Section: **Intraoperative Bildgebung**

ID: 148

Abstract-Title:
VASCULAR TREE RECONSTRUCTION WITH DISCRETE TOMOGRAPHY - A PRACTICAL APPROACH

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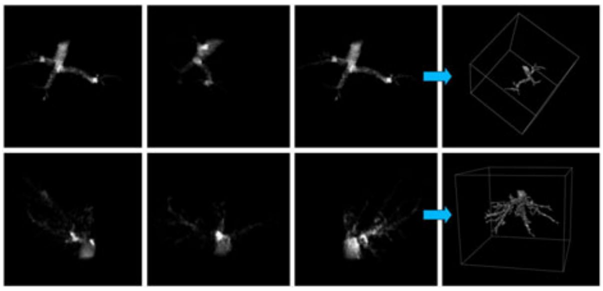
Abstract-Text:
Purpose:
Discrete tomography is concerned with the reconstruction of discrete valued objects from projections.
In medical imaging, subtraction angiography images of vessels can be treated this way. Taking into account the discrete nature of the imaged object, only a few projection pairs taken from a limited range of angles are necessary for the reconstruction process.
The realization of discrete tomography based reconstruction in practice brings a significant reduction of x-ray dose both for the patient and the personnel. Using this technique in combination with a robotised C-Arm we have conducted first practical experiments. Our final goal is to enable intra-operative 3d-imaging and navigation based on vascular structures.Methods:
The reconstruction task was formulated as a linear optimization problem (2)(1). Two of the various tested formulations are:
min -<1,x> + s(x), subject to Ax <= b, 0 <= x <= 1.0;
min <1,z> + s(x), subject to Ax + z = b, Ax - z = b; (A = system matrix, x = reconstruction volume, b = projection data, z models noise)
A regularization term s(x) introduced by Weber et al. (1) was used to favor spatially coherent solutions.
In order to reduce problem size, the volume reconstruction region is split into sub-problems by the mid plane defined through the C-Arm isocenter and the axis it rotates around while imaging the object. The implementation was evaluated with synthetic and real X-ray images.
Synthetic images were obtained by simulating the X-ray imaging process on liver vascular networks (HV and PV). The networks have been segmented by MeVis from MR and CT images of patients during liver resection planning. Afterwards sets consisting of 3-5 images were used to reconstruct the original vascular trees. Real x-ray images were acquired using our robotised C-Arm prototype (4). From the kinematics of the C-arm the coordinates of the radiation source and image intensifier were calculated. For testing, chess figures were inserted into a plastic box. This was then imaged from three to five perspectives before and after filling with contrast agent (Imeron 300). The geometric distortion was corrected using bivariate polynomials of degree five; its coefficients were determined using a calibration object placed on the image intensifier on a previous run. Additionally, a complete set of 40 CT images was used to generate the ground truth using a conventional ART algorithm.Results:

In the case of the synthetic projections, the imaged volume represents the ground truth. Thus the quality of the 3D–Reconstruction can be evaluated by direct voxel comparison. The reconstruction errors were minimal (volume size 128^3 voxels, incorrect voxels: min 5, max 220, average 46.3, 10 testcases).
The runtimes (Intel Xeon 3.8 GHz, 8Gig Ram) vary between one minute and 8 hours (average time 25 min), depending on the algorithm used for reconstruction and on the number of occurring occlusions.The reconstructions from real images yielded qualitatively correct results, but showed artifacts due to inconsistencies introduced by positioning errors and quantization. These issues should be resolved with the next C-Arm generation.Conclusion:
Although volume reconstruction by discrete tomography has been thoroughly researched, there are still few medical applications to implement it in practice. Most of the methods are computationally expensive and unstable. In our experiments the algorithms proved to be sensitive to image noise and positioning errors. The focus of future work is threefold: to better model image noise, improve the robustness of positioning, and speed up the reconstruction process through parallelization.
1) S. Weber, T. Schüle, J. Hornegger, C. Schnörr:
Binary Tomography by Iterating Linear Programs from Noisy Projections
Proceedings of International Workshop on Combinatorial Image Analysis (IWCIA), 2004. Auckland, New Zealand, Dec. 1.-3./2004, Lecture Notes in Computer Science, Springer Verlag2) Fishburn, P., P. Schwander, L. Shepp, and R. Vanderbei, The discrete radon transform and its approximate inversion via linear programming,
Discr. Appl. Math. 75 (1997), 39-61.3) A. Kuba, G.T. Herman, S. Matej, and A. Todd-Pokropek. Medical
applications of discrete tomography. Preprint, University of Szeged,
Hungary, 20034) N. Binder, C. Bodensteiner, L. Matthäus, R. Burgkart, A. Schweikard:
Image Guided Positioning For an Interactive C-arm Fluoroscope
Computer Assisted Radiology and Surgery (CARS), 20th International Congress, Osaka, Japan, June 28 - July 1 2006

Bild 1/JPG



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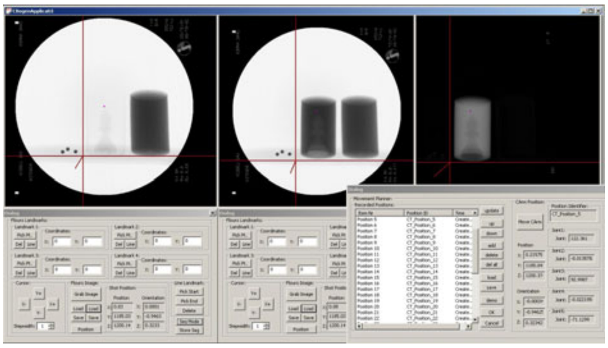

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