

# S2MPJ and CUTEst optimization problems for Matlab, Python and Julia

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## Abstract

A new decoder for the SIF test problems of the CUTEst collection is described, which produces problem files allowing the computation of values and derivatives of the objective function and constraints of most CUTEst problems directly within “native” Matlab, Python or Julia, without any additional installation or interfacing with MEX files or Fortran programs. When used with Matlab, the new problem files optionally support reduced-precision computations.

**Keywords:** nonlinear optimization, test problems, CUTEst, optimization software.

## 1 Introduction

Published nearly thirty years ago [2] and updated [7, 8] since, the CUTEst testing environment and its associated collection of test problems for continuous optimization have been used extensively<sup>\*</sup> by the mathematical optimization community for the design, testing and comparison of unconstrained and constrained optimization software. The test problem collection has indeed grown over time to cover many other proposals such as the Argonne test set [13], Toint’s collection [15], Buckley’s problems [3], COPS [1], the Maros and Mészáros quadratic programming problems [12], the Hock and Schittkowski collection [10] and the Lukšan and Vlček test set [11], to cite a few of the earlier ones. While the updates have provided new tools and new problems, the basic design of the environment has not fundamentally changed since 1995. Each of the test problem is described in a file written in “Standard Input Format” (SIF), an (admittedly somewhat obscure) scheme extending the previous MPS standard [5] for linear programming. To use this file, it was (and still is) necessary to “decode” it using a decoder/compiler written in Fortran, which produces a (possibly large) data file (OUTSDIF.d) and a small set of Fortran subroutines encoding the nonlinear parts of the problem. The user then compiles these Fortran subroutines and calls the Fortran tools provided in the CUTEst environment to evaluate the problem’s objective function and constraints, possibly with their first and second derivatives.

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<sup>\*</sup>Google Scholar reports more than 2300 citations, and growing.

While this setting has clearly proved its usefulness, its integration with the evolving computing environment and emerging programming languages has not always been easy. An interface with Matlab was first produced using the “MEX files” mechanism available in that language, but this proved difficult to maintain for all computer architectures. Other tools such as the `pycutest` interface [6] for Python, the `matcutest` [16] interface to Matlab and `CUTEst.jl` [14] interface to Julia have been proposed to make the test problem collection and associated tools available in today’s computing environment, sometimes at the cost of extra complications. For instance, using the `pycutest` interface requires the code to be executed in a well-defined environment running the Fortran decoder, which is typically made easy by using a “docker” container where the original Fortran tools are precompiled. The `matcutest` interface does not currently allow the user to modify the problem parameters (such as dimension or discretization mesh). Maybe more significantly, all these interfaces are interfaces with the Fortran SIF decoder and the Fortran CUTEst evaluation tools. Although this is fine for computing environments where Fortran is available or if working in a docker container is not too restrictive, one must admit that the use of Fortran has significantly declined since 1995, and that reliance on a unique tool written in this language could be problematic, in particular for the continued use of the test problem collection.

The purpose of this paper is to introduce S2MPJ<sup>†</sup>, a new tool allowing the computation of values of the objective function and constraints of most CUTEst problems, as well as that of their derivatives, directly within “native” Matlab, Python or Julia, without any additional installation or interfacing with MEX files or Fortran programs, using at most three lines of code. As it the case for CUTEst, S2MPJ also allows computing the product of the objective function’s or Lagrangian’s Hessian or constraints’ Jacobian times a user-supplied vector. When used in the Matlab environment, an option is provided to use the language variable-precision tools, allowing the user to select a smaller number of digits in all evaluations.

Our presentation is organized as follows. After recalling some details of the structure of the CUTEst problems in Section 2, we outline, in Section 3, the main features and mechanisms allowing S2MPJ to interpret SIF files directly and describe its formal specifications. We then focus, in Section 4, on the description of the newly-decoded problem files and on how to use them in practice, successively considering the Matlab, Python and Julia environments. The reduced-precision option is described in Section 5. Section 6 presents our methodology to ensure coherence of the new Matlab, Python and Julia problem files and evaluation tools with the Fortran-based version. Section 8 describes how S2MPJ, problem files and evaluation tools can be obtained. Finally, Section 9 briefly discusses advantages and drawbacks of our approach and provides some perspectives for future developments. However, the reader eager to use the tool as quickly as possible may directly read Sections 4.1.2, 4.2.2 and 4.3.2.

## 2 The group-partially-separable structure of the CUTEst problems

All problems in the CUTEst collection are specified as *group-partially-separable* (GPS) problems [4]. Because this is important for understanding what follows, we remind the reader of what this means. In a GPS problem of the type encoded in SIF files, one is interested in

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<sup>†</sup>For SIF to Matlab, Python and Julia.

minimizing a function from  $\mathbb{R}^n$  into  $\mathbb{R}$  of the form

$$\min_{x \in \mathbb{R}^n} f(x) = \sum_{i \in \mathcal{G}_{\text{obj}}} \frac{F_i[a_i(x), \omega_i]}{\sigma_i} + \frac{1}{2} x^T H x, \quad (2.1)$$

that is the sum of a quadratic term  $\frac{1}{2} x^T H x$  and of one or more *objective-function groups*  $F_i[a_i(x), \omega_i]/\sigma_i$  for  $i$  belonging to some index set  $\mathcal{G}_{\text{obj}}$ , with  $F_i[\cdot]$  a (possibly nonlinear) univariate *group function* with parameter(s)  $\omega_i$  and

$$a_i(x) = \sum_{j \in \mathcal{E}_i} w_{ij} f_j(U_j x_{ij}^e, \tau_{ij}) - \sum_{j=1}^n \alpha_{ij} \frac{x_j}{\varsigma_j} - \beta_i. \quad (2.2)$$

In (2.2),  $\mathcal{E}_i$  is the index set of *nonlinear elements* for group  $i$ , element  $j \in \mathcal{E}_i$  involving the *element weight*  $w_{i,j}$ , the (typically nonlinear) *element function*  $f_j$ , the (typically low rank and rectangular) *range matrix*  $U_j$ , the subvector  $x_{ij}^e$  of *elemental variables* occurring in this element, the *linear coefficients*  $\alpha_{ij}$ , the *elemental parameter(s)*  $\tau_{ij}$ , the *group constant*  $\beta_i$ , the nonzero *group scaling*  $\sigma_i$  and the nonzero *variable scalings*  $\{\varsigma_j\}_{j=1}^n$ . This objective function may be subject to (possibly infinite) bound constraints of the form

$$x_j^{\text{low}} \leq x_j \leq x_j^{\text{upp}} \quad (j \in \{1, \dots, n\}) \quad (2.3)$$

and to general constraints, each of them involving a single group and written as

$$c_i^{\text{low}} \leq c_i(x) \leq c_i^{\text{upp}} \quad (i \in \{1, \dots, m\}), \quad (2.4)$$

with possibly infinite  $c_i^{\text{low}}$  and  $c_i^{\text{upp}}$ , and

$$c_i(x) = \frac{C_i[a_i(x), \omega_i]}{\sigma_i} \quad (i \in \mathcal{G}_{\text{cons}}) \quad (2.5)$$

where  $\mathcal{G}_{\text{cons}}$  is the index set of the groups associated with constraints,  $C_i[\cdot]$  is the univariate constraint's group function,  $\omega_i$  gives its parameter(s) and  $\sigma_i$  is the constraint's scaling. The term  $a_i(x)$  also has the form (2.2) (for  $\mathcal{E}_i$  now the set of nonlinear elements of group  $i \in \mathcal{G}_{\text{cons}}$ ). Finally,  $H$  in (2.1) is a symmetric  $n \times n$  matrix. We let  $c(x) = (c_1(x), \dots, c_m(x))^T$ . We also consider the associated Lagrangian function

$$L(x, y) = f(x) + y^T c(x),$$

where  $y \in \mathbb{R}^m$  is the vector of Lagrange multipliers. As it may convenient to restrict one's attention to a subset  $I = \{i_1, \dots, i_p\}$  of the constraints' indices  $\{1, \dots, m\}$ , we also consider the ' $I$ -restricted' variants of  $c(x)$  and  $L(x, y)$  given by

$$c_I(x) = (c_{i_1}(x), \dots, c_{i_p}(x))^T$$

and

$$L_I(x, y) = f(x) + y_I^T c_I(x). \quad (2.6)$$

where  $y_I = (y_{i_1}(x), \dots, y_{i_p}(x))^T$ . Within SIF files, group functions ( $F_i$  and  $C_i$ ) and element functions ( $f_j$ ) are classified according to named *element types* and *group types*, each specifying whether and which parameters are defined for the type, and, for element types, the number of

elemental variables. When an element  $j$  is affected to a group  $i$  (that is  $j \in \mathcal{E}_i$ ), the name of its type, its weight  $w_{ij}$ , its elemental variables  $x_{ij}^e$  and (optionnally) its elemental parameters  $\tau_{ij}$  are specified. Similarly, the type's name and (optionally) the group parameters  $\omega_i$  are specified for each group  $i$ . In addition, SIF allows the definition of *global element parameters* and *global group parameters*, that is parameters whose value is constant across all elements or groups.

The notion of the GPS structure originates in the design of the LANCELOT package [4] where the low rank of the range matrices  $U_j$  was successfully exploited in the “partitioned updating” strategy for quasi-Newton Hessian approximations [9].

Now, given an optimization problem and a vector of variables  $x \in \mathbb{R}^n$ , we may typically be interested in

- computing the value of the objective function  $f(x)$ , possibly with its gradient  $g(x) = \nabla_x^1 f(x)$  and even its Hessian  $H(x) = \nabla_x^2 f(x)$ ;
- computing the vector of constraints' values  $c(x)$ , possibly with its Jacobian<sup>‡</sup> matrix  $J(x) = \nabla_x^1 c(x)$  and even the collection of the constraints' Hessian matrices  $\{H_i(x) = \nabla_x^2 c_i(x)\}_{i=1}^m$ ;
- given a vector  $y$  of multipliers, computing the value of the Lagrangian function  $L(x, y)$ , possibly with its gradient (with respect to  $x$ )  $\nabla_x^1 L(x, y)$  or even its Hessian  $\nabla_x^2 L(x, y)$ ;
- given a vector  $v \in \mathbb{R}^n$ , computing the product  $H(x)v$ ,  $J(x)v$  or, given  $y$ ,  $\nabla_x^2 L(x, y)v$ .

We may also be interested in performing the same evaluations using a user-specified “ $I$ -restricted” set of constraints, where  $I \subseteq \{1, \dots, m\}$ . The CUTEst environment provides Fortran tools for these evaluations, and so does also our new S2MPJ framework.

It is important to note that the description (2.1)-(2.6) differs from that used by the Fortran decoder on three points.

1. By default, S2MPJ numbers the problem's general constraints (in  $c(x)$ ,  $J(x)$  or  $\{H_i(x)\}_{i=1}^m$ ) starting with “less or equal” inequality ( $\leq$ ) constraints, followed by equality ( $=$ ) constraints, followed by “larger or equal” ( $\geq$ ) inequality constraints. The order in which constraints appear in the SIF file is preserved within these three subsets. By contrast, the Fortran decoder does not reorder constraints, thus preserving the order of appearance in the SIF file. When using S2PMJ, it is possible to adhere strictly to the Fortran decoder format when decoding the problem's SIF file by specifying the `options.keepcorder` flag appropriately (see Section 3.2).
2. The format (2.4) in which the constraints are described to the user also differs from that used by the Fortran decoder, where constraints are described, depending on their type, by

$$\begin{aligned}
 r_i &\leq c_i(x) \leq 0 && \text{(for } \leq \text{ constraints)} \\
 0 &= c_i(x) && \text{(for } = \text{ constraints)} \\
 0 &\leq c_i(x) \leq r_i && \text{(for } \geq \text{ constraints)}
 \end{aligned} \tag{2.7}$$

for *constraint ranges*  $r_i$  (optionally) specified in the problem's SIF file (see Section 2.1 of the SIF report). Note that  $r_i$  must be nonpositive for  $\leq$  constraints, or nonnegative

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<sup>‡</sup>The rows of the Jacobian are the transpose of the constraint's gradients.

for  $\geq$  ones. This format is, in the author's view, less intuitive, but may be best suited for use with an optimization code where inequality constraints are described by transforming them to equality ones by the introduction of slack variables. Maintaining the Fortran decode format is however possible by setting the `options.keepcformat` flag appropriately when decoding the problems' SIF file (see Section 3.2).

3. Finally, the SIF format allows the specification of the variable scaling factors  $\varsigma_j$  in (2.2). At this time, the Fortran decoder ignores them entirely (albeit there are plans to provide a tool to pass their values to the user). In S2MPJ, they are explicitly taken in to account in that the coefficients of the linear terms in each group are adapted according to (2.2). Again, it is possible to adhere to the Fortran decoder's choice to ignore them by suitably setting the flag `options.pbxscale` when decoding the problem's SIF file, in which case the values of the factors  $\varsigma_j$  are passed back to the user (see Section 3.2), but ... full compatibility with the Fortran decoder then requires to ignore their value.

### 3 The S2MPJ framework and its decoder

The S2MPJ software framework is somewhat simpler than that described in Section 1 for the Fortran one. It also starts by decoding each problem's SIF file (using the `s2mpj.m` Matlab script), but now produces a single executable output file, in Matlab, Python or Julia, which can then be called for evaluating quantities of interest directly from the native Matlab, Python or Julia environment, that is without further interfacing with Fortran. In order to avoid making these files longer than necessary, the problem-independent parts of the process are encapsulated in S2MPJ-supplied language-dependent libraries (`s2mpjlib.m`, `s2mpjlib.py` and `s2mpjlib.jl`) which are called while running the problem file.

We now turn to describing the first step of this process (decoding) and the `s2mpj` script in more detail.

#### 3.1 Decoder's overview

Let `sifpname` be the name of a problem's SIF file. Broadly speaking, this file consists of a "data" section, describing the structure of the problem as given by (2.1)-(2.6), with the exception of the definitions for the element functions  $f_j(U_j \cdot)$  and the group functions  $F_i(\cdot)$  and  $C_i(\cdot)$ . These are then specified in the second part of the SIF file, in sections called ELEMENTS and GROUPS.

This `sifpname` file (which must be in the Matlab path) is read one line at a time by S2MPJ, and each line is then translated, sometimes in a somewhat indirect way, into the corresponding Matlab/Python/Julia commands. The decoder

- first sets up the problem data structure, including the value of its constant parameters, in the 'setup' action<sup>§</sup>;
- then includes other actions defining the involved nonlinear functions, using information supplied by the Fortran statements in the SIF ELEMENTS and GROUPS sections;

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<sup>§</sup>That is the 'setup' `case` statement in the Matlab output file or `__init__` method in the Python output file or the outer `if-then-else` statement in the Julia output file.

- adds a final call to the S2MPJ-supplied libraries `s2mpjlib.m` (for Matlab), `s2mpjlib.py` (for Python) or `s2mpjlib.jl` (for Julia) that access the previously defined actions and data-structures to perform the required evaluation tasks.

As a result, S2PMJ produces an output file called `probname.m`, `probname.py` or `probname.jl` in the current directory, possibly overwriting an existing file with the same name (see Section 3.2 below to modify the directory where the SIF file is found and that where the output file is written). This file is intended for direct calls from Matlab, Python or Julia producing values of the objective function, constraints or Lagrangian (possibly with their derivatives), as well as products of the objective function's or Lagrangian's Hessian or constraints' Jacobian times a user-supplied vector (see below). Importantly, the produced Matlab/Python file, hereafter called the 'output file', is not extensive, meaning that loops are not unrolled (thereby maintaining a reasonably compact description).

The name `probname` of the output file is, in most cases, identical to `sifpname`, but differs from it when the `sifpname` string starts with a digit, in which case it is prefixed by `n`, or contains one or more of the characters `'+''`, `'-''`, `'*'` or `'/'`; these characters are then replaced by `p`, `m`, `t`, and `d`, respectively. This renaming<sup>¶</sup> is necessary to allow the output file to be used as a Matlab/Julia function or as a Python class.

Within the `'setup'/_init__` action, instructions are written in the output file to define the various problem parameters, as well as vectors of bounds on the variables, constraints and objective, and the variables/multipliers starting values. Loops in the SIF file are directly transformed into loops in the output file. Structured sets of the SIF files (such as variables, groups, elements) are characterized by the fact that their components may be defined using different names and multi-indexes. Because most optimization codes only recognize linear structures (a vector of variables, a vector of constraints), S2MPJ transforms entities such as variables, groups and elements into linear 'flat' unidimensional structures. Since this transformation may depend on problem internal parameters such as loop limits, themselves depending on problem input arguments only known at runtime, the output file uses a function<sup>||</sup> supplied in the `s2mpjlib` libraries to compute the relevant indices at runtime. S2MPJ also assign a Matlab/Python/Julia-compatible name to each of these entities. These names are then used in dictionaries associating names and values or names and index.

S2PMJ uses three different structures to pass information between the various components of the framework:

- `pbs` is a structure internal to `s1mpj.m` (and hence invisible to the user) used by the code to pass information on entities like loops, element's or group's type(s) across its different subfunctions;
- `pb` is the structure used to pass information on the problem to the user once the `setup/_init__` action is completed (it is described in more detail below);
- `pbm` is the structure used to pass information between the different actions of the output file (occurring on successive calls) and the evaluation functions/methods in the `s2mpjlib` libraries. It is visible to the user but should not be interfered with (again, it is described more formally below).

Formally, the `s2mpj` decoder is a Matlab function whose input parameters are

<sup>¶</sup>For instance, problems `C-RELOAD` and `10FOLDTR` are renamed `CmRELOAD` and `n10FOLDTR`.

<sup>||</sup>`s2mpj-ii`.

**sifpname:** a string containing the name of the problem to be decoded (S2MPJ then reads the `probname.SIF` file for input);

**varargin:** if present, `varargin{1}` allows the specification of decoding options (see Section 3.2). The use of the suitable option is mandatory for decoding SIF files into a Python or a Julia output file. Components of `varargin` beyond the first are ignored.

The function `s2mpj.m` has three output values:

**probname:** a string containing the name of the Matlab, Python or Julia output file (without the `.m`, `.py` or `.jl` suffix), possibly after renaming (see above);

**exitc:** the number of errors which occurred before termination (or crash). A zero value thus indicates error-free execution.

**errors:** a cell/list of length `exitc`, whose entries contain a brief description of the error(s) found.

Beyond those arguments, the `s2mpj` function produces an output file called `probname.m`, `probname.py` or `probname.jl` in the current directory.

### 3.2 Decoding options

S2MPJ allows the user to specify a number of options, typically to control file production during execution, save memory, help debugging or remain as close as possible to the original Fortran SIF decoder. These options are accessible by suitably setting the first (and only) variable input argument `varargin{1}`.

If `varargin{1}` is a struct then its fields have the following meaning.

`varargin{1}.language` is a string specifying the type of output produced by S2MPJ and can take different values:

**'matlab':** a Matlab problem file named `probname.m` is written in the current directory, possibly overwriting an existing file with the same name.

**'python':** a Python problem file named `probname.py` is written in the current directory, possibly overwriting an existing file with the same name.

**'julia':** a Julia problem file named `probname.jl` is written in the current directory, possibly overwriting an existing file with the same name.

**'stdma':** the content of a *potential* Matlab problem file is printed on the standard output (no file is produced);

**'stdpy':** the content of a *potential* Python problem file is printed on the standard output (no file is produced);

**'stdjl':** the content of a *potential* Julia problem file is printed on the standard output (no file is produced);

(default: `'matlab'`)

- `varargin{1}.showsiflines` is a binary flag which is true if the SIF data lines must be printed on the standard output. This is intended for debugging and requires the option `varargin{1}.language` to be set to `stdma`, `stdpy` or `stdjl`.  
(default: 0);
- `varargin{1}.getxnames` is a binary flag which is true if the names of the variables must be returned in `pb.xnames` on exit of the setup action.  
(default: 1)
- `varargin{1}.getcnames` is a binary flag which is true if the names of the constraints must be returned in `pb.cnames` on exit of the setup action.  
(default: 1)
- `varargin{1}.getenames` is a binary flag which is true if the names of the nonlinear elements  $f_j$  must be returned in `pbm.elnames` on exit of the setup action.  
(default: 0)
- `varargin{1}.getgnames` is a binary flag which is true if the names of the groups elements must be returned in `pbm.grnames` on exit of the setup action.  
(default: 0)
- `varargin{1}.pbxscale` is a binary flag which is true if the variable's scaling  $\varsigma_j$  (in (2.2)) must be provided in `pb.xscale`, instead of being applied internally.  
(default: 0)
- `varargin{1}.keepcorder` is a binary flag which is true iff, on exit of the setup action, the constraints must not be reordered to appear in the order  $\leq$ , followed by  $=$  and then by  $\geq$ , but should instead appear in the order in which they are defined in the SIF file.  
(default: 0)
- `varargin{1}.keepcformat` is a binary flag which is true if, on exit of the setup action, the constraints must be specified using the SIF format (ie specifying ranges and types, see above) instead of specifying lower and upper bounds (clower and cupper) on the constraints values. If set, the fields `clower` and `cupper` of `pb` are replaced by the field `ctypes` of (a cell whose  $i$ -th component contains a string (`'<='`, `'=='`, or `'>='` ) defining the type of the  $i$ -th constraint) and, if defined, a field `ranges` giving the ranges  $r_i$  (see (2.7)) of the constraints.  
(default: 0)
- `varargin{1}.writealtsets` is a binary flag which is true if alternative sets of constants, ranges, bounds, starting points or objective function bounds must be written (as comments) in the output file.  
(default: 0)
- `varargin{1}.sifcomments` is a binary flag which is true if the comments appearing in the SIF file must be repeated in the output file.  
(default: 0)
- `varargin{1}.addinA` is a binary flag which is true if repeated entries in the definition of the entries  $\alpha_{ij}$  in (2.2) must be summed, rather than overwritten. Activating this option



allows gracefully coping with the SIF error of specifying the same entry more than once (as is done by the Fortran SIF decoder), albeit at the price of more verbose output files.  
(default:1)

`varargin{1}.disperrors` is a binary flag which is true if the error messages are to be displayed on the screen as soon as the error is detected.  
(default: 1 )

`varargin{1}.sifdir` is a string giving the path to the directory where the problem's SIF file must be read (default: in the Matlab path)

`varargin{1}.outdir` is a string giving the path to the directory where the output file must be written.  
(default: '.' )

`varargin1.redprec` is a binary flag which is true iff variable precision support must be provided in the 'setup' section of the Matlab output file.  
(default: 1)

Not every of the above fields must be defined, each field being tested for presence and value individually. If `varargin{1}` is not a Matlab struct or is not present, all options take their default values.

### 3.3 Limitations

In its current form, the following features are *not* supported by S2PMJ:

1. the call to external FORTRAN subroutines;
2. the D data lines in the data GROUPS section;
3. the occurrence of blank characters within indices (probably against the standard anyway);
4. the FREE FORM version of the SIF file;
5. ... and probably other unforeseen strange SIF and FORTRAN constructs.

In addition, S2MPJ *does not* provide a comprehensive explanation of possible errors in the SIF file (it is supposed to adhere to the standard): it may thus crash on errors, or the produced output file may also crash. Should this happen, running S2MPJ with `varargin{1}.showsiflines = 1`, usually helps spotting the SIF error (or detecting the S2MPJ bug).

S2MPJ makes the assumption that RANGES  $r_i$  (in (2.7)) are only meaningful for inequality constraints. The SIF standard appears to leave open the possibility of ranges for other types of groups, but fails to mention what they can/could be used for. Thus S2MPJ ignores the ranges of equality constraints or objective groups, should them be supplied in the SIF file.

## 4 The problem files and how to use them

### 4.1 The Matlab problem files

#### 4.1.1 Matlab problem files: interface specification

The Matlab output file `probnam.m` is a Matlab function designed to provide the following user interface. A call of the form

```
varargout = probname( action, varargin )
```

produces result(s) stored in `varargout` according to the following choices of the 'action' argument and the number of requested outputs, according to the following rules.

```
[ pb, pbm ] = probname( 'setup', problem_parameters )
```

- The fields of the struct `pb` are defined as follows:

`pb.name` is a string containing the problem's name

`pb.sifpbname` if present, is a string containing the original name of the SIF file before its modification to ensure Matlab/Python/Julia compatibility

`pb.n` is an integer giving the problem's number of variables

`pb.nob` is an integer giving the number of objective groups

`pb.nle` if present, is an integer giving the number of  $\leq$  constraints

`pb.neq` if present, is an integer giving the number of  $=$  constraints

`pb.nge` if present, is an integer giving the number of  $\geq$  constraints

`pb.m` is an integer giving the total number of general constraints

`pb.lincons` if present, is a integer vector containing the indices of the linear constraints

`pb.pbclass` is the problem's SIF classification

`pb.x0` is a real vector giving the problem's starting point

`pb.xlower` is a real vector giving the problem's lower bounds on the variables  $x_j^{\text{low}}$  (see (2.3))

`pb.xupper` is a real vector giving the problem's upper bounds on the variables  $x_j^{\text{upp}}$  (see (2.3))

`pb.xtype` is a string whose  $i$ -th position describes the type of the  $i$ -th variable:

'r': the variable is real

'i': the variable is integer

'b': the variable is binary (zero-one)

If `xtype` is not a field of `pb`, all variables are assumed to be real.

`pb.xscale` if nonempty, is a real vector containing the scaling factors  $c_j$  to be applied by the user on the occurrences of the variables in the linear terms of the problem's groups (see (2.2)). If empty, the scaling factors (if any) are applied to the relevant terms internally to the decoder without need for further user action (see the `pbxscale` option of S2MPJ above)

**pb.y0** if present, is a real vector containing the starting values for the constraint's multipliers  
**pb.clower** if present, is the real vector of lower bounds on the constraints values  $c_i^{\text{low}}$  (see (2.4))  
**pb.cupper** if present, is the real vector of upper bounds on the constraints values  $c_i^{\text{upp}}$  (see (2.4))  
**pb.objlower** if present, is a real lower bound of the objective function's value  
**pb.objupper** if present, is a real upper bound of the objective function's value  
**pb.xnames** if present, is a cell of strings of length **pb.n** containing the name of the variables  
**pb.cnames** if present, is a cell of strings of length **pb.m** containing the name of the constraints.

In the 'setup' call to the problem file, **problem\_parameters** is a coma-separated list of parameters identified by a \$-PARAMETER string in the SIF file. They are assigned in the order in which they appear in **varargin**, which is the same as that used in the SIF file as well as in the Matlab, Python or Julia problem files. If **varargin** is too short in that it does not provide a value for a parameter of the SIF file, the SIF default value is used.

If constraints are present, they are ordered as follows:

1, ..., <b>pb.nle</b>	: constraints of $\leq$ type,
<b>pb.nle</b> +1, ..., <b>pb.nle</b> + <b>pb.neq</b>	: constraints of $=$ type,
<b>pb.nle</b> + <b>pb.neq</b> +1, ..., <b>pb.nle</b> + <b>pb.neq</b> + <b>pb.nge</b>	: constraints of $\geq$ type.

This ordering also be superseded by setting the **keepcorder** flag in the S2MPJ options (see above). If the problem has no constraints or bound constraints only, then **lincons**, **y0**, **clower**, **cupper** and **cnames** are not fields of the **pb** struct returned on setup. **pb.m** is still defined in this case, but its value is 0. The fields **objlower** and **objupper** may also be missing if no value is provided in the SIF file. When specific S2MPJ options are used (again, see above), the fields **xnames** and/or **cnames** may be missing from the **pb** struct.

- The **pbm** struct is produced by S2PMJ *for information and debugging only*. It must not be modified by the user. Its fields are defined as follows:

**pbm.name** is a string containing the name of the problem,  
**pbm.objgrps** if present, is the list of indeces of the objective groups, that is  $\mathcal{G}_{\text{obj}}$  in (2.1),  
**pbm.congrps** if present, is the list of indeces of the constraint groups, that is  $\mathcal{G}_{\text{cons}}$  in (2.5),  
**pbm.A** if present, is the real sparse matrix whose lines  $i$  contains the coefficients  $\alpha_{ij}$  of the linear terms in the groups (see (2.2)),  
**pbm.Ashape** if present, is an integer vector of length 2 containing the number of rows of **pbm.A** and its number of columns (for Python only),  
**pbm.gconst** if present, is a real vector containing the group's constants  $\beta_i$  of (2.2),  
**pbm.H** if present, is a symmetric sparse real matrix containing the Hessian matrix  $H$  of (2.1),

**pbm.enames** if present, is a cell of strings containing the names of the nonlinear elements,  
**pbm.elftype** if present, is a cell of strings containing the names of the element's types,  
**pbm.elvar** if present, is a cell of integer vectors containing the indices of the elemental variables for each element,  
**pbm.elpar** if present, is a cell of real vectors containing the values of the elemental parameters for each element,  
**pbm.gscale** if present, is a real vector containing the group's scaling factors  $\sigma_i$  in (2.1),  
**pbm.grnames** if present, is a cell of strings containing the group's names,  
**pbm.grftype** if present, is a cell of strings containing the group's types,  
**pbm.grelt** if present, is a cell of integer vectors containing the indices of the nonlinear elements occurring in each group,  
**pbm.grelw** if present, is a cell of real vectors containing the weights of the nonlinear elements occurring in each group, that is the  $w_{ij}$  in (2.2),  
**pbm.grpar** if present, is a cell of real vectors containing the values of the parameters  $\omega_i$  of the group functions,  
**pbm.efpar** if present, is a real vector containing the values of the global element parameters,  
**pbm.gfpar** if present, is a real vector containing the values of the global group parameters,  
**pbm.ndigs** if present is an integer giving the number of digits requested for reduced-precision evaluations (see Section 5).

Depending on the problem's nature, some fields may be missing from the **pbm** struct, but at least one of **objgrps** or **congrps** must be present and non-empty. The presence of the fields **enames** and **gnames** depends on the **getenames** and **getgnames** S2MPJ options (see Section 3.2).

A call to `probnam( 'setup', ... )` must precede any call to `probnam` with other actions (in order to setup the problem's data structure).

```
fx = probnam( 'fx', x )
```

**fx** is  $f(x)$ , the value of the objective function at  $x$ ,

```
[ fx, gx ] = probnam( 'fgx', x )
```

**fx** is  $f(x)$ , the value of the objective function at  $x$ ,

**gx** is  $\nabla_x^1 f(x)$ , the value of the objective function's gradient at  $x$ ,

Note that the call `[ fx, gx ] = probnam( 'fx', x )` produces the same results.

```
[ fx, gx, Hx ] = probnam( 'fgHx', x )
```

**varargout{1}** is  $f(x)$ , the value of the objective function at  $x$ ,

`varargout{2}` is  $\nabla_x^1 f(x)$ , the value of the objective function's gradient at  $x$ ,

`varargout{3}` is  $\nabla_x^2 f(x)$ , the value of the objective function's Hessian at  $x$ ,

Note that the call `[ fx, gx ] = probname( 'fx', x )` produces the same results.

```
cx = probname( 'cx', x )
```

`cx` is  $c(x)$ , the vector of constraint's values at  $x$ ,

```
[ cx, Jx ] = probname( 'cJx', x )
```

`cx` is  $c(x)$ , the vector of constraint's values at  $x$ ,

`Jx` is the matrix  $J(x)$ , the constraint's Jacobian at  $x$ ,

Note that the call `[ fx, gx ] = probname( 'cx', x )` produces the same results.

```
[ cx, Jx, Hix ] = probname( 'cJHx', x )
```

`cx` is  $c(x)$ , the vector of constraint's values at  $x$ ,

`Jx` is the matrix  $J(x)$ , the constraint's

`Hix` is a cell whose  $i$ -th entry is  $\nabla_x^2 c_i(x)$ , the Hessian of the  $i$ -th constraint at  $x$ ,

Note that the call `[ fx, gx, Hix ] = probname( 'cx', x )` produces the same results.

```
cIx = probname( 'cIx', x, I )
```

`cIx` is  $c_I(x)$ , the vector of the  $I$ -restricted constraint's values at  $x$ ,

```
[ cIx, JIx ] = probname( 'cIJx', x, I )
```

`cIx` is  $c_I(x)$ , the vector of the  $I$ -restricted constraint's values at  $x$ ,

`JIx` is the matrix  $J_I(x)$ , the Jacobian of the  $I$ -restricted constraints at  $x$ ,

```
[ cIx, JIx, HIx ] = probname( 'cIJHx', x, I )
```

`cIx` is  $c_I(x)$ , the vector of the  $I$ -restricted constraint's values at  $x$ ,

`JIx` is the matrix  $J_I(x)$ , the Jacobian of the  $I$ -restricted constraints at  $x$ ,

`HIx` is a cell whose  $i$ -th entry is  $\nabla_x^2 c_{\ell}(x)$ , the Hessian of the  $\ell$ -th constraint at  $x$  where  $\ell$  is the  $i$ -th entry in  $I$ ,

```
Hxv = probname( 'fHxv', x, v )
```

`Hxv` is the vector  $\nabla_x^2 f(x)v$ , the product of the objective function's Hessian at  $x$  times the vector  $v$ ,

```
Jxv = probname( 'cJxv', x, v )
```

$\mathbf{Jxv}$  is the vector  $J(x)v$ , the product of the constraint's Jacobian at  $x$  times the vector  $v$ ,

```
JIxv = probname( 'cIJxv', x, v )
```

$\mathbf{JIxv}$  is the vector  $J_I(x)v$ , the product of the constraint's  $I$ -restricted Jacobian at  $x$  times the vector  $v$ ,

```
Lxy = probname( 'Lxy', x, y )
```

$\mathbf{Lxy}$  is  $L(x, y)$ , the value of the problem's Lagrangian at  $(x, y)$ ,

```
[ Lxy, gLxy ] = probname( 'Lgxy', x, y )
```

$\mathbf{Lxy}$  is  $L(x, y)$ , the value of the problem's Lagrangian at  $(x, y)$ ,

$\mathbf{gLxy}$  is  $\nabla_x^1 L(x, y)$ , the value of the Lagrangian's gradient with respect to  $x$  taken at  $(x, y)$ ,

Note that the call `[ Lxy, Lgxy ] = probname( 'Lxy', x, y )` produces the same results.

```
[ Lxy, gLxy, HLxy ] = probname( 'LgHxy', x, y )
```

$\mathbf{Lxy}$  is  $L(x, y)$ , the value of the problem's Lagrangian at  $(x, y)$ ,

$\mathbf{gLxy}$  is  $\nabla_x^1 L(x, y)$ , the value of the Lagrangian's gradient with respect to  $x$  taken at  $(x, y)$ ,

$\mathbf{HLxy}$  is  $\nabla_x^2 L(x, y)$ , the value of the Lagrangian's Hessian with respect to  $x$  taken at  $(x, y)$ ,

Note that the call `[ Lxy, gLxy, HLxy ] = probname( 'Lxy', x, y )` produces the same results.

```
LIXy = probname( 'LIXy', x, y, I )
```

$\mathbf{LIXy}$  is  $L_I(x, y)$ , the value of the problem's  $I$ -restricted Lagrangian at  $(x, y)$ ,

```
[ LIXy, gLIXy ] = probname( 'LIgxy', x, y, I )
```

$\mathbf{LIXy}$  is  $L_I(x, y)$ , the value of the problem's  $I$ -restricted Lagrangian at  $(x, y)$ ,

$\mathbf{gLIXy}$  is  $\nabla_x^1 L_I(x, y)$ , the value of the  $I$ -restricted Lagrangian's gradient with respect to  $x$  taken at  $(x, y)$ ,

Note that the call `[ LIXy, gLIXy ] = probname( 'Lxy', x, y, I )` produces the same results.

```
[ LIXy, gLIXy, HLIXy ] = probname( 'LIgHxy', x, y, I )
```

$\mathbf{LIXy}$  is  $L_I(x, y)$ , the value of the problem's  $I$ -restricted Lagrangian at  $(x, y)$ ,

$\mathbf{gLxy}$  is  $\nabla_x^1 L_I(x, y)$ , the value of the  $I$ -restricted Lagrangian's gradient with respect to  $x$  taken at  $(x, y)$ ,

$\mathbf{HLxy}$  is  $\nabla_x^2 L_I(x, y)$ , the value of the  $I$ -restricted Lagrangian's Hessian with respect to  $x$  taken at  $(x, y)$ ,

Note that the call `[ LIxy, gLIxy, HLIxy ] = probname( 'LIxy', x, y )` produces the same results.

`HLxyv = probname( 'LHxyv', x, y, v )`

$\mathbf{HLxyv}$  is the vector  $\nabla_x^2 L(x, y)v$ , the product the problem's Lagrangian Hessian with respect to  $x$  taken at  $(x, y)$  times the vector  $v$ ,

`HLIxyv = probname( 'LIHxyv', x, y, v, I)`

$\mathbf{HLIxyv}$  is the vector  $\nabla_x^2 L_I(x, y)v$ , the product the problem's  $I$ -restricted Lagrangian Hessian with respect to  $x$  taken at  $(x, y)$  times the vector  $v$ .

The actions `cx`, `cIx`, `Jxv`, `JIxv`, `Lxy`, `LIxy`, `HLxyv` or `HLIxyv` are of course meaningless when the problem is unconstrained or only has bound constraints.

#### 4.1.2 Matlab problem files: how to use them

The use of S2MPJ in Matlab is typically as follows.

1. a SIF problem (`PROBNAME.SIF`, say) is decoded by the Matlab command

```
PROBLEM = s2mpj( 'SIFPROBLEM' );
```

or

```
PROBLEM = s2mpj( 'SIFPROBLEM', options );
```

where `options` is a struct whose content is described above in Section 3.2. This assumes that the `PROBNAME.SIF` file is in the Matlab path. A file `PROBLEM.m` is then produced in the current directory (potentially overwriting an existing one with the same name).

2. The problem data structure is then setup, along with the starting points, bounds and other components of the `pb` and `pbm` structs (see above) by issuing the command

```
pb = PROBLEM( 'setup', args{:} )
```

where `args{:}` is an optional comma-separated list of problem-dependent arguments (such as problem's dimension, for instance) identified by the string `$-PARAMETER` in the SIF file. If `args{:}` is missing, setup is performed using the SIF file defaults.

3. The value(s) of the problem functions (objective and constraints) at a vector  $x$ , together with values of their first and second derivatives (if requested) are then computed by issuing one of the commands

```
fx = PROBLEM( 'fx', x );
```

```
[ fx, gx ] = PROBLEM( 'fgx', x );
```

```
[ fx, gx, Hx ] = PROBLEM( 'fgHx', x );
```

for the objective function and (if constraints are present)

```
cx = PROBLEM( 'cx', x );
```

```
[ cx, Jx ] = PROBLEM( 'cJx', x );
```

```
[ cx, Jx, Hx ] = PROBLEM( 'cJHx', x );
```

for the constraints. In this case, it is possible to restrict one's attention to a subset  $I$  of the constraints (i.e. using  $c_I(x)$ , the ' $I$ -restricted' version of  $c(x)$ ) by using

```
cIx = PROBLEM( 'cIx', x, I );
```

```
[ cIx, JIx ] = PROBLEM( 'cIJx', x, I );
```

```
[ cIx, JIx, HIx ] = PROBLEM( 'cIJHx', x, I );
```

The product of the objective function's Hessian (at  $x$ ) times a user-supplied vector  $v$  can be obtained by the command

```
Hxv = PROBLEM( 'fHxv', xx, v );
```

while the product of the (potentially  $I$ -restricted) constraints' Jacobian (at  $x$ ) times  $v$  is computed by issuing one of the commands

```
Jxv = PROBLEM( 'cJxv', x, v );
```

```
JIxv = PROBLEM( 'cIJxv', x, v, I );
```

The value (and derivatives) of the Lagrangian function  $L(x, y)$  at  $(x, y)$  is obtained by one of the commands

```
Lxy = PROBLEM( 'Lxy', x, y );
```

```
[ Lxy, Lgxy ] = PROBLEM( 'Lgxy', x, y );
```

```
[ Lxy, Lgxy, LHxy ] = PROBLEM( 'LgHxy', x, y );
```

while the product of the Lagrangian's Hessian times a vector  $v$  can be computed with the command

```
HLxyv = PROBLEM( 'HLxyv', x, y, v );
```

Finally, and as above for constraints, the Lagrangian may be  $I$ -restricted in the commands

```
[ LIxy, gLIxy, HLIxy ] = PROBLEM( 'LIxy', x, y, I );
```



```
HLIxyv = PROBLEM( 'LIHxyv' , x, y, v, I );
```

Because `PROBNAME.m` uses a persistent structure to pass problem structure across its various actions, such calls are valid as long as the Matlab variable space is not cleared and as long as another `OTHERPROBLEM.m` file is not called.

## 4.2 The Python problem files

### 4.2.1 Python problem files: interface specification

The Python output file is a Python class whose name is that of the problem and which is derived from the parent `CUTEst_problem` class described in the `s2pmjlib.py` file. It inherits the evaluation methods of this parent class, which are organized in a manner similar to actions for the Matlab output file, except that the Matlab 'setup' action is replaced by a simple call to the class with the problem parameters, the setting up of the problem structure(s) being then performed by the `__init__` method of the class. So, if the problem is given by the `PROBNAME` class, setting it up is achieved by the call

```
pb, pbm = probname(args[:])
```

where `args[:]` is an optional comma-separated list of problem-dependent arguments, while the evaluation task corresponding to the Matlab call `[outputs] = probname( action, x, other_args );` is performed by the Python call

```
outputs = probname.action( x, other_args )
```

for all actions (except 'setup') listed above. The real vectors resulting from the various evaluations or being present in the `pb` and `pbm` structures are column-oriented `numpy.ndarrays`. Real matrices are `sparse.csr` matrices, or lists of `sparse.csr` matrices (for the Hessians of the constraints). Note that `pb` and `pbm` struct have the same fields as those described for the Matlab case, subject to the same conditions for being present or not.

### 4.2.2 Python problem files: how to use them

Again the use of the Python output file is very similar to that of the Matlab file. The various steps described above for the use of the Matlab output file are now (given the `PROBNAME.SIF` file) as follows. The decoding of the SIF file and production of the `PROBNAME.py` file containing the `PROBNAME` class is performed by the call

```
PROBNAME = s2mpj( 'SIFPBNAME', inpy )
```

where `inpy` is a struct describing the S2MPJ options (see Section 3.2) with `inpy.language = 'python'` (other options may be specified if desired.) After importing the functions of the `PROBNAME` module by

```
from PROBNAME import *
```

the setup of the problem is now performed by a call of the form

```
PROBNAME( arg[:] )
```

where `args[:]` is a comma separated list of problem-dependent arguments. The subsequent evaluation tasks are then obtained by calling one (or more) of

```

fx = PROBNAME.fx( x )
fx, gx = PROBNAME.fgx( x )
x, gx, Hx = PROBNAME.fgHx( x )
Hxv = PROBNAME.fHxv( x, v )
cx = PROBNAME.cx( x )
cx, Jx = PROBNAME.cJx( x )
cx, Jx, Hxs = PROBNAME.cJHx( x )
Jxv = PROBNAME.cJxv( x, v )
cIx = PROBNAME.cIx( x, I )
cIx, cIJx = PROBNAME.cIJx( x, I )
cIx, cIJx, cIJHx = PROBNAME.cIJHx( x, I )
cIHv = PROBNAME.cIHxv( x, v, I )
Lxxy = PROBNAME.Lxy( x, y )
Lxy, Lgxy = PROBNAME.Lgxy( x, y )
Lxy, gLxy, HLxy = PROBNAME.LgHxy( x, y )
LHxyv = PROBNAME.LHxyv( x, y, v )
LIxy = PROBNAME.LIxy( x, y, I )
LIxy, gLIxy = PROBNAME.LIgxy( x, y, I )
LIxy, gLIxy, HLIxy = PROBNAME.LIgHxy( x, y, I )
LIHxyv = PROBNAME.LIHxyv( x, y, v, I )

```

### 4.3 The Julia problem files

#### 4.3.1 Julia problem files: interface specification

The Julia output file is a cross between the Matlab and Python ones. It is a Julia function whose interface is identical to that of the Matlab output, *except* that the second argument in the call must be the `pbm` struct. This struct now has an additional field `call` so that `pbm.call` contains the Julia call to the output file after execution with the 'setup' action.

#### 4.3.2 Julia problem files: how to use them

Finally, the typical use of the Julia output file is as follows. The `PROBNAME.jl` output file is produced from the `PROBNAME.SIF` file by the call

```
PROBNAME = s2mpj( 'PROBNAME', injl )
```

where `injl` is a struct describing the S2MPJ options (see Section 3.2) with `injl.language = 'julia'` (other options may be specified if desired.) After including the `PROBNAME` functions in the Julia program using

```
include( "PROBNAME.jl" )
```

the setup of the problem is performed by a call of the form

```
pb, pbm = PROBNAME( "setup", args[:] )
```

where `args[:]` is an optional comma separated list of problem-dependent arguments. The subsequent evaluation tasks are then obtained by calling one (or more) of

```
fx = PROBNAM( "fx", pbm, x )
fx, gx = PROBNAM( "fgx", pbm, x )
fx, gx, Hx = PROBNAM( "fgHx", pbm, x )
Hxv = PROBNAM( "fHxv", pbm, x, v )
cx = PROBNAM( "cx", pbm, x )
cx, Jx = PROBNAM( "cJx", pbm, x )
cx, Jx, Hxs = PROBNAM( "cJHx", pbm, x )
Jxv = PROBNAM( "cJxv", pbm, x, v )
cIx = PROBNAM( "cIx", pbm, x, I )
cIx, cIJx = PROBNAM( "cIJx", pbm, x, I )
cIx, cIJx, cIJHx = PROBNAM( "cIJHx", pbm, x, I )
cIHv = PROBNAM( "cIHxv", pbm, x, v, I )
Lxxy = PROBNAM( "Lxy", pbm, x, y )
Lxy, Lgxy = PROBNAM( "Lgxy", pbm, x, y )
Lxy, Lgxy, LgHxy = PROBNAM( "LgHxy", pbm, x, y )
LHxyv = PROBNAM( "LHxyv", pbm, x, y, v )
LIxy = PROBNAM( "LIxy", pbm, x, y, I )
LIxy, LIgxy = PROBNAM( "LIgxy", pbm, x, y, I )
LIxy, LIgxy, LIgHxy = PROBNAM( "LIgHxy", pbm, x, y, I )
LIHxyv = PROBNAM( "LIHxyv", pbm, x, y, v, I )
```

Note that `pbm` always occurs as the second input argument.

#### 4.4 Ensuring full compatibility with the Fortran decoder

If, for the purpose of comparison with preexisting numerical experiments, one desires to run a version of the S2MPJ framework which is fully compatible with the Fortran decoder, one needs to (re)decode all SIF problems with S2MPJ using an `options` struct such that

```
options.keepcformat = 1;
options.keepcorder = 1;
options.pbxscale = 1;
```

(see Section 3.2).

### 5 Using reduced precision with S2MPJ in Matlab

When using S2MPJ in the Matlab environment, it is possible to use reduced precision arithmetic for all evaluations (of values, derivatives and Hessian-times-vector products), provided the Matlab Symbolic Math Toolbox is installed in the environment. If this is the case, setting up the problem data-structures may now be done by the call

```
[ pb, pbm ] = probname( 'setup_redprec', problem_parameters, ndigits )
```

Note that the action keyword is now `'setup_redprec'` and that a new input argument `ndigits` is now present at the end of the calling sequence. This new argument `ndigits` specifies the number of digits to use in the computation and it must be less or equal to 15.

If the action keyword `'setup_redprec'` is used, the problem data is converted to the requested number of digits at the end of the setup process. As a consequence, its accuracy remains limited by the double-precision computations performed during the setup operations (and also by the accuracy of the SIF-provided reals, see the next Section), justifying the bound `ndigits <= 15`. Thus only the *evaluation* of function values and derivatives is affected by the reduced-precision request. Moreover, this is only true if the vector  $\mathbf{x}$  at which evaluation is requested is itself passed by the user to the problem file in reduced-precision format. Also note that, for now, reduced-precision Hessians and Jacobians are no longer computed the sparse format.

Using reduced precision is of course optional: a call to problem setup using the action keyword `'setup'` as described in Section 4 results in standard double-precision computations and sparse Hessians and Jacobians. It is also possible to disable the reduced-precision option when decoding a SIF problem by setting the `redprec` option of `s2mpj` to 0 (see Section 3.2). The resulting `PROBNAME.m` file is then marginally shorter but will issue an error message if the keyword `'setup_redprec'` is specified. Disabling the default of requiring the reduced-precision option is automatic if the Symbolic Math Toolbox is not installed.

## 6 Testing

The validity of the S2MPJ decoder has been tested on 1098 problems of the CUTEst collection (see Section 8), avoiding large SIF files and problems involving external Fortran subroutines (see Section 3.3). The list of these problems and the corresponding files are part of the framework (see Section 8)

A first step was being able to decode all 1098 SIF files in the three programming languages of interest. Once this was achieved, we verified the coherence between the evaluations produced at the problem's starting point by the S2MPJ (in standard double precision) using the Python problem files and those produced by the Fortran decoder (as obtained from the `pycutest` wrapper). This turned out to be subject to a significant limitation due to a feature of the Fortran decoder inherited from the MPS format: the `OUTSDIF.d` data file written by the Fortran decoder and subsequently used by the CUTEst tools only stores real numbers with eight significant digits. Unfortunately, the methods used by Fortran and Matlab (when writing the Python problem files) to promote low precision numbers to double precision ones differ: Fortran first rounds the low precision number before completing it with zeros, while Matlab does not perform any rounding. One therefore has to live with a coherence between the Fortran and Python results of the order of single precision. When explicit numbers (such as least-squares data values) are explicitly given in the SIF file, this can be viewed as a minor limitation. It remains however an advantage of S2MPJ that, because the problem files are executable, computation of constants (such as meshsizes computed from problem dimension) not depending on SIF-provided reals are conducted in full precision. If, as is the case for a significant number of problems, all constants are of this type, then the relative difference between results obtained with S2MPJ and those obtained by the Fortran decoder typically falls below  $10^{-14}$ .

The final step was to verify the coherence of the evaluation produced by the Matlab and Julia problem files with those produced by the Python files. This was much more accurate, again typically resulting in relative differences below  $10^{-14}$ .

All validation tests, except the comparison Matlab-Python, were run on a Dell Precision

computer with 64 GiB of memory and running Ubuntu and Matlab R2024a, Python 3.8.10 and Julia 1.10.4. The Matlab-Python tests were performed on a Mac Macbook Pro with 36 GiB of memory under Sonoma 14.4.1 with Matlab R2024a and Python 3.11.5.

## 7 Writing your own optimization problem in S2PMJ format

It is of course possible to create new test examples directly in Matlab, Python or Julia. For making them compatible with the S2MPJ libraries, it is enough that they adhere to the specifications described above (the “S2MPJ format”). In doing so, the choice of detail in the GPS description of the new problem can be chosen freely: from very detailed (typically as provided by the CUTEst SIF files) to very synthetic. To illustrate this point, Appendix 9 gives several possible versions of the ROSENBR problem (in the Matlab context and using double precision):

- `ROSENBR.m` is the detailed and (here too) verbose version produced by S2MPJ, using two groups of type `gL2` and two nonlinear elements of type `sSQ`
- `ROSSIMP1.m` is simplified version where the detailed GPS structure is still used, but the (for this problem) unnecessary statements automatically generated by S2MPJ have been removed,
- `ROSSIMP2.m` is first simplification, using now one single `TRIVIAL` group and two nonlinear elements of types `E1` and `E2`,
- `ROSSIMP3.m` is a short synthetic version, with a single `TRIVIAL` group and one nonlinear elements of type `EROSNB`. This last version may be used as a template for the simplest possible specification of an unconstrained problem in S2PMJ format.

In addition, `ROSSIMP1NE` also presents the problem as a system of nonlinear equations (with one group per equation, the first one having one nonlinear element of type `eSQ`).

## 8 Distribution

The S2MPJ decoder `s2mpj.m` and its associated libraries `s2mpjlib.m`, `s2mpjlib.py` and `s2mpjlib.jl` are available on the Github repository <https://github.com/Gratton/S2MPJ>. This repository also provides the 1098 SIF files used in our test, as well as the corresponding Matlab, Python and Julia problems files (generated using the S2MPJ defaults). A Matlab tool `regenerate.m` is also available to regenerate the Matlab/Python/Julia problem files, should one desire to use different S2MPJ options.

## 9 Conclusion, discussion and perspectives

We have presented S2PMJ a new decoder for the SIF files defining the CUTEst problems. This decoder is written in Matlab and produces executable problem files in Matlab, Python or Julia, making the stand-alone use of the CUTEst collection of test problems possible directly within the Matlab, Python or Julia environments. The code for the decoder, its associated libraries and the generated problem files are publicly available on Github.

As it turned out, the design of S2MPJ was useful as an independent check of the collection SIF files (a few were either corrected or completed) and also resulted in an improved Fortran decoder. But the authors are well aware of the limitations of the S2MPJ framework: not all existing SIF files could be decoded, the format of the Matlab/Python/Julia problem files can be very verbose (it has to cover every possible SIF syntax) and they are intrinsically slower to execute than their Fortran counterparts, as expected for JIT compiled languages.

In particular, the 'setup' action and the first evaluation in Julia file can occasionally be very memory-intensive and slow, to the point of making the approach irrelevant for problems involving a large amount of data or a large number of variables. It is therefore clear that *both the Fortran and S2MPJ frameworks have complementary advantages*. Equally clear is the fact that improvements to S2MPJ (such as automatic storage of precompiled problem files and automatic code vectorization) are desirable.

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## The Rosenbrock example: from automatic to simplified

Version 0: the S2MPJ-produced file (two  $\ell_2$  groups, two nonlinear elements)

```
function varargout = ROSENBR(action,varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Problem : ROSENBR
%   The ever famous 2 variables Rosenbrock "banana valley" problem
%   Source:  problem 1 in
%   J.J. More', B.S. Garbow and K.E. Hillstom,
%   "Testing Unconstrained Optimization Software",
%   ACM Transactions on Mathematical Software, vol. 7(1), pp. 17-41, 1981.
%   SIF input: Ph. Toint, Dec 1989.
%   classification = 'SUR2-AN-2-0'
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
persistent pbm;
name = 'ROSENBR';
switch(action)
case 'setup'
    pb.name      = name;
    pbm.name     = name;
    %%%%%%%%%%  PREAMBLE  %%%%%%%%%%
    v_ = configureDictionary('string','double');
    ix_ = configureDictionary('string','double');
    ig_ = configureDictionary('string','double');
    %%%%%%%%%%  VARIABLES  %%%%%%%%%%
    pb.xnames = {};
    [iv,ix_] = s2mpjlib('ii','X1',ix_);
    pb.xnames{iv} = 'X1';
    [iv,ix_] = s2mpjlib('ii','X2',ix_);
    pb.xnames{iv} = 'X2';
    %%%%%%%%%%  DATA GROUPS  %%%%%%%%%%
    pbm.A = sparse(0,0);
    [ig,ig_] = s2mpjlib('ii','G1',ig_);
    gtype{ig} = '<';
    iv = ix_('X2');
    if(size(pbm.A,1)>=ig&&size(pbm.A,2)>=iv)
        pbm.A(ig,iv) = 1.0+pbm.A(ig,iv);
    else
        pbm.A(ig,iv) = 1.0;
    end
    pbm.gscale(ig,1) = 0.01;
    [ig,ig_] = s2mpjlib('ii','G2',ig_);
    gtype{ig} = '<';
```

```

iv = ix_('X1');
if(size(pbm.A,1)>=ig&&size(pbm.A,2)>=iv)
    pbm.A(ig,iv) = 1.0+pbm.A(ig,iv);
else
    pbm.A(ig,iv) = 1.0;
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% GLOBAL DIMENSIONS %%%%%%%%%%
pb.n = numEntries(ix_);
ngrp = numEntries(ig_);
pbm.objgrps = [1:ngrp];
pb.m = 0;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% CONSTANTS %%%%%%%%%%
pbm.gconst = zeros(ngrp,1);
pbm.gconst(ig_('G2')) = 1.0;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% BOUNDS %%%%%%%%%%
pb.xlower = -Inf*ones(pb.n,1);
pb.xupper = +Inf*ones(pb.n,1);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% START POINT %%%%%%%%%%
pb.x0(1:pb.n,1) = zeros(pb.n,1);
pb.x0(ix_('X1'),1) = -1.2;
pb.x0(ix_('X2'),1) = 1.0;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% ELFTYPE %%%%%%%%%%
iet_ = configureDictionary('string','double');
[it,iet_] = s2mpjlib('ii','eSQ',iet_);
elftv{it}{1} = 'V1';
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% ELEMENT USES %%%%%%%%%%
ie_ = configureDictionary('string','double');
pbm.elftype = {};
ielftype = [];
pbm.elvar = {};
ename = 'E1';
[ie,ie_] = s2mpjlib('ii',ename,ie_);
pbm.elftype{ie} = 'eSQ';
ielftype(ie) = iet_('eSQ');
vname = 'X1';
[iv,ix_,pb] = s2mpjlib('nlx',vname,ix_,pb,1,[],[],[]);
posev = find(strcmp('V1',elftv{ielftype(ie)}));
pbm.elvar{ie}(posev) = iv;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% GRFTYPE %%%%%%%%%%
igt_ = configureDictionary('string','double');
[it,igt_] = s2mpjlib('ii','gL2',igt_);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% GROUP USES %%%%%%%%%%
[pbm.grelt{1:ngrp}] = deal(repmat([],1,ngrp));
nlc = [];
for ig = 1:ngrp
    pbm.grftype{ig} = 'gL2';
end
ig = ig_('G1');
posel = length(pbm.grelt{ig})+1;
pbm.grelt{ig}(posel) = ie_('E1');
pbm.grelw{ig}(posel) = -1.0;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% OBJECT BOUNDS %%%%%%%%%%
pb.objlower = 0.0;

% Solution
% LO SOLTN 0.0
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% DEFAULT FOR MISSING SECTION(S) %%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% RETURN VALUES FROM THE SETUP ACTION %%%%%%%%%%

```



```

        pb.pbclass = 'SUR2-AN-2-0';
        varargout{1} = pb;
        varargout{2} = pbm;
% *****
%  SET UP THE FUNCTION *
%  AND RANGE ROUTINES *
%  *****
%  %%%%%%%%%% NONLINEAR ELEMENTS %%%%%%%%%%
    case 'eSQ'
        EV_ = varargin{1};
        iel_ = varargin{2};
        varargout{1} = EV_(1)*EV_(1);
        if(nargout>1)
            g_(1,1) = EV_(1)+EV_(1);
            varargout{2} = g_-;
            if(nargout>2)
                H_(1,1) = 2.0;
                varargout{3} = H_-;
            end
        end
%  %%%%%%%%%% NONLINEAR GROUPS %%%%%%%%%%
    case 'gL2'
        GVAR_ = varargin{1};
        igr_ = varargin{2};
        varargout{1} = GVAR_*GVAR_-;
        if(nargout>1)
            g_ = GVAR_+GVAR_-;
            varargout{2} = g_-;
            if(nargout>2)
                H_ = 2.0;
                varargout{3} = H_-;
            end
        end
%  %%%%%%%%%% THE MAIN ACTIONS %%%%%%%%%%
    case {'fx','fgx','fgHx','cx','cJx','cJHx','cIx','cIJx','cIJHx','cIJxv','fHxv',...
          'cJxv','Lxy','Lgxy','LgHxy','LIxy','LIgxy','LIgHxy','LHxyv','LIHxyv'}
        if(isfield(pbm,'name') && strcmp(pbm.name,name))
            pbm.has_globs = [0,0];
            [varargout{1:max(1,nargout)}] = s2mpjlib(action,pbm,varargin{:});
        else
            disp(['ERROR: please run ',name,' with action = setup'])
            [varargout{1:nargout}] = deal(repmat(NaN,1:nargout));
        end
    otherwise
        disp([' ERROR: unknown action ',action,' requested from ',name,'.m'])
    end
return
end
% %%%%%%%%%%

```

Version 1: the uncluttered full GPS description (two  $\ell_2$  groups, two nonlinear elements)

```

function varargout = ROSSIMP1(action,varargin)
% %%%%%%%%%%
%   Problem : ROSSIMP1
%   The ever famous 2 variables Rosenbrock "banana valley" problem.

```

```

% This version is constructed from ROSENBR.m, removing all (here)
% unnecessary statements automatically generated by S2MPJ.
% classification = 'SUR2-AN-2-0'
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
persistent pbm;
name = 'ROSSIMP1';
switch(action)
case 'setup'
    pb.name      = name;
    pbm.name     = name;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% DATA GROUPS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pbm.A = sparse(2,2);
    pbm.A(1,2) = 1.0;
    pbm.gscale(1) = 0.01;
    pbm.A(2,1) = 1.0;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% GLOBAL DIMENSIONS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pb.n      = 2;
    ngrp      = 2;
    pbm.objgrps = [ 1, 2 ];
    pb.m      = 0;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% CONSTANTS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pbm.gconst = [ 0.0; 1 ];
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% BOUNDS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pb.xlower = [ -Inf; -Inf ];
    pb.xupper = [ +Inf; +Inf ];
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% START POINT %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pb.x0 = [ -1.2; 1.0 ];
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% ELEMENT USES %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pbm.elftype{1} = 'eSQ';
    pbm.elvar{1}   = [ 1 ];
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% GROUP USES %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pbm.grftype = { 'gL2', 'gL2' };
    pbm.grelt{1} = [ 1 ];
    pbm.grelw{1} = [ -1.0 ];
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% OBJECT BOUNDS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pb.objlower = 0.0;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% DEFAULT FOR MISSING SECTION(S) %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% RETURN VALUES FROM THE SETUP ACTION %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    pb.pbclass = 'SUR2-AN-2-0';
    varargout{1} = pb;
    varargout{2} = pbm;
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% NONLINEAR ELEMENTS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
case 'eSQ'
    EV_ = varargin{1};
    varargout{1} = EV_(1)*EV_(1);
    if(nargout>1)
        g_(1,1) = EV_(1)+EV_(1);
        varargout{2} = g_;
        if(nargout>2)
            H_(1,1) = 2.0;
            varargout{3} = H_;
        end
    end
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% NONLINEAR GROUPS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
case 'gL2'
    GVAR_ = varargin{1};
    varargout{1} = GVAR_*GVAR_;

```

```

    if(nargout>1)
        g_ = GVAR_+GVAR_;
        varargout{2} = g_;
        if(nargout>2)
            H_ = 2.0;
            varargout{3} = H_;
        end
    end
    %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% THE MAIN ACTIONS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
    case { 'fx', 'fgx', 'fgHx', 'cx', 'cJx', 'cJHx', 'cIx', 'cIJx', 'cIJHx', 'cIJxv', 'fHxv', ...
           'cJxv', 'Lxy', 'Lgxy', 'LgHxy', 'LIxy', 'LIgxy', 'LIgHxy', 'LHxyv', 'LIHxyv' }
        if(isfield(pbm,'name') && strcmp(pbm.name,name))
            pbm.has_globs = [0,0];
            [varargout{1:max(1,nargout)}] = s2mpjlib(action,pbm,varargin{:});
        else
            disp(['ERROR: please run ',name,' with action = setup'])
            [varargout{1:nargout}] = deal(repmat(NaN,1:nargout));
        end
    otherwise
        disp([' ERROR: unknown action ',action,' requested from ',name,'.m'])
    end
return
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

Version 2: an intermediate version ((one trivial group, two nonlinear elements))

```

function varargout = ROSSIMP2(action,varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Problem : ROSSIMP2
%   The ever famous 2 variables Rosenbrock "banana valley" problem
%   This version is constructed from ROSSIMP1.m, reducing from 2 nonlinear
%   groups and 1 nonlinear element to 1 trivial group and 2 nonlinear elements.
%   S2MPJ input: Ph. Toint, June 2024
%   classification = 'SUR2-AN-2-0'
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
persistent pbm;
name = 'ROSSIMP2';
switch(action)
    case 'setup'
        pb.name      = name;
        pbm.name     = name;
        pb.n = 2;
        pbm.objgrps = [ 1 ];
        pb.m = 0;
        pb.xlower = [ -Inf; -Inf ];
        pb.xupper = [ +Inf; +Inf ];
        pb.x0 = [ -1.2; 1.0 ];
        pbm.elftype = { 'E1', 'E2' };
        pbm.elvar = { [ 1, 2 ], [ 1 ] };
        pbm.grelet{1} = [ 1, 2 ];
        pb.objlower = 0.0;
        pb.pbclass = 'SUR2-AN-2-0';
        varargout{1} = pb;
        varargout{2} = pbm;
    case 'E1'

```

```

x = varargin{1};
varargout{1} = 100.0*(x(2)-x(1)*x(1))^2;
if(nargout>1)
    g_(1,1) = -400.0*(x(2)-x(1)*x(1))*x(1);
    g_(2,1) = 200.0*(x(2)-x(1)*x(1));
    varargout{2} = g_;
    if(nargout>2)
        H_(1,1) = 1200.0*x(1)*x(1);
        H_(1,2) = -400.0;
        H_(2,2) = 200.0;
        varargout{3} = H_;
    end
end
case 'E2'
    x = varargin{1};
    varargout{1} = (x(1)-1.0)^2;
    if(nargout>1)
        g_(1,1) = 2*(x(1)-1.0);
        varargout{2} = g_;
        if(nargout>2)
            H_(1,1) = 2.0;
            varargout{3} = H_;
        end
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% THE MAIN ACTIONS %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
case {'fx','fgx','fgHx','cx','cJx','cJHx','cIx','cIJx','cIJHx','cIJxv','fHxv',...
      'cJxv','Lxy','Lgxy','LgHxy','LIxy','LIgxy','LIgHxy','LHxyv','LIHxyv'}
    if(isfield(pbm,'name')&&strcmp(pbm.name,name))
        pbm.has_globs = [0,0];
        [varargout{1:max(1,nargout)}] = s2mpjlib(action,pbm,varargin{:});
    else
        disp(['ERROR: please run ',name,' with action = setup'])
        [varargout{1:nargout}] = deal(repmat(NaN,1:nargout));
    end
end
otherwise
    disp([' ERROR: unknown action ',action,' requested from ',name,'.m'])
end
return
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

Version 3: the short synthetic version (one trivial group, one nonlinear element)

```

function varargout = ROSSIMP3(action,varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%   Problem : ROSSIMP3
%   The ever famous 2 variables Rosenbrock "banana valley" problem
%   This version uses 1 trivial group and 2 nonlinear elements.
%   classification = 'SUR2-AN-2-0'
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
persistent pbm;
name = 'ROSSIMP3';
switch(action)
    case 'setup'
        pb.name      = name;
        pbm.name     = name;

```

```

pb.n = 2;
pb.m = 0;
pbm.objgrps = [ 1 ];
pb.xlower = [ -Inf; -Inf ];
pb.xupper = [ +Inf; +Inf ];
pb.x0 = [ -1.2; 1.0 ];
pbm.elftype = { 'EROSNB' };
pbm.elvar = { [ 1, 2 ] };
pbm.grelt{1} = [ 1 ];
pb.objlower = 0.0;
pb.pbclass = 'SUR2-AN-2-0';
varargout{1} = pb;
varargout{2} = pbm;
case 'EROSNB' % The ever famous "banana" function!
x = varargin{1};
varargout{1} = 100.0*(x(2)-x(1)*x(1))^2+(x(1)-1.0)^2;
if(nargout>1)
    g_(1,1) = -400.0*(x(2)-x(1)*x(1))*x(1)+2.0*(x(1)-1.0);
    g_(2,1) = 200.0*(x(2)-x(1)*x(1));
    varargout{2} = g_;
    if(nargout>2)
        H_(1,1) = 1200.0*x(1)*x(1)+2.0;
        H_(1,2) = -400.0;
        H_(2,2) = 200.0;
        varargout{3} = H_;
    end
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%% THE MAIN ACTIONS %%%%%%%%%%%%%%
case { 'fx', 'fgx', 'fgHx', 'cx', 'cJx', 'cJHx', 'cIx', 'cIJx', 'cIJHx', 'cIJxv', 'fHxv', ...
      'cJxv', 'Lxy', 'Lgxy', 'LgHxy', 'LIxy', 'LIgxy', 'LIgHxy', 'LHxyv', 'LIHxyv' }
if(isfield(pbm, 'name') && strcmp(pbm.name, name))
    pbm.has_globs = [0,0];
    [varargout{1:max(1,nargout)}] = s2mpjlib(action, pbm, varargin{:});
else
    disp(['ERROR: please run ', name, ' with action = setup'])
    [varargout{1:nargout}] = deal(repmat(NaN, 1:nargout));
end
otherwise
    disp([' ERROR: unknown action ', action, ' requested from ', name, '.m'])
end
return
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

```

Version 4: as a sytem of two nonlinear equations

```

function varargout = ROSSIMP1NE(action, varargin)
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
% Problem : ROSSIMP1NE
% The ever famous 2 variables Rosenbrock "banana valley" problem
% This version considers the problem as a system of nonlinear equations.
% classification = 'NOR2-AN-2-0'
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
persistent pbm;
name = 'ROSSIMP1NE';
switch(action)

```

```

case 'setup'
    pb.name      = name;
    pbm.name     = name;
    %%%%%%%%%% DATA GROUPS %%%%%%%%%%
    pbm.A = sparse(2,2);
    pbm.A(1,2) = 1.0;
    pbm.gscale(1) = 0.1;
    pbm.A(2,1) = 1.0;
    %%%%%%%%%% GLOBAL DIMENSIONS %%%%%%%%%%
    pb.n      = 2;
    pbm.congrps = [ 1, 2 ];
    pb.neq     = 2;
    pb.m       = 2;
    %%%%%%%%%% CONSTANTS %%%%%%%%%%
    pbm.gconst = [ 0.0; 1 ];
    %%%%%%%%%% BOUNDS %%%%%%%%%%
    pb.xlower = [ -Inf; -Inf ];
    pb.xupper = [ +Inf; +Inf ];
    %%%%%%%%%% START POINT %%%%%%%%%%
    pb.x0 = [ -1.2; 1.0 ];
    %%%%%%%%%% ELEMENT USES %%%%%%%%%%
    pbm.elftype{1} = 'eSQ';
    pbm.elvar{1} = [ 1 ];
    %%%%%%%%%% GROUP USES %%%%%%%%%%
    pbm.grelt{1} = [ 1 ];
    pbm.grelw{1} = [ -1.0 ];
    %%%%%%%%%% OBJECT BOUNDS %%%%%%%%%%
    pb.objlower = 0.0;
    %%%%%% RETURN VALUES FROM THE SETUP ACTION %%%%%%%%%%
    pb.pbclass = 'NOR2-AN-2-0';
    varargout{1} = pb;
    varargout{2} = pbm;
case 'eSQ'
    EV_ = varargin{1};
    varargout{1} = EV_(1)*EV_(1);
    if(nargout>1)
        g_(1,1) = EV_(1)+EV_(1);
        varargout{2} = g_;
        if(nargout>2)
            H_(1,1) = 2.0;
            varargout{3} = H_;
        end
    end
    %%%%%%%%%% THE MAIN ACTIONS %%%%%%%%%%
case { 'fx', 'fgx', 'fgHx', 'cx', 'cJx', 'cJHx', 'cIx', 'cIJx', 'cIJHx', 'cIJxv', 'fHxv', ...
      'cJxv', 'Lxy', 'Lgxy', 'LgHxy', 'LIxy', 'LIgxy', 'LIgHxy', 'LHxyv', 'LIHxyv' }
    if(isfield(pbm,'name') && strcmp(pbm.name,name))
        pbm.has_globs = [0,0];
        [varargout{1:max(1,nargout)}] = s2mpjlib(action,pbm,varargin{:});
    else
        disp(['ERROR: please run ',name,' with action = setup'])
        [varargout{1:nargout}] = deal(repmat(NaN,1:nargout));
    end
otherwise
    disp([' ERROR: unknown action ',action,' requested from ',name,'.m'])
end
return

```

