Lehrstuhl II für Mathematik

RWTH AACHEN UNIVERSITY

Mathematical Heuristics Project

Optimal Wiring of Heliostats in Solar Tower Power Plants

Problem Setting

In a solar tower power plant, several hundred planar mirrors (heliostats) concentrate the sunlight onto a tower on which an absorber is mounted (cf. Fig. 1). The absorber transfers the heat into a medium (e.g. water) in order to power a turbine which generates electrical energy. Depending on the position of the sun and the arrangement of the mirrors, heliostats may block and shade each other, which has a great effect on the efficiency (and thus operational cost) of the solar tower power plant.

Figure 1: Solar tower plant PS10 in Spain.

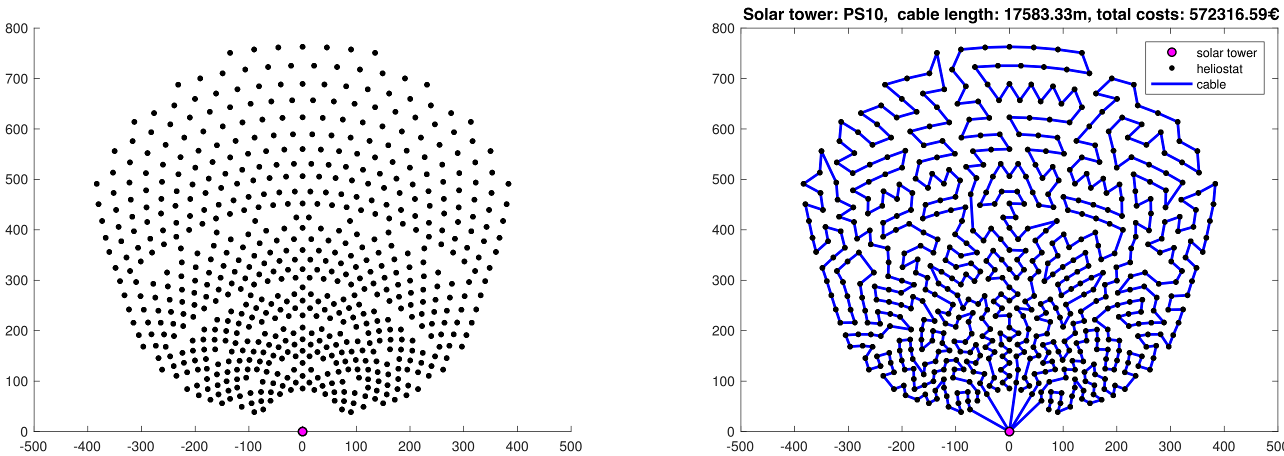
To overcome these issues, heliostats are usually mounted to movable bases which allow for position adjustments. The coordination and control of position adjustments requires all heliostats to be connected to a control station situated within the solar tower via data cables. The fiber optic cables used for this purpose as well as their laying are expensive and thus the following problem arises: How can we optimally (w.r.t. cost) connect all heliostats to the solar tower?

Optimal Wiring of Heliostats

Let us define the *heliostat wiring problem* (HWP): Connecting all heliostats to the solar tower, the following requirements have to be met:

- All heliostats have to be connected to the solar tower.
- Cables must not overlap to ease maintenance.
- The maximum number of connected heliostats per cable is limited to $h_{\max} = 128$.

The cost for buying and laying fiber optic cables are directly proportional to the length of the cable and we summarize the cost per meter for various countries in Table 1.



(a) (b)

Figure 2: (a) Layout of PS10. The tower is located at position (0,0). (b) Wiring of PS10 via paths.

Country	Price [€/m]
Australia	54
Spain	29
South Africa	14
United Arab Emirates	14

Table 1: Material and installation cost.

Local Control Units

Once the fiber optic cable is laid up to a heliostat, the optically coded directives have to be extracted and passed on to the movable base for execution by so-called local control units (LOC). The simplest available LOCs are conductors which allow for exactly one ingoing and up to one outgoing fiber optic cable. In particular, conductors consequently do not allow for cables to be split.

In order to split an incoming fiber cable at a heliostat, we have to install switches instead of conductors as LOC. Switches optically duplicate the incoming signal and therefore allow for one incoming and multiple outgoing fiber optic cables. The total number of outgoing cables connected to a switch is limited by its number of ports. For example, a 8-port switch can have one incoming and up to 8 outgoing cables.

The cost for setting up conductors or the two types of available switches are summarized in Table 2.

Local Control Unit	Price [€]
Conductor	100
8-port switch	800
16-port switch	1500

Table 2: Cost of local control units.

Project Organization

In order to pass the project, form groups of three people to work on the heliostat wiring problem (HWP) and reach the following milestones:

1. Prove or contradict the following statement: In an optimal solution to the HWP cables do not intersect, even if we don't force the corresponding constraint.
2. Formulate the HWP as an integer program.

} Hand-in until 11th June (LaTeX)

3. Develop at least two different heuristic approaches for the HWP.
4. Apply the developed algorithms to the real-world instance PS10 (cf. Figure 1) and:
   - Visualize your solutions.
   - Compare your algorithms with regard to solution quality and complexity.
   - Investigate how the location (and therefore installation cost) of a solar power plant influences the cable layout.
5. Present your results. Presentations will take place in the last week of June.

The instance PS10 is encoded in the file *positions-PS10.csv* which contains the coordinates of all 624 heliostats. The solar tower is located at the origin $(0, 0)$, refer to Figure 2a. Within the coordinate system, the Euclidean distance between any two points yields the distance in meters.