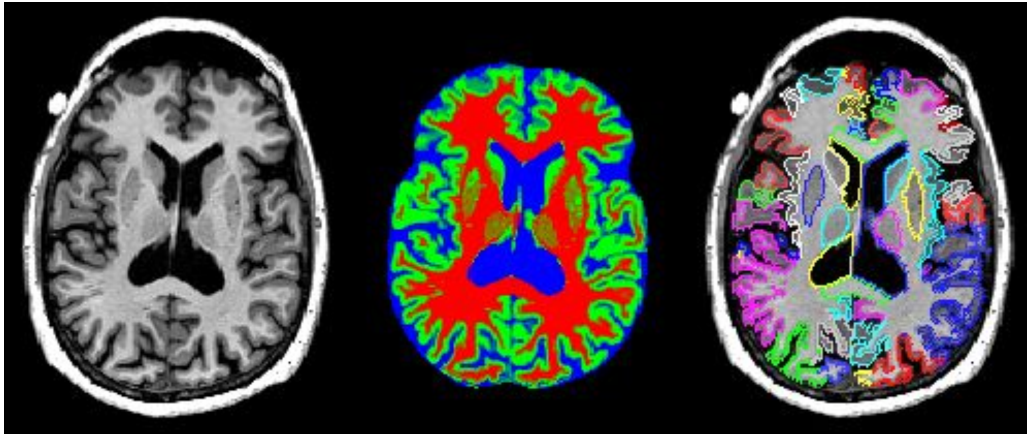
Optimization-based Segmentation of Brain Using a Genetic Algorithm

Tim Ruesink, Grant Roberts, Lawrence Lechuga

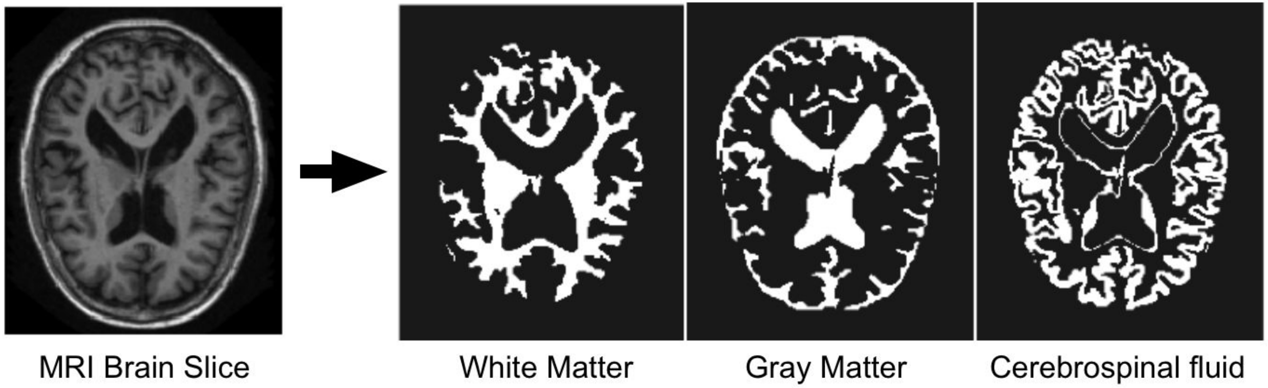


Background

Segmentation: Divide an image into set of meaningful, homogenous, and non-overlapping regions, based on attributes in the image.

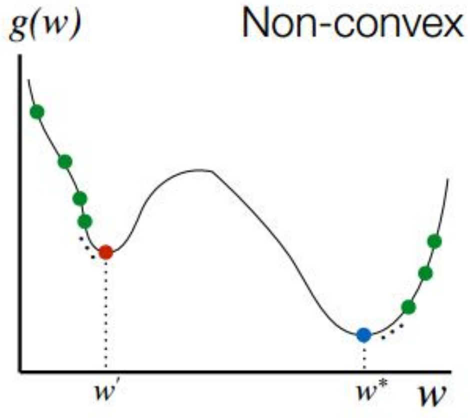
Challenges: Partial volume effect, artifacts (motion, etc), complex geometry of objects in question, and noise adds uncertainty to the process.

Common Methods: Thresholding, k-means clustering, atlas, and manual methods



Motivation

Find an optimization method that performs well in a non-convex solution space.



Specifically, we want to compare a gradient-based approach to a genetic algorithm approach using the Pott's model as our formulation.

Objective Function: Potts Model

- Formulation: $$\text{minimize } \gamma\|\nabla \mathbf{x}\|_0 + \|\mathbf{x} - \mathbf{y}\|_2^2$$

- Jump Penalty: Forces Piecewise constant solutions $\gamma\|\nabla \mathbf{x}\|_0$

- Data term: Couples minimizing candidate **x** to data **y** $\|\mathbf{x} - \mathbf{y}\|_2^2$

$$\boxed{\text{Non-Convex}}$$

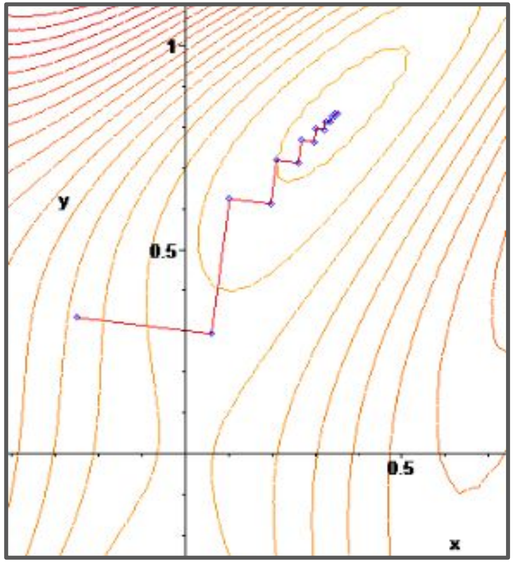
Gradient-Based Optimization Segmentation

How do Gradient-Based Methods work? Take a step proportional to the gradient of the cost function.

What are common gradient-based methods? Steepest descent, conjugate gradients, Newton’s method, Quasi-Newton

Advantages: Generality and simplicity, can handle many types of cost functions

Drawbacks: Converge slowly, sensitive to local minima



Genetic Algorithm Segmentation

What are genetic algorithms? Used to find global minimum solution for non-linear or non-convex optimization problems

How do Genetic algorithms work? Conceptualized using evolutionary biology

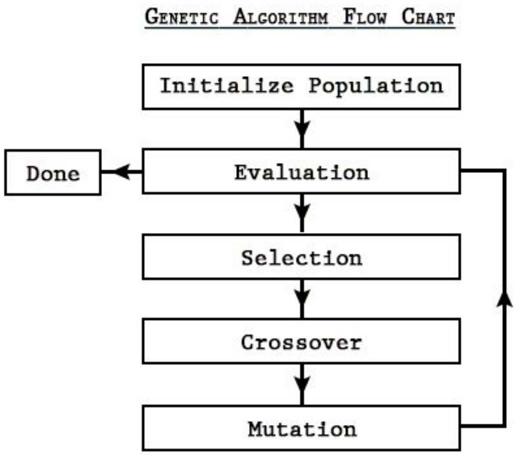


FIGURE 2

Selection: Keep best performing Solutions (Parents)

Crossover: Create new solutions (Children) from the Successful Parents

Mutation: Create new solutions (Children) by taking successful parent and mutating certain variable to take on random values.

Analysis and Comparison

1. Shepp-Logan Phantom segmentation using:
   a. Gradient-Based Algorithm
   b. Genetic Algorithm
2. Computational Time
3. Performance/Correctness
   a. Qualitative Results
   b. DICE Coefficient

$$DC = \frac{2|\hat{A} \cap A^*|}{|\hat{A} \cup A^*|}$$

Objectives

1. Understanding and modeling the segmentation problem using the Potts Model (Definition of cost function)
2. Learn how to implement a Gradient-Based Algorithm for segmentation optimization
3. Learn how to implement a Genetic Algorithm for segmentation optimization
4. Use both algorithm for a realistic medical imaging application
5. Compare the performance of each algorithm

Questions