Carnegie Mellon University

Robust optimization for the placement of and current through electrodes for neurostimulation

Meeting of the Minds 2023 CIT Honors Thesis Presentation

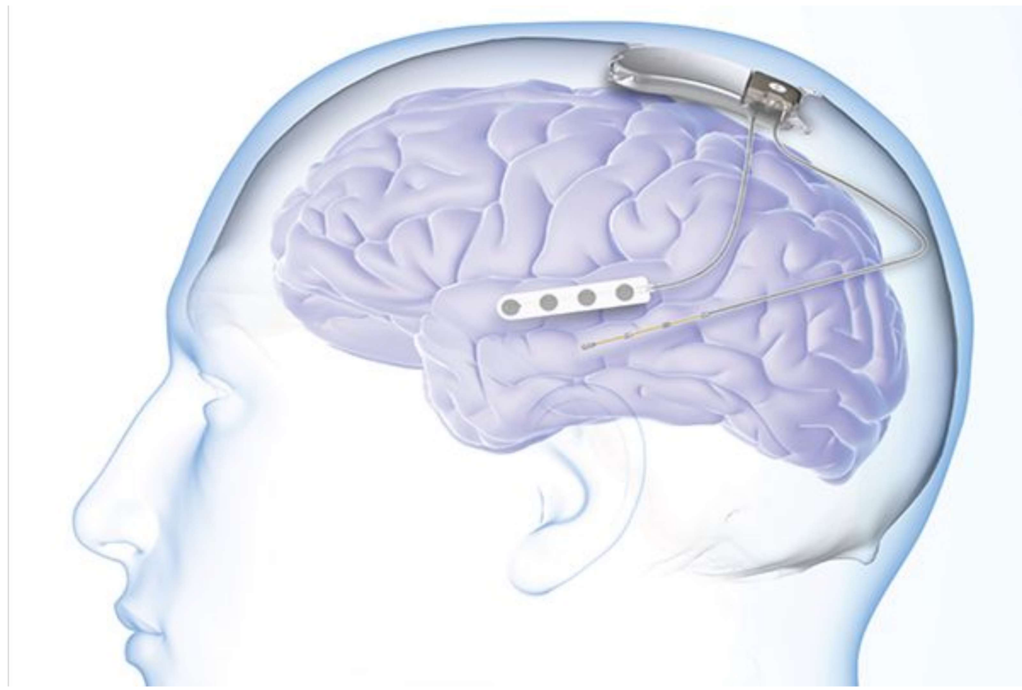
Shivank Joshi
Dr. Pulkit Grover
Chaitanya Goswami

Agenda

1. Background and Motivation
2. Robust Optimization Formulation
3. Results
4. Next Steps

Background

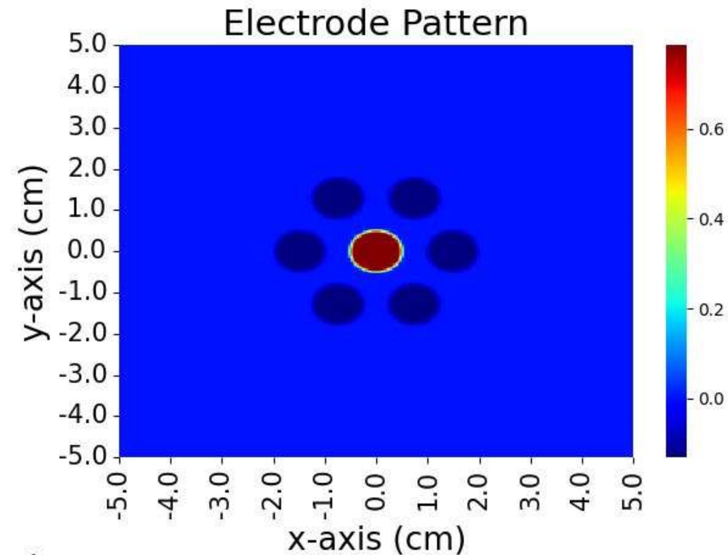
- Researchers use electrodes on the scalp to stimulate different regions of the brain
- Computational tools increasingly used to design electrode schemes

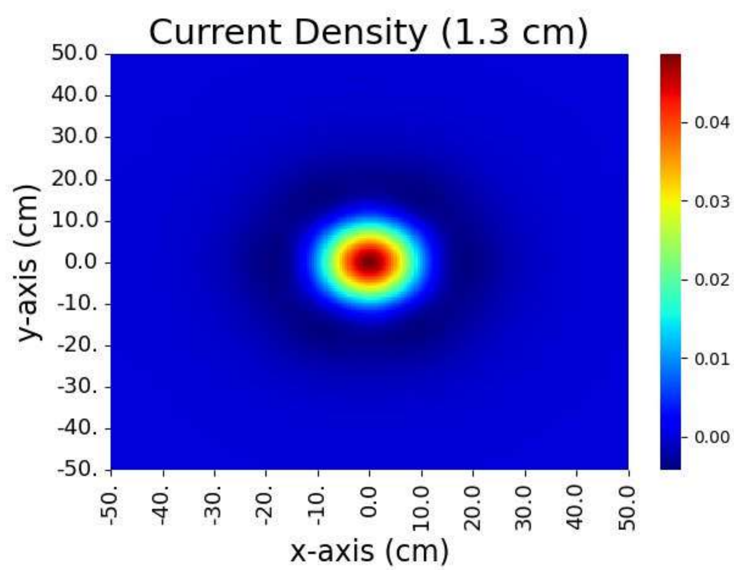


[1]

Which uncertainties are most important in the spherical brain model?

- Radii of different brain layers
- Conductivities of the layers
- Relationship between physical parameters, current, and resulting electric field in brain





The relationship between current passed through electrodes and the expected current can be represented by a transfer matrix

We select two subsets of the points inside the brain:

F - Focus points

C - Cancel points

And we have corresponding bounds on the thresholds:

J_D - Desired current in focus region

J_S - Safety threshold (upper limit)

The design of electrodes focuses on achieving activation in a 'focus' region and having minimal current in a 'cancel' region

A_F - Transfer matrix for focus points

A_C - Transfer matrix for cancel points

I - Current injected into each electrode

The optimization problem to get the best design for some A_F and A_C is convex

$$
\begin{aligned}
\min_{I} \quad & \|A_C I\| \\
\text{s.t.} \quad & A_F I = J_D \\
& \sum I = 0 \\
& I \preceq J_S \\
& \|I\| \leq \beta
\end{aligned}
$$

The reverse problem aims to get the transfer matrices, A_F and A_C, for designed I

c - original conductivities

c′ - conductivity variable

g - tolerance on how much

c can deviate from c′

$$\max_{c} \alpha * \|A_C(c)I\| + \|A_F(c)I - J_D\|$$
$$\text{s.t. } (c - c') \preceq g$$

The robust optimization approach sequentially

1. Solve for I using original approach.
   $I' = I$
2. Solve for worst case c yielding A'_F and A'_C using I'
3. Resolve for I' using original approach

How does the robust optimization compare to the original formulation?

Using particle swarm optimization to get worst-case

- This robust formulation yielded 12.5% improvement
- The robust formulation had slightly worst performance on average case

Conclusions and Next Steps

- A robust approach could help researchers design safer experiments
- Future work
  - Validating work on larger variety of parameters
  - Extend to include other uncertainties
  - Design other robust formulations

Thank you to Dr. Pulkit Grover and Chaitanya Goswami!