To compile the callable library form of BPMPD, the source files `bpmain.f`, `minput.f`, `mpsinp.f`, `mpsout.f` and `convert.f` have to be omitted. An interface, which simplifies the use of BPMPD as a subroutine can be created (we will describe such an interface in one of the forthcoming sections) and included to the source files. We would like to note that only one routine, *mprnt* (located in the file `mprnt.f`) contains write statements to external files.

3 Solution of a problem

The first step of the solution process is to generate an input file which describes the optimization problem. BPMPD supports the industry–standard MPS format with some extensions. In the input file A, b and c, furthermore the bounds on individual variables and rows are specified by the usual ROWS, COLUMNS, RHS, BOUNDS, RANGES records of the MPS format [10]. To specify the quadratic part of the problem, a new section "QUADOBJ" is introduced. It serves to specify the lower triangular part of the quadratic objective in that relative column order as it has been given in the COLUMNS section. One element of the quadratic objective One element of the quadratic objective Q_{ij} which corresponds to the term $x_i x_j$ is identified by the column names of x_i and x_j. Otherwise the data records in the QUADOBJ section are of the same structure than that of the COLUMNS section.

As example for the problem formulation, let us consider the following quadratic programming problem:

$$\begin{array}{rcrcrcrcrcr} \min\ f(x,y) = & 4 & + & 1.5x & - & 2y & + & 4x^2 & + & 2xy & + & 5y^2, \\ & & & 2x & + & y & \geq & 2, & & & & \\ & & & -x & + & 2y & \leq & 6, & & & & \\ & & & 0 \leq x \leq 20, & & y \geq 0. & & & & & & \end{array}$$

After implied rewriting:

$$\begin{array}{rcrcrcrcrcrcr} \min\ f(x,y) = & 4 & + & 1.5x & - & 2y & + & \frac{1}{2}(8x^2 & + & 2xy & + & 2yx & + & 10y^2), \\ & & & 2x & + & y & \geq & 2, & & & & & & \\ & & & -x & + & 2y & \leq & 6, & & & & & & \\ & & & 0 \leq x \leq 20, & & y \geq 0. & & & & & & & & \end{array}$$

Thus the Q matrix is

$$\begin{bmatrix} 8 & 2 \\ 2 & 10 \end{bmatrix}$$

for which the lower triangular part (to be given) is:

$$\begin{bmatrix} 8 & \\ 2 & 10 \end{bmatrix}.$$

Below we have shown the MPS file corresponding to the example. Note that the additive term in the objective function is given in the RHS section by opposite sign.

```
NAME          QP example
ROWS
 N  obj
 G  r1
 L  r2
COLUMNS
    c1        r1                 2.0   r2                -1.0
    c1        obj                1.5
    c2        r1                 1.0   r2                 2.0
    c2        obj               -2.0
RHS
    rhs1      obj               -4.0
    rhs1      r1                 2.0   r2                 6.0
BOUNDS
 UP bnd1      c1                20.0
QUADOBJ
    c1        c1                 8.0
    c1        c2                 2.0
    c2        c2                10.0
ENDATA
```

After the input file has been created the problem can be solved. The optimizer can be called by the *bpmpd* command. First, BPMPD will read its parameter file called *bpmpd.par* if presented. If the parameter file exists and the problem file name

is specified in it, BPMPD will start to read the problem and to solve it. Otherwise BPMPD will prompt the user for the the input file name. It is assumed by BPMPD that the extension of the input file is either *.mps* or *.qps*. The name of the MPS input file has to be given by the user without extension.

Depending on the specifications BPMPD will create an optimization report file (with extension *.log*) and a solution file (with extension *.out*).

4 Using the package as callable library

BPMPD is a modularized software package, written in Fortran 77, in which the problem input/output and optimization are completely separated. As a stand-alone solver, BPMPD is prepared to read optimization problems from MPS files. The main program (`bpmain.f`) contains subroutine call to the MPS input reader (*finput*), to the optimizer driver routine (*solver*) and to the output writer routine (*mpsout*). Additionally, the "built–in" values of the optimization parameters are defined here.

BPMPD operates in a column file and in a row file. The column file consists of two working arrays (one double precision called *colnzs* and one integer called *colidx*) which are of the same dimension. The row file is one integer working array (called *rowidx*). The column file contains the A and the lower off–diagonal part of Q as part of the input in form of sparse vectors. They need to be placed continuously from the first position of the working arrays. The remaining part of the column file will be used to hold the factorization during the algorithm, while the purpose of the row file is to support row-wise representation of data when necessary.

The problem and memory dimensions are put in the common block /dims/ which has the following structure:

```
common/dims/ n,qn,n1,m,mn,nz,qnz,cfree,pivotn,denwin,rfree
integer*4    n,qn,n1,m,mn,nz,qnz,cfree,pivotn,denwin,rfree
```

The following values needed to be set prior to calling the optimization driver routine: