minimized by setting all insignificant voxels (voxels with a low attenuation value) to zero. For display image is added to prior. The workflow of this algorithm called prior image dynamic interventional computed tomography (PrIDICT) [1,2] is illustrated in Fig. 2 on page 5.

Motion Correction

In case of patient motion the PrIDICT algorithm does not work. For this reason we propose a running prior that adapts itself by the combination of the two concepts, registration and substitution (see Fig. 3 on page 5). In the registration step a combination of affine registration (based on mutual information [3]) and deformable registration [4] adapts the prior to a target prior which shows the current situation by reconstructing the latest N_T projections (in our case N_T=120, corresponds to about four scanner rotations with sparse sampling). In the substitution step a forward projection of the deformed prior (N_P=600 projections, same number of projections as for the static prior) yields virtual rawdata that are densely sampled in the angular direction. The projections measured for the current update (in our case N_U=15 projections) are used to substitute the corresponding virtual projections. A reconstruction of these substituted data yields the running prior. In Fig. 3 on page 5 a more efficient but equivalent method is demonstrated, where only the forward projections at the angular positions which are to replace are calculated.

Simulation

We validated the proposed method with a 2D simulation study. By this study we verified that the proposed method works for motion during the intervention scan. In addition we investigated if both steps, registration and replacement of projections, are necessary to get satisfying results. We calculated 1800 projections within 60 rotations with 1024 detector bins in fan beam geometry of the head phantom. After N_P=600 projections we added an ellipsoid with an attenuation of 300 HU to the phantom and started moving the head phantom for the next 600 projections (see Fig. 4 on page 6). Before reconstruction we added Poisson distributed noise to the data resulting in a standard deviation of 150 HU in water.

Measurements

We also applied the running prior technique to real data acquired by a prototype volume CT system since no dedicated 3D+temporal interventional CT system exists nowadays. This CT system consists of a flat detector mounted on a continuously rotating clinical CT gantry. The intervention (insertion of a guide wire) was done with an in vivo head scan of a pig (see Fig. 5 on page 7).

Images for this section:

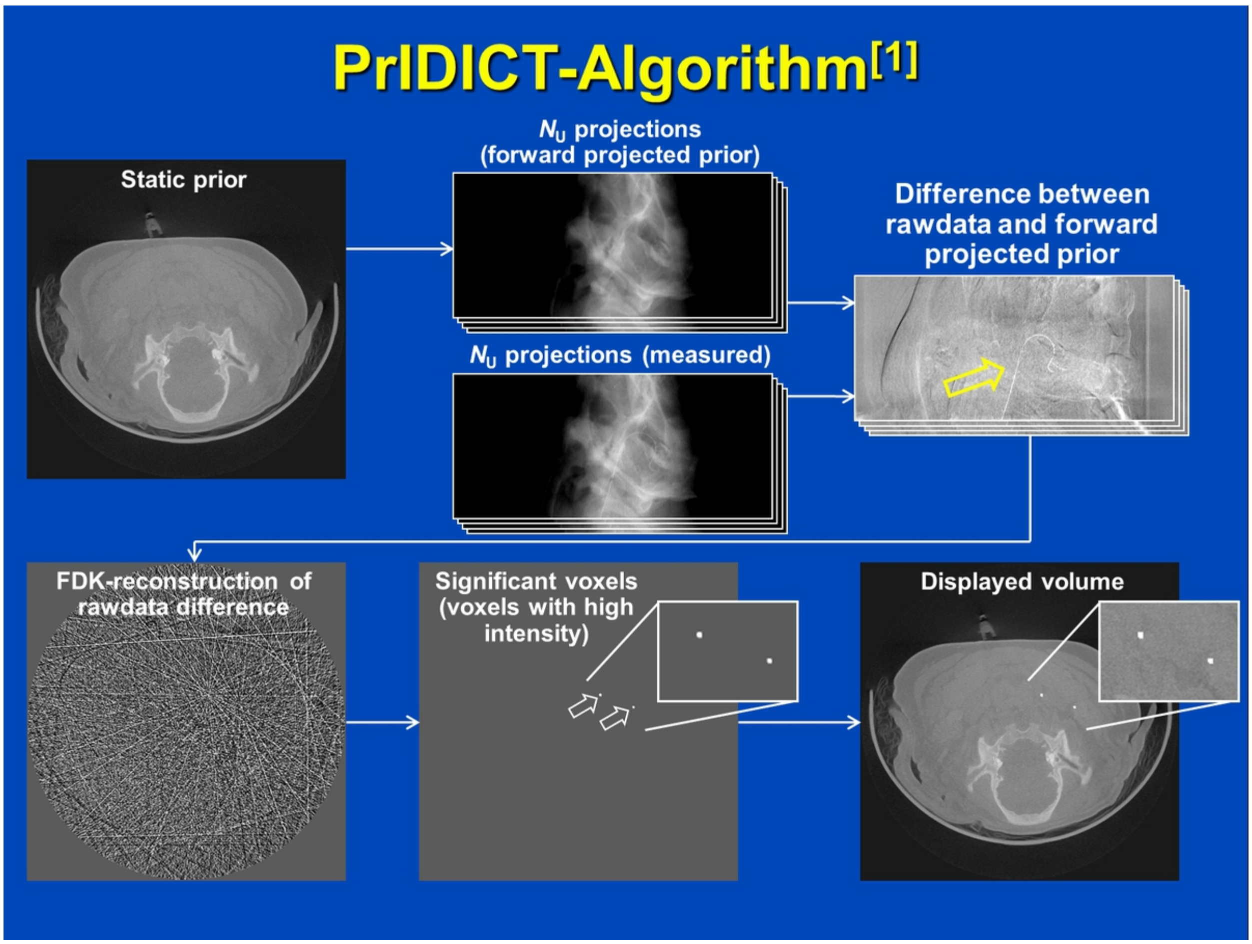

Fig. 2: Workflow of PrIDICT algorithm

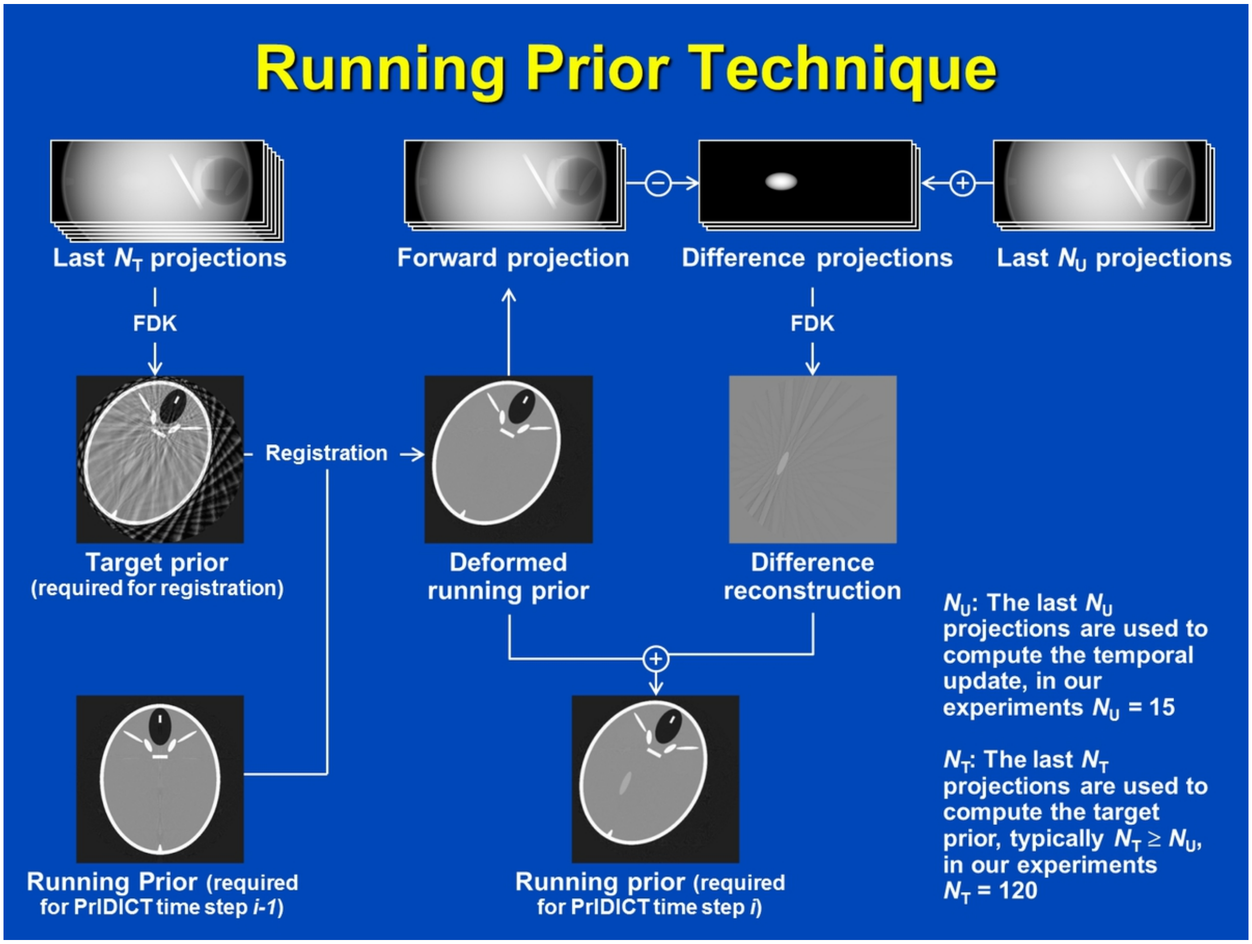

Fig. 3: Workflow of Running Prior technique

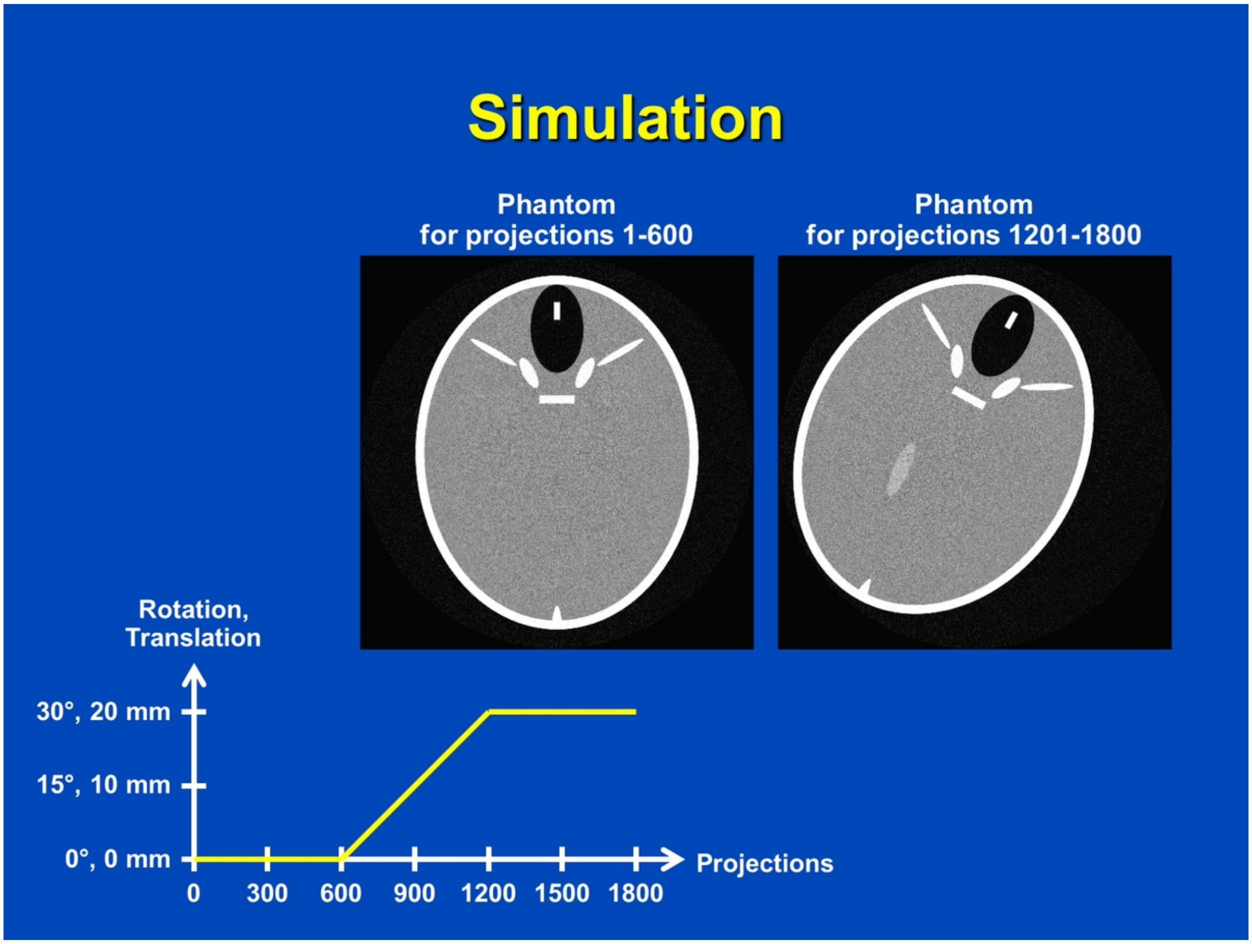

Fig. 4: Phantom and its position for simulation

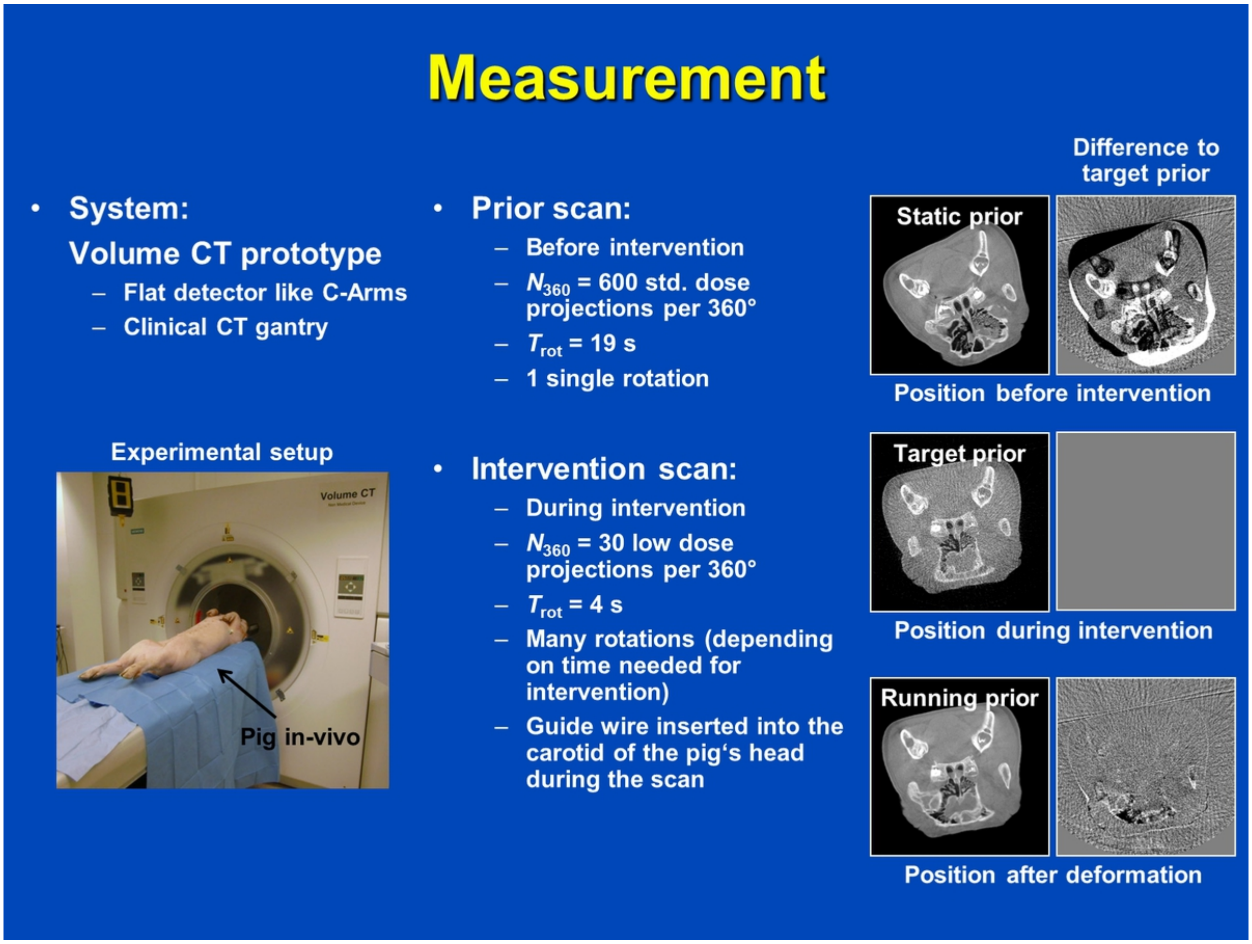

Fig. 5: Setup for real measurements

Results

Simulation

By the simulation we demonstrate that the replacement step is necessary to bring new soft tissue into the prior (see Fig. 6 on page 9). Without this step low contrast objects not present during prior scan but during intervention scan would never appear in the running prior image and therefore never in the temporal updates.

In addition the registration is necessary to correct for motion (see Fig. 7 on page 10). Using only the replacement step leads to artifacts because the new projections do not fit to the position in the running prior.

When the combination of both steps, as suggested by the running prior technique, is applied, the running prior shows a high accordance to the actual situation (see Fig. 8 on page 11).

Measurements

Using the running prior technique it is possible to correct for motion of the pig's head up to 30 mm between the prior scan and the intervention scan. The resulting running prior images are of high image quality without introducing new artifacts. Hence in the difference between forward projected running prior and the rawdata of the current update only interventional material and almost no discrepancies resulting from patient motion are visible (see Fig. 9 on page 12). In consequence the temporal updates show less inconsistency artifacts when using the running prior compared to using the static prior image (see Fig. 10 on page 13). Even if image quality is not disturbed using the static prior (as in another slice of the dataset) it is not possible to display the correct position of the interventional material after patient motion which in contrast is no problem when using the running prior technique (see Fig. 11 on page 14, wire cannot be inserted into bone).

Images for this section:

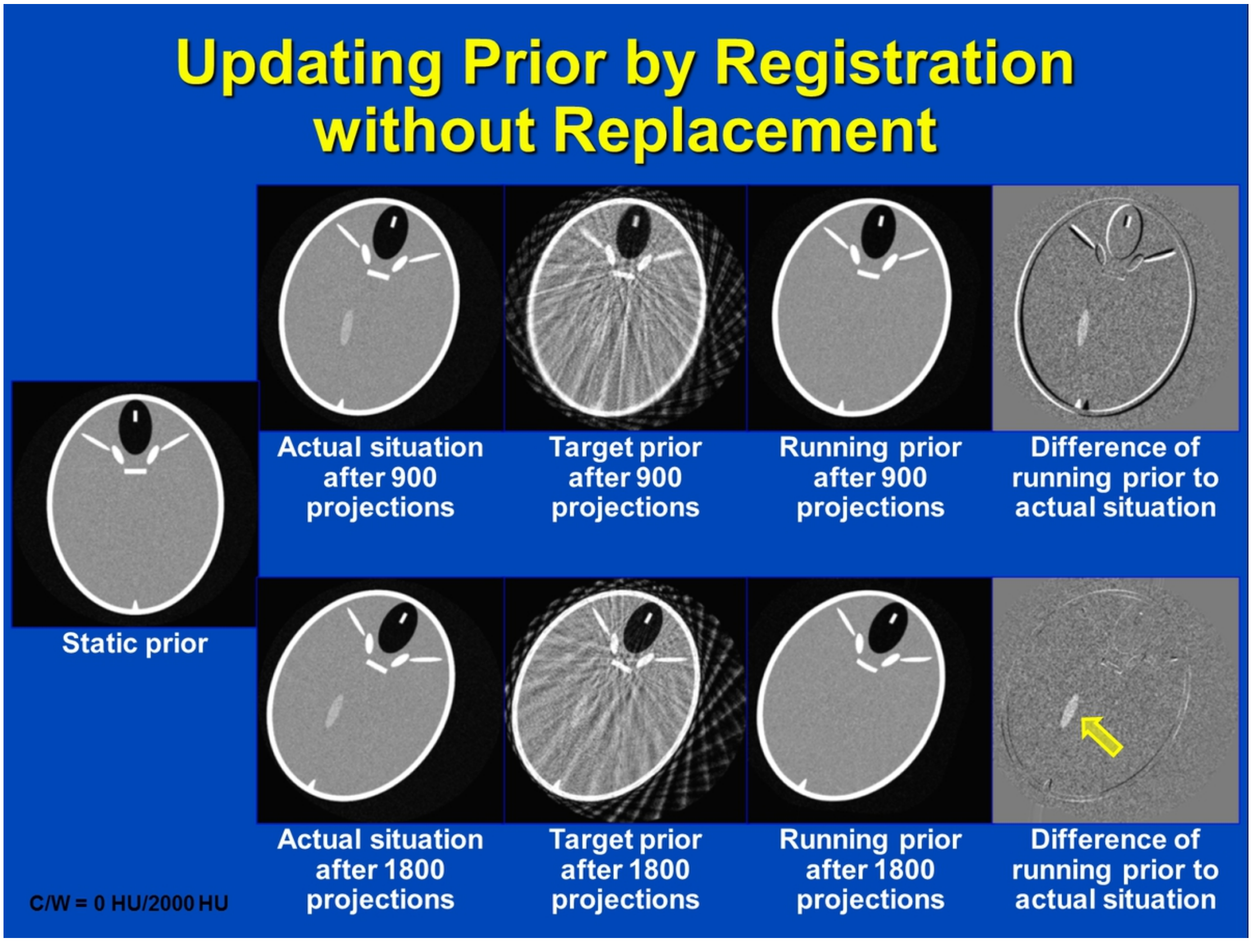

Fig. 6: Demonstration that the replacement step is necessary to bring new soft tissue into the running prior

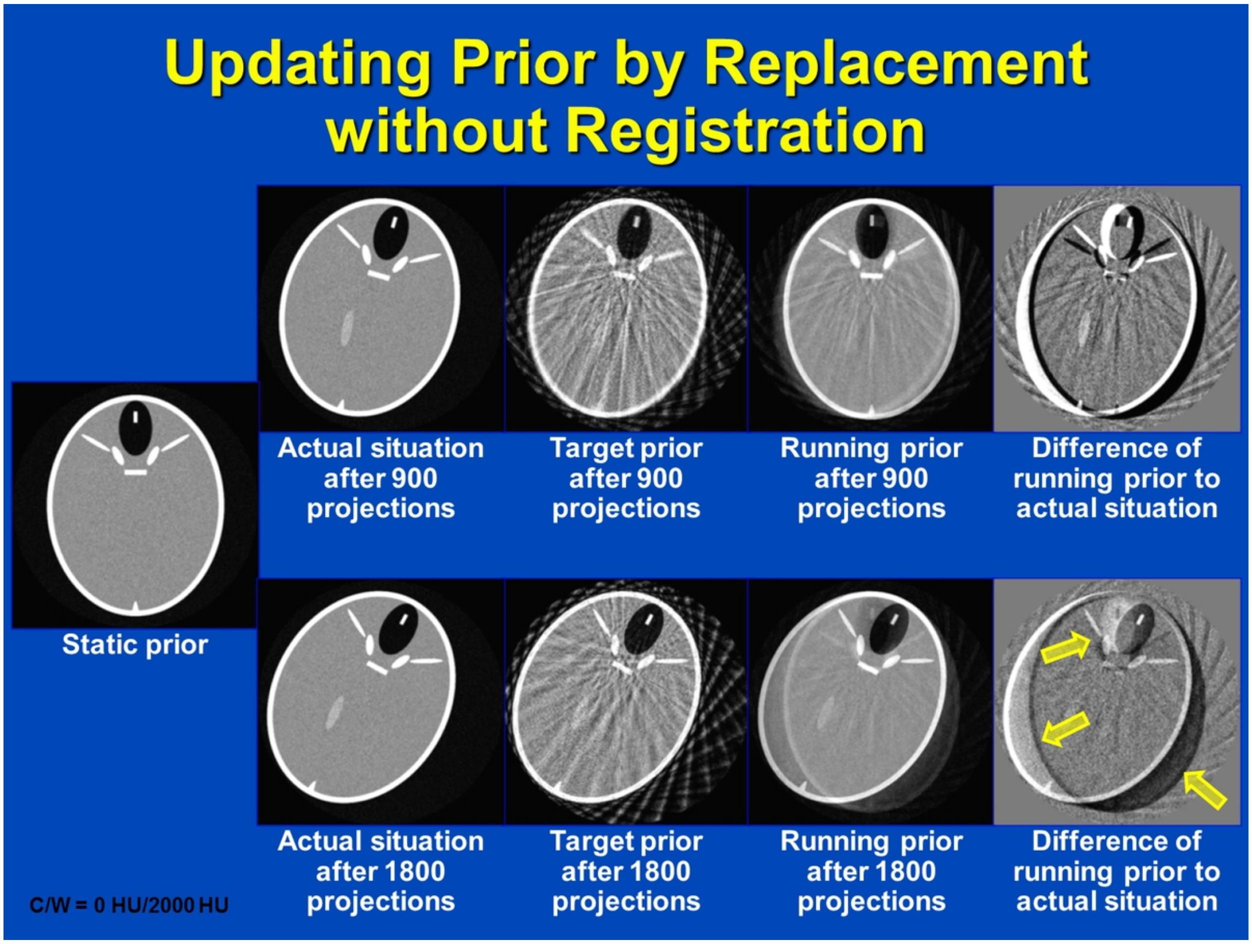

Fig. 7: Demonstration that the registration step is necessary to correct for motion

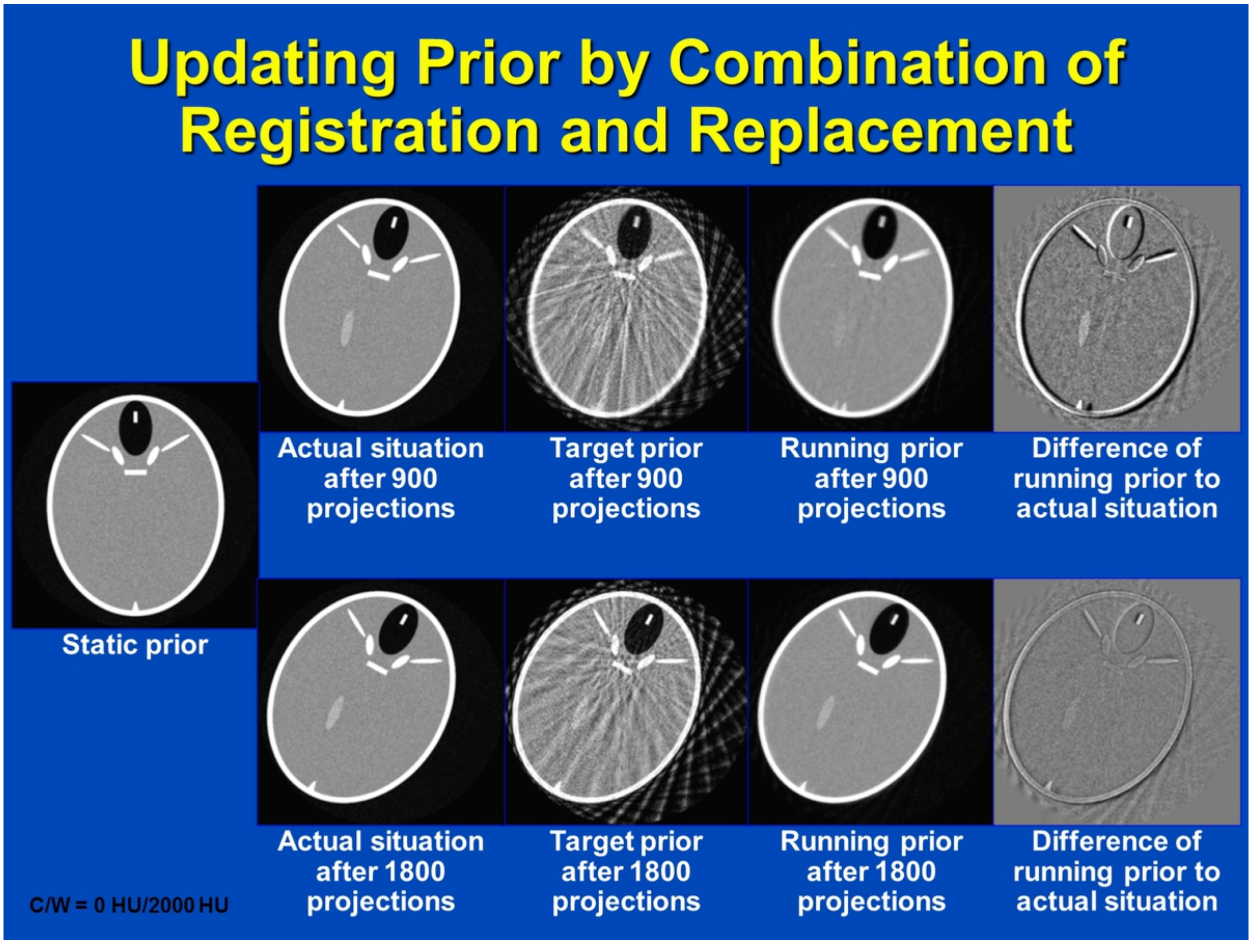

Fig. 8: Demonstration that the prior can be updated with the proposed method

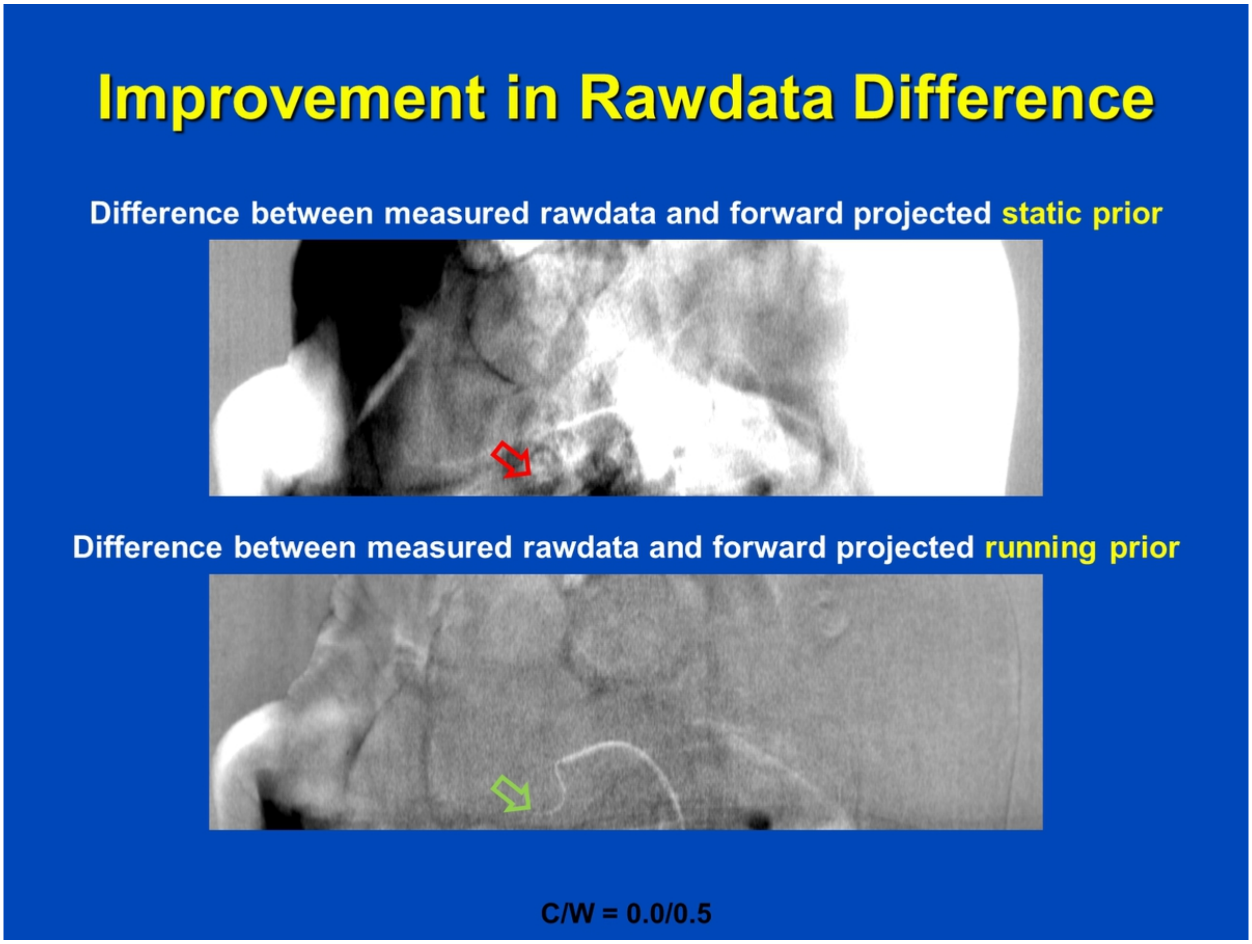

Fig. 9: Difference of the rawdata used for the temporal updates to the forward projected static respectively running prior

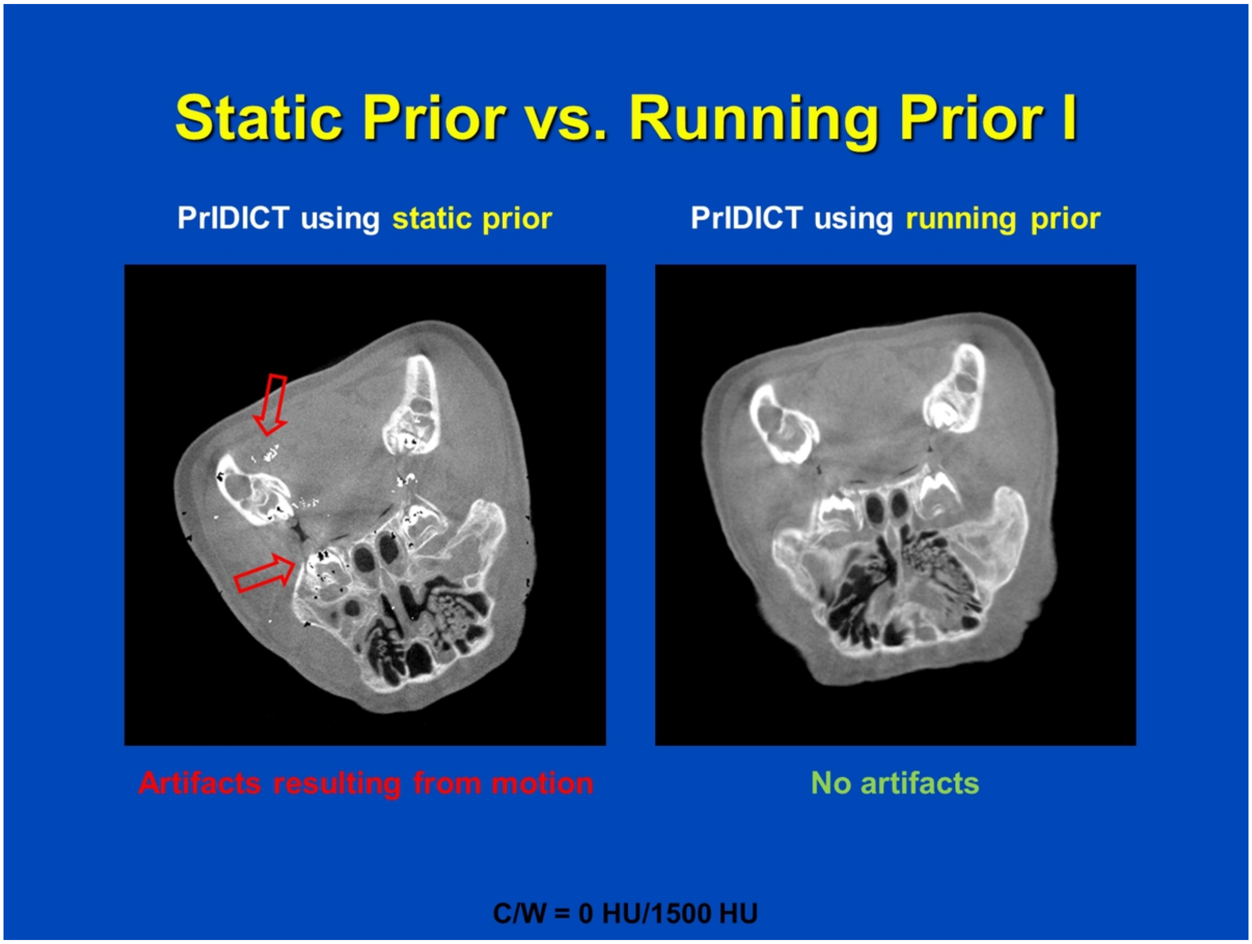

Fig. 10: Results of PrIDICT using the static respectively the running prior

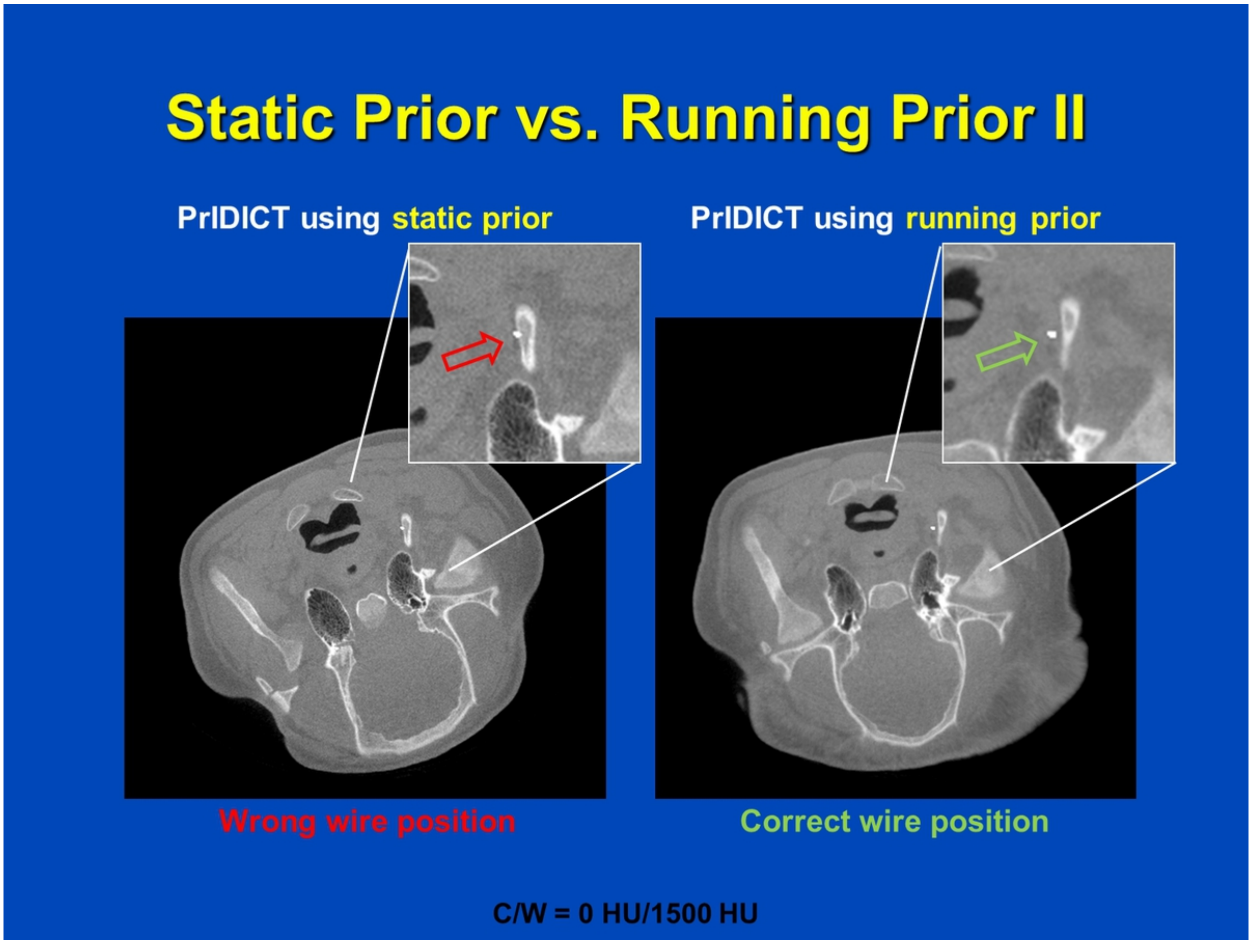

Fig. 11: Results of PrIDICT using the static respectively the running prior

Conclusion

We conclude that the running prior technique is equivalent to the static prior in case of no patient motion and superior in case of motion. The temporal updates show less artifacts when using the running prior technique. This is reached without additional patient dose because no additional projections need to be acquired.

And so 4D interventional guidance at dose level comparable to fluoroscopy may become possible also with patient motion by using the running prior technique (see Fig. 12 on page 16).

Images for this section:

Fig. 12: Volumerendering of intervention with patient motion

References

[1] J. Kuntz, S. Bartling, S. Schönberg, R. Gupta, W. Semmler and M. Kachelrieß. "Time-resolved X-ray based 4D image guidance of minimally-invasive interventions". European Radiology. 2013

[2] J. Kuntz, B. Flach, R. Kueres, W. Semmler, M. Kachelrieß and S. Bartling. "Constrained Reconstructions for 4D Intervention Guidance". Submitted to Phys. Med. Biol. for publication.

[3] P. Viola, and W.I. Wells. "Alignment by Maximization of Mutual Information". International Journal of Computer Vision. 24(2): 137-154. 1997

[4] J.-P. Thirion. "Image matching as a diffusion process: an analogy with Maxwell's demons". Medical Image Analysis. 2(3): 243-260. 1998

Personal Information

Barbara Flach, Marcus Brehm, and Prof. Dr. Marc Kachelrieß: Institute of Medical Physics, University of Erlangen-Nürnberg, Henkestr. 91, 91052 Erlangen, Germany.

Barbara Flach, Marcus Brehm, Jan Kuntz, Dr. Sönke Bartling, and Prof. Dr. Marc Kachelrieß: Medical Physics in Radiology, German Cancer Research Center (DKFZ), Im Neuenheimer Feld 80, 69120 Heidelberg, Germany.

Dr. Sönke Bartling: Institute for Clinical Radiology and Nuclear Medicine, University Medical Center Mannheim, Theodor-Kutzer-Ufer 1-3, 68167 Mannheim, Germany.

Corresponding author: barbara.flach@dkfz.de

Acknowledgements

This study was supported by the Deutsche Forschungsgemeinschaft (DFG) under grant KA 1678/6-1.

The high performance compute hardware was provided by the Universitätsbund Erlangen-Nürnberg e.V., Erlangen, Germany.

Parts of the reconstruction software were provided by RayConStruct® GmbH, Nürnberg, Germany.