Prediction of Ventricular Boundary Evolution in Hydrocephalic Brain via a Combined Level Set and Adaptive Finite Element Mesh Warping Method

- ADMOS 2015 -

Suzanne M. Shontz* and Corina S. Drapaca†

* Department of Electrical Engineering and Computer Science
Graduate Program in Bioengineering
Information and Telecommunication Technology Center
University of Kansas
Lawrence, KS 66045 United States
e-mail: shontz@ku.edu, web page: http://people.eecs.ku.edu/~shontz

† Department of Engineering Science and Mechanics
Center for Neural Engineering
The Pennsylvania State University
University Park, PA 16802 United States
e-mail: csd12@psu.edu - web page: http://www.esm.psu.edu/wiki/research:csd12:start

ABSTRACT

Hydrocephalus is a serious neurological disorder caused by abnormalities in cerebrospinal fluid (CSF) flow, resulting in large brain deformations and neuronal damage. Treatments drain the excess CSF from the ventricles either via a CSF shunt or an endoscopic third ventriculostomy. However, patients' response to these treatments is poor. Mathematical models of hydrocephalus mechanics could aid neurosurgeons in hydrocephalus treatment planning. Current models and corresponding computational simulations of hydrocephalus are still in their infancy, despite this being a disease with serious long-term implications.

We propose a novel geometric computational approach for tracking the evolution of hydrocephalic brain tissue – ventricular CSF interface via the level set method and an adaptive mesh warping technique. In our previous work [1], we evolved the ventricular boundary in 2D CT images which required a backtracking line search for obtaining valid intermediate meshes for use with FEMWARP, a finite element-based mesh warping method. In [2], we automatically evolved the ventricular boundary deformation for 2D CT images via the level set method. To help surgeons determine where to implant a shunt, we also computed the brain ventricle volume evolution for 3D MR images using FEMWARP.

In this work, we generalize the results from [1,2] and incorporate adaptive mesh refinement following mesh deformation. Based on the use of the solution gradient of the PDE in the mesh warping approach as an enrichment indicator, the mesh is refined where the solution gradient is large and is coarsened where it is small. We present computational simulations of the onset and treatment of pediatric hydrocephalus based on 2D CT images which demonstrate the success of our combined level set/adaptive finite element-based mesh warping approach.

REFERENCES

[1] J. Park, S.M. Shontz, and C.S. Drapaca, *A combined level set/mesh warping algorithm for tracking brain and cerebrospinal fluid evolution in hydrocephalic patients*, Ed. Yongjie Zhang, Image-Based Geometric Modeling and Mesh Generation, Springer, Lecture Notes in Computational Vision and Biomechanics, Vol. **3**, pp. 107-141, (2013).

[2] J. Park, S.M. Shontz, and C.S. Drapaca, "*Automatic boundary evolution tracking via a combined level set method and mesh warping technique: Application to hydrocephalus*", Proc. of the Mesh Processing in Medical Image Analysis 2012 - MICCAI 2012 International Workshop, MeshMed 2012, pp. 122-133, (2012).