PRELIMINARY STUDY OF A MESH-BASED CORTICAL SURFACE RANGE ESTIMATION METHOD WITHIN A STEREOPSIS SYSTEM

Z. Wu, H. Sun, and **K. D. Paulsen**

Thayer School of Engineering, Dartmouth College
Hanover, NH 03755-8000
Ziji.Wu@Dartmouth.EDU

Brain displacement and deformation during surgery compromise the accuracy of image-guided procedures based on preoperative images. Several groups including ours have developed finite element (FE) based non-rigid registration for updating preoperative data to compensate for brain shift. [1-3] The accuracy of these computational models may benefit from incorporating intraoperatively acquired information on brain motion. One potential source of such data is cortical surface displacement. Stereopsis is a suitable technique for obtaining range estimation of cortical surface movement. Towards this end, we have attached two CCD cameras to the binocular optics of the operating microscope. The stereo rig is calibrated prior to the surgery to obtain both the intrinsic and extrinsic camera parameters. Stereo images of the surgical field are then acquired during the course of a procedure to track cortical surface displacement.

This paper focuses on a mesh-based method of cortical surface range estimation from the stereo images. The craniotomy site is segmented from the first frame of the stereo images. A conformal triangular mesh is generated at user specified resolution. [4] The 3D coordinates of the mesh nodes are reconstructed from the stereo images at each time point. Several matching constraints have been implemented to provide a reliable and robust strategy for digitization of cortical surface. Because the tangential shift of the cortical surface during neurosurgery is generally small compared to the brain deformation in the normal direction to the cranial opening, the cortical surface displacement over time is approximated by the motion of the mesh nodes. These numerical results can be mapped onto 3D finite element brain models generated from the pre-operative MR scans for the recovery of the brain shift during surgery. Preliminary studies conducted on clinical cases show that the accuracy of the system is within 1.5mm.

Higher mesh resolution leads to more accurate range estimation because more image information from the stereo pairs is applied. However, when the nodal density involves sufficient image resolution, use of additional information in the images will not necessarily increase the range estimation accuracy. On the other hand, the computation time is proportional to the number of points for which the range is estimated. Experiments comparing the range estimation accuracy as a function of the mesh resolution have been completed. Through user controlled mesh resolution, this mesh-based strategy allows us to strike a suitable balance between range estimation accuracy and the cost of computation. Another advantage of the system is that the geometry of the craniotomy site is preserved over time.

References

[1] M. Ferrant, A. Nabavi, B. Macq, *et al*, “Registration of 3D intraoperative MR images of the brain using a finite-element biomechanical model”, *IEEE Transactions on Medical Imaging*, v 20, p. 1384-1397, 2001.
[2] O. Skrinjar, A. Nabavi, J. Duncan, “Model-driven brain shift compensation”, *Medical Image Analysis*, v 6, p. 361-373, 2002.
[3] K.D. Paulsen, M. Miga, F. Kennedy, *et al*, “A computational model for tracking subsurface tissue deformation during stereotactic neurosurgery”, *IEEE Transactions on Biomedical Engineering*, v. 46, p. 213-225, 1999.
[4] Z. Wu, J.M. Sullivan, K.D. Paulsen, “A normal-offsetting node deployment strategy for high quality equilateral triangular elements”, Proc. 8th Int. Conf. on Numerical Grid Generation in CFS, ISGG Press, ISBN 0-9651627-4-5, pp 671-680, 2002, Hawaii.

Submitted to the 7th US National Congress on Computational Mechanics (Computational Bioengineering)