Anticipation of Brain Shift in Deep Brain Stimulation Automatic Planning
Noura Hamzé1,4, Alexandre Bilger2, Christian Duriez3, Stéphane Cotin3,4, Caroline Essert1,4
1 ICube, Université de Strasbourg, Strasbourg, France
2 University of Luxembourg
3 INRIA, Lille, France
4 Institut Hospitalo-Universitaire de Strasbourg, France

Introduction
Context:
- Automatic preoperative trajectory planning for Deep Brain Stimulation (DBS)
- Typical approaches perform planning on static images data sets without considering intra-operative changes

Problem:
Brain tissues may deform during the surgery and alter the preoperative planning “Brain Shift phenomenon”

Objective:
Patient-specific automatic preoperative planning for DBS which accounts for the brain shift.

METHODS

Illustration showing the components of the simulation

- The brain is modeled using Finite Element Method FEM.
- The main cause of brain shift is a loss of Cerebro-Spinal Fluid (CSF).
- Brain shift occurs in low velocity, we treat the problem as quasi-static.
- We consider the configuration of the brain only at the equilibrium state.
- When the brain deforms and moves, it may collide the endocranium. The detected, contacts are solved using Signorini’s law.

Tests and Results
- We have compared both feasible insertion zones Ω, and Ωd computed in E, and Ed:
  - The feasible insertion zone is reduced by 54.8% (green to red patch percentage on the skin patch image).
- We have compared the optimization results in both E, and Ed:
  - Nelder-Mead could converge in Ed
  - The resulting trajectory is sufficiently safe.
  - The computation time remains acceptable for clinical practice.

Observation:
By comparing (a) and (b): Blue zones (very safe) can be withdrawn from the set of safe trajectories in case of brain shift.

Conclusions
- A novel approach for DBS automatic preoperative planning coupling physical simulations with geometric optimization.
- The obtained results illustrate an important variation of size and shape of the safe insertion zones between static and dynamic conditions.

Perspectives
- Use of intra-operative images to validate the simulations and predictions.
- Improving brain shift model’s accuracy by using more complex deformation and fluid models.
- Investigating and comparing different optimization techniques.

Acknowledgements
The authors thank the French National Research Agency (ANR), and the Institut Hospitalo-Universitaire de Strasbourg (IHU) through ACouStic and HAYSTACK projects.

References