Many software packages exist for optimization. Some SW packages use the natural mathematical algebra language for formalizing the problem, e.g., The General Algebraic Modeling System (GAMS) https://www.gams.com/ and the Python library Pyomo[1]. Some SW packages use the general approach of programming languages using arrays and matrices, e.g., the python libraries SciPy[2] and PyOpt[3]

1. Install the packages mentioned above. **Hint:** GAMS is proprietary SW; however, there is a free license with limitations that will be more than enough for this exercise and for larger projects.
2. Consider the two optimization problems (Chong and Zak, 2001, Ex. 15.1, P.307) and (Chong and Zak, 2001, Ex. 14.3). The first is a constrained LP problem and the second is a non-constrained non-linear problem. Each problem has just two variables. For each problem do the following:
   a) Plot the objective function (in 3D plot), along with a planar contour plot (on the $x_1 - x_2$ plane) on the same 3d plot.
   b) Use the appropriate function in each of the 4 packages above to optimize both problems.
   c) In particular, for the non-linear optimization problem, try to run the optimizer several times with several parameters to see how many times it will find the global minima and how many times it will be trapped in the local minima.
   d) For both problems write your own code to solve using the brute-force method (by building a 2d mesh ($r \times r$) for the two variables, evaluating the objective function on each point of the mesh, then find the minimum value.) Repeat this step at different mesh resolution r and plot the execution time as a function of r.

Remark 1 *This assignment is due next week; however, each two students can form a team and submit together a single report.*

Bibliography

Chong, E. K. and Zak, Stanislaw, H. (2001), *An Introduction to Optimization*, Wiley-Interscience, 4th ed.

[1] http://www.pyomo.org/
[2] https://docs.scipy.org/doc/scipy/reference/tutorial/optimize.html
[3] http://www.pyopt.org/