**High-Fidelity Controlled-Resolution Atlas and Deformable Model-based Anatomical Modeling for Medical Simulation and Therapy Planning**

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This poster summarizes work underway on neurosurgery simulation and planning, with an emphasis on anatomical modeling techniques related to segmentation and meshing, while describing plans for therapy modeling. We believe that this research has broad applicability to Computational Neuroscience, Biomechanics and Multiscale Systems Biology.

We describe innovations that center on patient-specific representation of the brain, including skull base anatomy, and spine. In general, we advocate a model-based approach to segmentation that leverages a digital atlas of the anatomy, which in turn can be in 2D or 3D image format or better still, expressed as a deformable contour or surface mesh model that can be warped to patient image data; furthermore, in many cases, we proceed in a manner that represents several tissue boundaries at once, whereby an atlas is expressed as a deformable multi-surface 2-Simplex model, which imbeds static collision detection to prevent spatial overlap (published by Gilles). An N-Simplex is an N+1-connected mesh; the 2-Simplex is a 3-connected surface mesh, which produces a triangulated surface by geometric duality.

We endow Gilles' multi-surface Simplex model with an internal force based on statistical shape models (SSMs), with applications to spine segmentation; we are currently applying this technique to simulation-based scoliosis surgery planning. The Gilles 2-Simplex also features rotationally symmetric topological operators that confer on it exquisite control over surface mesh resolution, and the dual triangulated surface mesh that results can serve as a first stage for controlled-resolution variational tetrahedralization (based on the Alliez tet meshing method found in CGAL). Finally, based on this duality between 2-Simplex and triangulated surface, we are currently developing an initialization of the 2-Simplex mesh from a multi-material contouring algorithm of ours, which leads to a 2-Simplex deformable mesh model with shared faces. The application of the latter technique is a shared-face multi-surface mesh of a deep-brain atlas, towards real-time brain shift estimation for robotic deep-brain stimulation that produces continuous deformation across atlas boundaries, assuming brain tissue as a continuum.

The implications for the Biomechanics and Multiscale Systems Biology communities is that we can achieve controlled-resolution meshing with high-fidelity surface agreement and precise control over resolution, possibly with shared faces when appropriate. This meshing framework can also lead to SSM-compliant, multi-resolution anatomical models, with

applications in multi-grid finite elements for surgery simulation (with finer scales within the surgical corridor) or possibly multi-scale meshing of any anatomy with a means of relating elements at any single scale to overlapping elements at any other scale.

We also describe innovations on deformable 3D 1-Simplex contour models that have been applied to identifying the intra-cranial portion of cranial nerves, including the integration of statistical shape models (SSMs) into the deformable contour model. These contour models have a number of planned, feasible extensions: i) combination with tree-space analysis to produce deformable tree contours for identifying the extra-cranial portion of cranial nerves as well as peripheral, enteric and spinal nerves; ii) combination of SSM-enabled 3D contour models with DTI or HARDI-based tractography towards an average brain template and a "thermometer" for neurodisorders severity and neuroplastic improvement. There are myriad applications of interest to the Computational Neuroscience community. Planned applications will also leverage open-source tractographic reconstruction and neuroactivation software.