Optimization of curved trajectories for the placement of surgical tools in soft tissues*

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Introduction

Context

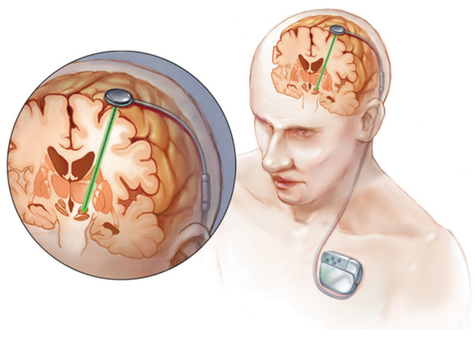


Figure 1: Deep Brain Stimulation DBS

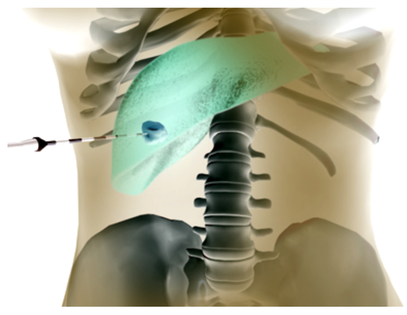


Figure 2: Liver Radiofrequency Ablation

- A successful minimally invasive intervention needs an efficient planning.
- Minimally invasive surgery faces two major challenges: difficulty and reliability.

Problem

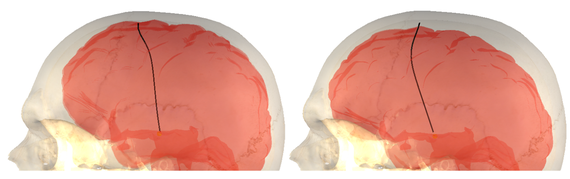


Figure 3: IntraOp(in) - PostOp(out) [1]

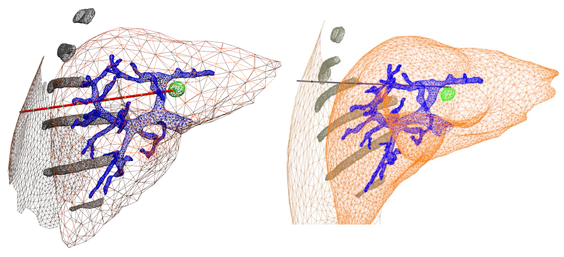


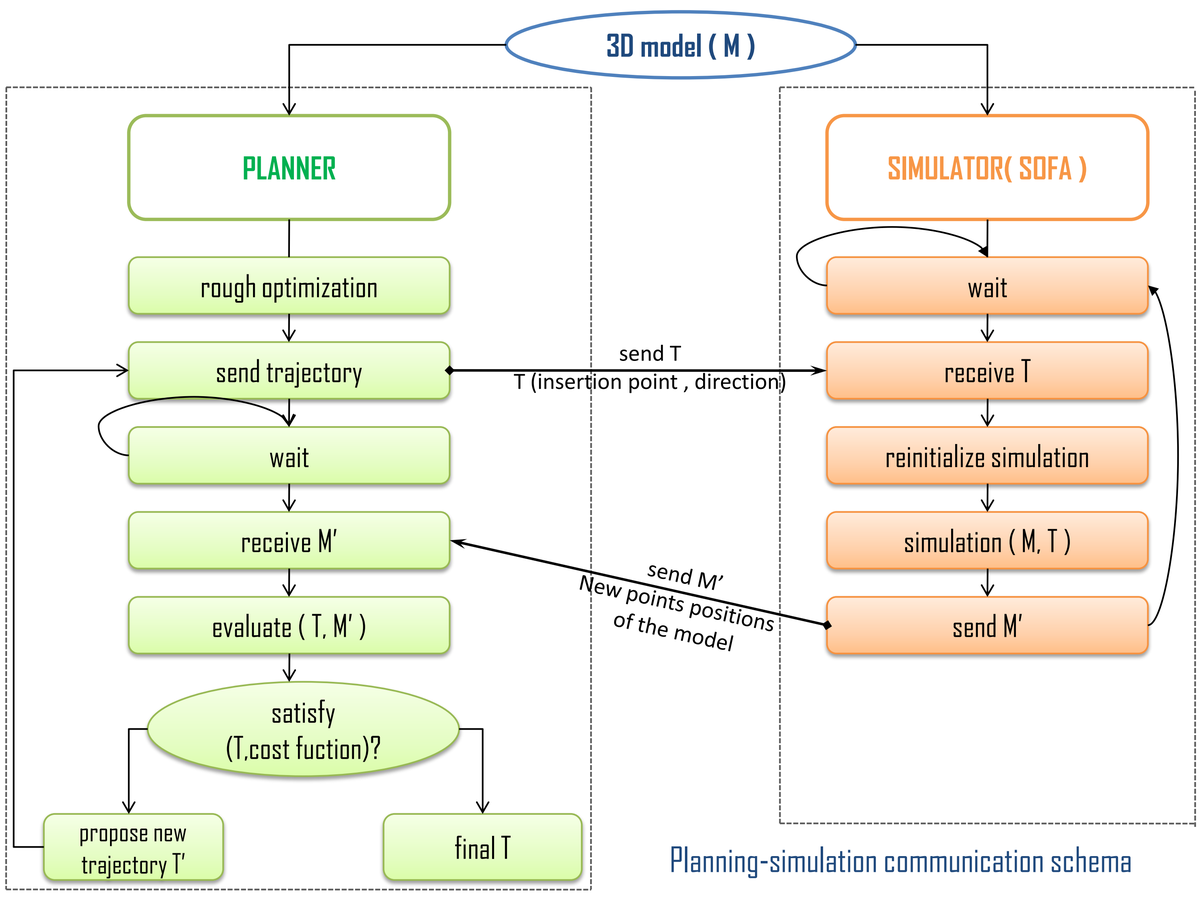
Figure 4: PreOp(in) - IntraOp(out)

- The implanted electrode gets out of the target (Subthalamic Nucleus) after the intervention because of the *brain shift* effect.
- The needle missed the tumor because of the biomechanical deformations of the anatomical tissues during the intervention (breathing, friction, etc.)

Objective

Study a reliable minimally invasive surgery planning method which takes into account the deformability of the tissues

Methods & Results



Planning-simulation communication schema

Approach

- **Start point:**
  We start from an initial solution obtained thanks to an existent constraint solver for static case [2] which manipulates 2 types of constraints:
  - Strict constraints: eliminate all impossible or unsafe trajectories (avoid crossing anatomical risky structures, reach the anatomical target, etc.)
  - Soft constraints: a refinement of the solution by optimizing cost functions (distance to vessels, path length, etc.)
- **First contribution:**
  We implemented a communication pipeline between planning and biomechanical simulation framework (SOFA) to introduce the deformations that occur during the intervention.
- **Second contribution:**
  We are experimenting different optimization algorithms to minimize the number of iterations to reduce the simulation time:
  - Nelder-Mead
  - Simulated annealing
  - Genetic algorithm

Future works

- Compare the optimization algorithms on different 3D models, and select the fastest one.
- Define for each type of intervention the appropriate pipeline of planning with deformations.
- Investigate an intuitive visualization of the possible scenarios.
- Validate results on a large dataset of patients (neurosurgery and liver surgery).

References:

- [1] A. Bilger, J. Dequidt, C. Duriez , S. Cotin. Biomechanical Simulation of Electrode Migration for Deep Brain Stimulation. In 14th International Conference on Medical Image Computing and Computer-Assisted Intervention - MICCAI 2011, Part I, Springer LNCS 6891, pp. 339–346, oct. 2011.
- [2] C. Baegert, C. Villard, P. Schreck, L. Soler, A. Gangi. Trajectory optimization for the planning of percutaneous radiofrequency ablation on hepatic tumors. In Journal of Computer Aided Surgery, 12(2):82-90, Informa Healthcare, Mar. 2007.

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