Exercise 1. Use linear relaxation, greedy algorithm and local improvement to solve an instance of the uncapacitated facility location problem with

$$C' = \begin{pmatrix} 3 & 9 & 2 & 6 \\ 5 & 9 & 7 & 6 \\ 0 & 7 & 6 & 6 \\ 6 & 7 & 4 & 0 \end{pmatrix}, \qquad f = \begin{pmatrix} 3 \\ 2 \\ 3 \\ 3 \end{pmatrix}.$$

Exercise 2. Use Lagrangian relaxation and linear relaxation to solve the binary knapsack problem:

$$\begin{array}{lrl} \max & 9x_1 + 4x_2 + 15x_3 & \\ \text{s.t.} & 3x_1 + 2x_2 + \ 4x_3 & \leq 5 \\ & x_1, x_2, x_3 & \in \{0, 1\} \end{array}$$

Exercise 3. Apply Lagrangian relaxation with the subgradient method to the integer program:

$$\begin{array}{lrl} \max & 16x_1 + 10x_2 + 4x_4 & \\ \text{s.t.} & 8x_1 + \ 2x_2 + x_3 + 4x_4 & \leq 10 \\ & x_1 + \ x_2 & \leq 1 \\ & x_3 + \ x_4 & \leq 1 \\ & x_1, x_2, x_3, x_4 & \in \{0, 1\} \end{array}$$

Exercise 4. Solve the 1-tree relaxation of the symmetric TSP given by the distance matrix

$$\begin{pmatrix} - & 10 & 2 & 4 & 6 & 2 \\ 10 & - & 9 & 3 & 1 & 3 \\ 2 & 9 & - & 5 & 6 & 1 \\ 4 & 3 & 5 & - & 2 & 5 \\ 6 & 1 & 6 & 2 & - & 3 \\ 2 & 3 & 1 & 5 & 3 & - \end{pmatrix}.$$

Exercise 5. Approximate the optimal solution of the following set covering instance using the greedy algorithm:

$$A = \begin{pmatrix} 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 1 \end{pmatrix}, \qquad c = \begin{pmatrix} 5 \\ 2 \\ 4 \\ 6 \\ 7 \end{pmatrix}.$$

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