Computation and Visualization of Risk Assessment in Deep Brain Stimulation

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Inria
Introduction: DBS

- Deep brain stimulation (DBS)
  - Neurosurgery, treatment for disorders symptoms (Parkinson's disease) or affective symptoms
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- Deep brain stimulation (DBS)
  - Neurosurgery, treatment for disorders symptoms (Parkinson's disease) or affective symptoms
  - Stimulation of specific deep part of the brain using electrodes
Introduction: Pre-operative planning

- Selection of target coordinates + trajectory
  - Constraints:
    - Avoid vital structures (blood vessels, lateral ventricles)
Introduction: Brain Shift

• Intra-operative brain deformation

  – Causes
  • Cerebro-spinal fluid (CSF) loss when opening the skull

  – Consequences
  • Vital structures have moved
  • **Risk of damaging vessels or ventricles if relying on initial trajectory planning**
Introduction: Risk volume

• Current pre-operative planning:
  – Consider safety margin around a trajectory
  – Cylinder centered around the trajectory, with guessed radius

• Contribution:
  – Definition of physics based brain shift-aware volume to better estimate the risk

• Definition: risk volume = volume around a trajectory where the surgeon checks intersection with vital structures
Methods: Brain Shift Simulation

- 2 independent hemispheres, FEM
- CSF forces model
- Contacts between brain tissue and skull/falx

\[
M \ddot{x} + B \dot{x} + K x = f + H^T \lambda
\]
Methods: Brain Shift Simulation

\[ m \overrightarrow{g} \] \[ \rightarrow \overrightarrow{f}_{CSF} \]

Brain

CSF

Displacement
Methods: Brain Shift Simulation
Methods: Risk Volume

\[ V = \{ x \in \mathbb{R}^3 \mid \| x - x_T \| \leq r, \forall x_p \in [P, \Phi^{-1}(P)], \forall P \in T \} \]
Results
Results

- CSF loss variation
Conclusion

- Methods handles:
  - Trajectory angle
  - Depth in the brain tissue
  - Patient's head orientation compared to gravity direction

- Benefits:
  - More accurate estimation of the safety margin
  - Can be integrated in automatic planning software
Perspectives

- Unknown CSF loss
- Intra-operative evaluation
- Planning validation
Thank you

Questions?

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