

Title: Soft Tissue Image-Guided Surgery: Computational Modeling Enabling Therapy

Authors: Michael I. Miga, Amber L. Simpson, Kay Sun, Thomas S. Pheiffer, Logan W. Clements, D. Caleb Rucker, William R. Jarnagin, and Reid C. Thompson

Often within the medical community, the practical translation of computational modeling for therapeutic benefit is criticized as being limited and non-sensitive to real clinical workflow. As a result, the benefit of computational approaches is diminished and adoption is inhibited. However, with the continued improvements in high performance computing, the ability to translate complex models using large systems of equations from predictive roles to ones that are more integrated within therapeutic systems is becoming a rapid reality. Model-embedded systems designed to enable soft-tissue image guided surgical resection are an excellent example of these efforts. In order to achieve these advances, not only are accurate soft-tissue models necessary, but an intimate understanding of surgical goals, intraoperative workflow, and the appropriate assembly of surgical technologies is necessary. In fact, the paradigm we suggest is that intervention itself is as patient-specific as the data that guides. More specifically, we assert that patient-specific therapy is not limited to the collection of patient-specific data (e.g. imaging, biomarkers, physiological variables, etc.) but rather intervention could represent a dynamic patient-specific relationship between presentation, measurement technology, computation, and surgical approach. This is a paradigm that challenges convention and shifts surgical care to diverse collaborative teams whereby patients, engineers, scientists, and physicians select the optimal combination of technologies to treat based on presentation and surgical goals. One area we have found considerable benefit is in the field of image-guided brain surgery. During image-guided brain surgery, a patient's preoperative images are coupled to the patient using three-dimensional tracking technology. This allows the surgeon to navigate within the brain while observing anatomical locations derived from magnetic resonance data rendered on displays within the operating room. Unfortunately, image-to-patient alignment can be compromised by common surgical events such as retraction, resection, sag due to organ weight, or from the use of hyperosmotic drugs. We report on a computer-model-driven inverse framework that acquires sparse data from the intraoperative environment measuring tissue deformations and then compensates for the complete volume of deformation such that accurate guidance is re-established for soft-tissue brain tumor resection. As an example, results from a 16 patient bystander study are reported whereby the average shift of the brain was approximately 10.1 mm +/- 5.5 mm. After correction the remaining error was 2.7 +/- 1.0 mm. In addition to this remarkable result, we will also report on recent extensions into image-guided liver and breast surgery.

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