Section: **Intraoperative Bildgebung**

ID: 146

Abstract-Title:
3-D-RECONSTRUCTION FROM C-ARM X-RAY IMAGES FOR REGISTER-FREE NAVIGATION IN NEUROSURGERY3D-REKONSTRUKTION AUS RÖNTGENBILDERN EINES C-BOGENS ZUR REGISTRIERUNGSFREIEN NAVIGATION IN DER NEUROCHIRURGIE

Authors:
U. Kirschstein[1], J. Kötters[1], M.J. Mirzayan[2], A. Hein[1], J.K. Krauss[2]
[1] University of Oldenburg, Automation and Measurement Technologies (AMT)
[2] Hannover Medical School (MHH), Clinic of Neurosurgery

Abstract-Text:
Purpose
In this article, a new system for navigated imaging and milling in neurosurgery is proposed. The system is supposed to assist the surgeon during milling tasks in the neurosurgery. It features intraoperative and register-free image acquisition. The image data are used to plan a working volume for the active instrument for excisions.
Decompression of the spinal dura (laminotomy) includes removal of osseous or ligamentous hypertrophies to expose the dura or nerve roots. This task is done under visual control via operation microscope and C-arm radiography.
Posterior lumbar interbody fusion (PLIF) is a standard procedure for degenerative diseases of the spine. It features the reinforcement and stabilization of the lumbar spine using titan screws and interbody cages. It is demanding because of the tight operative relations and the proximity to neural structures. There is the need for a highly accurate position of screws because the size of screws and pedicle varies only in a range of 1 to 2 mm.

Method
To increase the intraoperative 3-d imaging possibilities in spine surgery the aim is to use conventional C-arms, which are typically available in operating room setup. Three aspects prevent usage of typical 3-d reconstruction techniques: absence of an iso-center, motion besides an orbit, and unbalanced sampling. Great benefits are supposed by avoidance of the deficient registration process.
A 2-step-calibration has to be carried out first to determine orientation of the image plane, pixel dimensions, and position of X-ray source in respect to the image plane [1][2]. The principle of navigated imaging is shown in Fig. 1.
The aim of this experiment was an accuracy evaluation of navigated imaging. The registration-free adjustment of patient model and patient will be verified by scanning artificial landmarks (steel balls) on the spine phantom and determine these points in the reconstruction slices (Fig. 2/3 show spine slices, with and without landmarks).
The reconstruction process will be carried out with two different reconstruction techniques: a) weighted unfiltered back-projection with subsequent morphological filtering [2] and b) algebraic reconstruction technique (ART) each using a cone-beam model. The reconstruction will be carried out with 17 projection images (orbital movement: 160°).

Results

A preliminary evaluation showed a mean error of [0.2 mm; -0.1 mm; -0.3 mm] in x-, y- and z-direction (std: [1.0 mm; 0.8 mm; 1.1 mm], N = 8) in positioning accuracy with unfiltered back-projection. Similar errors are produced by ART with mean error of [-1.5 mm; 0.7 mm; -0.9 mm] in x-, y- and z-direction (std: [1.9 mm; 1.1 mm; 1.8 mm], N = 8) in positioning accuracy.

The two reconstruction techniques are performed with different voxel dimensions each. The cubic volume in unfiltered back-projection is divided into 85 slices with resolution of 256-by-256 pixels. Hence a voxel's size is 0.33 mm * 0.33 mm * 1.0 mm. The cubic volume in algebraic reconstruction is an isotropic volume with 75-by-75-by-75 voxels. The edge length of a voxel is 2.1 mm.

Conclusion

The results of the preliminary evaluation show no significant differences in spatial accuracy. In ART the resolution of reconstruction volume is not as high as in unfiltered back-projection. This effect is an accommodation to high computing efforts. To lower these requirements the resolution was sized down. Because of higher voxel's size in ART, the standard deviation dithers more than in unfiltered back-projection. These effects show that both reconstruction methods generate equal spatial accuracy. Besides the spatial accuracy, the different reconstruction methods show different image quality (see Fig. 2 and Fig. 3). The ART generates images with higher quality; the lumbar vertebra (Fig. 3a) and the steel balls (Fig. 3b) can be determined easier than in Fig. 2a and Fig. 2b.

References

[1] Hein A., Kirschstein U. (2004): Navigated Imaging for Angiography – Concept and Calibration, IEEE Conf. on Mechatronics and Robotics (MechRob) 2004, Aachen, Germany, Sept. 13-15, 2004, pp. 1409-1414

[2] Kirschstein U., Hein A. (2006): Navigated Imaging for Neurosurgery, Proc. of IEEE Intl. Conf. on Biomedical Robotics and Biomechatronics (BioRob), Pisa, Italy, 20.-22. Febr. 2006, ISBN 1-4244-0040-6Figures

Fig. 1: Navigated imaging principle: calibration of imaging system and reconstruction of singular x-ray beams [2]

Fig. 2: Spine's slices with and without landmarks out of the unfiltered back-projection: a) lumbar vertebra without steel balls, b) lumbar vertebra with steel ballsFig. 3: Spine's slices with and without landmarks out of algebraic reconstruction: a) lumbar vertebra without steel balls, b) lumbar vertebra with steel balls

Bild 1/JPG

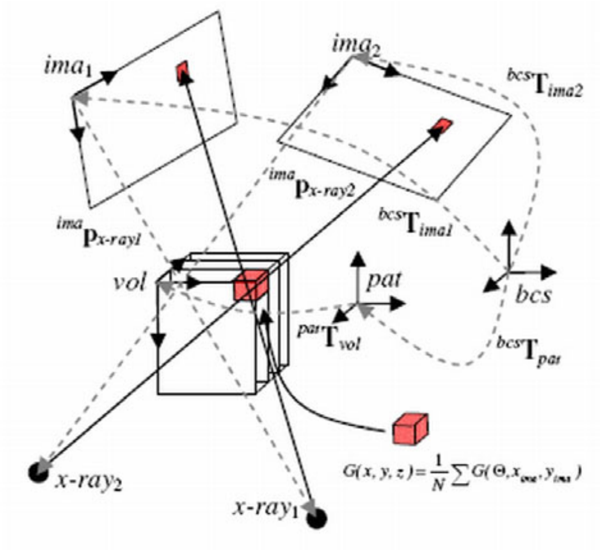

Bild 2/JPG

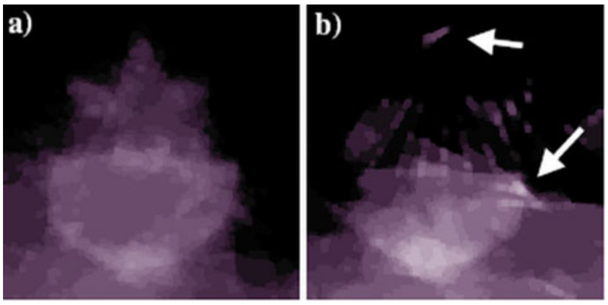

Bild 3/JPG