Toward Real Time Image to Mesh Conversion for Non Rigid Registration

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***Abstract*—In image guided neurosurgery, Magnetic Resonance Images (MRI) obtained before the procedure (pre-operative) provide extensive information which can help surgeons to plan a resection path. Current practices of neurosurgical resection involve the opening of the scull and the dura. This results in a deformation of the brain (known as the *brain shift* problem) which creates discrepancies between the pre-operative imaging data and the reality during the operation. A correction is possible using *non-rigid registration* of intra-operative MRI with pre-operative data.**

In this project, we target Finite Element (FE) based approaches for non-rigid registration [1, 2]. Real-time Image-to-Mesh (I2M) conversion is a critical component for FE-based non-rigid registration of brain images(Figure 1).

I2M conversion should address three issues that affect the speed of registration:

- **Fidelity: how well the mesh boundary resembles the image boundary**
- **Quality: how small the dihedral angles of the mesh elements are**
- **Size: number of elements**

Previous work of our team [2] has shown that low fidelity and quality decrease the speed of solver convergence. Also, the size of the output mesh affects the speed of both mesh creation and solver completion.

We propose a new three dimensional I2M conversion algorithm based on Generalized Delaunay Refinement (GDR) techniques introduced by our team [3]. The motivation for our current work is that most existing algorithms either do not offer guarantees on fidelity and quality or produce meshes with high number of elements [4, 5]. Our algorithm, on the contrary, lets users define the fidelity they desire and produces a mesh with guaranteed quality. Our algorithm does not require an initial triangulated surface: it recovers the image boundary while maintaining good quality at the same time. Most importantly, the desired fidelity does not impact the quality of the final mesh: our algorithm, for the given fidelity criteria, guarantees the best possible quality.

We measure fidelity as the symmetric (2-sided) Hausdorff distance. Users are able to define an upper bound for this distance which can be arbitrarily close to zero (a zero upper bound means that the mesh boundary perfectly recovers the image boundary).

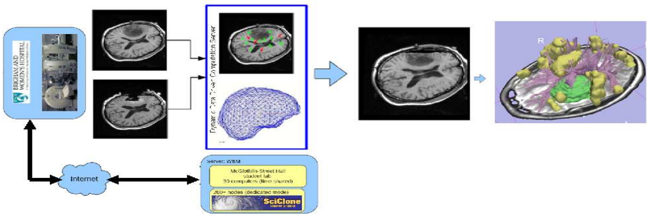
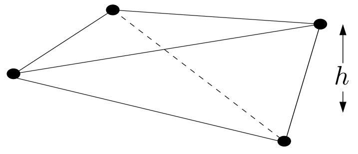
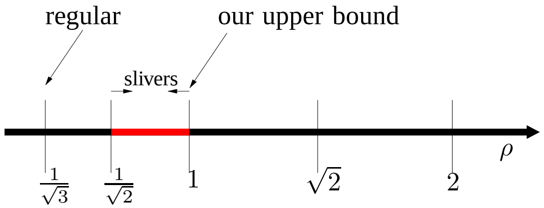


Fig. 1. Non-rigid registration (courtesy of SPL at BWH)



(a) The height of a sliver can be close to zero while having a very good quality.



(b) When slivers are created.

Fig. 2. The notorious slivers

We measure the quality ρ of an element (tetrahedron) as its circumradius-to-shortest edge ratio. Our algorithm guarantees that the ratio for every element will be smaller than 1, which implies that all planar angles will be more than 30 degrees. This guarantee removes most of the small dihedral angles from the mesh. Unfortunately, *slivers* may survive. A sliver is a tetrahedron with good quality, but very small dihedral angles (Figure 2).

Every time a Delaunay refinement procedure removes a sliver, it may introduce very short edges, thus compromising termination. We are eliminating slivers by employing an *amortization* technique: we “buy” short edges when we split a sliver, but we “pay” back later stopping in this way the creation of even smaller edges.

ACKNOWLEDGMENTS

This research was supported in part by NSF grants CCF-0916526, CCF-0833081, CSR-0719929, CCS-0750901, and by John Simon Guggenheim Memorial Foundation.

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