

# Distributed and Scalable Optimization for Robust Proton Treatment Planning

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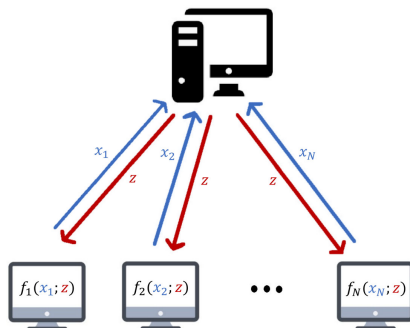
# Robust Proton Therapy

- Proton therapy vulnerable to errors during treatment planning
- Robust optimization used to develop plan that performs well in multiple error scenarios
- Robust proton treatment planning:
  - 1 Identify potential errors/uncertainties
  - 2 Simulate dose distribution in each scenario
  - 3 Optimize plan so clinical objectives met, taking into account all possible scenarios

# Motivation

- To achieve clinically optimal plan, must consider many error scenarios
- But robust optimization problem grows more complex as the number of scenarios increases
- Need an optimization method that is **fast**, **scalable**, and **efficient** in navigating the search space of feasible plans

# Distributed Optimization



- Multiple agents collaborate to solve an optimization problem
- Typically, each agent handles part of problem, then results combined to produce solution
- Fast, memory efficient, scales well with size of data

# Alternating Direction Method of Multipliers (ADMM)

- Distributed optimization method dating back to 1970's
- Used in many fields: ML, data science, imaging, robotics, engineering, biology, finance...

## Distributed optimization and statistical learning via the **alternating direction method of multipliers**

[S Boyd](#), [N Parikh](#), [E Chu](#), [B Peleato...](#) - ... and Trends® in ..., 2011 - nowpublishers.com

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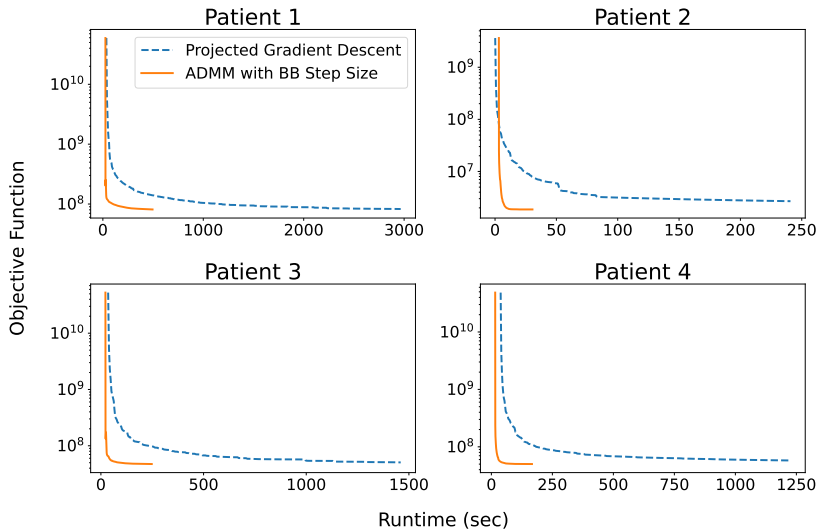
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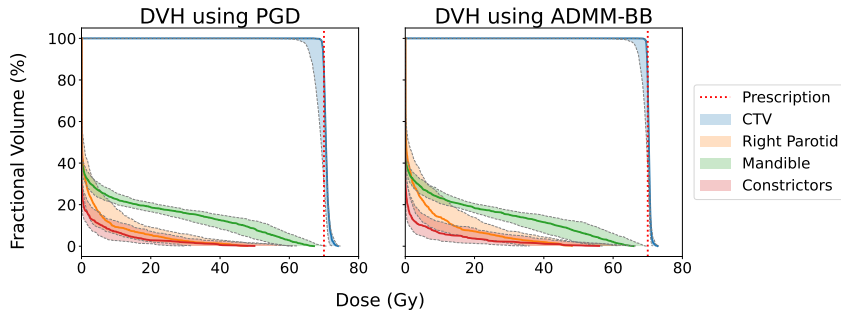
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- **Key point:** ADMM splits the problem into simpler subproblems, which can be *distributed* and solved *in parallel* on multiple processors (e.g., CPUs)

# Objective Value vs. Algorithm Runtime

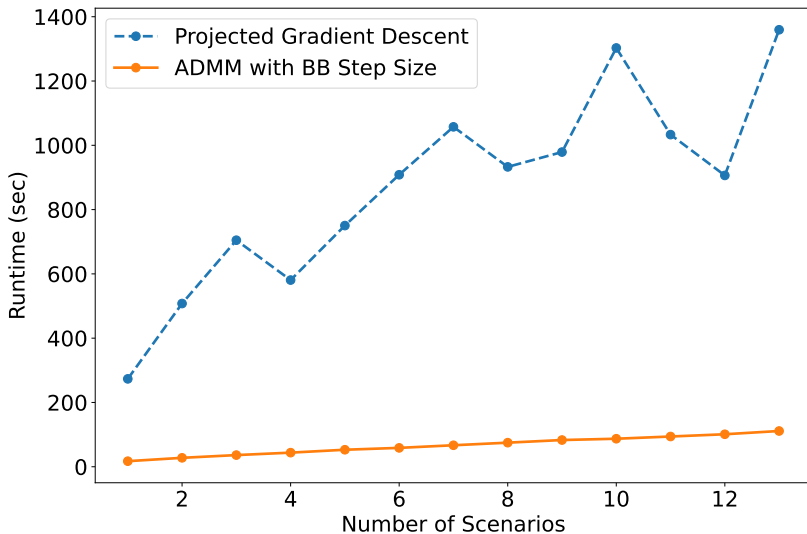


# Dose-Volume Histogram (DVH) Bands





# Algorithm Runtime vs. Number of Scenarios



# Conclusion

- Robust optimization used in clinic, but suffers from slow speed and high computational overhead
- ADMM splits optimization problem so workload can be distributed efficiently across multiple CPU cores/threads
- Results in shorter planning time and improved plan quality
- Future work: implement ADMM in the cloud

**A. Fu**, V. T. Taasti, M. Zarepisheh. "Distributed and Scalable Optimization for Robust Proton Treatment Planning." *Medical Physics*. Revised and Resubmitted, June 2022.