An open 3D X-ray system for intraoperative cone-beam computed tomography

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Abstract

Intraoperative cone-beam computed tomography supports surgeons during surgery by providing a three-dimensional representation of the patient's anatomy. This allows direct control of the current situation and thus the result of the operation. In this thesis, a novel open 3D X-ray system for intraoperative cone-beam computed tomography is presented. The system is characterized by a separate arrangement of X-ray source and X-ray detector using two separate robot kinematics. This feature allows a space-saving integration of the system into the operating room. The robot-guided movement of X-ray source and X-ray detector enables the design and application of non-planar scanning trajectories to generate accurate 3D-reconstructions of the scanned volume. To apply non-planar scanning trajectories with freely definable rotation and tilt angles with respect to one stationary scanning center, a geometric calibration method was developed, which calculates the projection geometry of X-ray images from arbitrary directions. In order to support the design of suitable scanning trajectories within predefined ranges of movement, a method that evaluates the obtainable reconstruction quality was designed and implemented. The method considers the available directions of projections of a given set of X-ray source positions and works independently of reconstruction algorithms. An experimental model of the open 3D-X-ray system was realized and evaluated regarding the 3D image quality using technical and clinical test phantoms. In these studies, the benefit of a non-planar movement of the X-ray source with respect to geometrical accuracy and reduction of metal artifacts has been demonstrated. The results show that the open 3D X-ray system is able to generate high quality three-dimensional image data.