A Method for Solving the Correspondence Problem for an n-Camera Navigation System for Image Guided Therapy

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Purpose – Precise navigation or tracking is a key component of image-guided procedures including biopsy, surgery, and radiation therapy. Users of optical navigation systems (that typically comprise of a pair of stereoscopic cameras) are well aware that having multiple cameras covering the field of view significantly facilitates workflow by minimizing the disruption of line of sight between the cameras and the tracked instruments. An algorithmic challenge in the use of an *n*-camera system for triangulation is the correspondence problem between the $n \cdot (n-1)/2$ resulting different binocular camera systems, and we describe a method for solving it.

Methods – We setup a tetra-optical camera system [1] and used five fiducial markers to localize an object (Fig. 1) or a patient in 3-space. If all fiducial markers are visible to all cameras, and correspondences between them are not known, up to 25 solutions are possible for a camera pair, and 125 for 6 camera pairs (or 4 cameras). Narrowing these to a single solution or knowledge of correspondences between the points leads to a unique solution and is the focus of this work.

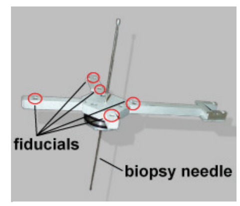

Figure 1

In a pin-hole camera geometry all image points on one epipolar line correspond to points on a single epipolar line in the second image [2]. If a point in 3-space is visible in *m* images, then the intersection of the *m* resulting epipolar lines is used to reconstruct its 3D coordinates. Because of measurement errors, the lines often do not intersect in a point, and in our algorithm, we develop an efficient method for determining the approximate intersection points of these line clusters. In the case when $m=2$, we compute center point of the minimal distance between the lines. When $m > 3$, we compute the pairwise center points, and average the point cloud of centers thus obtained. The resulting points are matched with the (known) tracker or patient model via translation and rotation [3].

Results – For evaluation we performed navigation in several scenarios using a tetra-optical camera system. We used standard CCD video cameras (Teli CS8320BC) and LEDs with wavelength of 890±45 nm. The correspondence algorithm was able to recover 3-space coordinates in all experiments, and repeated position measurements of the same position and orientation of the models could be reproduced within 0.5 mm. To accomplish the repeatability evaluation, we fixed the models to a robot (Mitsubishi RV-E2) with a positioning accuracy of ca. 0.4 mm [4].

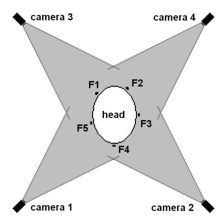

Figure 2

Conclusions – We have introduced an algorithm for solving the correspondence problem for a multi-camera navigation system that can be used to track patient or instrument position in an operating or interventional suite. Compared to using a single stereo pair, a multi-camera navigation system allows a significantly larger field of view and is more robust to occlusions caused by breach of line of sight. Such a system is being planned for the **A**dvanced ***M****ultimodality* ***I****mage* ***G****uided* ***O****perating* (*AMIGO*) Suite of the ***N****ational* ***C****enter for* ***I****mage* ***G****uided* ***T****herapy* (*NCIGT*) funded in part by the NIH Grant P41RR019703 [5].

References

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[4] D. Richter, J. Egger, G. Straßmann. *An Algorithm to Determine the Position of Patients and Biopsy-Needles with a Tetraoptical Camera System* (in German). Proceedings of Bildverarbeitung für die Medizin (BVM), Hamburg, Germany, pp. 316-320, Springer Press, 2006.
[5] National Center for Image Guided Therapy (NCIGT), *Advanced Multimodality Image Guided Operating (AMIGO) Suite* funded by NIH Grant P41RR019703 (http://www.ncigt.org/pages/AMIGO)