Tensor Network Hackathon

Team 9: Optimizing Camera Placement for Emergency Prevention and Response

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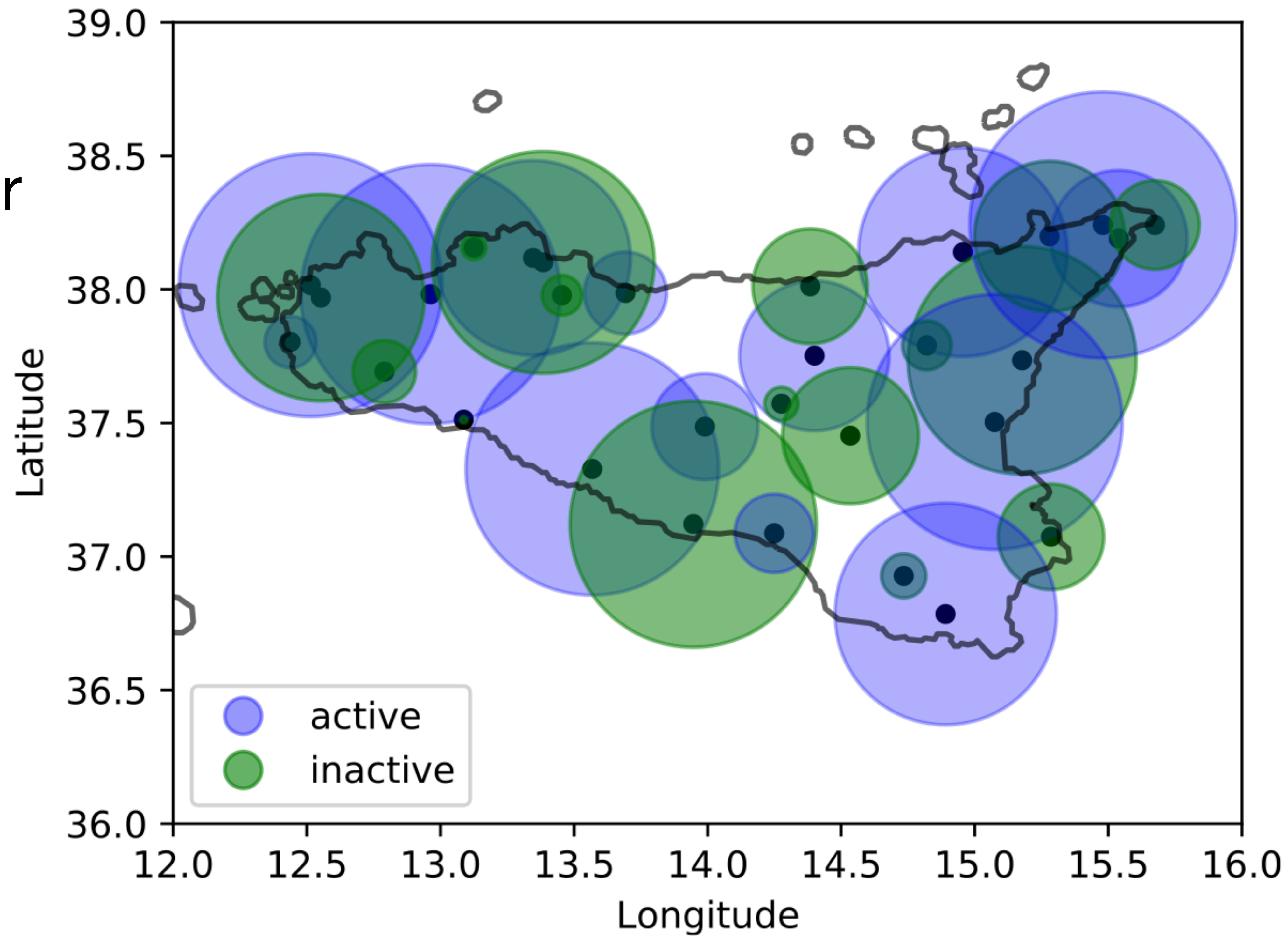
Introduction

Camera Placement problem

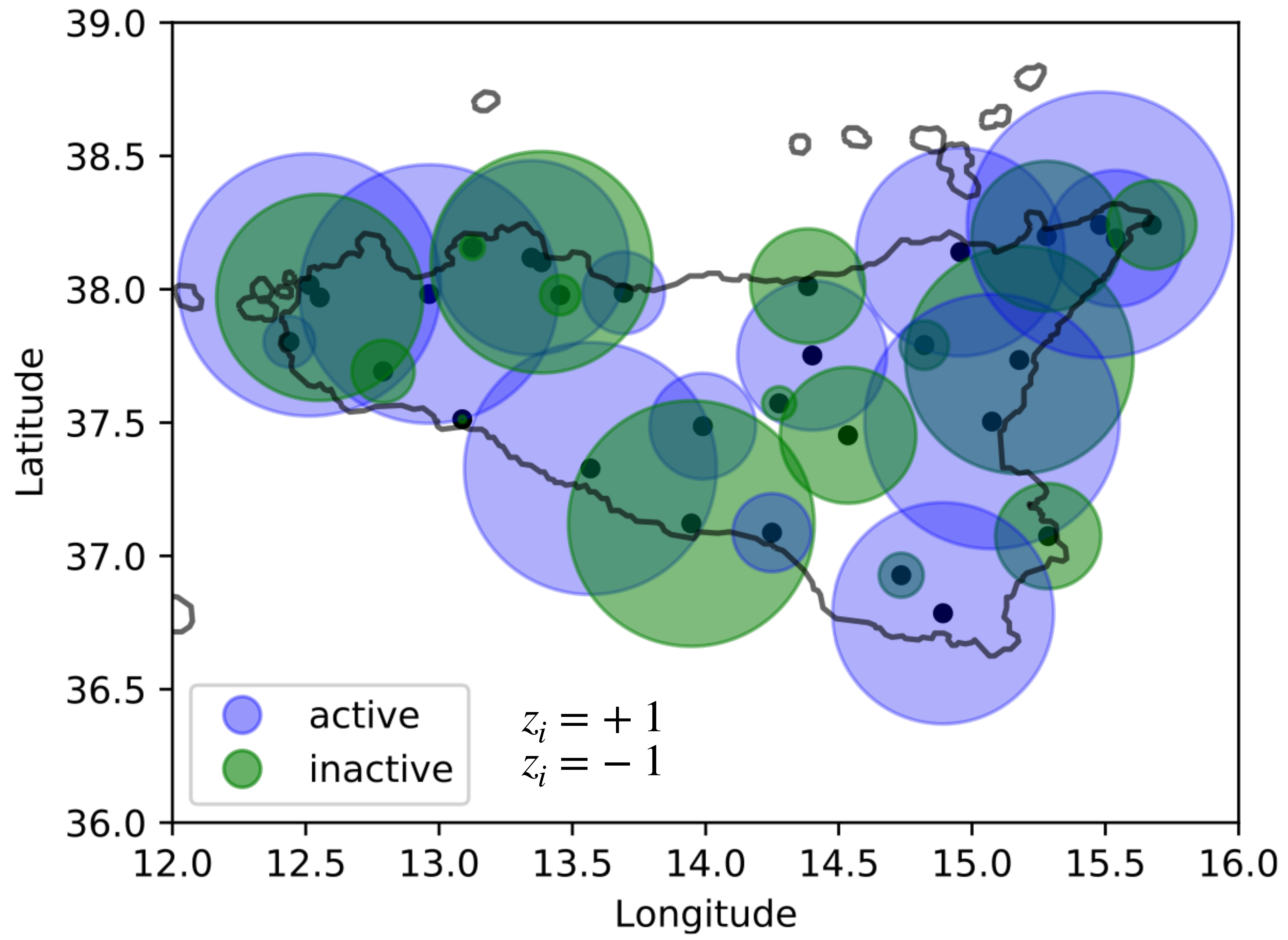
- Deployment of hyper-spectral cameras in case of natural disaster
- High cost → goal is to maximise utility
  - Maximize coverage
  - Minimize overlap
  - Satisfy constraints

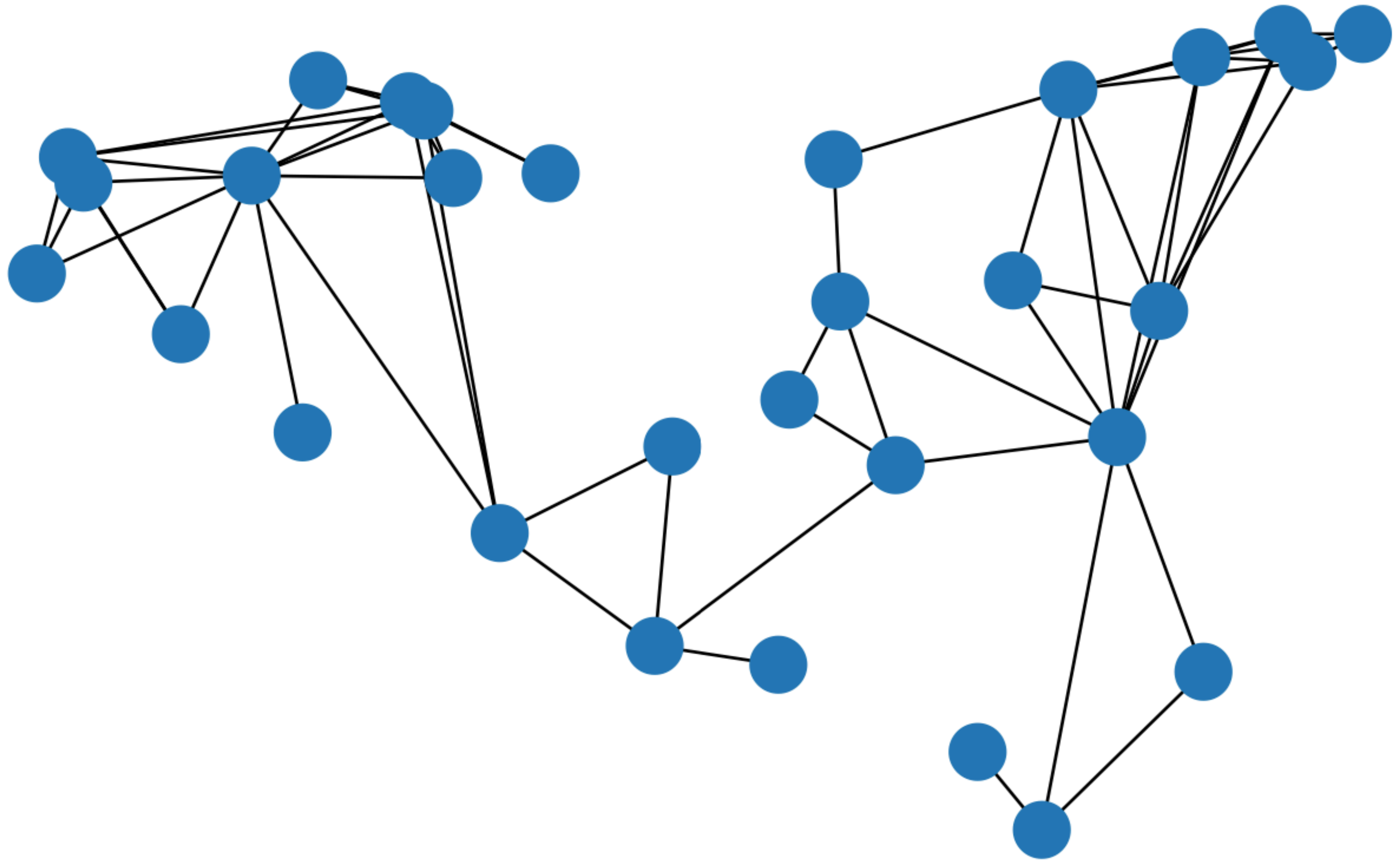


Vandelli, M., Lignarolo, A., Cavazzoni, C., & Dragoni, D. (2023). Beyond Theory: Evaluating the Practicality of Quantum Optimization Algorithms for Prototypical Industrial Applications. *arXiv preprint arXiv:2311.116*

Introduction

Camera Placement problem in Ising formulation



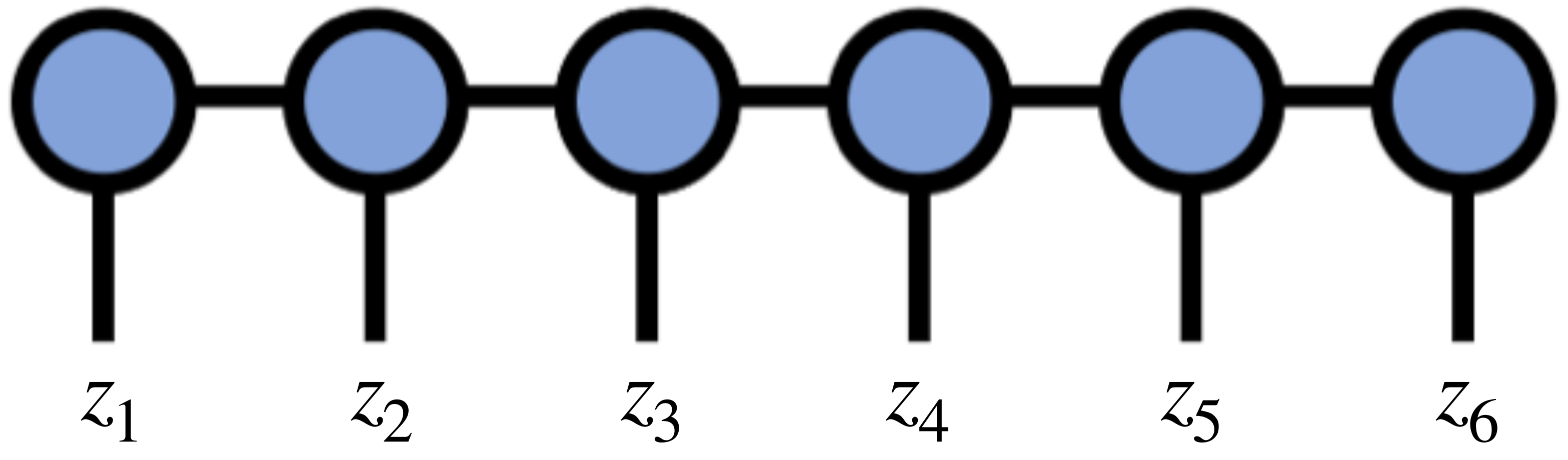


$$H(z) = \sum_{i<j}^{N} W_{ij} z_i z_j - \xi \sum_{i=1}^{N} A_i z_i$$

W_{ij} — symmetric overlap between camera i and j

A_i — area covered by camera i

TN ansatz



Ground state search with DMRG and imag. time evolution (ITE)

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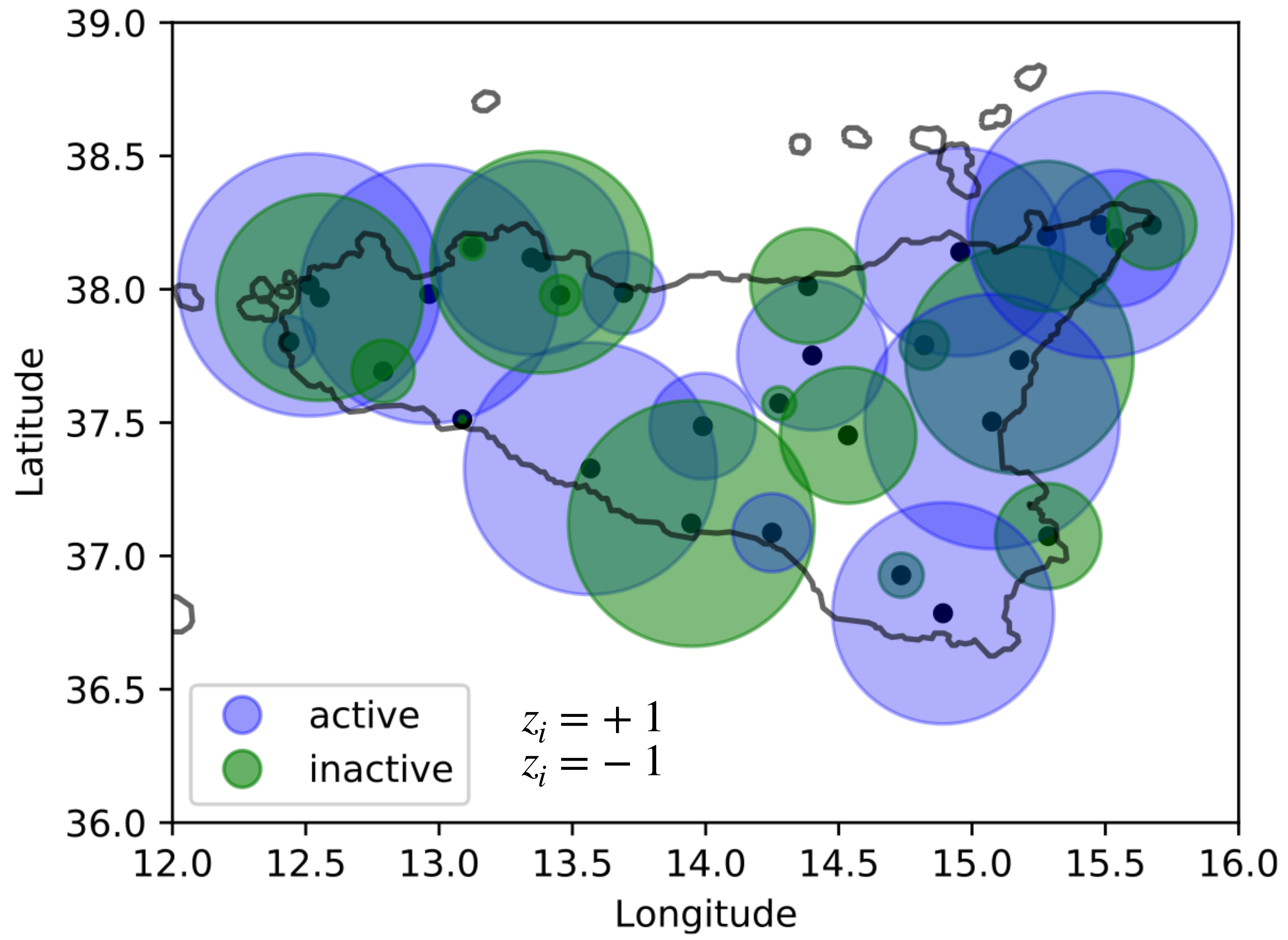
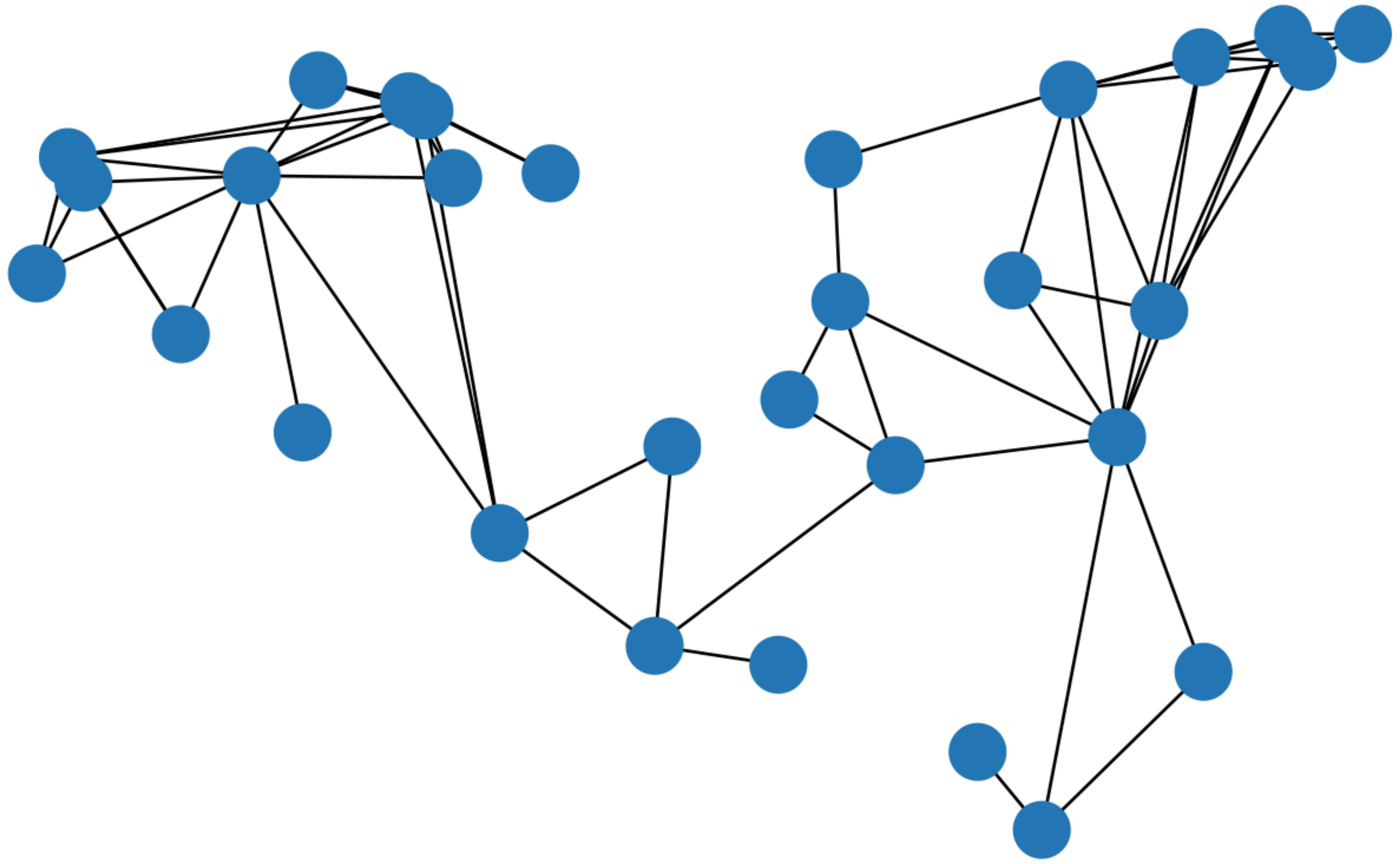
Introduction

Camera Placement problem: Constrained case





$$H(z) = \sum_{i<j}^{N} W_{ij} z_i z_j - \xi \sum_{i=1}^{N} A_i z_i + P \left(\sum_{i=1}^{N} z_i - N + 2C \right)^2$$

$$H(z) = \sum_{i<j}^{N} \tilde{W}_{ij} z_i z_j - \sum_{i=1}^{N} \tilde{A}_i z_i \qquad \begin{aligned} \tilde{W}_{ij} &= W_{ij} + 2P(N - 2C) \\ \tilde{A}_i &= 2P(N - 2C) - \xi A_i \end{aligned}$$

with penalty term P, available antennas C (set to $N/2$)

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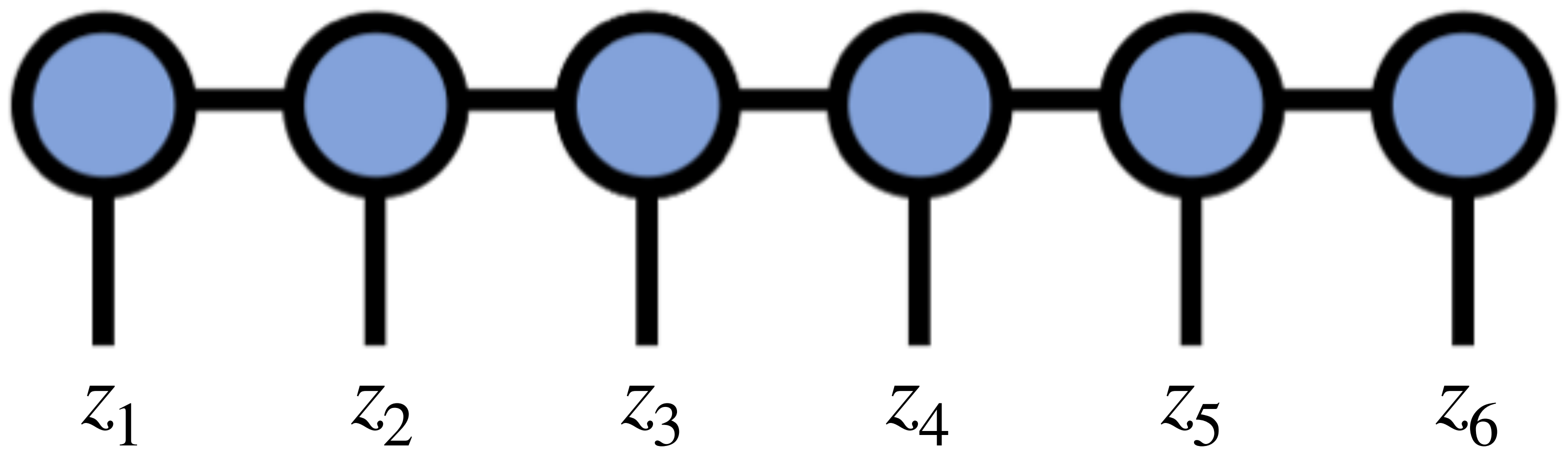
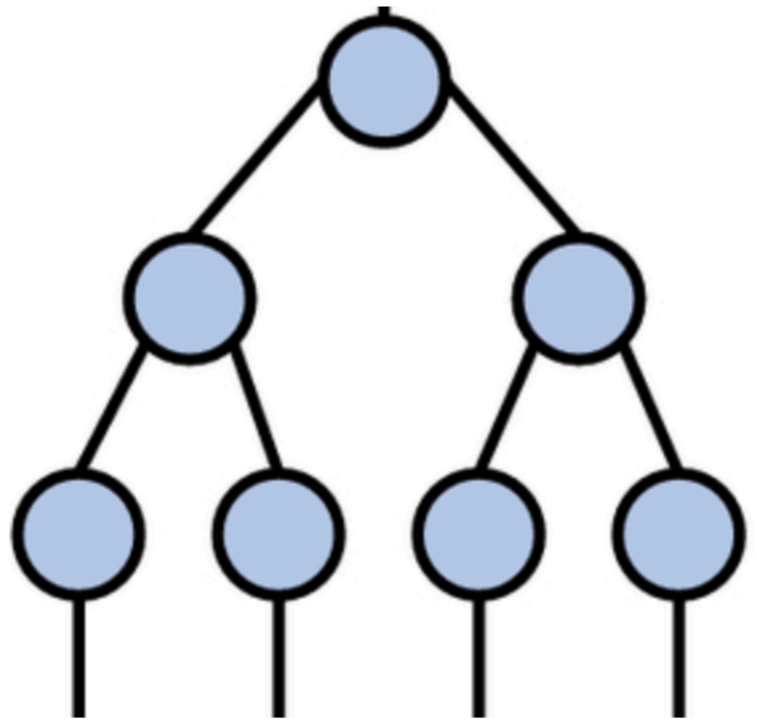
Introduction

Implementation





- Quantum Tea Leaves:
  - Tensor network ansatz with MPS, TTN
  - Ground state search with DMRG, ITE

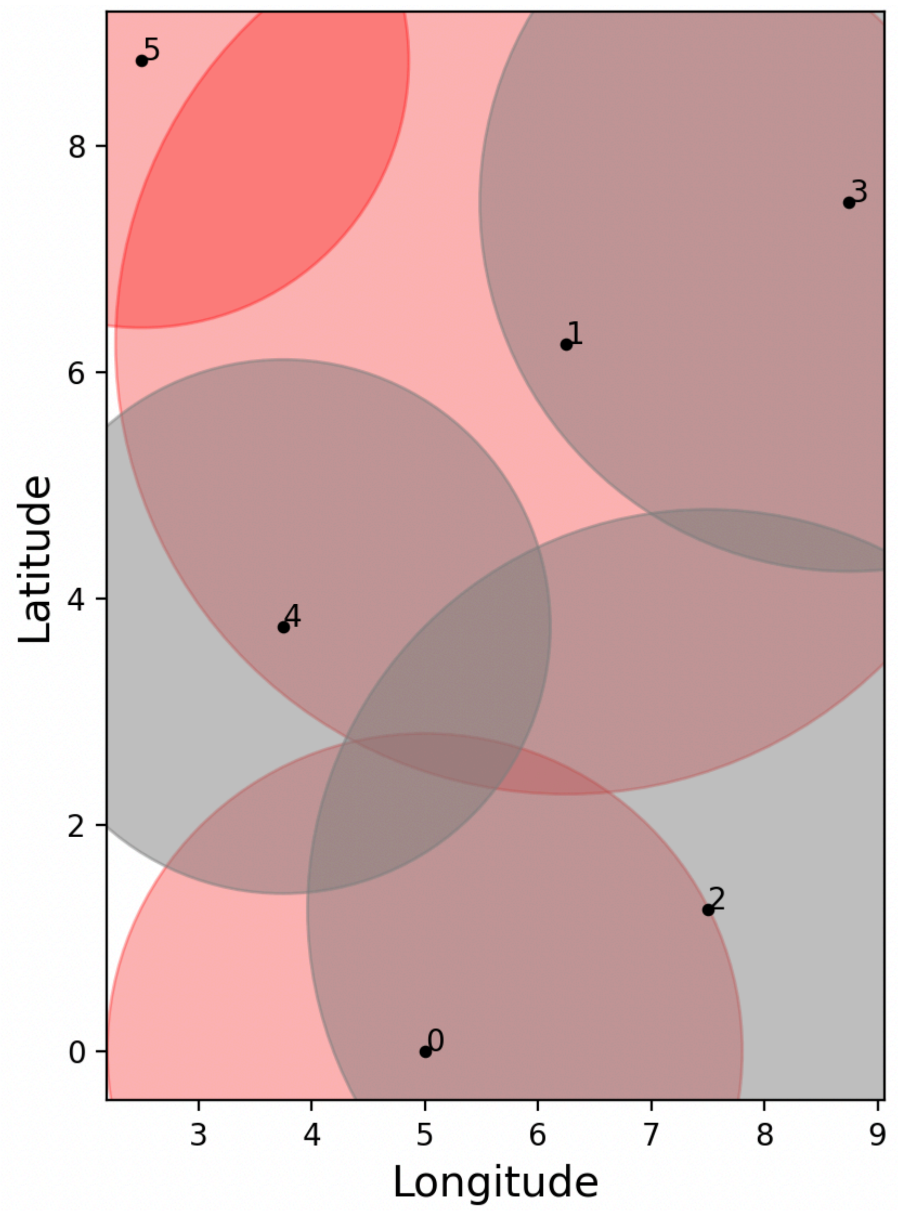
ITE: $t \to -i\tau,\ |\psi(t)\rangle = e^{-\tau\hat{H}}|\psi(t=0)\rangle$

- Brute force:

generate

(-1,+1,-1,+1,+1)
(+1,-1,-1,+1,+1)
(+1,-1,+1,-1,+1)

$\xrightarrow{\text{evaluate}}$ $H(z)$



- Commercial Solver: GUROBI

Ground state search via DMRG & ITE

Hyperparameter optimization

- To optimize:
  - Max. number of steps/sweeps: 500
  - Max. bond dimension: 32
  - (TTN+DMRG) Sweep order: simple vs. random
  - (ITE): Time-step (“temperature”): 0.1

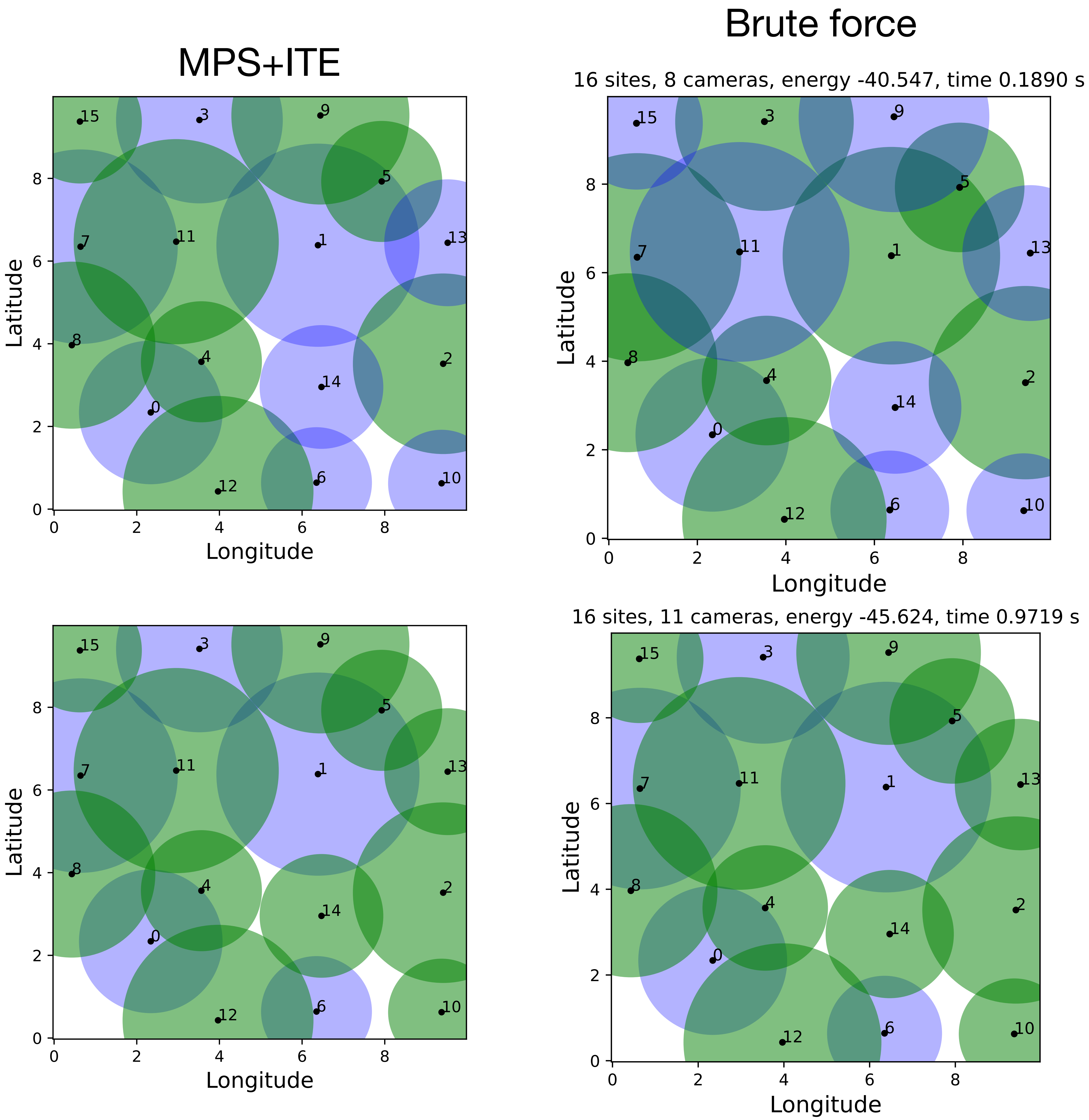
Performance comparison

Visual agreement ...?

- Test case:
  - N=16 sites
  - $\xi = 0.25$
  - constraint:
C=N/2
P=50

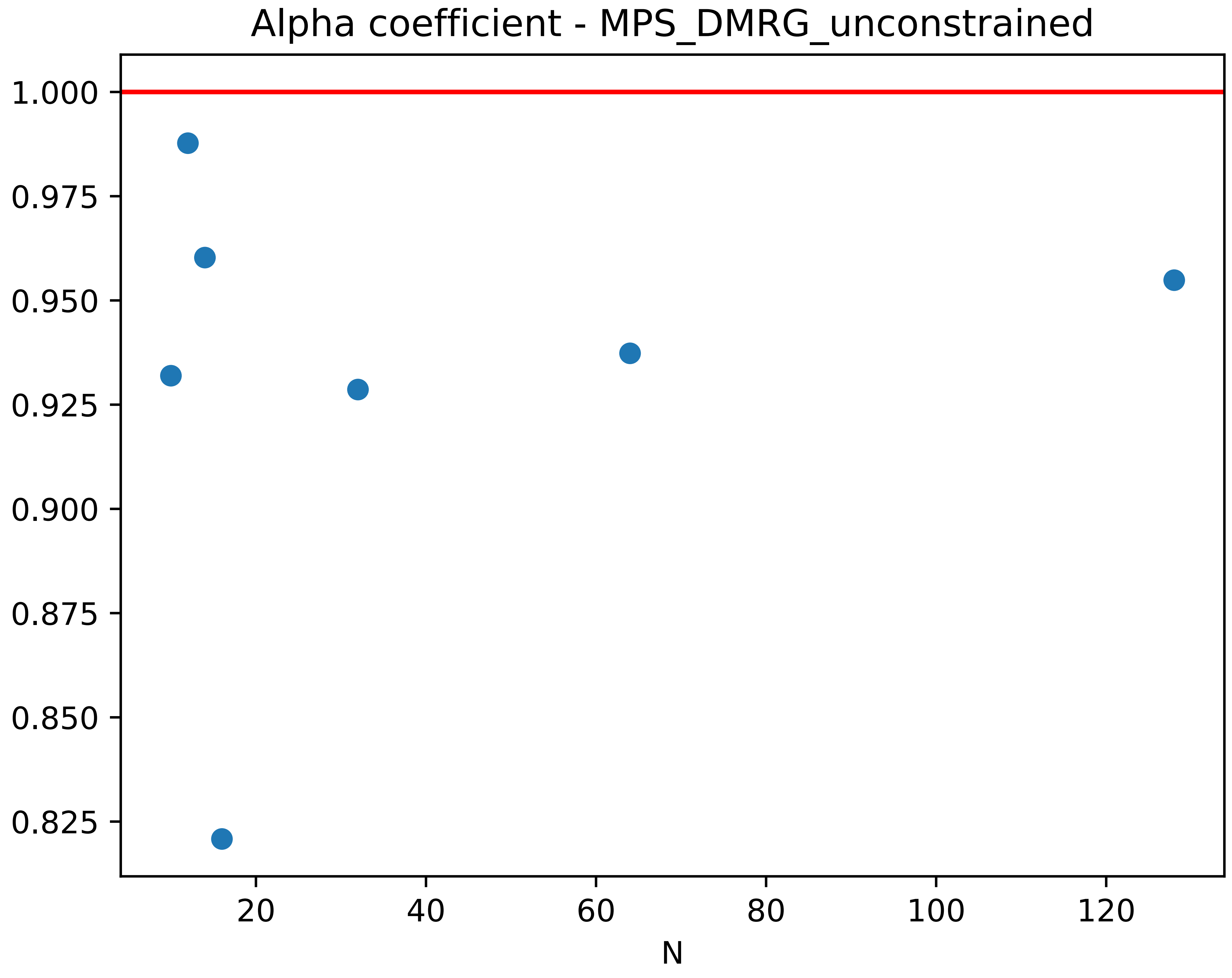
Constrained

Unconstrained

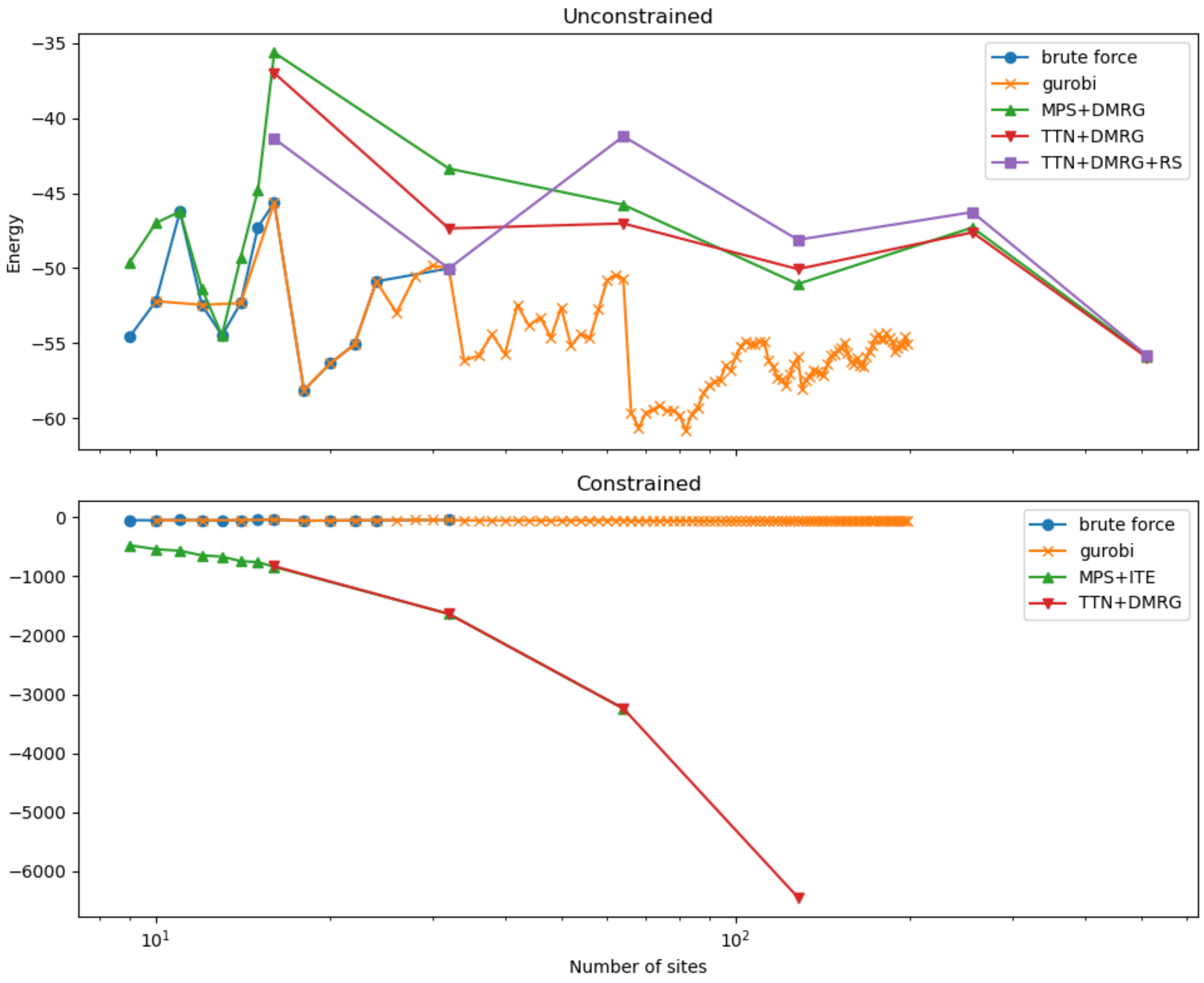


Performance comparison

Energy&approximation ratio of the optimal solution



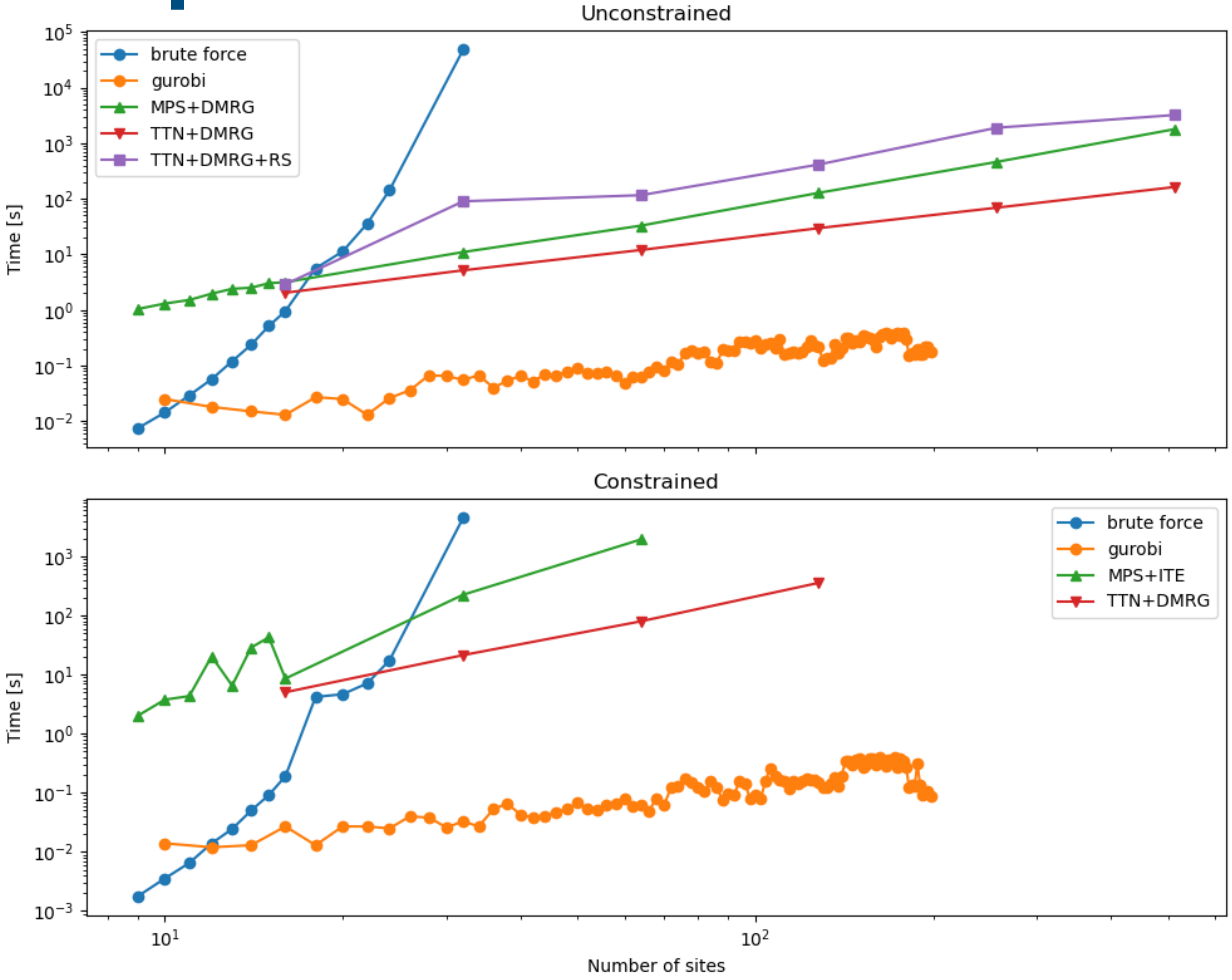
$$\alpha(E) = 1 - \frac{E - H_{\min}}{H_{\max} - H_{\min}}$$



Performance comparison

Time to solution

- Time scaling
  - BF: exponential
  - TN: linear



Thank you!