# CS730 Programming Project

Program an instructor-approved algorithm to solve a nonlinear programming problem and test it by solving the two attached problems from **ALL GIVEN STARTING POINTS**. The attached report form, **ONE FOR EACH STARTING POINT AND PROBLEM**, is due in class, on the day assigned. No late reports will be accepted. Each student must write his/her own program in MATLAB or any other language. Hand in a copy of your program. Highlight in color the output for **EACH STARTING POINT AND PROBLEM**.

### Possible Sources for Algorithms


1. M. Avriel: "Nonlinear Programming Analysis and Methods", Prentice Hall, Englewood Cliffs, New Jersey, 1976.
2. M. S. Bazaraa, H. D. Sherali & C. M. Shetty: "Nonlinear Programming Theory and Algorithms", Second Edition, Wiley, New York, 1993.
3. D. P. Bertsekas: "Nonlinear Programming", Second Edition, Athena Scientific, Belmont, MA 1999.
4. D. P. Bertsekas: "Constrained Optimization and Lagrange Multiplier Methods", Academic Press, New York, 1982.
5. A. Fiacco & G. P. McCormick: "Nonlinear Programming: Sequential Unconstrained Minimization Techniques", Wiley, New York, 1968, SIAM, Philadelphia 1990.
6. U. M. Garcia Palomares & O. L. Mangasarian: "Superlinearly Convergent Quasi-Newton Algorithms for Nonlinearly Constrained Optimization Problems", Math. Prog. 11, 1976, 1-13.
7. P. E. Gill, W. Murray & M. H. Wright: "Practical Optimization", Academic Press, New York, 1981.
8. S.-P. Han: "A Globally Convergent Method for Nonlinear Programming", J. Opt. Theory & Appl. 22, 1977, 297-309.
9. S.-P. Han & O. L. Mangasarian: "Exact Penalty Functions in Nonlinear Programming", Math. Prog. 17, 1979, 251-269.
10. O. L. Mangasarian: "Unconstrained Methods in Nonlinear Programming", Vol. IX, SIAM-AMS Proceedings, Amer. Math. Soc., Providence, Rhode Island, 1976, 169-184.
11. G. P. McCormick: "Nonlinear Programming Theory, Algorithms and Applications", Wiley, New York, 1983.

12. J. Nocedal and S. J. Wright: "Numerical Optimization", Springer-Verlag, New York 1999.

13. E. Polak: "Computational Methods in Optimization", Academic Press, New York, 1971.

14. M. J. D. Powell: "Algorithms for Nonlinear Constraints that Use Lagrangian Functions", Math. Prog. 14, 1978, 224-248.

15. W. Zangwill: "Nonlinear Programming: A Unified Approach", Prentice Hall, Englewood Cliffs, New Jersey, 1969.

16. G. Zoutendijk: "Mathematical Programming Methods", North Holland, Amsterdam, 1976.

17. Recent issues of SIAM Journal on Optimization, Mathematical Programming, Computational Optimization and Applications, Journal of Optimization Theory and Applications and Optimization Methods and Software.

# Nonlinear Programming Algorithm Test Problem 1

$$\min\ e^{-x_2} + x_2 + e^{-x_5} + x_5 + \tfrac{1}{2}[x_1 x_2 x_3 x_4 x_5] \begin{pmatrix} 5 & 4 & 4 & 3 & 3 \\ 4 & 4 & 4 & 3 & 3 \\ 4 & 4 & 6 & 3 & 3 \\ 3 & 3 & 3 & 5 & 3 \\ 3 & 3 & 3 & 3 & 9 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} - [44\ 39\ 42\ 31\ 29] \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix}$$

$$\text{s.t.} \quad \begin{array}{rcrcrcrcrcl}
-x_1 & + & 6x_2 & - & x_3 & - & 10x_4 & + & 7x_5 & \leq & 10 \\
x_1 & + & x_2 & + & x_3 & + & x_4 & + & x_5 & \leq & 9 \\
 & & x_2 & - & 10x_3 & - & 20x_4 & + & 6x_5 & \leq & 6 \\
2x_1 & + & 3x_2 & + & x_3 & & & & & \leq & 14 \\
 & & x_2 & & & & & - & x_5 & \leq & 23 \\
 & & & & x_3 & + & x_4 & + & x_5 & \leq & 3 \\
(x_1)^2 & + & (x_2)^2 & + & (x_3)^2 & + & (x_4)^2 & + & (x_5)^2 & \leq & 41 \\
x_1 & , & x_2 & , & x_3 & , & x_4 & , & x_5 & \geq & 0
\end{array}$$

Nonnegativity constraints are optional. They may be dropped or included.

Starting Feasible Point: $x_i = 0,\ i = 1, \ldots, 5$.

Starting Infeasible Point: $x_i = 10,\ i = 1, \ldots, 5$.

Minimum Value = -200.5

# Nonlinear Programming Algorithm Test Problem 2
# The Shell Dual: Colville Test Problem No. 2[1]

Number of Independent Variables: 15

Number of Constraints: 20

Objective Function:

$$\min \sum_{i=1}^{k} -b_i x_i + \sum_{i=1}^{m} \sum_{j=1}^{m} c_{ij} y_i y_j + 2 \sum_{j=1}^{m} d_j y_j^3$$

$$m = 5,\ b_i,\ c_{ij},\ d_j \text{ on attached page}$$

Constraints:

$$\text{s.t.} \sum_{i=1}^{k} a_{ij} x_i \leq e_j + 2 \sum_{i=1}^{m} c_{ij} y_i + 3 d_j y_j^2$$

$$y_j \geq 0 \quad x_i \geq 0 \qquad j = 1, \ldots, m$$

$$i = 1, \ldots, k$$

$$k = 10$$

$a_{ij},\ c_{ij},$ on attached page

Feasible Starting Point:

$$\begin{aligned} x_i &= .0001,\ i \neq 7,\ i = 1, \ldots, 10 \\ x_7 &= 60 \\ y_j &= .0001,\ j = 1, \ldots, 5 \end{aligned}$$

Non-feasible Starting Point:

$$\begin{aligned} y_1 &= y_2 = y_3 = y_4 = 0 \\ y_5 &= 1 \\ x_i &= b_i,\ i = 1, \ldots, k \end{aligned}$$

Minimum Value = 32.34868

[1] D. M. Himmelblau: "Applied Nonlinear Programming", McGraw-Hill, New York 1972, Problem 10, pp 404-405.

## Data for Test Problem 2

| | $j$ | 1 | 2 | 3 | 4 | 5 | | |
|---|---|---|---|---|---|---|---|---|
| | $e_j$ | $-15$ | $-27$ | $-36$ | $-18$ | $-12$ | | |
| $c_{ij}$ : | 1 | 30 | $-20$ | $-10$ | 32 | $-10$ | | |
| | 2 | $-20$ | 39 | $-6$ | $-31$ | 32 | | |
| | 3 | $-10$ | $-6$ | 10 | $-6$ | $-10$ | | |
| | 4 | 32 | $-31$ | $-6$ | 39 | $-20$ | | |
| | 5 | $-10$ | 32 | $-10$ | $-20$ | 30 | | |
| | $d_j$ | 4 | 8 | 10 | 6 | 2 | | |
| $a_{ij}$ : | 1 | $-16$ | 2 | 0 | 1 | 0 | $-40$ | : $b_i$ |
| | 2 | 0 | $-2$ | 0 | 0.4 | 2 | $-2$ | |
| | 3 | $-3.5$ | 0 | 2 | 0 | 0 | $-.25$ | |
| | 4 | 0 | $-2$ | 0 | $-4$ | $-1$ | $-4$ | |
| | 5 | 0 | $-9$ | $-2$ | 1 | $-2.8$ | $-4$ | |
| | 6 | 2 | 0 | $-4$ | 0 | 0 | $-1$ | |
| | 7 | $-1$ | $-1$ | $-1$ | $-1$ | $-1$ | $-40$ | |
| | 8 | $-1$ | $-2$ | $-3$ | $-2$ | $-1$ | $-60$ | |
| | 9 | 1 | 2 | 3 | 4 | 5 | 5 | |
| | 10 | 1 | 1 | 1 | 1 | 1 | 1 | |

**CS 730 : Nonlinear Programming Algorithms**
**Report on NLP Algorithm Test Problem 1**

(Hand in computer output. Mark in color information given below on output.)

1. **Student Name:** **Date:**
2. **Test Problem Number:**
3. **Algorithm Used:**
4. **Minimum Value of Objective:**
5. **Computer Used & Time in Seconds:**
6. **Number of Major Iterations of Algorithm:**
7. **Starting Vector:**
8. **Solution Vector:**

**CS 730 : Nonlinear Programming Algorithms**
**Report on NLP Algorithm Test Problem 2**

(Hand in computer output. Mark in color information given below on outpu t.)

**1. Student Name:** **Date:**

**2. Test Problem Number:**

**3. Algorithm Used:**

**4. Minimum Value of Objective:**

**5. Computer Used & Time in Seconds:**

**6. Number of Major Iterations of Algorithm:**

**7. Starting Vector:**

**8. Solution Vector:**