Topic 9: Optimizing Camera Placement for Emergency Prevention and Response

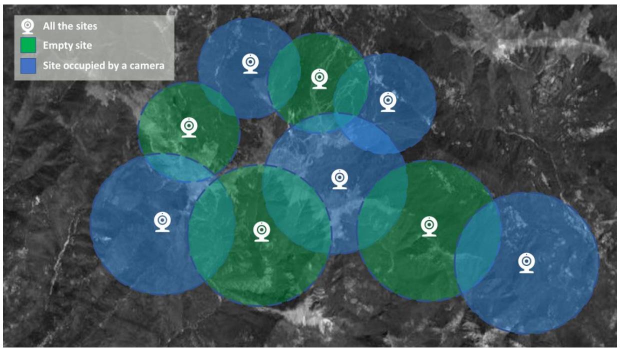
What to expect

In this project, the participants will be asked to solve a simplified instance of an industrial problem using the TN approach. While problems emerging in physics or chemistry usually involve the calculation of expectation values, in industrial use-cases the focus is on the generation of a high-quality solution string that can be used to take effective actions. The focus of this project is the extrapolation of key performance metrics of the TN algorithms on the Camera Placement problem, as the problem size is increased. This project will require basic knowledge of combinatorial optimization problems and TNs, as well as a good command of the Python language, especially for analysis of the results and visualization.

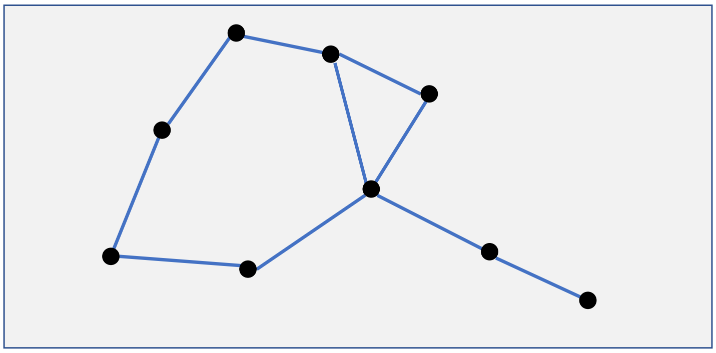
Overview

The goal of this project is to apply a tensor-network (TN) approach to a combinatorial optimization problem of industrial interest, the Camera Placement problem, and to estimate the scaling towards realistic problem sizes.

Example of solution of the camera placement problem



Corresponding graph describing the connectivity of the problem



Hyper-spectral cameras can be deployed to monitor a territory to identify signatures of an imminent extreme natural event, such as floods, earthquakes, and wildfires. Depending on the nature of the risk, this kind of systems can also be equipped with sensors to monitor air parameters and seismic activity. The utility of these monitoring systems extends to the emergency response phase, in which it allows to collect useful information to the rescuers, ensuring efficient and swift Search & Rescue operations. Since this kind of high-resolution and hyper-spectral cameras is very expensive, a limited number of them is available to be deployed. Usually, this number is much smaller than the number of candidate sites.

In this project, we propose an Ising formulation of the Camera Placement Problem similar to that introduced in Ref.[12], which is a proxy to real-world applications. Specifically, the problem amounts to finding the optimal placement of the cameras on several available sites. The cameras must be distributed on the territory at optimal locations to maximize the coverage and to reduce overlaps between the field-of-vision of the cameras. This Ising problem will be provided in two variants: a model with sparse connectivity between the sites, in which the number of cameras is not fixed, and a model with full connectivity, due to the soft constraint on the camera number. Since the problem is already in the Ising form, its solution can readily be obtained with a ground state search of the corresponding quantum Hamiltonian.

Tasks

- Solve a small-scale problem instance using exact methods, such as brute-force search or *state-of-the-art* solvers, as a benchmark
- Translation to a TN-based ground state search using variational ground-state search and imaginary-time evolution
- Implementation and validation of the code w.r.t. the benchmark
- Evaluation of selected performance metrics, including (but not limited to):
  - ☐ Convergence of the algorithmic hyper-parameters (variational steps, temperature, number of steps...)
  - ☐ Estimation of the time-to-solution (TTS) *vs* the number of sites (qubits) N
  - ☐ Comparison of the solution quality attainable with TNs for the constrained and unconstrained problems
- **Optional**: comparison of the TN performances with those obtained with commercial solvers (f.i. GUROBI, CPLEX...)

[12] M. Vandelli et al., arXiv preprint, arXiv: 2311.11621 (2024).