# Distributed and Scalable Optimization for Robust Proton Treatment Planning

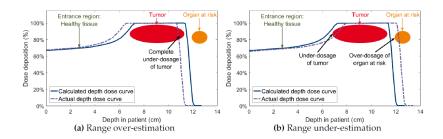
**Anqi Fu**<sup>1</sup> Vicki T. Taasti<sup>2</sup> Masoud Zarepisheh<sup>1</sup>

<sup>1</sup>Memorial Sloan Kettering Cancer Center <sup>2</sup>Maastricht University Medical Center, Maastro Clinic fua@mskcc.org

> AAPM Annual Meeting July 10–14, 2022

> > | ロ ト 4 昼 ト 4 昼 ト | 夏 | 夕 Q ()

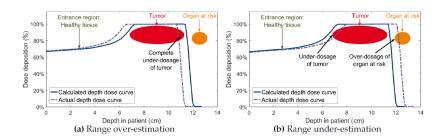
## **Robust Proton Therapy**



Proton plans susceptible to uncertainties

2/9

## **Robust Proton Therapy**



- Proton plans susceptible to uncertainties
- Robust optimization desensitizes the plans to uncertainties
- Main steps:
  - 1 Identify errors/uncertainties
  - Simulate dose distribution in each uncertainty scenario
  - Optimize for all possible scenarios

<□▶<₫▶<≣▶<≣▶ 열 ∽9٩℃

2/9

#### Motivation

- Downsides:
  - 1 Computationally expensive and slow
  - 2 Problem size grows as number of scenarios increases
  - 3 Less parameter tuning ⇒ potential plan sub-optimality

Fu, Taasti, Zarepisheh

#### Motivation

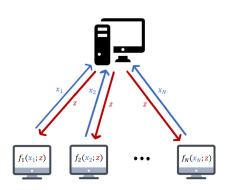
- Downsides:
  - Computationally expensive and slow
  - Problem size grows as number of scenarios increases
  - 3 Less parameter tuning ⇒ potential plan sub-optimality

• Solution: fast and scalable distributed optimization



Fu, Taasti, Zarepisheh

# Distributed Optimization



- Multiple agents collaborate to solve optimization problem
- Each agent handles part of the problem
- Fast, memory efficient, scales well with size of data

Fu, Taasti, Zarepisheh July 10, 2022 4/9

# Alternating Direction Method of Multipliers (ADMM)

- Distributed optimization method dating back to 1970's
- Recently gained attention in machine learning & data science

# 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 Many problems of recent interest in statistics and machine learning can be posed in the framework of convex optimization. Due to the explosion in size and complexity of modern ...
```

☆ Save 59 Cite Cited by 17674 Related articles All 47 versions ≫

5/9

## Alternating Direction Method of Multipliers (ADMM)

- Distributed optimization method dating back to 1970's
- Recently gained attention in machine learning & data science

# 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

Many problems of recent interest in statistics and machine learning can be posed in the framework of convex optimization. Due to the explosion in size and complexity of modern ...

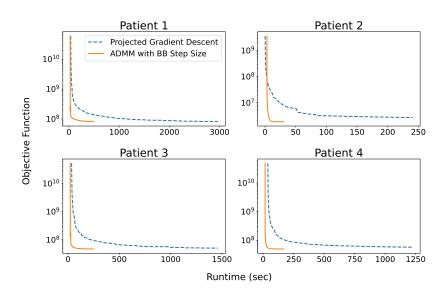
☆ Save 切 Cite Cited by 17674 Related articles All 47 versions ≫
```

#### • Key points:

- Split the problem into simpler subproblems
- Solve each subproblem with a separate agent (CPU, GPU)

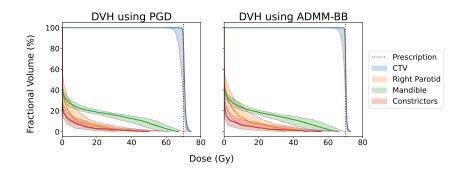
Fu, Taasti, Zarepisheh July 10, 2022 5/9

#### Objective Value vs. Algorithm Runtime



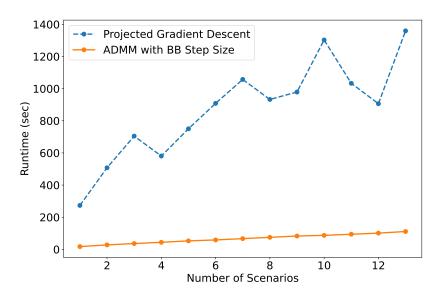
6/9

#### Dose-Volume Histogram (DVH) Bands



7/9

#### Algorithm Runtime vs. Number of Scenarios



8/9

#### 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*. Under minor revision, June 2022.