Dynamic Link Library • Version 3.5

Solver User's Guide

By Frontline Systems, Inc.

```
#include "frontmip.h"
#include "frontkey.h"
#include <stdio.h>

INTARG _CC FuncEval (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG rhs, LPREALARG var, INTARG varone, INTARG vartwo)
{
   objval[0] = var[0] * var[0] + var[1] * var[1]; /* objective */
   lhs[0] = var[0] + var[1]; /* constraint left hand side: =  1.0 */
   lhs[1] = var[0] * var[1]; /* constraint left hand side: >= 0.0 */
   return 0;
}

int main() /* Solve example constrained nonlinear optimization problem */
{
   double obj[2];
   double rhs[2] = { 1.0, 0.0 };
   char sense[2] = "EG";
   double matval[4];
   double lb[] = { -INFBOUND, -INFBOUND };
   double ub[] = { +INFBOUND, +INFBOUND };
   long stat, i;
   double x[2] = {0.0, 0.0 };
   double objval, piout[2], slack[2];
   HPROBLEM lp;
   printf("Example NLP problem\n");
   lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, x, lb, ub, NULL, 4, FuncEval, NULL);
   optimize (lp);
   solution (lp, &stat, &objval, x, piout, slack, NULL);
   printf("Status = %ld  Objective = %g\n", stat, objval);
   printf("Final values: x[0] = %7g  x[1] = %7g\n", x[0], x[1]);
   for (i = 0; i <= 1; i++)
      printf("slack[%ld] = %7g  dual value[%ld] = %7g\n",
         i, slack[i], i, piout[i]);
   return 0;
}
```

How to Order

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Introduction

The Solver Dynamic Link Libraries

Welcome to Frontline Systems' Small-Scale Solver Dynamic Link Library (DLL). The Solver DLL provides the tools you need to solve linear, quadratic, nonlinear, and nonsmooth optimization problems, and mixed-integer problems of varying size. It can be called from a program you write in any programming language, macro language, or scripting language for Microsoft Windows that is capable of calling a DLL. Some of the possibilities that will be covered in this User Guide are Microsoft Visual C++, Visual Basic, Delphi Pascal, and Fortran Powerstation. There are many others, including Visual Basic Application Edition in each of the Microsoft Office applications.

Frontline offers two Solver DLL product lines with compatible calling conventions: the Small-Scale Solver DLL, which handles smaller, "dense matrix" problems, and the Large-Scale Solver DLL, which handles larger, "sparse matrix" problems.

The Small-Scale Solver DLL handles linear and quadratic programming problems with up to 2000 decision variables, depending on the version, and nonlinear and nonsmooth optimization problems of up to 400 decision variables. (Any of the variables may be general integer or binary integer.) It is offered in five different configurations that include only the Solver "engines" (linear, quadratic and/or nonlinear/nonsmooth) that you need for your application.

The Large-Scale Solver DLL handles linear and mixed-integer linear programming problems of up to 16,384 decision variables. At present, the Large-Scale Solver DLL does not include facilities for solving quadratic, nonlinear, or nonsmooth optimization problems, but future versions may include these capabilities.

Both Solver DLLs are offered in 32-bit versions for Windows 95/98 and Windows NT/2000 and in 16-bit versions for Microsoft Windows 3.1. (You can also run 16-bit applications, which call the 16-bit Solver DLLs, under Windows 95/98 or NT.)

The Small-Scale Solver DLL

Frontline's Small-Scale Solver DLL is a compact and efficient solver for linear programming (LP), mixed integer programming (MIP), and optionally quadratic programming (QP) problems of up to 2000 decision variables, depending on the version, and smooth nonlinear programming (NLP) problems or nonsmooth

optimization problems of up to 400 decision variables and 200 constraints (in addition to bounds on the variables).

The Small-Scale Solver DLL is an enhanced version of the linear, mixed integer and nonlinear programming "engine" used in the Microsoft Excel Solver, which was developed by Frontline Systems for Microsoft. This Solver has been proven in use over nine years in tens of millions of copies of Microsoft Excel. Microsoft selected Frontline Systems' technology over several alternatives because it offered the best combination of robust solution methods, performance and ease of use.

The Small-Scale Solver DLL is also a "well-behaved" Microsoft Windows Dynamic Link Library. It respects Windows conventions for loading and sharing program code. Under Windows NT/2000 or Windows 95/98, the Solver DLL runs in 32-bit protected mode and supports preemptive multitasking. When used under Windows 3.1, the Solver DLL shares the processor with other applications through Windows non-preemptive multitasking. It also solves the problems of 16-bit Windows memory management through use of a "two-level" storage allocator, which draws upon Windows global memory resources in an efficient manner.

The algorithmic methods used in the Small-Scale Solver DLL include:

- Simplex method with bounds on the variables for linear programming problems
- Very fast "exact" quadratic method for solving QP problems such as portfolio optimization models
- Generalized Reduced Gradient method for solving smooth nonlinear programming problems
- Evolutionary Solver (based on genetic algorithms) for solving nonsmooth optimization problems
- Memory-efficient Branch & Bound method for mixed-integer problems
- Preprocessing and Probing strategies for fast solution of zero-one integer programming problems
- Very fast on "sparse" LP models with fewer nonzero matrix coefficients
- Automatic scaling, degeneracy control and other features for robustness
- Sensitivity analysis (shadow prices and reduced costs) for linear, quadratic and nonlinear problems
- Optional objective coefficient and constraint right hand side sensitivity "range" information for linear problems
- Automatic diagnosis of infeasible linear and nonlinear problems, computing an Irreducibly Infeasible Subset (IIS) of constraints

The Large-Scale Solver DLL

Frontline's Large-Scale Solver DLL is a state of the art implementation of linear programming (LP) and mixed-integer programming (MIP) solution algorithms. The 16-bit version of the Large-Scale Solver DLL can handle problems of up to 8,192 decision variables and 8,192 constraints in addition to bounds on the variables. The 32-bit version (which can be called from a 32-bit application under Windows 95/98 or NT/2000) can handle problems of up to 16,384 variables and 16,384 constraints.

The Large-Scale Solver DLL efficiently stores and processes LP models in sparse matrix form. It uses modern matrix factorization methods to control numerical

stability during the solution of large LP models, where the cumulative effect of the small errors inherent in finite precision computer arithmetic would otherwise compromise the solution process. These same methods often result in solution speeds far beyond earlier generations of LP solvers. Thanks to these methods, the Large-Scale Solver DLL can readily handle all of the problems in the well-known NETLIB test suite – virtually all with the default tolerance settings.

The Large-Scale Solver DLL is also a "well-behaved" Microsoft Windows Dynamic Link Library. Like the Small-Scale Solver DLL, it respects Windows conventions for loading and sharing program code. Under Windows NT/2000 or Windows 95/98, the Solver runs in 32-bit protected mode and supports preemptive multitasking. When used under Windows 3.1, the Large-Scale Solver DLL shares the processor with other applications through Windows non-preemptive multitasking, and draws upon Windows global memory resources in an efficient manner.

The Large-Scale Solver DLL uses many of the best published solution methods and has been proven in use on large LP models in industry and government around the world. These algorithmic methods include:

- Simplex method with two-sided bounds on both variables and constraints
- Memory-efficient Branch & Bound method for mixed-integer problems
- Matrix factorization using the LU decomposition, with the Bartels-Golub update
- Refactorization using dynamic Markowitz methods for speed and stability
- Steepest-edge techniques which often substantially reduce the number of pivots
- Sophisticated "crash-like" methods for finding an effective initial basis
- Basis restart for faster solution of MIP subproblems
- Automatic row and column scaling, plus control of various algorithm tolerances

The Large-Scale Solver DLL is described in a separate Solver User's Guide, which is available on request from Frontline Systems. In the rest of this User's Guide, the term "Solver DLL" refers to the Small-Scale version.

Which Solver DLL Should You Use?

The Solver DLL is offered in five different configurations that include only the Solver "engines" (linear, quadratic, nonlinear and nonsmooth) that you need for your application. The possible configurations are:

- Linear (Simplex) Solver only
- Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers only
- Both Linear (Simplex) Solver and Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers
- Linear (Simplex) Solver plus Quadratic and MIP enhancements
- Both Linear (Simplex) Solver plus Quadratic and MIP enhancements, and Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers

Linear Solver

The linear (LP) Solver is the preferred Solver "engine" for linear programming problems. It uses the Simplex method to solve the problem, which is guaranteed (in

the absence of severe difficulties with scaling or degeneracy) to find the optimal solution if one exists, or to find that there is no feasible solution or that the objective function is unbounded.

The LP Solver is designed to accept a matrix of coefficients (called *matval* later in this Guide) which allows the Solver itself to compute values for the problem functions (objective and constraints). If you supply the matrix of coefficients, you don't have to write a function (*funceval()*) to evaluate the problem functions. In most cases, the coefficients are readily available from the data accepted as input or computed by your application. In other situations, the coefficients might not be so readily available and you might find it easier to write a *funceval()* routine. If your Solver DLL includes both the nonlinear (NLP) and LP Solver "engines," you can ask the Solver DLL to compute the matrix of coefficients for you, by calling your *funceval()* routine, and then solve the problem using the faster and more reliable LP Solver "engine."

Quadratic Solver

The quadratic (QP) Solver is an extension to the LP Solver which solves quadratic programming problems, such as portfolio optimization problems, with a quadratic objective function and all linear constraints. It uses the fast and reliable Simplex method to solve a series of subproblems leading to the optimal solution for the quadratic programming problem.

The QP Solver is designed to accept a matrix of coefficients (*matval*) for the linear constraints, and another matrix of coefficients (*qmatval*) for the quadratic objective function. (In a portfolio optimization problem, the objective function is normally the portfolio variance, and the *qmatval* coefficients are the covariances between pairs of securities in the portfolio.)

If you wish to minimize variance in a portfolio optimization problem, the QP Solver is the preferred Solver "engine" since it will be faster and more accurate than the NLP Solver. If, however, you wish to maximize portfolio return and treat portfolio variance as a constraint, your problem will not be a QP (since its constraints are not all linear) and you will need to use the NLP Solver.

Nonlinear Solver

The nonlinear (GRG) Solver can solve smooth nonlinear, quadratic, and linear programming problems. It may also be the easiest-to-use Solver "engine" if it is natural for you to describe the optimization problem by writing a function (called *funceval()* later in this Guide) that evaluates the objective and constraints for given values of the decision variables.

However, this generality comes at a price of both speed and reliability: On smooth nonlinear problems, the NLP Solver (like all similar gradient-based methods) is guaranteed only to find a locally optimal solution which may or may not be the true (globally) optimal solution within the feasible region.

Moreover, since the NLP Solver treats QP and LP problems as if they were general nonlinear problems, it is likely to take considerably more time to solve such problems, and it may find solutions which are less accurate or less exact than solutions found by the Solver "engine" most appropriate to the task.

Problems such as poor scaling or degeneracy also cause greater difficulty for the NLP Solver than for the QP or LP Solver. If you have a linear (or quadratic) problem, or a mix of nonlinear and linear (or quadratic) problems, we highly

recommend that you experiment with each of the Solver "engines" and compare both solution time and accuracy of the results.

Nonsmooth (Evolutionary) Solver

The nonsmooth (Evolutionary) Solver, based on genetic or evolutionary algorithms, is the most general-purpose Solver "engine" in that it makes no assumptions about the mathematical form of the problem functions (objective and constraints): They may be linear, quadratic, smooth nonlinear, nonsmooth, or even discontinuous and nonconvex functions. Moreover, for smooth nonlinear problems where the GRG Solver is guaranteed to find only a locally optimal solution, the Evolutionary Solver can often find a better, globally optimal solution. Like the nonlinear Solver, it calls a function *funceval()* that you write to evaluate the objective and constraints for given values of the decision variables.

However, this generality comes at a considerable price of both speed and reliability. Unlike the Simplex and GRG Solvers which are *deterministic* optimization methods, the Evolutionary Solver is a *nondeterministic* method: Because it is based partly on random choices of trial solutions, it will often find a different "best solution" each time you run it, even if you haven't changed your problem at all. And unlike the Simplex and GRG Solvers, the Evolutionary Solver has no way of knowing for certain that a given solution is optimal – even "locally optimal." Similarly, the Evolutionary Solver has no way of knowing for certain whether it should stop, or continue searching for a better solution – it is forced to rely on tests for slow improvement in the solution to determine when to stop.

Solving Mixed-Integer Problems

The Branch & Bound method for solving mixed integer programming problems is included in all configurations of the Solver DLL. It can call any of the classical Solver "engines" to solve its subproblems – so you can solve integer linear problems with the LP Solver, integer quadratic problems with the QP Solver, and integer nonlinear problems with the NLP Solver. (The Evolutionary Solver "engine" handles integer variables on its own, so the Branch & Bound method is not used in conjunction with it.) Also, because the NLP Solver (or any similar method) is not guaranteed to find the globally optimal solution to any subproblem, the Branch & Bound method is not guaranteed to find the true optimal solution to an integer nonlinear problem – though it will often find a "good" but not provably optimal integer solution. Solving integer linear problems with the LP Solver, or integer quadratic problems with the QP Solver, is an intrinsically faster and more reliable process.

If you have an integer linear problem with many binary or 0-1 integer variables, we recommend that you try solving it with a Solver DLL configuration that includes the QP Solver. Packaged with the QP Solver are a set of Preprocessing and Probing strategies for linear constraints that often greatly speed up the solution of problems with many 0-1 integer variables.

16-Bit Versus 32-Bit Versions

The choice of 16-bit versus 32-bit versions of the Solver DLL will probably be dictated by the programming language or other tool you are using to write your application program. For example, Visual Basic 3.0 is a 16-bit system which can call only the 16-bit Solver DLL, whereas Visual Basic for Applications as shipped with Microsoft Office 95, 97 and 2000 can call only the 32-bit versions of the DLL.

The 32-bit versions of the Solver DLL takes full advantage of the instruction set features of the Intel 386, 486, Pentium and above processors, yielding a speed advantage which may be as great as a factor of two on larger problems.

Support for 16-bit versions of the Solver DLL will be limited in the future. We highly recommend that you use the 32-bit versions of the Solver DLL and develop your application for 32-bit platforms such as Windows 95/98 and Windows NT.

What's New in Version 3.5

Version 3.5 of the Solver DLL product line introduces a number of new features including the Evolutionary Solver, reentrant versions of the Solver DLL for multi-threaded applications, routines to support use-based licensing for Web server and similar applications, and the ability to read in and solve a linear, quadratic, or mixed-integer problem written in algebraic notation from a external text file.

Evolutionary Solver

The new Evolutionary Solver "engine," included with the nonlinear GRG Solver in Version 3.5 of the Solver DLL, is designed to find good – though not provably optimal – solutions for problems where the "classical" gradient methods in the GRG Solver are not sufficient. The GRG Solver assumes that the problem functions (objective and constraints) are *smooth* functions of the variables (i.e. the gradients of these functions are everywhere continuous); its guaranteed ability to converge to a local optimum depends on this assumption. In problems with nonsmooth or even discontinuous functions, the GRG Solver often has difficulty reaching a solution. In such problems, the Evolutionary Solver – which makes no assumptions about the problem functions – can often find a good solution. Even in smooth nonlinear problems, the GRG Solver is guaranteed only to find a locally optimal solution, but it may miss a better solution far from the starting point you provide. The Evolutionary Solver has a much better chance of finding the globally optimal solution in such problems.

Multi-Threaded Applications

Version 3.5 of the Solver DLL is offered in both single-threaded and multi-threaded versions. The single-threaded versions – like all earlier versions of the Solver DLL – are serially reusable but not reentrant: They can solve multiple problems serially, but not concurrently, nor can they solve problems recursively, for example where computation of the objective or constraints for one optimization problem involves solution of another optimization subproblem. The multi-threaded versions of the Solver DLL V3.5 are fully reentrant: They can solve multiple problems concurrently and/or recursively. They are especially suitable for Web server or Intranet-based applications, which may be accessed by many users at unpredictable moments which may overlap in time.

Use-Based Licensing

With the ability to solve multiple problems concurrently, the Solver DLL Version 3.5 is being deployed in Web server and similar applications where the number of users is unknown in advance, or may become very large. In such cases, the normal user-based (or "seat-based") licensing for multiple copies of the Solver DLL may not be appropriate. To meet this requirement, Frontline Systems has developed alternative

use-based licensing terms, which permit any number of users or seats, but which monitor the number of uses or calls to the optimizer. Developers can choose user-based or use-based licensing. On either basis, they can prepay for a quantity of licenses to bring down the average cost on a steeply declining discount schedule, and they can arrange that the total license cost will not exceed a certain fixed amount for a period such as a year, or for the lifetime of the application.

To support use-based licensing, certain configurations of the Solver DLL V3.5 include the ability to count uses (i.e. calls to the *loadlp()* or *loadnlp()* functions, and calls to the *optimize()* or *mipoptimize()* functions) and report this information both to the user and to Frontline Systems. Use information can be written to a text file or emailed to Frontline Systems, either automatically or under the control of the application program (via the new *getuse()* and *reportuse()* functions.)

Problems in Algebraic Notation

Previous versions of the Solver DLL featured the ability to write out a text file containing an algebraic description of a linear, quadratic or mixed-integer problem. The primary use of this feature was in testing and debugging an application program, to ensure that the problem being defined by calls to the Solver DLL routines was in fact the problem intended. Version 3.5 of the Solver DLL features the new *lpread()* function to complement the *lpwrite()* or *lprewrite()* functions. With *lpread()*, the application can read in a problem previously written to disk by *lpwrite()*, or a problem generated in the correct format by another program or via hand editing of the text file. This provides a wide range of new options for saving problems across multiple sessions, and solving problems interactively or in combination with other programs.

How to Use This Guide

This User Guide includes a chapter on installing the Solver DLL files, and a chapter providing an overview of the Solver DLL API calls and how they may be used to define and solve linear (LP), quadratic (QP), nonlinear (NLP), nonsmooth (NSP), and mixed-integer (MIP) programming problems. It also includes chapters giving specific instructions for writing, compiling and linking, and testing application programs in four languages: C/C++, Visual Basic, Delphi Pascal, and FORTRAN.

We highly recommend that you read the installation instructions and the overview of the Solver DLL API calls first. Then you may turn directly to the chapter that covers the language of your choice. Each chapter gives step-by-step instructions for building and testing a simple example program – included with the Solver DLL – written in that language. You can use these example programs as a starting point for your own applications.

The chapter "Solver API Reference" provides comprehensive documentation of all of the Solver DLL's Application Program Interface (API) routines. It covers many details besides those features illustrated in the various example applications. You'll want to consult this chapter as you develop your own application.

Included with the Solver DLL are source code header files (defining the Solver DLL callable routines) and source code for example programs in four languages: C/C++, Visual Basic, Delphi Pascal, and FORTRAN.

Language	*Example File*	*Header File*
C/C++	vcexamp1.c, vcexamp2.c	frontmip.h
Visual Basic	vbexamp1.vbp, vbexamp2.vbp	frontmip.bas, safrontmip.bas
Delphi Pascal	psexamp.dpr	frontmip.pas
FORTRAN	flexamp.for	frontmip.for

For all four languages, the example programs define and solve two optimization problems – a simple LP (linear programming) problem, and a simple NLP (nonlinear programming) problem. (*Note*: If your version of the Solver DLL includes only the LP or only the NLP Solver engine, you will be able to solve only one of these two problems; the other will display an error message dialog.) For C/C++ and Visual Basic, more extensive examples are included as outlined below.

For C/C++ and FORTRAN, the example files are text files containing source code; the instructions in the appropriate chapters explain how to create a project that will compile, link and run the sample programs. For Visual Basic and Delphi Pascal – which are designed to create forms-oriented applications – a complete project with supporting files is included. These projects create simple forms that display the results of solving the two optimization problems when a button is pressed.

The example programs for C/C++ and Visual Basic provide a total of eleven examples of using the Solver DLL. The first set (source code file vcexamp1.c or VB project vbexamp1.vbp) includes five examples: (1) A simple two-variable LP problem, (2) A simple MIP (mixed-integer linear programming) problem, (3) An example illustrating the Solver DLL features for diagnosing infeasibility, (4) A simple quadratic programming problem, which uses the classic Markowitz method to find an efficient portfolio of five securities, and (5) An example using the *lpread()* function to read and solve a problem defined in algebraic notation in an external text file.

The second set (source code file vcexamp2.c or VB project vbexamp2.vbp) includes four examples of nonlinear problems, plus two examples of nonsmooth problems: (1) A simple two-variable NLP problem, (2) The same NLP problem with an optional user-written routine for computing partial derivatives, (3) An example illustrating the diagnosis of infeasibility for nonlinear problems, (4) An example showing how you can solve a series of linear and nonlinear problems, testing them for linearity, and switching between the NLP and LP Solver engines, (5) An example where the Evolutionary Solver finds the global minimum of a function with several local minima, and (6) An example where the Evolutionary Solver finds the optimal solution to a problem with a nonsmooth (discontinuous) objective.

If you are using the 16-bit version of the Solver DLL, and you are either solving a large-scale problem or you wish to use the "callback functions" to gain control during the solution process, be sure to read the chapter "Special Considerations for Windows 3.x" – even if you are running your 16-bit application under Windows 95/98 or NT/2000 in Windows 3.x compatibility mode.

The chapter "Native Windows Applications" provides the C source code of a native Windows application, written to the Win16/Win32 API. This source code can be compiled into either a 16-bit or 32-bit application, and run under Windows 3.x, Windows 95/98 or Windows NT/2000. It makes use of the Solver DLL's callback

functions, and takes into account the special considerations for Windows 3.x. Also included in this chapter is the C source code of a simple multi-threaded application calling the reentrant version of the Solver DLL, written to the Win32 API.

Installation

Running the Installation Program

Most versions of the Solver DLL are provided in the form of single executable installation program file, such as SolvLP.exe, that can be run to uncompress and install all of the Solver DLL files, library and header files, and example source code files discussed later in this User Guide. The name of the executable file reflects the configuration of the Solver DLL you ordered from Frontline Systems:

SolvLP.exe – Linear (Simplex) Solver only

SolvNp.exe – Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers only

SolvNpLp.exe – Both Linear (Simplex) Solver and Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers

SolvLpQp.exe – Linear (Simplex) Solver plus Quadratic and MIP enhancements

SolvNpLpQp.exe – Both Linear (Simplex) Solver plus Quadratic and MIP enhancements, and Nonlinear (GRG) plus Nonsmooth (Evolutionary) Solvers

Simply run this executable program to install the Solver DLL files into the directory structure outlined in the next section (for manual installation). The installation program will prompt you for two pieces of information:

- An installation password
- A 16-character license key string, specific to your application(s)

Both pieces of information are included in the physical package you received from Frontline Systems, or they may be provided to you by phone, fax or email. Carefully enter the license key string exactly as given to you – use uppercase for any letters. If you have any questions, please contact Frontline Systems as shown on the inside title page of this User Guide.

Copying Disk Files Manually

The Solver DLL files can be provided in uncompressed form on floppy disk, so they may be copied to a convenient directory on your hard disk with standard Windows commands. We recommend that you create a directory FRONTMIP in your hard disk root directory (e.g. `c:\frontmip` if your hard disk drive letter is `c:`) and copy the entire contents of the distribution floppy disk to this directory. You can

drag and drop the files in the Windows Explorer, or you can use the DOS command `xcopy a:\*.* c:\frontmip /s`. The resulting directory structure is:

```
Frontmip
   Examples
      Flexamp
      Psexamp
      Vbexamp
      Vcexamp
      Win16
      Win32
   Help
   Include
   Win16
   Win32
```

The Examples subdirectory contains source code for example programs in four different languages: C/C++, Visual Basic, Delphi Pascal, and FORTRAN. The Win16 and Win32 subdirectories within the Examples directory hold compressed archives (`examples.zip`) containing 16-bit and 32-bit executable of the example programs, compiled from the source code, plus a compatible version of frontmip.dll.

The `Include` subdirectory contains an appropriate header file, declaring the Solver DLL entry points, for each language:

`frontmip.h`	C/C++ header file – reference in your source code
`frontmip.bas`	Visual Basic header file – add to your VB project
`safrontmip.bas`	VB header file w/SAFEARRAYs – add to your project
`frontmip.pas`	Delphi Pascal header file – add to your Delphi project
`frontmip.for`	FORTRAN header file – reference in your source code
`frontcbi.for`	FORTRAN header file – use with callback functions

It also contains a license key file, which declares a character string constant containing your own, customized license key:

`frontkey.h`	C/C++ license key file – reference in your source code
`frontkey.bas`	Visual Basic license key file – add to your VB project
`frontkey.pas`	Delphi Pascal license key file – add to your project
`frontkey.for`	FORTRAN license key file – reference in your source

The `Win16` and `Win32` subdirectories contain the Solver DLL and import library files. These files have the same names in each subdirectory, but `Win16` contains 16-bit versions and `Win32` contains 32-bit versions of the files:

`frontmip.dll`	Solver DLL (Dynamic Link Library) executable code
`frontmip.lib`	Import library – used by linker in C++/FORTRAN

Directory Paths

As you write, compile and link, and execute your application program, you will need to reference the Solver DLL files mentioned above. Since only single files are needed at each step, you may find it convenient to copy the Solver DLL files to the directory where you are building or running your application. If your application may be run from many different directories, you may wish to place the Solver DLL file in the `c:\windows` or `c:\windows\system` directory in Windows 3.x or Windows 95/98, or the `c:\winnt\system32` directory (for the 32-bit version of the DLL) in Windows NT/2000.

- When you *compile* the program that calls the Solver DLL routines you will reference the appropriate header file: `frontmip.h`, `frontmip.bas`, `safrontmip.bas`, `frontmip.pas` or `frontmip.for`.
- If you are using "load-time dynamic linking," when you *link* the program that calls the Solver DLL routines you will use the import library `frontmip.lib`. If you are using "run-time dynamic linking," the import library is not used. Note that Visual Basic and Delphi Pascal use run-time dynamic linking.
- When you *execute* the program that calls the Solver DLL routines, you will reference the dynamic link library file `frontmip.dll`. No other files are needed at execution time.

Licensing the Solver DLL

Please bear in mind that in order to lawfully distribute copies of the Solver DLL within your organization or to external customers, or to lawfully use the Solver DLL in a server-based application that serves multiple users, you will need an appropriate license from Frontline Systems. Licenses to use and/or distribute the Solver DLL in conjunction with your application are available at substantial discounts that increase with volume. As discussed in the Introduction, you have the option of choosing either user-based ("seat-based") or use-based licensing. Please contact Frontline Systems for licensing and pricing information.

The copy of the Solver DLL that you license, either for development purposes or for distribution, is customized for use by your application program(s). It recognizes a specific 16-character license key string which you provide as the *probname* argument to the *loadlp()* or *loadnlp()* function. Without this license key string, the Solver DLL will not function – all Solver DLL routines will return without doing anything. It is important that you keep your license key string confidential, and use it only in your application programs. Frontline Systems will treat you as responsible for the use of any copies of the Solver DLL that recognize your specific license key string.

Registry Entries for Use-Based Licensing

If you have chosen use-based licensing, you'll receive a version of the Solver DLL that is designed to count the number of uses (i.e. calls to the *loadlp()* or *loadnlp()* functions, or calls to the *optimize()* or *mipoptimize()* functions) over time, and report this information both to you and to Frontline Systems. To maintain the counts across different executions of your application, the Solver DLL uses several entries under a single key in the system Registry. To use the Solver DLL on a given PC (e.g. your development system, or a production server), you must first run a supplied program, CreateUseKey.exe, to create the Registry key and associated entries.

To do this, simply select **Start Run** and type the path of this program (normally **C:\Frontmip\ CreateUseKey.exe**). Assuming that it successfully creates the Registry entries, this program displays a confirming MessageBox. If run more than once on a given PC, it will display a MessageBox noting that the entries already exist in the Registry, and it will not modify them. For complete information on the Solver DLL's Registry key and associated entries, see the description of the *getuse()* function in the chapter "Solver API Reference."

During development and testing of your application, you can run the Solver DLL in "Evaluation/Test mode," where it does not counts uses; in this mode, the DLL will

not reference the Registry entries, so they need not exist on the development system. Once the DLL is placed into production, it should be run in "Use Counting mode," where the Registry entries must be present. For information on how to set the mode in which the Solver DLL runs, consult the section "Use-Based Licensing" in the following chapter, "Designing Your Application."

On Windows NT and Windows 2000 systems, the CreateUseKey.exe program must be run under a user account with privileges to create Registry entries. Since the Solver DLL only updates existing Registry entries, it does not need to run under an account with these privileges.

Designing Your Application

Calling the Solver DLL

This chapter provides an overview of the way your application program should call the Solver DLL routines to define and solve an optimization problem. We'll use the syntax of the C programming language, but the order of calls, the names of routines, the arguments, and most other programming considerations are the same in other languages.

You build your application program with a header file, specific to the language you are using, which declares the Solver DLL routines, their arguments and return values, and various symbolic constants. At run time, your application program uses dynamic linking to load the Solver DLL and call various routines within it. Details of the process of compiling, linking and running your application with the Solver DLL are provided in the chapters on the various languages.

Solving Linear and Quadratic Problems

The overall structure of an application program calling the Solver DLL to solve a linear programming problem is as follows:

```
main()
{
/* Get data and set up an LP problem */
...
loadlp(..., matval, ...);       /* Load the problem */
optimize(...);                  /* Solve it         */
solution(...);                  /* Get the solution */
unloadprob(...);                /* Free memory      */
...
}
```

Your program should first call *loadlp()*. This function returns a "handle to a problem." Then you'll call additional routines, passing the problem handle as an argument. Optionally, you may call *loadquad()* to specify a quadratic objective, and/or *loadctype()* to specify integer variables. Then you call *optimize()* (or *mipoptimize()*, if there are integer variables) to solve the problem. To retrieve the solution and sensitivity information, call *solution()*. Finally, call *unloadprob()* to free memory. This cycle may be repeated to solve a series of Solver problems.

When you call *loadlp()*, you pass information such as the number of decision variables and constraints, arrays of (constant) bounds on the variables and the constraints, an array of coefficients of the objective function, and a matrix of coefficients (called *matval* above) of the constraint functions.

Solving Nonlinear Problems

In a linear or quadratic problem, you can describe the objective and constraints with an array or matrix of constant coefficients; the Solver DLL can determine values for the objective and constraints by computing the sums of products of the variables with the supplied coefficients. In a nonlinear problem, however, the problem functions cannot be described this way; the coefficients represent first partial derivatives of the objective and constraints with respect to the variables, and these derivatives change as the values of the variables change.

Hence, you must write a "callback" function (called *funceval()* below) that computes values for the problem functions (objective and constraints) for any given values of the variables. The Solver DLL will call this function repeatedly during the solution process. You supply the address of this callback function as an argument to *loadnlp()*, which defines the overall nonlinear optimization problem. You also supply arrays for the objective and constraint coefficients (*matval*), as you do when you call *loadlp()*, but these arrays need not be initialized to specific values – the Solver DLL will fill them in when it calls your callback function(s). The overall structure of a program calling the Solver DLL to solve a nonlinear programming problem is:

```
funceval(...)
{
/* Receive values for the variables, compute values */
/* for the constraints and the objective function   */
}

main()
{
/* Get data and set up an LP problem */
...
loadnlp(..., funceval, ...);    /* Load the problem */
optimize(...);                  /* Solve it         */
solution(...);                  /* Get the solution */
unloadprob(...);                /* Free memory      */
...
}
```

Your program should first call *loadnlp()*. Like *loadlp()*, this function returns a "handle to a problem." Then you'll call additional routines, passing the problem handle as an argument. Optionally, you may call *loadnltype()* to give the Solver more information about linear and nonlinear functions in your problem, *testnltype()* to have the Solver determine the *loadnltype()* information through a numerical test, or *loadctype()* to specify integer variables – defining an integer nonlinear problem. Then call *optimize()* (or *mipoptimize()*, if there are integer variables) to solve the problem. To retrieve the solution and sensitivity information, call *solution()*. Finally, call *unloadprob()* to free memory. As with *loadlp()*, this cycle may be repeated to solve a series of Solver problems.

Solving Nonsmooth Problems

You define and solve a problem with nonsmooth or discontinuous functions in much the same way as you would for a problem defined by smooth nonlinear functions. In a nonsmooth problem, however, the first partial derivatives of the objective and constraints may not be continuous functions of the variables, and they may even be undefined for some values of the variables. Because of this property, the gradient-based methods used by the nonlinear GRG Solver are not appropriate, and instead the Evolutionary Solver "engine" must be used to solve the problem.

As for smooth nonlinear problems, you write a "callback" function *funceval()* that computes values for the problem functions for any given values of the variables, and you supply the address of this function as an argument to *loadnlp()*. But you cannot use the optional *jacobian()* callback function (described below) to speed up the solution of a nonsmooth problem.

Your program should first call *loadnlp()*, which returns a "handle to a problem." Then you must call *loadnltype()*, supplying this problem handle, to tell the Solver that some or all of your problem functions are nonsmooth or discontinuous. This can be as simple as:

```
loadnltype (lp, NULL, NULL); /* nonsmooth problem */
```

You may optionally call *loadctype()* to specify integer variables – defining an integer nonsmooth problem. Then call *optimize()* (or *mipoptimize()*, if there are integer variables) to solve the problem. To retrieve the solution and sensitivity information, call *solution()*. Finally, call *unloadprob()* to free memory. This cycle may be repeated to solve a series of Solver problems.

Genetic and Evolutionary Algorithms

A non-smooth optimization problem generally cannot be solved to optimality, using any known general-purpose algorithm. But the Evolutionary Solver can often find a "good" solution to such a problem in a reasonable amount of time, using methods based on genetic or evolutionary algorithms. (In a "genetic algorithm," the problem is encoded in a series of bit strings that are manipulated by the algorithm; in an "evolutionary algorithm," the decision variables and problem functions are used directly. Most commercial Solver products are based on evolutionary algorithms.)

An evolutionary algorithm for optimization is different from "classical" optimization methods in several ways. First, it relies in part on random sampling. This makes it a *nondeterministic* method, which may yield different solutions on different runs.

Second, where most classical optimization methods maintain a single best solution found so far, an evolutionary algorithm maintains a *population* of candidate solutions. Only one (or a few, with equivalent objectives) of these is "best," but the other members of the population are "sample points" in other regions of the search space, where a better solution may later be found. The use of a population of solutions helps the evolutionary algorithm avoid becoming "trapped" at a local optimum, when an even better optimum may be found outside the vicinity of the current solution.

Third – inspired by the role of mutation of an organism's DNA in natural evolution – an evolutionary algorithm periodically makes random changes or *mutations* in one or more members of the current population, yielding a new candidate solution (which may be better or worse than existing population members). There are many possible ways to perform a "mutation," and the Evolutionary Solver actually employs three

different mutation strategies. The result of a mutation may be an infeasible solution, and the Evolutionary Solver attempts to "repair" such a solution to make it feasible; this is sometimes, but not always, successful.

Fourth – inspired by the role of sexual reproduction in the evolution of living things – an evolutionary algorithm attempts to combine elements of existing solutions in order to create a new solution, with some of the features of each "parent." The elements (e.g. decision variable values) of existing solutions are combined in a *crossover* operation, inspired by the crossover of DNA strands that occurs in reproduction of biological organisms. As with mutation, there are many possible ways to perform a "crossover" operation – some much better than others – and the Evolutionary Solver uses multiple variations of two different crossover strategies.

Fifth – inspired by the role of natural selection in evolution – an evolutionary algorithm performs a *selection* process in which the "most fit" members of the population survive, and the "least fit" members are eliminated. In a constrained optimization problem, the notion of "fitness" depends partly on whether a solution is feasible (i.e. whether it satisfies all of the constraints), and partly on its objective function value. The selection process is the step that guides the evolutionary algorithm towards ever-better solutions.

A drawback of an evolutionary algorithm is that a solution is "better" only in comparison to other, presently known solutions; such an algorithm *actually has no concept of an "optimal solution,"* or any way to test whether a solution is optimal. (For this reason, evolutionary algorithms are best employed on problems where it is difficult or impossible to test for optimality.) This also means that an evolutionary algorithm has no definite rule for *when to stop*, aside from the length of time, or the number of iterations or candidate solutions, that you wish to allow it to explore. Aside from such limits, the Evolutionary Solver uses two heuristics to determine whether it should stop – one based on the "convergence" of solutions currently in the population, and the other based on the rate of progress recently made by the algorithm. For more information, see the section "Solver Parameters" in the chapter "Solver API Reference."

Problems in Algebraic Notation

As outlined above, problems for the Solver DLL are generally defined by a series of calls made by your application program. In particular, for linear and quadratic problems, you must be careful to supply the correct values for objective and constraint coefficients and constraint and variable bounds to define the problem you want to solve. Problems you define exist only in main memory for the duration of your calls to the Solver DLL – they do not "persist" across runs of your application.

To make it easier to work with linear and quadratic problems, the Solver DLL can read and write text files containing a problem description in a form very similar to standard algebraic notation. An example of such a text file for a simple linear integer problem is shown below:

```
Maximize LP/MIP
  obj: 2.0 x1 + 3.0 x2
Subject To
  c1:  9.0 x1 + 6.0 x2 <= 54.0
  c2:  6.0 x1 + 7.0 x2 <= 42.0
  c3:  5.0 x1 + 10.0 x2 <= 50.0
Bounds
  0.0 <= x1 <= +infinity
  0.0 <= x2 <= +infinity
```

```
Integers
  x1
  x2
End
```

If you define this problem via calls to *loadlp()* and *loadctype()*, you can produce a text file with the contents shown above by calling *lpwrite()* or *lprewrite()*. (This provides a convenient way to verify that the problem you defined programmatically is the problem you intended, by examining the resulting text file.) If you have such a text file containing your problem, you can define it by calling *lpread()*, without setting up all of the array arguments normally required by *loadlp()* and *loadctype()*.

You can use *lpwrite()* and *lpread()* to "persist" the definition of a problem on disk between runs of your application program, without having to write code to store this data in some file format of your own design. You can also use an external program to generate a text file containing a problem definition in the format expected by *lpread()*, then use the Solver DLL to read in the problem and solve it.

Using Other Solver DLL Routines

You can set various parameters and tolerances using the routines *setintparam()* and *setdblparam()*, or get current, default, and minimum and maximum values for the parameters with other routines.

To obtain control during the solution process (in order to display a message, check for a user abort action, etc.), you can set the address of a callback routine through a call to *setlpcallbackfunc()* (for any type of problem) or *setmipcallbackfunc()* (for problems with integer variables). This feature – and the nonlinear Solver, which also requires a callback routine – can be used only in languages, such as C/C++ and 32-bit Visual Basic 5.0 and above, which permit you to define callback procedures and pass procedure names as parameters.

Determining Linearity Automatically

As explained above, the primary difference between solving a nonlinear problem and solving a linear problem is that you must provide a "callback" routine *funceval()* to evaluate the nonlinear problem functions, at trial points (values for the variables) determined by the Solver DLL. However, you do not have to initialize the arrays of coefficients passed to *loadnlp()* with values.

It is possible to use *loadnlp()* and a *funceval()* routine for any Solver problem – even if it is an entirely linear problem – but this will be significantly slower than calling *loadlp()* for a linear problem, which employs the Simplex method.

If you are solving a specific problem or class of problems, you will probably know in advance whether your problem is linear or nonlinear. If you know whether each variable occurs linearly or nonlinearly in the objective and each constraint function, you can supply this information to the Solver through *loadnltype()*. (Such information can be used by advanced nonlinear solution algorithms to save time and/or improve accuracy of the solution.)

If you are solving a general series of problems, however, you might have some nonlinear and some linear problems, all represented by a *funceval()* routine. The *testnltype()* routine lets you ask the Solver to determine, through a numerical test, whether the problem is linear or nonlinear. In addition, *testnltype()* computes the information you would otherwise have to supply through a call to *loadnltype()*, and if

the problem is entirely linear, *testnltype()* computes the LP coefficients and places them in the *matval* array that you supplied when you called *loadnlp()*. You can then switch from the nonlinear Solver to the linear Simplex method by calling *unloadprob()*, and calling *loadlp()* with the same arguments used for *loadnlp()*.

Supplying a Jacobian Matrix

The nonlinear Solver algorithm uses the callback function *funceval()* in two different ways: (i) to compute values for the problem functions at specific trial points as it seeks an optimum, and (ii) to compute estimates of the partial derivatives of the objective (the gradient) and the constraints (the Jacobian). The partial derivatives are estimated by a "rise over run" calculation, in which the value of each variable in turn is perturbed, and the change in the problem function values is observed. For a problem with N variables, the Solver DLL will call *funceval()* N times on each occasion when it needs new estimates of the partial derivatives (2*N times if the "central differencing" option is used). This often accounts for 50% or more of the calls to *funceval()* during the solution process.

To speed up the solution process, and to give the Solver DLL more accurate estimates of the partial derivatives, you can supply a second callback function *jacobian()* which returns values for all elements of the objective gradient and constraint Jacobian matrix in one call. The callback function is optional – you can supply NULL instead of a function address – but if it is present, the Solver DLL will call it instead of making repeated calls to *funceval()* to evaluate partial derivatives.

Writing a *jacobian()* function can be difficult – it is easy to make errors in computing the various partial derivatives. To aid in debugging, the Solver DLL has the ability to call your *jacobian()* function *and* compute its own estimates of the partial derivatives by calling *funceval()*. It will compare the results and display error messages for mismatching partial derivatives. To use this feature, set the PARAM_DERIV parameter value to 3 (see the chapter "Solver API Reference").

The Evolutionary Solver "engine," which is used if any of your problem functions are nonsmooth or discontinuous (as indicated by *loadnltype()*), does not make use of the *jacobian()* function, even if you supply it as an argument to *loadnlp()*.

Diagnosing Infeasible Problems

When a call to *optimize()* finds no feasible solution to your optimization problem, the Solver DLL returns a status value indicating this result when you call *solution()*. This means that there is no combination of values for the variables that will satisfy all of the constraints (and bounds on the variables) at the same time. If your model correctly describes the real-world problem, it may be that no solution is possible unless you can find a way to relax some of the constraints. But more often, this result means that you made a mistake in specifying some constraint(s), such as indicating 'G' (for >=) when you meant to use 'L' (for <=).

If you have many constraints, it can be difficult to determine which of them contains a mistake, or conflicts with some other (combination of) constraints. To aid you, the Solver DLL includes a facility to find a subset of your constraints such that your problem, with just those constraints, is still infeasible, but if any one constraint is dropped from the subset, the problem becomes feasible. Such a subset of constraints is called an Irreducibly Infeasible Set (IIS) of constraints.

(Note: If a call to *mipoptimize()* finds no feasible solution, your first step in diagnosing the problem should be to try to solve the "relaxation" of the MIP problem, ignoring the integer restrictions on the variables. You can do this by calling *setintparam*(lp, PARAM_RELAX, 1) before you call *mipoptimize()* again. If the relaxation of the original problem is still infeasible, you can use the API calls described in this section to isolate the infeasibility.)

To find an Irreducibly Infeasible Set of constraints, call the routine *findiis()*. This routine returns the number of rows (constraints) and the number of columns (variable bounds) contained in the IIS; these numbers should always be less than or equal to the total number of constraints and bounds in your problem. In many cases, there will be only a few constraints in the IIS, and by inspecting your code which sets up these constraints, you can often quickly identify the source of the infeasibility.

To obtain the IIS itself, call the routine *getiis()*. This routine returns the indices of the constraints and the indices of the variable bounds that are included in the IIS. If you have both lower and upper bounds on the same variable(s), *getiis()* tells you which bound is contributing to the infeasibility.

If your problem is a linear or quadratic programming problem (i.e. if you are calling *loadlp()*), there is an even more convenient way to obtain the IIS: Call the routine *iiswrite()*. This routine calls *findiis()* for you (if it has not already been called) and then writes out a text file, in the same "algebraic" format used by *lpwrite()*, but containing only the constraints and bounds that are included in the IIS. When you use *iiswrite()*, you don't have to write any code to analyze or display the information returned by *getiis()*.

In general, when a model is infeasible, there can be more than one subset of constraints (possibly many subsets) that qualify as an IIS. Some of these will contain fewer constraints than others, making them easier to analyze. However, finding the "minimal-size" IIS can be computationally very expensive; hence, the IIS finder is designed to find an IIS that contains as few constraints (rows) as possible in a reasonable amount of time. Since variable bounds are easier to analyze than full constraints, the IIS finder favors fewer rows over fewer bounds.

Solution Properties of Quadratic Problems

A quadratic programming (QP) problem is one in which the objective is a quadratic function, and the constraints are all linear functions of the variables. A general quadratic function may be written as the sum of a quadratic term $x^T Q x$ and a linear term $c x$:

$$F(x) = x^T Q x + c x$$

The matrix Q is the Hessian (matrix of second partial derivatives) of the objective function. Because the function is quadratic or second degree, all elements of this matrix are constant. You supply the elements of the Q matrix when you call the *loadquad()* function, and the elements of the *c* vector when you call the *loadlp()* function (via the *obj* argument).

Depending on the properties of the Q matrix, a quadratic function may have one, many, or no optimal (minimum or maximum) values. If the Q matrix is *positive definite* (for a minimization problem; *negative definite* for a maximization problem), the function will have a "bowl" shape and a single optimal solution (a *strong minimum*). If the Q matrix is *positive semi-definite*, the function will have a "trough" and (infinitely) many optimal solutions, all with the same objective function value (a *weak minimum*). If the Q matrix is *indefinite*, the function will have a "saddle point"

(which has many, but not all, of the properties of an optimal solution), however the true optimal solution(s) – one or many of them – will lie somewhere on the boundaries of the constraints.

Quadratic programming algorithms are specialized (for speed and accuracy) to solve problems where the Q matrix is positive definite (when minimizing) or negative definite (maximizing). The QP algorithm used in the Solver DLL is somewhat more general: It can handle problems where the Q matrix is positive semi-definite (or negative semi-definite), in which case it will converge to a point in the "trough" with the correct minimum (maximum) objective function value. If applied to a problem where the Q matrix is *indefinite*, however, the Solver DLL may converge either to a saddle point, or to (one of) the optimal solution(s) on the constraint boundary – depending on the initial values of the variables. In this case a call to the *solution()* function will return a status code of PSTAT_FRAC_CHANGE to indicate that the solution is not necessarily optimal.

The *loadquad()* function tests the Q matrix you supply to determine whether it is positive (negative) definite, semi-definite or indefinite. If it is indefinite, *loadquad()* will return a nonzero value, and if you have set the PARAM_ARGCK parameter to warn about errors in the arguments, it will display an error message dialog.

Most problems based on real-world data yield a Q matrix which is positive definite. For example, if you are solving a portfolio optimization problem where the Q matrix represents variances and covariances of pairs of securities calculated from a historical price series, it can be shown that the matrix will be positive definite if the number of observations in the price series is greater than the number of variables.

If, however, you are solving problems based on arbitrary user-provided data, you should take care to test the return value of the *loadquad()* function and the status value returned by the *solution()* function. If the Q matrix is indefinite, you may wish to use the nonlinear Solver "engine" instead of the quadratic Solver "engine" – but you must bear in mind that either solution algorithm will find only a local optimum which is not necessarily the global optimum.

The *loadquad()* function also accepts a *var* argument which provides initial values for the variables. If the problem is positive (negative) semi-definite or indefinite, these initial values will influence the path taken by the solution algorithm and the final solution to which it converges. If you must solve problems of this type, you can use the *var* argument to exercise some control over the solutions returned by the Solver DLL.

Passing Dense and Sparse Array Arguments

In most large optimization problems, the constraint coefficient matrix (the Jacobian) (and – in some quadratic problems – the Q matrix) are *sparse* – meaning that most of the matrix elements are zero. For example, in many larger problems there are groups of constraints that are functions of a small subset of the variables, but that do not depend on any of the other variables – leading to many zero coefficients in the constraint matrix.

When these matrices are sparse, it is more efficient to store – and to process – only the nonzero matrix elements. A common way of doing this is to have auxiliary arrays that supply the row and column indices of the nonzero elements. This means that no storage at all is needed for the zero elements, which can include 90% to 95% of all elements in large, sparse problems.

For further memory savings, the nonzero elements can be ordered by column (i.e. by variable), so that the column index need be stored only once for a set of consecutive nonzero elements. (Alternatively, they could be ordered by row, i.e. by constraint; but the Solver DLL uses the "column-wise" method of storage.)

In the *loadlp()*, *loadquad()* and *loadnlp()* functions, the Solver DLL allows you to pass the constraint matrix (and the Q matrix, if used), in either *dense* or *sparse* form. In *dense* form, you supply a "full-size" array of *numcols* * *numrows* elements (*numcols*^{2} elements in the case of the Q matrix), which may include both zero and nonzero elements; you need not supply any auxiliary information. In *sparse* form, you supply a smaller array containing only the nonzero elements, plus auxiliary arrays which provide the row and column indices.

In the *loadlp()* function (*loadquad()* and *loadnlp()* are similar), you pass the constraint matrix via the arguments *matbeg*, *matcnt*, *matind* and *matval*. To pass the matrix elements in *dense* form, you supply NULL values for *matbeg*, *matcnt* and *matind*, and you supply a "full-size" array of *numcols* * *numrows* elements for *matval*. Note that *matval* must be a single-dimensioned array where the elements are stored so that the row (constraint) index is varied most rapidly. To pass the matrix elements in *sparse* form, you supply arrays for all four of *matbeg*, *matcnt*, *matind* and *matval*. The *matbeg* array contains column (variable) indices; the *matcnt* array contains counts of elements in a column; the *matind* array contains row (constraint) indices; and the *matval* array contains the nonzero elements. All column and row indices are 0-based.

As an example, consider the following sparse matrix:

$$\begin{vmatrix} 1.2 & 0.0 & 3.4 \\ 0.0 & 5.6 & 0.0 \\ 7.8 & 0.0 & 0.0 \\ 0.0 & 9.0 & 0.0 \end{vmatrix}$$

Here, *numcols* = 3 and *numrows* = 4; there are *nzspace* = 5 nonzero elements. To pass this matrix in sparse form, you'd supply *matbeg* and *matcnt* arrays (of *numcols* elements) and *matind* and *matval* arrays (of *nzspace* elements), as follows:

matbeg[0] = 0	matcnt[0] = 2
matbeg[1] = 2	matcnt[1] = 2
matbeg[2] = 4	matcnt[2] = 1

matind[0] = 0	matval[0] = 1.2
matind[1] = 2	matval[1] = 7.8
matind[2] = 1	matval[2] = 5.6
matind[3] = 3	matval[3] = 9.0
matind[4] = 0	matval[4] = 3.4

The array element *matbeg[j]* contains offsets from the beginning of the *matind* and *matval* arrays where the nonzero coefficients of variable *j* will be found. The corresponding element *matcnt[j]* contains a count of consecutive elements of *matind* and *matval* which pertain to the same variable (i.e. are in the same column of the matrix). Note that *matbeg[j+1] = matbeg[j] + matcnt[j]* – the Solver DLL checks the arrays you supply to ensure that this is true. For *k = matbeg[j] to matbeg[j+1] - 1*, there is a nonzero coefficient *M[i,j]* at column *j* and row *i = matind[k]*, with value *matval[k]*.

Arrays and Callback Functions in Visual Basic

The Solver DLL uses the calling conventions standardized for the Windows API routines, which use argument data types drawn from C/C++. In particular, array arguments are passed as pointers to the base of the block of memory containing the array values.

In Visual Basic, however, arrays declared in the language are created using the COM Automation conventions for SAFEARRAYs. A SAFEARRAY consists of a block of memory called an array descriptor, which contains information about array element sizes, dimensions and bounds, and a pointer to the memory holding the array values.

Visual Basic programs that call Windows API routines usually handle array arguments by declaring the argument as `ByRef` and passing the first element of the array (rather than the "whole" array) as the argument. For example, `obj(0)` passed by reference is a pointer to the first array element, i.e. the base address of the block of memory holding the array values; the SAFEARRAY descriptor is stored elsewhere in memory by Visual Basic and is not "seen" by the Solver DLL. The Solver DLL is able to access additional array elements beyond the first element by indexing into the block of memory holding the array data.

This approach does not work in reverse, however: When Visual Basic is used to write a callback function such as *funceval()* or *jacobian()*, where the Solver DLL makes the call and passes blocks of memory for C-style arrays as arguments, the Visual Basic code can reference only the first array element. Subscripting in Visual Basic is permitted only if the argument is actually declared as an array (e.g. `obj()`), and in this case Visual Basic expects to receive a SAFEARRAY as the argument. (This argument must be a pointer to a pointer to the SAFEARRAY descriptor.)

To permit callback functions to be written in Visual Basic, the Solver DLL provides an option to treat *all* arrays as SAFEARRAYs rather than C-style arrays. To use this option, call *setintparam()* as shown below, *before* calling *loadlp()*, *loadnlp()* or any of the other problem setup routines:

```
ret = setintparam( NULL, PARAM_ARRAY, 1 )
```

When this parameter is set to 1, *all* arrays passed to the Solver DLL must be SAFEARRAYs. In Visual Basic, this means that the array arguments must be declared as (for example):

```
ByRef obj() As Double
```

rather than

```
ByRef obj As Double
```

and the *array name* (e.g. `obj`), instead of the *first array element* (e.g. `obj(0)`) must be passed as the actual argument. In your callback routines, you can then use subscripting to refer to elements of the arrays passed to you as arguments.

The Visual Basic header file `frontmip.bas` contains declarations of the Solver DLL routines that define the arguments as C-style arrays. The header file `safrontmip.bas` contains declarations of the routines that define the arguments as SAFEARRAYs. If you are using Visual Basic for a new Solver DLL application, you will probably want to use `safrontmip.bas` as your header file (and be sure to call *setintparam*(NULL, PARAM_ARRAY, 1) before calling other Solver DLL routines).

Using the Solver DLL in Multi-Threaded Applications

The Solver DLL is offered in both single-threaded and multi-threaded versions. The single-threaded versions are serially reusable but not reentrant: They can solve multiple problems serially – a call to *loadlp()* or *loadnlp()* must be followed by a call to *unloadprob()* before the next call to *loadlp()* or *loadnlp()* is encountered.

The multi-threaded versions of the Solver DLL are fully reentrant. They can solve multiple problems concurrently: You may call *loadlp()* or *loadnlp()* several times, keeping track of the "problem handles" returned by each call, and freely mix calls to any of the other Solver DLL routines, passing the appropriate problem handle to each call. (You must still call *unloadprob()* for each problem handle when you are finished with it, to release memory.)

The multi-threaded versions may be used to solve decomposition problems (which involve both a "master problem" and a "slave problem"), or any recursive problem where the computation of the objective or constraints for a main problem requires the solution of another optimization subproblem. The multi-threaded versions may also be used in Web server or Intranet applications, where the application calling the Solver DLL consists of several threads of execution executing concurrently, each thread dealing with a specific user session.

Use of the multi-threaded versions is identical to use of the single-threaded versions, except that calls to *loadlp()* or *loadnlp()* that would return an error in the single-threaded versions (because a previous problem had not yet been unloaded) will return a new, valid "problem handle" without an error in the multi-threaded versions. Your application simply needs to keep track of each problem handle, for example by saving it in local variable storage that is unique to each thread of your program.

Use-Based Licensing

The Solver DLL can be licensed for distribution to multiple users with your application, or for use on a server where the application serves multiple users. Licensing for a server-based application is usually based on the number of users (or "seats"). However, if this number is difficult to determine or if it may be very large – as in a Web server application – licensing may be based on the number of uses of the DLL. To support this latter form of licensing, the Solver DLL can track and report the number of calls your application makes to the *loadlp()* / *loadnlp()* routines and/or the *optimize()* / *mipoptimize()* routines.

Use tracking and reporting is under the control of your application. You determine the type of tracking and reporting with a call such as:

```
ret = setintparam( NULL, PARAM_USERP, 1)
```

If the PARAM_USERP parameter is set to 0 (the default setting), the Solver DLL does not track uses – it operates in "Evaluation / Test mode," where it displays a MessageBox on the system console once every ten minutes. If PARAM_USERP is 1, the Solver DLL does track uses; the first time it runs in a new calendar month, it automatically sends a report of cumulative uses to date via email to Frontline Systems. If PARAM_USERP is 2, the Solver DLL tracks uses, but it does not generate any reports automatically – use reports are created only when your application calls the *reportuse()* function, which can either write a text file or send an email message, containing a report of cumulative uses.

Calling the Solver DLL from C/C++

C/C++ Compilers

To use the Solver DLL from C or C++, you must have an appropriate compiler and linker capable of building Windows applications, such as Microsoft Visual C++, Borland C++, Symantec C++ or WATCOM C++. This Guide will give explicit instructions for use with Microsoft Visual C++ 5.x and 6.x (32-bit) and Visual C++ 1.5x (16-bit), but use with other compilers should be similar.

Most C++ compilers for Windows allow you to easily port DOS or UNIX C and C++ applications (which use *printf* or *cout* for "glass teletype" output) to Windows. To simplify the input/output and focus on the Solver DLL routines and arguments, the example applications in this chapter use *printf* calls for output and will be built as "Win32 console applications" in Microsoft Visual C++ (or as "QuickWin" applications in 16-bit Visual C++).

To build a native Windows application in C or C++, you'll have to learn something about the Windows API and/or a C++ class library such as the Microsoft Foundation Classes. A single-threaded and a multi-threaded example application using the Windows API and the Solver DLL's callback functions are presented in the later chapter "Native Windows Applications."

Basic Steps

To create an application that calls the Solver DLL, you must perform the three following steps:

1. Include the header file **frontmip.h** in your C or C++ source program. (You should also include the license file **frontkey.h** to obtain the license key string.)
2. Include the import library file **frontmip.lib** in your project or your linker response file. (Alternatively, you can write code to use "run-time dynamic linking" by calling Windows API routines such as *LoadLibrary()*.)
3. Call at least the routines *loadlp()* or *loadnlp()*, *optimize(), solution()* and *unloadprob()* in that order.

You can use any of the example programs as a guide for getting the arguments right. Vcexamp1.c contains five examples of solving linear, integer and quadratic programming problems, including an example using the infeasibility (IIS) finder, an example of portfolio optimization using the QP Solver, and an example that reads a problem from a text file using the *lpread()* function. Vcexamp2.c contains four examples of solving nonlinear programming problems, including an example using the IIS finder and an example of testing a problem for linearity and switching between the NLP and LP Solvers. It also contains two examples that use the Evolutionary Solver to find the global optimum in a problem with multiple local optima, and to find the optimum in a problem with nonsmooth functions.

Building a 32-Bit C/C++ Program

This section will outline the steps required to compile, link and run the example Solver DLL application VCEXAMP1.EXE, using 32-bit Microsoft Visual C++ 5.x or 6.x under Windows 95/98 or Windows NT/2000. The steps required to compile, link and run VCEXAMP2.EXE are the same, and the steps involved in using other C/C++ compilers will be similar.

First, follow the steps in the "Installation" chapter, which will copy the example programs into the **examples** subdirectory of the **frontmip** directory on your hard disk. If you wish, you can run the pre-built version of VCEXAMP1.EXE by double-clicking on the filename, before you try to compile and link from the source code.

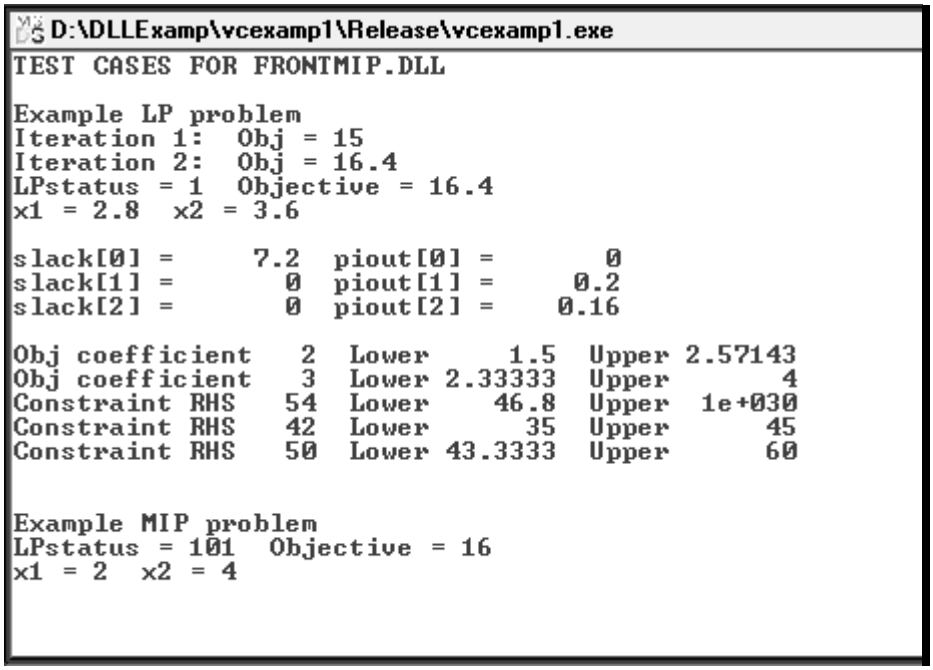
1. **Create a Project.** Start Microsoft Visual Studio. Select File New... and in the Projects tab of the displayed dialog, select Win32 Console Application. Type **vcexamp1** in the Project name edit box, and **c:\frontmip\examples\vcexamp1** (or a path of your choosing) in the Location edit box. Then click OK. In Visual C++ 6.x, click Finish and then OK in the New Project Wizard dialog boxes, to create an empty project.

2. **Add Files.** Select Project | Add to Project | Files... In the dialog, navigate if necessary to the proper directory, select the file **vcexamp1.c**, and click OK.

   Now select Select Project | Add to Project | Files... again. In the dialog, open the Files of type dropdown list and select Library Files (*.lib). Navigate to the Win32 subdirectory that contains the 32-bit version of the import library frontmip.lib. Select **frontmip.lib** and click OK.

   If you now select the FileView pane in the Project Workspace window and open Vcexamp1 Files, the vcexamp1.c and frontmip.lib files should be listed. You can double-click on vcexamp1.c to see the C source code.

3. **Build and Run the Application.** To compile and link vcexamp1.c and produce vcexamp1.exe, select Build Rebuild All. Then use Build Execute vcexamp1.exe to run the program. An output window like the one on the next page should appear. (Press the ENTER key to continue running the program and produce more output.)



Building a 16-Bit C/C++ Program

A 16-bit version of the example Solver DLL application VCEXAMP1.EXE, which runs under Windows 3.x, may be built using Microsoft Visual C++ 1.5x. The steps involved in using other 16-bit C/C++ compilers will be very similar

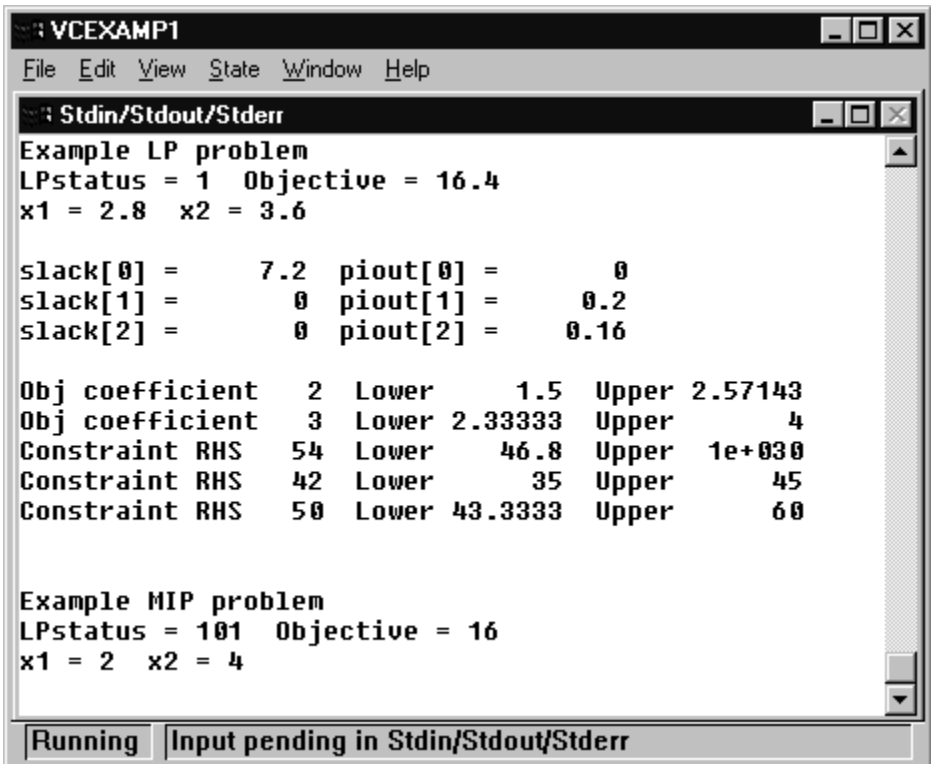
1. **Create a Project.** Start Visual C++ 1.5x. Select Project New... In the New Project dialog, click the Browse... button and navigate to the vcexamp1 subdirectory (this is **c:\frontmip\examples\vcexamp1** in the default directory structure). In the File name edit box, type **vcexamp1.mak**, then click OK. Again in the New Project dialog, select QuickWin Application (.EXE) in the Project Type dropdown list, ensure that "Use Microsoft Foundation Classes" is *not* checked, and click OK.

2. **Add Files.** The Project Edit dialog is immediately displayed. Navigate if necessary to the proper directory, select the file **vcexamp1.c**, and click on Add. In Visual C++ 1.5x, the Project Edit dialog remains open at this point.

   Open the List Files of Type dropdown list and select Library (*.lib). Navigate to the directory containing the 16-bit version of the import library frontmip.lib (in the default directory structure, move two levels up and then down to Win16). Select **frontmip.lib** and click on Add. Then click on Close.

   If you want to examine the C source code, select File Open, navigate to the appropriate directory if necessary, select vcexamp1.c and click OK.

3. **Build and Run the Application.** To compile and link vcexamp1.c and produce vcexamp1.exe, select Project Rebuild All VCEXAMP1.EXE. Then select Project Execute VCEXAMP1.EXE to run the program. This QuickWin application displays a window like the one shown on the next page. (Press the ENTER key to continue running the program and produce more output.)



The first few lines of output have scrolled beyond the top of this window. You should also note that the C source code in vcexamp1.c uses a callback function to display the LP iterations *only in the Win32 version* of this example. In Windows 3.x, you must set up callback function addresses with the *MakeProcInstance* API call. This call requires an instance handle argument that is not readily available in a QuickWin program. For an example of the use of callback functions in both Win32 and Win16 programs, see the chapter "Native Windows Applications."

C/C++ Source Code: Linear / Quadratic Problems

The source code file vcexamp1.c is listed below. Note that it includes five example problems for the Solver DLL, which are set up and solved in turn. The first example is a simple two-variable LP problem. The second example – for which source code in Visual Basic, Delphi Pascal and FORTRAN is also included – is a MIP problem, identical to the previous LP problem except that the decision variables are required to have integer values. The third example attempts to solve an LP problem that is infeasible, then it uses the IIS finder to diagnose the infeasibility. The fourth example is a quadratic programming problem, using the classic Markowitz method to find an efficient portfolio of five securities. The fifth example uses the *lpread()* function to read in a problem in "algebraic notation" from a text file that was created by the *lpwrite()* function in the second example.

You are encouraged to study this source code (or the Visual Basic source code) and the /* comments */ in each problem, even if you plan to use a language other than C/C++ for most of your work. The C/C++ and Visual Basic example code is more extensive than the examples for the other languages, and illustrates most of the features of the Solver DLL including the Quadratic Solver, the Evolutionary Solver, automatic diagnosis of infeasible problems, and use of the *lpread()* and *lpwrite()* functions.

```
/* ********************************************************************
   Frontline Systems Small-Scale Solver Dynamic Link Library Version 3.5
   Frontline Systems Inc., P.O. Box 4288, Incline Village, NV 89450 USA
   Tel (775) 831-0300 ** Fax (775) 831-0314 ** Email info@frontsys.com

   Example LP, MIP and QP problems in C/C++: Build as Win32 console app
   or Win16 QuickWin project containing files VCEXAMP1.C and FRONTMIP.LIB
   ******************************************************************** */

#include "frontmip.h"
#include "frontkey.h"
#include <stdio.h>


/*
   Example 1: Solves the LP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= 50
   x1, x2 non-negative
   LP solution: x1 = 2.8, x2 = 3.6
   Objective = 16.4

   This example shows the simple form of passing arguments to loadlp():
   A dense (full-size N by M) matrix is passed as the matval argument
   and NULL pointers are passed as the matbeg, matcnt & matind arguments.

   This example also shows how to obtain LP sensitivity analysis info
   by calling the objsa() and rhssa() functions.  These calls are valid
   only for LP problems.  For QP problems, only dual values (the piout
   and dj arguments of solution()) are available; for MIP problems, no
   sensitivity analysis info is available (none would be meaningful).

   This example uses a callback function to display the LP iterations.
*/

/* The following function is called on each LP iteration in example1 */

long _CC lpcallback (HPROBLEM lpinfo, long wherefrom)
{
   long iters; double obj;
   getcallbackinfo (lpinfo, wherefrom, CBINFO_ITCOUNT, (void*)&iters);
   getcallbackinfo (lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, (void*)&obj);
   printf("Iteration %ld:  Obj = %g\n", iters, obj);
   return PSTAT_CONTINUE;
}

void example1(void)
{
   double obj[] = { 2.0, 3.0 };
   double rhs[] = { 54.0, 42.0, 50.0 };
   char sense[] = "LLL";  /* L's for <=, E's for =, G's for >= */
   double matval[] = { 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 };
   double lb[] = { 0.0, 0.0 };
   double ub[] = { INFBOUND, INFBOUND };
   long stat, i;
   double objval;
   double x[2], piout[3], slack[3], dj[2];
   double varlow[2], varupp[2], conlow[3], conupp[3];
   HPROBLEM lp = NULL;
   printf("\nExample LP problem\n");


   /* set up the LP problem */
```

```
   lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
      NULL, NULL, NULL, matval, lb, ub, NULL, 2, 3, 6);
   if (!lp) return;

#ifdef WIN32
   setlpcallbackfunc (lp, lpcallback); /* set up the callback */
#endif

   /* solve the problem */
   optimize (lp);

   /* obtain the solution: display objective and variables */
   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("LPstatus = %ld  Objective = %g\n", stat, objval);

   /* display constraint slacks and dual values */
   printf("x1 = %g  x2 = %g\n\n", x[0], x[1]);
   for (i = 0; i <= 2; i++)
      printf("slack[%ld] = %7g  piout[%ld] = %7g\n",
      i, slack[i], i, piout[i]);
   printf("\n");

   /* obtain and display sensitivity analysis information */
   objsa (lp, 0, 1, varlow, varupp);
   for (i = 0; i <= 1; i++)
      printf("Obj coefficient %3.0f  Lower %7g  Upper %7g\n",
         obj[i], varlow[i], varupp[i]);
   rhssa (lp, 0, 2, conlow, conupp);
   for (i = 0; i <= 2; i++)
      printf("Constraint RHS  %3.0f  Lower %7g  Upper %7g\n",
         rhs[i], conlow[i], conupp[i]);
   printf("\n");

#ifdef WIN32
   setlpcallbackfunc (lp, NULL); /* remove the callback function */
#endif

   /* important - call unloadprob() to release memory */
   unloadprob (&lp);
}

/*
   Example 2: Solves the MIP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= 50
   x1, x2 non-negative, integer
   MIP solution: x1 = 2, x2 = 4
   Objective = 16.0

   This example illustrates the full set of arguments, used to pass a
   potentially sparse matrix to loadlp.  For each variable (column) i,
   matbeg[i] and matcnt[i] are the beginning index and count of non-
   zero coefficients in the matind and matval arrays.  For each such
   coefficient, matind[k] is the constraint (row) index and matval[i]
   is the coefficient value.  See the documentation for more details.

   In this example, we also use two debugging features of the Solver
   DLL:  (1) We call setintparam() to enable the display of error
   MessageBoxes by the DLL routines if they detect an invalid value
   in one of the arguments we pass (since there are no errors, none
   will appear).  (2) We call lpwrite() to write out a file which
   summarizes the LP/MIP problem in algebraic form.  This can help
   us verify that the arguments we pass have defined the right problem.
*/
```

```
void example2(void)
{
   double obj[] = { 2.0, 3.0 };
   double rhs[] = { 54.0, 42.0, 50.0 };
   char sense[] = "LLL";
   long matbeg[] = { 0, 3 };
   long matcnt[] = { 3, 3 };
   long matind[] =   {   0,   1,   2,   0,   1,    2 };
   double matval[] = { 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 };
   double lb[] = { 0.0, 0.0 };
   double ub[] = { INFBOUND, INFBOUND };
   char ctype[] = "II";
   long stat;
   double objval;
   double x[2];
   HPROBLEM lp = NULL;

   printf("\nExample MIP problem\n");

   /* enable display of error MessageBoxes on argument
      errors (since the arguments are correct, none will
      appear).  Note - on argument errors, loadlp returns
      a NULL pointer and all other routines return a non-
      zero value; you can and should check for this!  But
      the MessageBoxes can help you identify errors early. */
   setintparam (lp, PARAM_ARGCK, 1);

   /* set up the LP portion of the problem */
   lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
      matbeg, matcnt, matind, matval, lb, ub, NULL, 2, 3, 6);
   if (!lp) return;

   /* now define integer variables:  for each variable i,
      ctype[i] is 'C' for continuous, 'I' for general
      integer and 'B' for a binary integer variable */
   loadctype (lp, ctype);

   /* lpwrite() can be called anytime after the problem
      is defined, and before unloadprob() is called.  It
      will write out the following text in file vcexamp1:
      Maximize LP/MIP
      obj: 2.0 x1 + 3.0 x2
      Subject To
        c1:  9.0 x1 + 6.0 x2 <= 54.0
        c2:  6.0 x1 + 7.0 x2 <= 42.0
        c3:  5.0 x1 + 10.0 x2 <= 50.0
      Bounds
        0.0 <= x1 <= +infinity
        0.0 <= x2 <= +infinity
      Integers
        x1
        x2
      End
   */
   lpwrite( lp, "vcexamp1");

   /* solve the problem; obtain and display the solution */
   mipoptimize (lp);
   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("LPstatus = %ld  Objective = %g\n", stat, objval);
   printf("x1 = %g  x2 = %g\n", x[0], x[1]);

   /* don't forget to free memory */
   unloadprob (&lp);
}

/*
```

```
   Example 3: Attempt to solve the LP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= -50
   x1, x2 non-negative
   Infeasible (due to non-negative variables and negative RHS)

   When solution() returns stat = PSTAT_INFEASIBLE, ask Solver DLL
   to find an Irreducibly Infeasible Subset (IIS) of the constraints:
   Row 2 (with the negative RHS) and lower bounds on both variables

   The constraint matrix is passed in simple (dense) form in matval[].
*/

void example3(void)
{
   double obj[] = { 2.0, 3.0 };
   double rhs[] = { 54.0, 42.0, -50.0 };
   char sense[] = "LLL";
   double matval[] = { 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 };
   double lb[] = { 0.0, 0.0 };
   double ub[] = { INFBOUND, INFBOUND };
   long stat, i, iisrows, iiscols;
   long rowind[3], rowbdstat[3], colind[2], colbdstat[2];
   double objval;
   double x[2];
   HPROBLEM lp = NULL;

   printf("\nExample IIS diagnosis of infeasible problem\n");
   setintparam (lp, PARAM_ARGCK, 1);

   /* set up the LP problem */
   lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
      NULL, NULL, NULL, matval, lb, ub, NULL, 2, 3, 6);
   if (!lp) return;

   /* attempt solve the problem */
   optimize (lp);

   /* check the status of the solution */
   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("LPstatus = %ld  Objective = %g\n", stat, objval);

   /* if infeasible, find and display an Irreducibly
      Infeasible Subset (IIS) of the constraints */
   if (stat == PSTAT_INFEASIBLE)
   {
      findiis (lp, &iisrows, &iiscols);
      printf("\nfindiis: iisrows = %ld  iiscols = %ld\n",
         iisrows, iiscols);
      getiis (lp, &stat, rowind, rowbdstat, &iisrows,
         colind, colbdstat, &iiscols);
      for (i = 0; i < iisrows; i++)
         printf("rowind[%ld] = %ld  rowbdstat[%ld] = %ld\n",
            i, rowind[i], i, rowbdstat[i]);
      for (i = 0; i < iiscols; i++)
         printf("colind[%ld] = %ld  colbdstat[%ld] = %ld\n",
            i, colind[i], i, colbdstat[i]);
      iiswrite (lp, "iisexamp.txt");
   }
   printf("\n");

   /* don't forget to free memory */
   unloadprob (&lp);
}
```

```
/*
   Example 4: Use the QP solver to perform
   Markowitz-style portfolio optimization.
   Variables are the percentages to be allocated
   to each investment or asset class:
      0 <= x1, x2, x3, x4 x5 <= 1
   Minimize portfolio variance: [xi] Q [xi]
   Subj to allocations: Sum (xi) = 1
      and portfolio return: Sum (Ri xi) >= 0.085

   The efficient portfolio is the QP solution (approx):
      x1 = 0.462  x2 = 0  x3 = 0.313  x4 = 0  x5 = 0.225
   The objective = approx. 0.00014 (minimum variance)

   Both the constraint matrix and the Q matrix are passed
   using the full set of arguments for sparse matrices.
*/

void example4(void)
{
   double obj[] = { 0.0, 0.0, 0.0, 0.0, 0.0 };
   double rhs[] = { 1.0, 0.085 };
   char sense[] = "EG";
   long matbeg[] = { 0, 2, 4, 6, 8 };
   long matcnt[] = { 2, 2, 2, 2, 2 };
   long matind[] = { 0, 1, 0, 1, 0, 1, 0, 1, 0, 1 };
   double matval[] = { 1.0, 0.086, 1.0, 0.071, 1.0, 0.095,
                       1.0, 0.107, 1.0, 0.069 };
   double lb[] = { 0.0, 0.0, 0.0, 0.0, 0.0 };
   double ub[] = { 1.0, 1.0, 1.0, 1.0, 1.0 };
   long qmatbeg[] = {  0,  5, 10, 15, 20 };
   long qmatcnt[] = {  5,  5,  5,  5,  5 };
   long qmatind[] = { 0, 1, 2, 3, 4, 0, 1, 2, 3, 4, 0, 1, 2, 3, 4,
                      0, 1, 2, 3, 4, 0, 1, 2, 3, 4 };
   /* The Q matrix specifies the covariance between each pair of assets */
   double qmatval[] =
      { 0.000204,  0.000424,  0.000170,  0.000448, -0.000014,
        0.000424,  0.012329,  0.001785,  0.001633, -0.000539,
        0.000170,  0.001785,  0.000365,  0.000425, -0.000075,
        0.000448,  0.001633,  0.000425,  0.005141,  0.000237,
       -0.000014, -0.000539, -0.000075,  0.000237,  0.000509 };
   long stat;
   double objval;
   double x[5];
   HPROBLEM lp = NULL;

   printf("\nExample QP problem (Portfolio Optimization)\n");

   /* set up the LP portion of the problem.  The LP portion
      of the objective is all 0's here; it could be elaborated
      to include transaction costs or other factors. */
   lp = loadlp (PROBNAME, 5, 2, 1, obj, rhs, sense,
      matbeg, matcnt, matind, matval, lb, ub, NULL, 5, 2, 7);
   if (!lp) return;

   /* now set up the Q matrix to define the quadratic objective
      (test whether this DLL supports loadquad(), if not return) */
   if (loadquad (lp, qmatbeg, qmatcnt, qmatind, qmatval, 25, x))
      return;

   /* solve the problem; obtain and display the solution */
   optimize (lp);
   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("LPstatus = %ld  Objective = %7.5f\n", stat, objval);
   printf("x1 = %5.3f x2 = %5.3f x3 = %5.3f x4 = %5.3f x5 = %5.3f\n\n",
      x[0], x[1], x[2], x[3], x[4]);
```

```
   /* once more: don't forget to free memory */
   unloadprob (&lp);
}

/* Example 5: Use the lpread() function to read a
   problem definition from a disk file and solve it.
   We read the file written by example2():

      Maximize LP/MIP
      obj: 2.0 x1 + 3.0 x2
      Subject To
        c1:  9.0 x1 + 6.0 x2 <= 54.0
        c2:  6.0 x1 + 7.0 x2 <= 42.0
        c3:  5.0 x1 + 10.0 x2 <= 50.0
      Bounds
        0.0 <= x1 <= +infinity
        0.0 <= x2 <= +infinity
      Integers
        x1
        x2
      End

   As in Example 2, the MIP solution is:
   x1 = 2, x2 = 4
   Objective = 16.0
*/

void example5(void)
{
   double obj[2];
   double rhs[3];
   char sense[3] = "EEE";
   long matbeg[2];
   long matcnt[2];
   long matind[6];
   double matval[6];
   double lb[2];
   double ub[2];
   char ctype[2] = "CC";
   long stat, nzspace, i;
   double objval;
   double x[2];
   long objsen, numcols, numrows, numints;
   HPROBLEM lp = NULL;

   setintparam (lp, PARAM_ARGCK, 1);

   /* First, we assume that the dimensions of the problem
      are known.  We call loadlp(), passing array arguments
      of the proper dimension.  Since the sense[] and ctype[]
      arrays are checked for validity, we initialize them. */

   printf("\nExample: Read in MIP problem of known size\n");

   lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
      NULL, NULL, NULL, matval, lb, ub, NULL, 2, 3, 6);
   if (!lp) return;
   loadctype( lp, ctype);

   /* call lpread() to read in the actual array values */

   lpread( lp, "vcexamp1", NULL, NULL, NULL, NULL, NULL, NULL);

   /* call mipoptimize() and display the solution */

   mipoptimize (lp);
   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
```

```
   printf("LPstatus = %ld  Objective = %g\n", stat, objval);
   printf("x1 = %g  x2 = %g\n", x[0], x[1]);
   unloadprob (&lp);

   /* Next, we assume that the dimensions of the problem are
      not known in advance.  We can call lpread() with a NULL
      first argument to read the file and obtain the actual
      problem dimensions.  Then, we would allocate arrays of
      appropriate size (to keep this example simple, we'll
      re-use the arrays from the first example above).  We call
      loadlp() to define a problem and return a pointer to it.
      Next, we call lpread() again to read in the actual array
      values.  Then we'll be ready to call mipoptimize(). */

   printf("\nExample: Read in MIP problem of unknown size\n");

   /* Call lpread() to obtain the problem dimensions.  If
      the matcnt argument is passed (needed only for sparse
      problems), it must have at least as many elements as the
      number of variables in the largest problem to be handled.
      (If necessary, you can call lpread() twice, the first
      time to get this size via the numcols argument.) */

   lpread( NULL, "vcexamp1", &objsen, &numcols, &numrows, &numints,
      matcnt, NULL);

   /* We would now allocate the x[], obj[], lb[], ub[], and
      (if used) ctype[] and matbeg[] arrays to have numcols
      elements, and the rhs[] and sense[] arrays to have
      numrows elements.  For a dense problem, matval[] should
      be allocated to have numcols * numrows elements.  For a
      sparse problem, the matind[] and matval[] arrays should
      be allocated to have nzspace elements, where nzspace is
      the sum of the counts in matcnt[] as returned by lpread().
      (To keep this example simple, we'll re-use the arrays
      from the first example above). */

   for (nzspace = i = 0; i < numcols; i++) nzspace += matcnt[i];
   /* (we could now allocate matind[] and matval[] based on nzspace) */
   for (i = 0; i < nzspace; i++) matval[i] = matind[i] = 0;
   /* matval[] and matind[] will be filled in by our next call to
      lpread(); we need only initialize matbeg[] based on matcnt[] */
   for (i = 0; i < numcols; i++)
      matbeg[i] = (i == 0 ? 0 : matbeg[i-1] + matcnt[i-1]);

   /* Next, call loadlp() and loadctype() to define the problem
      and pass in arrays of appropriate dimension. */

   lp = loadlp (PROBNAME, numcols, numrows, objsen, obj, rhs, sense,
      matbeg, matcnt, matind, matval, lb, ub, NULL,
      numcols, numrows, nzspace);
   if (!lp) return;
   loadctype( lp, ctype);

   /* Now we call lpread() to read in the actual array values. */

   lpread( lp, "vcexamp1", NULL, NULL, NULL, NULL, NULL, NULL);

   /* Finally, we call mipoptimize() and display the solution. */

   mipoptimize (lp);
   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("LPstatus = %ld  Objective = %g\n", stat, objval);
   printf("x1 = %g  x2 = %g\n", x[0], x[1]);
   unloadprob (&lp);
}
```

```
int main(void)
{
   char buf[32];
   printf("TEST CASES FOR FRONTMIP.DLL\n");
   example1();
   example2();
   gets(buf);
   example3();
   example4();
   gets(buf);
   example5();
   return 0;
}
```

C/C++ Source Code: Nonlinear / Nonsmooth Problems

The source code file vcexamp2.c is listed below. It includes four example problems using the nonlinear GRG Solver, which are set up and solved in turn. The first example is a simple two-variable nonlinear optimization problem, which defines a *funceval()* routine to evaluate the problem functions. The second example is identical to the first one, except that a *jacobian()* routine is also defined, to give the Solver faster and more accurate partial derivatives of the problem functions. The third example attempts to solve a nonlinear problem that is infeasible, then it uses the IIS finder to diagnose the infeasibility. The fourth example illustrates how you can solve a series of linear and nonlinear problems, using the *testnltype()* function to determine whether the problem defined by your *funceval()* routine is linear, and how you can switch to the LP Solver engine if *testnltype()* finds that a problem is entirely linear.

Also included in vcexamp2.c are two example problems using the Evolutionary Solver. The first of these finds the global optimum of a classic two-variable problem, the Branin function, which has three local optima. The second one finds the optimal solution of a three-variable problem where the objective function involves an "IF statement," which is nonsmooth (in fact discontinuous) in the variable X.

You are encouraged to study this source code (or the Visual Basic source code) and the /* comments */ in each problem, even if you plan to use a language other than C/C++ for most of your work. Like the example source code for linear and quadratic problems, this example file is more extensive than the ones for the other languages.

```
/* ********************************************************************
   Frontline Systems Small-Scale Solver Dynamic Link Library Version 3.5
   Frontline Systems Inc., P.O. Box 4288, Incline Village, NV 89450 USA
   Tel (775) 831-0300 ** Fax (775) 831-0314 ** Email info@frontsys.com

   Example NLP and NSP problems in C/C++: Build as Win32 console app or
   Win16 QuickWin project containing files VCEXAMP2.C and FRONTMIP.LIB
   ******************************************************************** */

#include "frontmip.h"
#include "frontkey.h"
#include <stdio.h>
#include <math.h>

/* Example routine to check the capabilities and problem size limits of
   the Solver DLL we are using.  A return value of 0 for the number of
   variables or constraints means that the corresponding Solver engine
```

```
   is not included. */

void getlimits(void)
{
   long cols, rows, ints;

   getproblimits (NULL, PROB_LP, &cols, &rows, &ints);
   printf("LP limits: %ld variables, %ld constraints, %ld integers\n",
      cols, rows, ints);

   getproblimits (NULL, PROB_QP, &cols, &rows, &ints);
   printf("QP limits: %ld variables, %ld constraints, %ld integers\n",
      cols, rows, ints);

   getproblimits (NULL, PROB_NLP, &cols, &rows, &ints);
   printf("NLP limits: %ld variables, %ld constraints, %ld integers\n",
      cols, rows, ints);

   getproblimits (NULL, PROB_NSP, &cols, &rows, &ints);
   printf("NSP limits: %ld variables, %ld constraints, %ld integers\n",
      cols, rows, ints);
}


/*
   Example C program calling the nonlinear Solver DLL.
   Solves the problem:

   Minimize X^2 + Y^2
   Subject to:
      X + Y  = 1
      X * Y >= 0

   (Solution is X = Y = 0.5, Objective = 0.5)
*/


/* Define a "callback" function which computes the objective and constraint
   left hand sides, for any supplied values of the decision variables. */

INTARG _CC funceval1 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
{
   objval[0] = var[0] * var[0]  + var[1] * var[1] ; /* objective */
   lhs[0] = var[0] + var[1]; /* constraint left hand side */
   lhs[1] = var[0] * var[1]; /* constraint left hand side */
   return 0;
}


/* Define a "callback" function which displays progress information
   when called on major iterations by the nonlinear Solver engine. */

INTARG _CC showiter1 (HPROBLEM lpinfo, INTARG wherefrom)
{
   long itercount; double objval;
   getcallbackinfo (lpinfo, wherefrom, CBINFO_ITCOUNT, &itercount);
   getcallbackinfo (lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, &objval);
   printf("Iteration %d:  Objective = %g\n", itercount, objval);
   return 0;
}


/* Now set up the NLP problem (including the "sense" and right hand sides
   of constraints), call the nonlinear Solver, and display the solution. */
```

```
void example1(void)
{
   double obj[2];
   double rhs[2] = {  1.0, 0.0 };
   char sense[2] = "EG";
   double matval[4];
   double lb[] = { -INFBOUND, -INFBOUND };
   double ub[] = { +INFBOUND, +INFBOUND };
   long i, stat; double objval;
   double x[2] = { 0.0, 0.0 };
   double piout[2], slack[2], dj[2];
   HPROBLEM lp = NULL;

   printf("\nExample NLP problem 1\n");
   setintparam (lp, PARAM_ARGCK, 1);

   lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, x, lb, ub, NULL, 4,
      funceval1, NULL);
   if (!lp) return;
   setlpcallbackfunc (lp, showiter1);

   optimize (lp);

   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("\nStatus = %d  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g\n", x[0], x[1]);
   for (i = 0; i <= 1; i++)
      printf("slack[%ld] = %7g  piout[%ld] = %7g\n",
      i, slack[i], i, piout[i]);
   printf("\n");

   unloadprob (&lp);
}


/*
   Example C program calling the nonlinear Solver DLL.
   Solves the problem:

   Minimize X^2 + Y^2
   Subject to:
      X + Y  = 1
      X * Y >= 0

   (Solution is X = Y = 0.5, Objective = 0.5)

   Here we define the function jacobian() as well as funceval(), to help
   speed up the evaluation of first partial derivatives at trial points.
   We re-use the functions funceval1() and showiter1() from Example 1.
*/


INTARG _CC jacobian1 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   INTARG nzspace, LPREALARG objval, LPREALARG obj, LPINTARG matbeg,
   LPINTARG matcnt, HPINTARG matind, HPREALARG matval, LPREALARG var,
   LPBYTEARG objtype, LPBYTEARG matvaltype)
{
   printf("jacobian evaluated at: x1 = %g   x2 = %g\n", var[0], var[1]);
   /* Value of the objective function */
   objval[0] = var[0] * var[0] + var[1] * var[1];
   /* Partial derivatives of the objective */
   obj[0] = 2.0 * var[0];
   obj[1] = 2.0 * var[1];
   /* Partial derivatives of X + Y (constant) */
   matval[0] = 1.0;
   matval[2] = 1.0;
```

```
   /* Partial derivatives of X * Y (variable) */
   matval[1] = var[1];
   matval[3] = var[0];
   return 0;
}


void example2(void)
{
   double obj[2];
   double rhs[2] = {  1.0, 0.0 };
   char sense[2] = "EG";
   double matval[4];
   double lb[] = { -INFBOUND, -INFBOUND };
   double ub[] = { +INFBOUND, +INFBOUND };
   long i, stat; double objval;
   double x[2] = { 0.25, 0.25 };
   double piout[2], slack[2], dj[2];
   HPROBLEM lp = NULL;

   printf("\nExample NLP problem 2\n");
   setintparam (lp, PARAM_ARGCK, 1);

   lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, x, lb, ub, NULL, 4,
         funceval1, jacobian1);
   if (!lp) return;

   /* Ask the Solver DLL to call our jacobian() routine, and *check*
      the partial derivatives we supply against its own "rise over run"
      derivative calculations */
   setintparam (lp, PARAM_DERIV, 3);

   optimize (lp);

   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("\nStatus = %d  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g\n", x[0], x[1]);
   for (i = 0; i <= 1; i++)
      printf("slack[%ld] = %7g  piout[%ld] = %7g\n",
      i, slack[i], i, piout[i]);
   printf("\n");

   setlpcallbackfunc (lp, NULL);
   setintparam (lp, PARAM_DERIV, 0);
   unloadprob (&lp);
}


/*
   Example C program calling the nonlinear Solver DLL.
   Attempts to solve the problem:

   Minimize X^2 + Y^2
   Subject to:
      X * Y  = 1
      X * Y  = 0

   This problem is infeasible, because the two constraints conflict.
   We will call findiis() and getiis() to help isolate the source
   of the infeasibility.
*/


INTARG _CC funceval3 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
```

```
{
   objval[0] = var[0] * var[0] + var[1] * var[1]; /* objective */
   lhs[0] = var[0] * var[1]; /* constraint left hand side */
   lhs[1] = var[0] * var[1]; /* constraint left hand side */
   return 0;
}


void example3(void)
{
   double obj[2];
   double rhs[2] = {  1.0, 0.0 };
   char sense[2] = "EE";
   double matval[4];
   double lb[] = { -INFBOUND, -INFBOUND };
   double ub[] = { +INFBOUND, +INFBOUND };
   long i, stat, iisrows, iiscols; double objval;
   long rowind[2], rowbdstat[2], colind[2], colbdstat[2];
   double x[2] = { 0.25, 0.25 };
   double piout[2], slack[2], dj[2];
   HPROBLEM lp = NULL;

   printf("\nExample NLP problem 3\n");
   setintparam (lp, PARAM_ARGCK, 1);

   lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, x, lb, ub, NULL, 4,
      funceval3, NULL);
   if (!lp) return;

   optimize (lp);

   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("Status = %ld (%s)  Objective = %g\n", stat,
      stat == PSTAT_INFEASIBLE ? "INFEASIBLE" : "FEASIBLE", objval);
   printf("Final values: x1 = %g  x2 = %g\n", x[0], x[1]);

   if (stat == PSTAT_INFEASIBLE)
   {
      findiis (lp, &iisrows, &iiscols);
      printf("\nfindiis: iisrows = %ld  iiscols = %ld\n",
         iisrows, iiscols);
      getiis (lp, &stat, rowind, rowbdstat, &iisrows,
         colind, colbdstat, &iiscols);
      for (i = 0; i < iisrows; i++)
         printf("rowind[%ld] = %ld  rowbdstat[%ld] = %ld\n",
            i, rowind[i], i, rowbdstat[i]);
      for (i = 0; i < iiscols; i++)
         printf("colind[%ld] = %ld  colbdstat[%ld] = %ld\n",
            i, colind[i], i, colbdstat[i]);
   }

   unloadprob (&lp);
}


/*
   Example C program calling the nonlinear Solver DLL for a series of
   problems which may be linear or nonlinear.  This situation might
   arise if you are calling some external program, or using your own
   interpreter, to evaluate the problem functions.  We will define and
   solve two example problems:

   Nonlinear problem:

   Minimize X^2 + Y^2
   Subject to:
```

```
      X + Y  = 1
      X * Y >= 0

   (Solution is X = Y = 0.5, Objective = 0.5)

   Alternate linear problem:

   Minimize 2 * X + Y
   Subject to:
      X + Y  = 1
      3 * X - Y >= 0

   (Solution is X = 0.25, Y = 0.75, Objective = 1.25)

   In this example, we call testnltype() to determine whether
   the problem is linear or nonlinear.  If it is linear, we
   solve it first with the nonlinear Solver engine, then solve
   it again with the linear (Simplex) Solver engine.
*/

typedef enum { Nonlin, Linear } Problem;
Problem Ex1 = Nonlin;

/*
   We define one funceval() routine, which can compute the
   objective and constraint values for both of the example
   problems.  The values returned by this funceval() depend
   on the setting of the global variable Ex1.
*/

INTARG _CC funceval4 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
{
   switch (Ex1)
   {
   case Nonlin:
      objval[0] = var[0] * var[0]  + var[1] * var[1] ; /* objective */
      lhs[0] = var[0] + var[1]; /* constraint left hand side */
      lhs[1] = var[0] * var[1]; /* constraint left hand side */
      break;
   case Linear:
      objval[0] = 2.0 * var[0] + var[1] ; /* objective */
      lhs[0] = var[0] + var[1]; /* constraint left hand side */
      lhs[1] = 3.0 * var[0] - var[1]; /* constraint left hand side */
      break;
   }
   return 0;
}


void example4(void)
{
   double obj[2];
   double rhs[2] = {  1.0, 0.0 };
   char sense[2] = "EG";
   double matval[4];
   double lb[] = { -10.0, -10.0 };
   double ub[] = { +10.0, +10.0 };
   long stat, nlstat; double objval;
   double x[2] = { 0.0, 0.0 };
   double piout[2], slack[2], dj[2];
   HPROBLEM lp = NULL;

   printf("\nExample NLP/LP problem 4\n");
   setintparam (lp, PARAM_ARGCK, 1);
```

```
   /* Set up the problem for solution by the NLP Solver */
   lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, x, lb, ub, NULL, 4,
      funceval4, NULL);
   if (!lp) return;

   /* Test the problem to determine linearity / nonlinearity */
   testnltype(lp, 1, NULL, &nlstat, NULL, NULL);
   printf("\ntestnltype: %s\n", nlstat ? "NONLINEAR" : "LINEAR");

   /* Solve the problem (using the NLP Solver) */
   optimize (lp);

   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("Status = %ld  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g\n", x[0], x[1]);

   unloadprob (&lp);
   if (nlstat) return;

   /* The problem was linear.  Set it up to be solved by the
      linear Simplex Solver -- it should find the same solution. */
   printf("\nSolve same problem with loadlp\n");
   lp = loadlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
      NULL, NULL, NULL, matval, lb, ub, NULL, 2, 2, 4);

   /* Solve the problem (using the LP Solver) */
   optimize (lp);

   solution (lp, &stat, &objval, x, piout, slack, dj);
   printf("Status = %ld  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g\n\n", x[0], x[1]);

   unloadprob (&lp);
}


/*
   Example C program calling the Evolutionary Solver DLL.
   Solves the problem:

   Minimize the Branin function:
   term1 = X/PI * (5.1 * X/PI/4 - 5)
   term2 = (Y - term1 - 6)^2
   term3 = 10 * (1 - 1/PI/8) * cos X + 10
   objective = term2 + term3
   -5 <= X, Y <= 10

   (3 local optima; 1 global optimum = approx 0.3978)
*/

#define PI 3.141593


INTARG _CC funceval5 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
{
   double term1, term2, term3;
   term1 = var[0] / PI * (5.1 * var[0] / PI / 4.0 - 5.0);
   term2 = (var[1] - term1 - 6) * (var[1] - term1 - 6);
   term3 = 10.0 * (1.0 - 1.0 / PI / 8.0) * cos(var[0]) + 10.0;
   objval[0] = term2 + term3;
   return 0;
}
```

```
INTARG _CC showiter5 (HPROBLEM lpinfo, INTARG wherefrom)
{
   int itercount; double objval;
   getcallbackinfo (lpinfo, wherefrom, CBINFO_ITCOUNT, &itercount);
   getcallbackinfo (lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, &objval);
   printf("Iteration %ld:  Objective = %g\n", itercount, objval);
   return 0;
}


int example5()
{
   double obj[2];
   double lb[2] = { -5.0, -5.0 };
   double ub[2] = { 10.0, 10.0 };
   int stat; double objval;
   double x[2] = { 1.0, 1.0 };
   double mid[2], disp[2], lower[2], upper[2];
   HPROBLEM lp = NULL;

   printf("\nExample NSP problem 5: Branin function\n");
   setintparam (lp, PARAM_ARGCK, 1);

   lp = loadnlp (PROBNAME, 2, 0, 1, obj, NULL, NULL,
      NULL, NULL, NULL, NULL, x, lb, ub, NULL, 0,
      funceval5, NULL);
   if (!lp) return 1;
   setintparam (lp, PARAM_NOIMP, 1); /* 1 second */
   setlpcallbackfunc (lp, showiter5);

   printf("Calling loadnltype\n");
   loadnltype (lp, NULL, NULL);

   optimize (lp);

   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("\nStatus = %ld  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g\n", x[0], x[1]);

   varstat (lp, 0, 1, mid, disp, lower, upper);
   printf("\nx1: mid = %g  disp = %g  lower = %g  upper = %g\n",
      mid[0], disp[0], lower[0], upper[0]);
   printf("x2: mid = %g  disp = %g  lower = %g  upper = %g\n",
      mid[1], disp[1], lower[1], upper[1]);

   unloadprob (&lp);
   return 0;
}


/*
   Example C program calling the Evolutionary Solver DLL.
   Solves the problem:

   Maximize (if X > 10 then Y + Z else Y - Z)
   0 <= X, Y, Z <= 20

   (Solution is X > 10, Y = Z = 20, objective = 40)
*/

INTARG _CC funceval6 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
{
   objval[0] = (var[0] > 10.0 ? var[1] + var[2] : var[1] - var[2]);
      /* objective */
   return 0;
```

```
}

int example6()
{
   double obj[3];
   double lb[3] = { 0.0, 0.0, 0.0 };
   double ub[3] = { 20.0, 20.0, 20.0 };
   int stat; double objval;
   double x[3] = { 5.0, 5.0, 5.0 };
   HPROBLEM lp = NULL;

   printf("\nExample NSP problem 6: IF function\n");
   setintparam (lp, PARAM_ARGCK, 1);

   lp = loadnlp (PROBNAME, 3, 0, -1, obj, NULL, NULL,
      NULL, NULL, NULL, NULL, x, lb, ub, NULL, 0,
      funceval6, NULL);
   if (!lp) return 1;
   setintparam (lp, PARAM_NOIMP, 1); /* 1 second */

   printf("Calling loadnltype\n");
   loadnltype (lp, NULL, NULL);

   optimize (lp);

   solution (lp, &stat, &objval, x, NULL, NULL, NULL);
   printf("\nStatus = %ld  Objective = %g\n", stat, objval);
   printf("Final values: x1 = %g  x2 = %g  x3 = %g\n", x[0], x[1], x[2]);

   unloadprob (&lp);
   return 0;
}

int main()
{
   char buf[80];
   printf("NONLINEAR TEST CASES FOR FRONTMIP.DLL\n\n");
   getlimits(); gets(buf);
   example1(); gets(buf);
   example2(); gets(buf);
   example3(); gets(buf);
   Ex1 = Nonlin;
   example4(); gets(buf);
   Ex1 = Linear;
   example4(); gets(buf);
   example5(); gets(buf);
   example6();
   return 0;
}
```

Solver Memory Usage

When you pass array arguments to the *loadlp(), loadnlp(), loadquad()* and *loadctype()* routines, the Solver DLL stores pointers to these arrays – it does not make copies of the data. When you call *optimize()* or *mipoptimize()* to solve a problem, these arrays are used, and additional storage is allocated internally by the Solver DLL. Some of the additional storage is maintained after *optimize()* or *mipoptimize()* returns, so that you can retrieve solution and sensitivity data by calling routines such as *solution(), objsa() and rhssa()*. This remaining storage is freed when you call *unloadprob()*.

Lifetime of Solver Arguments

Storage for the arguments passed to the Solver DLL routines may be allocated statically (outside a function definition or by using the `static` keyword), on the stack at runtime (the normal case for a variable declared within a function), or on the heap when allocated with *malloc* or operator *new*. But you must ensure that storage *remains* allocated for the arguments from the time you call *loadlp()* or *loadnlp()* to the time you call *unloadprob()* or exit your program.

Statically allocated and heap-based arguments normally will not present a problem in this regard. The situation you must avoid is illustrated below.

```
void main()
{
   HPROBLEM lp;
   lp = setup();
   solve(lp);
}

HPROBLEM setup()
{
   long matbeg[100], matcnt[100], ...
   return loadlp( ... matbeg, matcnt, ...);
}

void solve (HPROBLEM lp)
{
   optimize(lp);
}
```

The arrays *matbeg* and *matcnt* (and perhaps others) are allocated on the stack when the routine *setup()* is entered. When *setup()* exits, it returns the "problem handle" provided by *loadlp()*, but at this point the arrays *matbeg*, *matcnt*, etc. are deallocated and the stack space is reused in subsequent calls. This means that the call to *optimize()* in the routine *solve()* will fail (probably with a General Protection fault in the Solver DLL) when the Solver tries to reference the memory formerly allocated to *matbeg* and *matcnt*. You can avoid this situation by ensuring that arguments passed to the Solver DLL are always allocated statically or on the heap, or by calling all of the Solver DLL routines from a single function in your program.

Solving Multiple Problems Sequentially

In all versions of the Solver DLL, you can call the DLL routines repeatedly to solve a series of optimization problems in memory. But you must start each problem with a call to *loadlp()* or *loadnlp()*, and end each problem with a call to *unloadprob*(), in order to ensure that all memory allocated by the Solver DLL is freed before the next problem begins. You must also ensure that any memory allocated by your own application code is freed at the appropriate time.

In the single-threaded versions of the Solver DLL, which are serially reusable but not reentrant, you can solve a series of problems sequentially, but you cannot solve multiple problems *at the same time*. If you call *loadlp()* or *loadnlp()* a second time, without calling *unloadprob()* to end the first problem, the returned "problem handle" will be NULL, and if PARAM_ARGCK is 1, an error message will appear.

Solving Multiple Problems Concurrently

In the multi-threaded versions of the Solver DLL, you *can* solve multiple problems at the same time. Even in a single-threaded application, you can start multiple problems with calls to *loadlp()* or *loadnlp()*, keeping track of the separate "problem handles" that they return, and freely call the other DLL routines, passing the appropriate problem handle as an argument. In a multi-threaded application, you can call *loadlp()* or *loadnlp()* as required in each thread – you need only keep track of the returned problem handles in variables that are local to each thread. In any case, you must end each problem with a call to *unloadprob()* to free memory.

Multi-threaded versions of the Solver DLL can also solve problems recursively, where an optimization subproblem must be solved in order to compute the objective and/or constraints for a larger problem. In this scenario, you would call *loadlp()* or *loadnlp()*, *optimize()* or *mipoptimize()*, and *unloadprob()*, passing the new problem handle as an argument, from within your own *funceval()* or other callback routine.

One sequence of calls that is illegal in every version of the Solver DLL is a call to *optimize()* or *mipoptimize()* for a given problem, then a second call to *optimize()* or *mipoptimize()* for that same problem, made before the first call returns (e.g. made from within your *funceval()* or other callback routine). Such a second call will return –1, and if PARAM_ARGCK is 1, an error message will appear; the status value returned by a subsequent call to *solution()* will be PSTAT_ENTRY_ERROR.

Special Considerations for Windows 3.x

Programming for 32-bit systems such as Windows 95/98 and Windows NT/2000 is simpler than programming for 16-bit Windows 3.x, most notably because the 32-bit systems feature a "flat address space" whereas Windows 3.x assumes a "segmented address space." In a flat address space, all pointers are alike, and can address any location in memory. In the Windows 3.x segmented address space, there are "near" pointers, which can address only the current segment (limited to 64K bytes in size); "far" pointers, which can address other segments; and "huge" pointers, which are used to address arrays or other data objects which are greater than 64K bytes and therefore must span more than one segment. Programs can be compiled for various "memory models," which use certain types of pointers for code and for data.

The 16-bit Solver DLL code and data are in segments different from those of your application program. This means that the Solver DLL routines, and argument data passed to the DLL, must be referenced through far pointers. Moreover, when the Solver DLL makes calls during the solution process to a callback function in your application, it must (i) call your function through a far pointer and (ii) ensure that the data referenced by your function is addressable when it is called from the Solver DLL. This chapter discusses these special considerations for 16-bit Windows 3.x.

Far and Huge Pointers

In Windows 3.x, the Solver DLL routines themselves must be called through far pointers. In the header file frontmip.h, these routines are prototyped with the _CC calling convention, which is #defined as _export _far _pascal (versus _stdcall in 32-bit Windows) – ensuring that the C/C++ compiler will call them appropriately.

Far Pointers

The Solver DLL expects many of its arguments to be passed by reference, which means that a pointer to the actual data is passed to the DLL. As noted above, these must be far pointers in Windows 3.x. The header file frontmip.h defines typedefs for the required data types, such as LPINTARG (far pointer to long integer) and LPREALARG (far pointer to double). Since the arguments of each DLL routine are prototyped in frontmip.h, the C/C++ compiler will perform default conversions for you, so you can (for example) write:

```
char sense[] = "LLEEGG"; lp = loadlp (...,sense,...);
```

and *sense* will be converted, if necessary, to type LPSTR (i.e. far pointer to character in Windows 3.1). Remember that array names represent the base address of the array and do not need a leading & when passed as arguments.

Huge Pointers

"Far" pointers can address data located in any segment, anywhere in memory. However, far pointers are designed to manipulate data objects that are at most 64K bytes long (the maximum segment size in the Intel 8086 architecture). Larger data objects in a 16-bit environment require special address arithmetic, which is provided by the C/C++ compilers when you declare "huge" pointers. For example, imagine that the following C code appears in a Solver DLL routine, where numcols = 10000 and x is an array of double:

```
for (i = 0; i < numcols; i++) x[i] = 0.0;
```

Since a double value requires 8 bytes, the array x occupies 80,000 bytes. In the for loop, the address of the ith element of x is determined by adding 8 * i to the base address of x. Even if the array x is located at the very beginning of a 64K segment, when i reaches 8192 the address will overflow the segment boundary. The C/C++ compiler will provide for this situation if the base address of x is a huge pointer – at the expense of extra space and time, for code to handle the overflow situation.

In frontmip.h, the two arguments *matind* and *matval*, representing the nonzero coefficients of the LP matrix, are prototyped as HPINTARG and HPREALARG respectively. (Similar comments apply to the arguments *qmatind* and *qmatval* for quadratic problems.) In 16-bit Windows, these typedefs represent huge pointers. Hence these arrays can specify as many nonzeroes as desired. For efficiency, other arguments such as *obj* and *rhs* are prototyped as far pointers; since the maximum size of a far data object is 64K bytes and a double value requires 8 bytes, you must use no more than 8192 variables and 8192 constraints with the 16-bit versions of the Large-Scale LP/MIP Solver DLL.

Default conversions are performed for huge pointer arguments, just as they are for far pointers, so you can, for example, declare double arrays for *matind* and *matval* and use them without any special casting as arguments to *loadlp()*.

Callback Functions

The *loadnlp()* routine and the *setlpcallbackfunc()* and *setmipcallbackfunc()* routines take arguments which are the addresses of "callback" functions. Using these callbacks, you can more closely control the optimization process and create user-responsive "native Windows" applications.

In the example program vcexamp1.c, a callback function is used only when a 32-bit version of the program is compiled. This was done for simplicity, to avoid the complications discussed in this chapter. In the first example program shown in the next chapter, "Native Windows Applications", we will create a very simple LP pivot callback procedure, and pass its address as an argument to *setlpcallbackfunc()*. To make this program work in 16-bit Windows 3.x as well as in 32-bit Windows 95/98 and NT/2000, we must deal with the issues described in this section.

MakeProcInstance

Windows allows more than one "instance" of your application to be run at the same time. Each instance executes the same compiled code, but maintains its data in a different data segment. Windows supplies the address of the proper instance data segment (in the Data Segment or DS register) when it starts up your program. As you call different procedures and functions in your own code, this data segment address is maintained.

When you call a Solver DLL routine, which has its own code and data segments, and the Solver DLL in turn makes a call to one of your functions (which you have set up as a callback function), the proper data segment address must be restored so that your function can execute and reference its local data. This data segment address will be different for each instance of your application. How can the Solver DLL call the same callback function every time, yet have different data segment addresses restored in each instance?

In Windows, this is done by calling the API function *MakeProcInstance()* with the address of your callback function, and the "instance handle" which Windows passes to your main entry point when an instance of your application is started. The return value of *MakeProcInstance()* is actually a pointer to code within Windows (called a "thunk") which restores the data segment address and then passes control to your callback function. You pass this special "thunk" pointer to *setlpcallbackfunc()* or *setmipcallbackfunc()*, and the Solver DLL uses it to call your function.

For example, you can write:

```
long _CC pivot (HPROBLEM lpinfo, long wherefrom);
_CCPROC lpPivot;

lpPivot = (_CCPROC)MakeProcInstance ((FARPROC)pivot, hInst);
setlpcallbackfunc (lpPivot);
```

Now the Solver DLL will be able to call your callback function through the lpPivot pointer. This same code will work in 32-bit Windows 95/98 and Windows NT/2000, but in these environments the *MakeProcInstance()* call is superfluous, and Microsoft recommends that you omit it. Life is simpler in 32 bits!

Using Callback Functions

Your callback routines can perform any actions you want. Usually, however, the LP pivot or the MIP branch callback routine will inform the user of the progress of the optimization, perhaps displaying the current value of the objective function. It may also check for a user interaction, such as a key press or mouse click, signalling that the optimization process should be aborted. Here is an excerpt from the code in the next chapter, "Native Windows Applications", which shows how the callback function can be used:

```
getcallbackinfo( lpinfo, wherefrom, CBINFO_ITCOUNT,
   &NumPivot);
getcallbackinfo( lpinfo, wherefrom, CBINFO_PRIMAL_OBJ,
   &Objective);
FPSTR (Objective, ObjStr);
wsprintf( PivotMsg, "Pivot # %ld:  Obj = %s", NumPivot,
   (LPSTR)ObjStr);
SetWindowText (hWnd, PivotMsg);
if (PeekMessage ((MSG FAR *) &msg, hWnd,
    WM_KEYDOWN, WM_KEYDOWN, PM_NOREMOVE))
   if (msg.wParam == VK_ESCAPE) return PSTAT_USER_ABORT;
return PSTAT_CONTINUE;
```

This code uses the Solver API function *getcallbackinfo()* to obtain the LP pivot number and the current value of the objective. It formats these values into a string that is displayed in the application window title bar (a "real" application would use a dialog box or other user interface element). Then it returns with a code indicating whether the solution process should continue, or stop at this point.

The *PeekMessage()* function lets you "peek" at a message in the application's message queue without actually processing it. If there are no pending messages, *PeekMessage()* returns 0. In this code, we look for the specific Windows message WM_KEYDOWN (the user pressed a key while our application had the focus) and if it arrives, we check the virtual key code. We take the ESCape key as a signal from the user that he or she wants to interrupt the optimization process, and we return the value PSTAT_USER_ABORT (defined in frontmip.h) to the DLL.

A similar approach can be used to respond to a mouse click or a menu command. Another strategy would be to set a global flag when the appropriate message was processed in your window procedure, and check this flag in the LP pivot or MIP branch callback routine.

Non-Preemptive Multitasking

The Solver DLL lets you easily write applications that will "optimize in the back-ground" while the user performs other tasks. In Windows 95/98 and Window NT/2000, which are preemptive multitasking systems, this is straightforward – the operating system periodically interrupts each application and lets another one run. However, Windows 3.x relies on cooperative, "non-preemptive multitasking," which requires that each running application periodically yield control to Windows, which then allows another application to run.

The Solver DLL takes care of this for you. In addition to calling your callback functions (if specified), the Solver DLL will periodically call the Windows API function *PeekMessage()* in order to yield control to Windows. These calls are more frequent than calls to the callback functions, since in a large problem a single LP pivot or Simplex iteration can take several seconds.

Native Windows Applications

The programs winexamp1.c and winexamp2.c are "native Windows" applications that call Windows API functions to create a window, and write the results of calling the Solver DLL into it. To compile and link these programs, follow the steps in the chapter "Calling the Solver DLL from C/C++," but substitute the file winexamp1.c or winexamp2.c for vcexamp1.c, and select a project type of "Win32 Application" in Visual C++ 6.x, or "Windows Application (.EXE)" in Visual C++ 1.5x. (The multi-threaded behavior of winexamp2.c can be seen only on Win32 systems.)

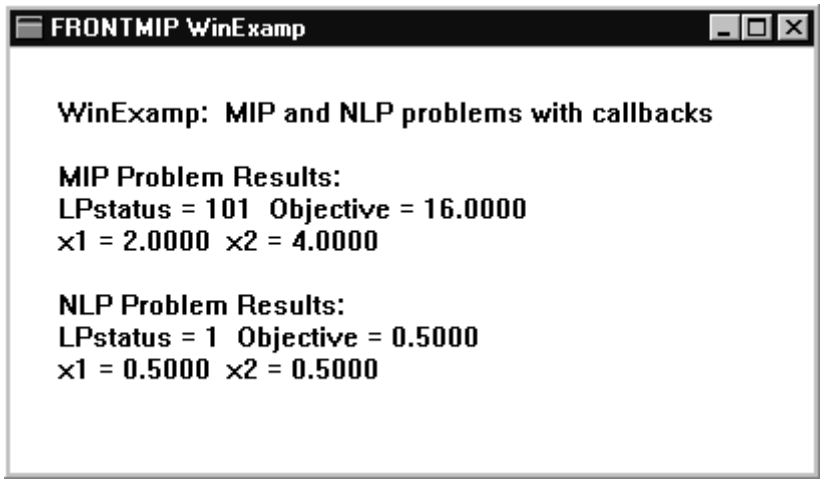
A Single-Threaded Application

The source file winexamp1.c (found in the Examples/Vcexamp subdirectory) begins with some #includes and prototypes, followed by the *WinMain()*, *InitApplication()* and *InitInstance()* procedures common to almost all Windows applications. In the window procedure *MainWndProc()*, we set up a device context, paint structure and text metrics and call the API procedure *TextOut()* to write text into the application window whenever a WM_PAINT message arrives. On the first such message, we call *RunLPSolver()* and *RunNLPSolver()* to solve two example problems. (*Note:* if your copy of the Solver DLL does not include both the linear and nonlinear Solver engines, one of these routines will display a MessageBox noting this fact, and the corresponding example problem will display 0.0 for the variables and objective.)

RunNLPSolver() uses the callback routine funceval1() to compute values for the objective and the left hand sides of constraints during the solution process – as required for all nonlinear problems. Both *RunLPSolver()* and *RunNLPSolver()* use the callback routine *pivot()* to display information on each major iteration about the progress of the optimization.

The *pivot()* procedure uses *wsprintf()* and a supporting procedure *FPSTR()* to build a text message reporting the iteration number and the current objective function value. These values are obtained through calls to the function *getcallbackinfo()*. The text message is set into the application window's title bar. (The title bar is reset after the example problems are solved in *MainWndProc()*.) The *pivot()* procedure then executes the code described in the previous chapter to watch for a press of the ESC key. If ESC is pressed before the optimization is complete, *pivot()* returns PSTAT_USER_ABORT to its caller (the DLL), which will result in a return to your main line code from *optimize()*. The return status code, which may be either PSTAT_ABORT_FEAS or PSTAT_ABORT_INFEAS depending on whether a feasible solution was found, is passed back to the main line code in the *pstat* argument of *solution()*.

Since the example problems are solved in a small fraction of a second, the winexamp program will normally run to completion, displaying a window like the one shown below.



The complete C source code of winexamp1.c is shown on the following pages. For newly-written application programs, you will find it preferable to use a C++ class library such as MFC (Microsoft Foundation Classes) together with the "wizards" or "experts" included in your C/C++ development system (such as the AppWizard in Visual C++) to create the basic structure of your application program.

```
/* ********************************************************************
   Frontline Systems Small-Scale Solver Dynamic Link Library Version 3.5
   Frontline Systems Inc., P.O. Box 4288, Incline Village, NV 89450 USA
   Tel (775) 831-0300 ** Fax (775) 831-0314 ** Email info@frontsys.com
   ******************************************************************** */

/*
   Problem 1: Solve the MIP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= 50
   x1, x2 non-negative, integer
   MIP solution: x1 = 2, x2 = 4
   Objective = 16.0

   Problem 2: Solve the NLP model:
   Minimize X^2 + Y^2
   Subject to:
      X + Y  = 1
      X * Y >= 0
   x1, x2 non-negative
   Solution is X = Y = 0.5, Objective = 0.5

   This is a "native Windows" application.  It includes two examples of
   "callback" routines:  One to compute the objective and constraints
   for the nonlinear Solver, and another which displays the iteration
   and current objective value, & quits if the user presses the ESC key.

   If your copy of the Solver DLL does not include the LP or NLP Solver
   "engine", a MessageBox will appear, and the results will show all
   zeroes for the solution status, objective and final variable values.
*/

#include <windows.h>
```

```
#include <string.h>
#include "frontmip.h"
#include "frontkey.h"

/* Prototype the procedures to follow... */
int WINAPI WinMain(HINSTANCE, HINSTANCE, LPSTR, int);
BOOL InitApplication(HINSTANCE);
BOOL InitInstance(HINSTANCE, int);
LRESULT CALLBACK MainWndProc(HWND, UINT, WPARAM, LPARAM);
PBYTE FPSTR( double value, PBYTE lpstr);
long _CC pivot (HPROBLEM lpinfo, long wherefrom);
void RunLPSolver(long *pstat, double *pobj, double *x);
void RunNLPSolver(long *pstat, double *pobj, double *x);

/* Global data... */
HANDLE hInst;  /* current instance */
HWND hWnd;     /* main window handle */
char szClassName[] = "ExampleClass";
char szAppTitle[] = "FRONTMIP WinExamp";


int WINAPI WinMain (HINSTANCE hInstance, HINSTANCE hPrevInstance,
     LPSTR lpCmdLine, int nCmdShow)
{
    MSG msg;
    if (!hPrevInstance)
        if (!InitApplication(hInstance))
            return (FALSE);

    if (!InitInstance(hInstance, nCmdShow))
        return (FALSE);

    while (GetMessage(&msg, 0, 0, 0)) {
        TranslateMessage(&msg);
        DispatchMessage(&msg);
    }
    return (msg.wParam);
}


BOOL InitApplication (HINSTANCE hInstance)
{
    WNDCLASS  wc;
    wc.style = 0;
    wc.lpfnWndProc = MainWndProc;
    wc.cbClsExtra = 0;
    wc.cbWndExtra = 0;
    wc.hInstance = hInstance;
    wc.hIcon = LoadIcon(NULL, IDI_APPLICATION);
    wc.hCursor = LoadCursor(NULL, IDC_ARROW);
    wc.hbrBackground = GetStockObject(WHITE_BRUSH);
    wc.lpszMenuName =  NULL;
    wc.lpszClassName = szClassName;
    return (RegisterClass(&wc));
}


BOOL InitInstance (HINSTANCE hInstance, int nCmdShow)
{

    hInst = hInstance;

    hWnd = CreateWindow(
        szClassName,
        szAppTitle,
        WS_OVERLAPPEDWINDOW,
        CW_USEDEFAULT, CW_USEDEFAULT,
```

```
        CW_USEDEFAULT, CW_USEDEFAULT,
        NULL,
        NULL,
        hInstance,
        NULL);
    if (!hWnd) return (FALSE);

    ShowWindow(hWnd, nCmdShow);
    UpdateWindow(hWnd);
    return (TRUE);
}


LRESULT CALLBACK MainWndProc
    (HWND hWnd, UINT message, WPARAM wParam, LPARAM lParam)
{
    HDC hDC;                          /* display-context variable  */
    PAINTSTRUCT ps;                   /* paint structure           */
    TEXTMETRIC textmetric;
    int nDrawX, nDrawY, nSpacing;
    char szText[80], szObj[12], szVar1[12], szVar2[12];

    /* We call the Solver DLL on the 1st WM_PAINT message */
    static long LPstat = 0, NLPstat = 0;
    static double LPobj = 0.0, NLPobj = 0.0;
    static double LPx[2] = { 0.0, 0.0 }, NLPx[2] = { 0.0, 0.0 };
    static char LPtitle[] = "MIP Problem Results:";
    static char NLPtitle[] = "NLP Problem Results:";

    switch (message) {

    case WM_PAINT:
        hDC = BeginPaint (hWnd, &ps);
        GetTextMetrics (hDC, &textmetric);
        nSpacing = textmetric.tmExternalLeading + textmetric.tmHeight;

        /* Initialize drawing position to 1/4" from the top left */
        nDrawX = GetDeviceCaps (hDC, LOGPIXELSX) / 4;    /* 1/4" */
        nDrawY = GetDeviceCaps (hDC, LOGPIXELSY) / 4;    /* 1/4" */

        strcpy (szText, "WinExamp:  MIP and NLP problems with callbacks");
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += 2 * nSpacing;

        if (!LPstat)
        {
          RunLPSolver (&LPstat, &LPobj, LPx);
          RunNLPSolver (&NLPstat, &NLPobj, NLPx);
          SetWindowText (hWnd, szAppTitle);
        }

        FPSTR (LPobj, szObj);
        FPSTR (LPx[0], szVar1); FPSTR (LPx[1], szVar2);

        TextOut (hDC, nDrawX, nDrawY, LPtitle, strlen (LPtitle));
        nDrawY += nSpacing;

        wsprintf (szText, "LPstatus = %ld  Objective = %s",
          LPstat, (LPSTR)szObj);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += nSpacing;

        wsprintf(szText, "x1 = %s  x2 = %s", (LPSTR)szVar1, (LPSTR)szVar2);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += 2 * nSpacing;

        FPSTR (NLPobj, szObj);
```

```
        FPSTR (NLPx[0], szVar1); FPSTR (NLPx[1], szVar2);

        TextOut (hDC, nDrawX, nDrawY, NLPtitle, strlen (NLPtitle));
        nDrawY += nSpacing;

        wsprintf (szText, "LPstatus = %ld  Objective = %s",
          NLPstat, (LPSTR)szObj);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += nSpacing;

        wsprintf(szText, "x1 = %s  x2 = %s", (LPSTR)szVar1, (LPSTR)szVar2);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += 2 * nSpacing;

        EndPaint (hWnd,  &ps);
        break;

      case WM_DESTROY:
        PostQuitMessage(0);
        break;

      default:
        return (DefWindowProc(hWnd, message, wParam, lParam));
    }
    return 0;
}


PBYTE FPSTR( double value, PBYTE lpstr)
{
    PBYTE   buf = lpstr;
    int     length = 0;
    DWORD   dwFraction;
    if (value < 0.00) { *buf = '-'; length++; value = -value; }
    length += wsprintf( &buf[ length ], "%lu.", (DWORD) value);
    dwFraction = (DWORD) (1.00E+04 * (value - (DWORD) value));
    length += wsprintf( &buf[ length ], "%4.4lu", dwFraction);
    return lpstr;
}


/* Define a "callback" function which displays the iteration and current
   objective value in the window title bar, and checks for the ESC key */

long _CC pivot (HPROBLEM lpinfo, long wherefrom)
{
    long NumPivot; double Objective;
    char PivotMsg[64], ObjStr[12];
    MSG msg;

    getcallbackinfo( lpinfo, wherefrom, CBINFO_ITCOUNT, &NumPivot);
    getcallbackinfo( lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, &Objective);
    FPSTR (Objective, ObjStr);
    wsprintf( PivotMsg, "Pivot # %ld:  Obj = %s", NumPivot, (LPSTR)ObjStr);
    SetWindowText (hWnd, PivotMsg);
    if (PeekMessage ((MSG FAR *) &msg, hWnd,
        WM_KEYDOWN, WM_KEYDOWN, PM_NOREMOVE))
        if (msg.wParam == VK_ESCAPE) return PSTAT_USER_ABORT;
    return PSTAT_CONTINUE;
}

/* Define and solve the example MIP problem */

void RunLPSolver (long *pstat, double *pobj, double *x)
{
    double obj[] = { 2.0, 3.0 };
    double rhs[] = { 54.0, 42.0, 50.0 };
```

```
    char sense[] = "LLL";
    long matbeg[] = { 0, 3 };
    long matcnt[] = { 3, 3 };
    long matind[] =   {   0,   1,   2,   0,   1,    2 };
    double matval[] = { 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 };
    double lb[] = { 0.0, 0.0 };
    double ub[] = { INFBOUND, INFBOUND };
    char ctype[] = "II";
    HPROBLEM lp = NULL;
    _CCPROC lpPivot;

    setintparam( lp, PARAM_ARGCK, 1);
    lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
         matbeg, matcnt, matind, matval, lb, ub, NULL, 2, 3, 6);
    if (!lp) return;
    loadctype (lp, ctype);

    lpPivot = (_CCPROC)MakeProcInstance ((FARPROC)pivot, hInst);
    setlpcallbackfunc( lp, lpPivot);
    optimize (lp);
    solution (lp, pstat, pobj, x, NULL, NULL, NULL);
    unloadprob (&lp);
    return;
}


/* Define a "callback" function that computes the objective and constraint
   left hand sides, for any supplied values of the decision variables. */

INTARG _CC funceval1 (HPROBLEM lp, INTARG numcols, INTARG numrows,
   LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
   INTARG vartwo)
{
    objval[0] = var[0] * var[0]  + var[1] * var[1] ; /* objective */
    lhs[0] = var[0] + var[1]; /* constraint left hand side */
    lhs[1] = var[0] * var[1]; /* constraint left hand side */
    return 0;
}

/* Define and solve the example NLP problem */

void RunNLPSolver (long *pstat, double *pobj, double *x)
{
    double obj[2];
    double rhs[2] = {  1.0, 0.0 };
    char sense[2] = "EG";
    double matval[4];
    double lb[] = { -INFBOUND, -INFBOUND };
    double ub[] = { +INFBOUND, +INFBOUND };
    HPROBLEM lp = NULL;
    _FUNCEVAL lpFuncEval;
    _CCPROC lpPivot;

    setintparam( lp, PARAM_ARGCK, 1);
    lpFuncEval = (_FUNCEVAL)MakeProcInstance ((FARPROC)funceval1, hInst);
    lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
          NULL, NULL, NULL, matval, x, lb, ub, NULL, 4, lpFuncEval, NULL);
    if (!lp) return;

    lpPivot = (_CCPROC)MakeProcInstance ((FARPROC)pivot, hInst);
    setlpcallbackfunc( lp, lpPivot);
    optimize (lp);
    solution (lp, pstat, pobj, x, NULL, NULL, NULL);
    unloadprob (&lp);
    return;
}
```

A Multi-Threaded Application

The source file winexamp2.c (found in the Examples/Vcexamp subdirectory) is a very simple example of a multi-threaded application. It will run and exhibit multi-threaded behavior only when compiled for a Win32 target system and only when used with a multi-threaded version of the Solver DLL. Since the Win32 API calls to create threads are surrounded by #ifdefs, winexamp2.c will compile and run on Win16 systems such as Windows 3.1, but it won't exhibit multi-threaded behavior.

Winexamp2.c is similar in structure to winexamp1.c, in that it begins with the *WinMain()*, *InitApplication()* and *InitInstance()* procedures common to almost all Windows applications. However, in *WinMain()* we call *InitInstance()* twice to create two windows – both using the same window procedure *MainWndProc()* – and, on Win32 systems, we create a thread corresponding to each window. A Solver DLL problem is created and solved in each window. Code at the beginning of *MainWndProc()* selects the appropriate problem based on the window handle passed on each call by Windows.

MainWndProc() is similar to the corresponding function in winexamp1.c, with one important difference: Whereas in winexamp1.c we set up and solve both problems only on the first WM_PAINT message (and we save the results in static variables for redisplay on subsequent WM_PAINT messages), in winexamp2.c we re-create and re-solve a problem on each WM_PAINT message in each window. We do this to demonstrate what happens when both problems are being solved concurrently. (*Note:* if your copy of the Solver DLL doesn't include both the linear and nonlinear Solver engines, you can change the #defines PROBLEM1 and PROBLEM2 at the beginning of winexamp2.c so that the same problem will be created and solved in both windows.)

The two threads we create in *WinMain()* execute a common function *RunThread()*, which receives as an argument the window handle of the first or second window. *RunThread()* simply calls the Win32 *Sleep()* function to wait for a randomly chosen number of seconds, then calls *InvalidateRect()* and *UpdateWindow()* to generate a new WM_PAINT message for the argument window. The effect is to cause the *MainWndProc()* function and the Solver DLL routines to be executed at randomly chosen, and often overlapping, times in the two windows.

If you compile, link and run winexamp2.c on a Win32 system with a single-threaded version of the Solver DLL, you will see one or more error MessageBoxes informing you that "another problem is currently loaded." If you run it with a multi-threaded version of the Solver DLL, you'll see both windows updating concurrently with results from calling the Solver DLL routines.

```
/* ********************************************************************
   Frontline Systems Small-Scale Solver Dynamic Link Library Version 3.5
   Frontline Systems Inc., P.O. Box 4288, Incline Village, NV 89450 USA
   Tel (775) 831-0300 ** Fax (775) 831-0314 ** Email info@frontsys.com
   ******************************************************************** */

/*
   Problem 1: Solve the MIP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= 50
   x1, x2 non-negative, integer
   MIP solution: x1 = 2, x2 = 4
   Objective = 16.0
```

```
   Problem 2: Solve the NLP model:
   Minimize X^2 + Y^2
   Subject to:
      X + Y  = 1
      X * Y >= 0
   x1, x2 non-negative
   Solution is X = Y = 0.5, Objective = 0.5

   This is a multi-threaded Windows application.  It creates two threads
   and two windows:  One thread repeatedly solves Problem 1 and displays
   the results in the first window, while the other thread repeatedly
   solves Problem 2 and displays the results in the second window.

   If your copy of the Solver DLL does not include the LP or NLP Solver
   "engine", you may change the #defines PROBLEM1 and PROBLEM2 so that
   they both refer to the routine (either RunLPSolver or RunNLPSolver)
   that calls the Solver engine that you have -- then the same results
   will appear in both windows.
*/

#include <windows.h>
#include <stdlib.h>
#include <string.h>
#include "frontmip.h"
#include "frontkey.h"

#define PROBLEM1 RunLPSolver
#define PROBLEM2 RunNLPSolver

/* Prototype the procedures to follow... */

int WINAPI WinMain (HINSTANCE, HINSTANCE, LPSTR, int);
LRESULT CALLBACK MainWndProc (HWND, UINT, WPARAM, LPARAM);
BOOL InitApplication(HINSTANCE);
BOOL InitInstance(HINSTANCE, HWND *, char *, long, long, long, long);

/* Threads are not available in Win16... */
#ifdef WIN32
    DWORD WINAPI RunThread(LPVOID);
#endif

PBYTE FPSTR( double value, PBYTE lpstr);
long _CC pivot (HPROBLEM lpinfo, long wherefrom);
typedef long RunSolver(HWND hWnd, long *pstat, double *pobj, double *x);
RunSolver RunLPSolver, RunNLPSolver;

/* Global data... */
HANDLE hInst;  /* current instance */
HWND hWnd1, hWnd2;  /* window handles */
HPROBLEM lp1, lp2;  /* problem handles */
DWORD dwID1, dwID2; /* thread IDs in Win32 */
char szWinTitle1[] = "FRONTMIP Example 1";
char szWinTitle2[] = "FRONTMIP Example 2";
char szClassName[] = "FRONTMIP Class";
long Calls = 0; /* counts calls to RunLPSolver / RunNLPSolver */


int WINAPI WinMain (HINSTANCE hInstance, HINSTANCE hPrevInstance,
     LPSTR lpCmdLine, int nCmdShow)
{
    MSG msg;
    if (!hPrevInstance)
        if (!InitApplication (hInstance))
            return (FALSE);

    if (!InitInstance (hInstance, &hWnd1, szWinTitle1, 10, 10, 300, 300))
```

```
        return (FALSE);
    if (!InitInstance (hInstance, &hWnd2, szWinTitle2, 330, 10, 300, 300))
        return (FALSE);

#ifdef WIN32
    srand( GetTickCount());
    CreateThread( NULL, 0, RunThread, (LPVOID)hWnd1, 0, &dwID1);
    CreateThread( NULL, 0, RunThread, (LPVOID)hWnd2, 0, &dwID1);
#endif

    while (GetMessage(&msg, 0, 0, 0)) {
        TranslateMessage(&msg);
        DispatchMessage(&msg);
    }
    return (msg.wParam);
}


BOOL InitApplication (HINSTANCE hInstance)
{
    WNDCLASS  wc;
    wc.style = 0;
    wc.lpfnWndProc = MainWndProc;
    wc.cbClsExtra = 0;
    wc.cbWndExtra = 0;
    wc.hInstance = hInstance;
    wc.hIcon = LoadIcon(NULL, IDI_APPLICATION);
    wc.hCursor = LoadCursor(NULL, IDC_ARROW);
    wc.hbrBackground = GetStockObject(WHITE_BRUSH);
    wc.lpszMenuName =  NULL;
    wc.lpszClassName = szClassName;
    return (RegisterClass(&wc));
}


BOOL InitInstance(HINSTANCE hInstance, HWND *hWnd, char *szWinTitle,
                  long nX, long nY, long nWidth, long nHeight)
{

    hInst = hInstance;

    *hWnd = CreateWindow(
        szClassName,
        szWinTitle,
        WS_OVERLAPPEDWINDOW,
        nX, nY, nWidth, nHeight,
        NULL, NULL, hInstance, NULL);
    if (!*hWnd) return (FALSE);

    ShowWindow(*hWnd, SW_SHOW);
    UpdateWindow(*hWnd);
    return (TRUE);
}


#ifdef WIN32
DWORD WINAPI RunThread( LPVOID lpVoid)
{
    HWND hWnd = (HWND)lpVoid;
    int i;
    /* Cause Solver DLL to be called 9 more times for each window... */
    for (i = 1; i < 10; i++)
    {
        Sleep( rand() * 1000 / RAND_MAX ); /* wait random time (0-1 sec) */
        InvalidateRect( hWnd, NULL, TRUE); /* cause WM_PAINT for window  */
        UpdateWindow( hWnd);
    }
```

```
    return 0;
}
#endif


LRESULT CALLBACK MainWndProc
    (HWND hWnd, UINT message, WPARAM wParam, LPARAM lParam)
{
    HDC hDC;                          /* display-context variable  */
    PAINTSTRUCT ps;                   /* paint structure           */
    TEXTMETRIC textmetric;
    int nDrawX, nDrawY, nSpacing;
    char szText[80], szObj[12], szVar1[12], szVar2[12];

    /* We call the Solver DLL on each WM_PAINT message */
    RunSolver *lpRunSolver;
    char *szWinTitle, *szProblem, *szResults;
    long stat = 0, calls = 0;
    double obj = 0.0;
    double x[2] = { 0.0, 0.0 };

    if (hWnd == hWnd1)
    {
        lpRunSolver = PROBLEM1;
        szWinTitle = szWinTitle1;
    }
    else /* hWnd == hWnd2 */
    {
        lpRunSolver = PROBLEM2;
        szWinTitle = szWinTitle2;
    }
    if (lpRunSolver == RunLPSolver)
    {
        szProblem = "WinExamp:  MIP problem";
        szResults = "MIP Problem Results:";
    }
    else /* lpRunSolver == RunNLPSolver */
    {
        szProblem = "WinExamp:  NLP problem";
        szResults = "NLP Problem Results:";
    }

    switch (message) {

    case WM_PAINT:
        hDC = BeginPaint (hWnd, &ps);
        GetTextMetrics (hDC, &textmetric);
        nSpacing = textmetric.tmExternalLeading + textmetric.tmHeight;

        /* Initialize drawing position to 1/4" from the top left */
        nDrawX = GetDeviceCaps (hDC, LOGPIXELSX) / 4;    /* 1/4" */
        nDrawY = GetDeviceCaps (hDC, LOGPIXELSY) / 4;    /* 1/4" */

        calls = lpRunSolver (hWnd, &stat, &obj, x);
        /* SetWindowText (hWnd, szWinTitle); */

        wsprintf (szText, "Call %ld:  %s", calls, szProblem);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += 2 * nSpacing;

        FPSTR (obj, szObj);
        FPSTR (x[0], szVar1); FPSTR (x[1], szVar2);

        TextOut (hDC, nDrawX, nDrawY, szResults, strlen (szResults));
        nDrawY += nSpacing;

        wsprintf (szText, "Status = %ld  Objective = %s",
```

```
          stat, (LPSTR)szObj);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += nSpacing;

        wsprintf(szText, "x1 = %s  x2 = %s", (LPSTR)szVar1, (LPSTR)szVar2);
        TextOut (hDC, nDrawX, nDrawY, szText, strlen (szText));
        nDrawY += 2 * nSpacing;

        EndPaint (hWnd,  &ps);
        break;

      case WM_DESTROY:
        PostQuitMessage(0);
        break;

      default:
        return (DefWindowProc(hWnd, message, wParam, lParam));
    }
    return 0;
}


PBYTE FPSTR( double value, PBYTE lpstr)
{
    PBYTE   buf = lpstr;
    int     length = 0;
    DWORD   dwFraction;
    if (value < 0.00) { *buf = '-'; length++; value = -value; }
    length += wsprintf( &buf[ length ], "%lu.", (DWORD) value);
    dwFraction = (DWORD) (1.00E+04 * (value - (DWORD) value));
    length += wsprintf( &buf[ length ], "%4.4lu", dwFraction);
    return lpstr;
}


/* Define a "callback" function which displays the iteration and current
   objective value in the window title bar, and checks for the ESC key */

long _CC pivot (HPROBLEM lpinfo, long wherefrom)
{
    long NumPivot; double Objective;
    char PivotMsg[64], ObjStr[12];
    MSG msg; HWND hWnd;

    getcallbackinfo( lpinfo, wherefrom, CBINFO_ITCOUNT, &NumPivot);
    getcallbackinfo( lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, &Objective);
    FPSTR (Objective, ObjStr);
    wsprintf( PivotMsg, "Pivot # %ld:  Obj = %s", NumPivot, (LPSTR)ObjStr);
    hWnd = (lpinfo == lp1 ? hWnd1 : hWnd2);
    SetWindowText (hWnd, PivotMsg);
    if (PeekMessage ((MSG FAR *) &msg, hWnd,
        WM_KEYDOWN, WM_KEYDOWN, PM_NOREMOVE))
       if (msg.wParam == VK_ESCAPE) return PSTAT_USER_ABORT;
    return PSTAT_CONTINUE;
}

/* Define and solve the example MIP problem */

long RunLPSolver (HWND hWnd, long *pstat, double *pobj, double *x)
{
    double obj[] = { 2.0, 3.0 };
    double rhs[] = { 54.0, 42.0, 50.0 };
    char sense[] = "LLL";
    long matbeg[] = { 0, 3 };
    long matcnt[] = { 3, 3 };
    long matind[] =   {   0,   1,   2,   0,   1,    2 };
    double matval[] = { 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 };
```

```
    double lb[] = { 0.0, 0.0 };
    double ub[] = { INFBOUND, INFBOUND };
    char ctype[] = "II";
    HPROBLEM lp = NULL;
    _CCPROC lpPivot;

    setintparam( lp, PARAM_ARGCK, 1);
    lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
         matbeg, matcnt, matind, matval, lb, ub, NULL, 2, 3, 6);
    if (!lp) return 0;
    if (hWnd == hWnd1) lp1 = lp; else lp2 = lp;
    loadctype (lp, ctype);

    lpPivot = (_CCPROC)MakeProcInstance ((FARPROC)pivot, hInst);
    setlpcallbackfunc( lp, lpPivot);
    optimize (lp);
    solution (lp, pstat, pobj, x, NULL, NULL, NULL);
    unloadprob (&lp);
    return ++Calls;
}


/* Define a "callback" function which computes the objective and constraint
   left hand sides, for any supplied values of the decision variables. */

INTARG _CC funceval1 (HPROBLEM lp, INTARG numcols, INTARG numrows,
    LPREALARG objval, LPREALARG lhs, LPREALARG var, INTARG varone,
    INTARG vartwo)
{
    objval[0] = var[0] * var[0]  + var[1] * var[1] ; /* objective */
    lhs[0] = var[0] + var[1]; /* constraint left hand side */
    lhs[1] = var[0] * var[1]; /* constraint left hand side */
    return 0;
}

/* Define and solve the example NLP problem */

long RunNLPSolver (HWND hWnd, long *pstat, double *pobj, double *x)
{
    double obj[2];
    double rhs[2] = {  1.0, 0.0 };
    char sense[2] = "EG";
    double matval[4];
    double lb[] = { -INFBOUND, -INFBOUND };
    double ub[] = { +INFBOUND, +INFBOUND };
    HPROBLEM lp = NULL;
    _FUNCEVAL lpFuncEval;
    _CCPROC lpPivot;

    setintparam( lp, PARAM_ARGCK, 1);
    lpFuncEval = (_FUNCEVAL)MakeProcInstance ((FARPROC)funceval1, hInst);
    lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
         NULL, NULL, NULL, matval, x, lb, ub, NULL, 4, lpFuncEval, NULL);
    if (!lp) return 0;
    if (hWnd == hWnd1) lp1 = lp; else lp2 = lp;

    lpPivot = (_CCPROC)MakeProcInstance ((FARPROC)pivot, hInst);
    setlpcallbackfunc( lp, lpPivot);
    optimize (lp);
    solution (lp, pstat, pobj, x, NULL, NULL, NULL);
    unloadprob (&lp);
    return ++Calls;
}
```

Calling the Solver DLL from Visual Basic

You can use many features of the Solver DLL with both 32-bit and 16-bit versions of Visual Basic 4.0 and above, and with most versions of Visual Basic Application Edition as embedded in various application programs such as Microsoft Office.

To use the nonlinear GRG Solver or the Evolutionary Solver with Visual Basic, however, you *must* use Visual Basic 5.0 or above, or Visual Basic Application Edition in Microsoft Office 2000 or above. Earlier versions of Visual Basic do not support the *AddressOf* operator, which is needed to pass the addresses of callback functions to the Solver DLL.

It is straightforward to use the Solver DLL with Visual Basic. You need only include the header file frontmip.bas or safrontmip.bas in your Visual Basic project, supply your license key (for example by including the header file frontkey.bas), and make calls to the Solver DLL entry points at the appropriate points in your program.

Basic Steps

To create a Visual Basic application that calls the Solver DLL, you must perform the following steps:

1. Include one of the header files **frontmip.bas** or **safrontmip.bas** in your Visual Basic project. (You should also include the license file **frontkey.bas** to obtain the license key string.)
2. Call at least the routines *loadlp()* or *loadnlp()*, *optimize(), solution()* and *unloadprob()* in that order.

You can use the example Visual Basic code in vbexamp1.frm and examp1.frm (when using frontmip.bas), or vbexamp2.frm and examp2.frm (when using safrontmip.bas) as a guide for getting the arguments right.

Passing Array Arguments

Before you write a Visual Basic application using the Solver DLL, you should read the section “Arrays and Callback Functions in Visual Basic” in the chapter “Designing Your Application.” You must decide whether to pass array arguments as C-style arrays or as SAFEARRAYs. C-style arrays were the only option in the Solver DLL

Versions 2.0 and 1.0 – but they cannot be used with the nonlinear GRG Solver or the Evolutionary Solver in the Solver DLL Version 3.5. For new applications built with the Solver DLL V3.5 and Visual Basic 5.0 or above, we recommend that you use SAFEARRAYs.

To pass arguments as SAFEARRAYs, follow all of these steps:

1. Include the header file **safrontmip.bas** in your project.
2. Set the parameter PARAM_ARRAY to 1 *before* you call any of the other Solver DLL routines (except as needed to set other parameters). To do this, use a statement such as:

```
setintparam PARAM_ARRAY, 1
```

3. When you pass an array argument, use the name of the array (such as `obj` or `matval`) without any subscript.

To pass array arguments as C-style arrays, follow all of these steps:

1. Include the header file **frontmip.bas** in your project.
2. Ensure that the parameter PARAM_ARRAY is 0 *before* you call any of the other Solver DLL routines (it is 0 by default, unless you change it).
3. When you pass an array argument, use the first element of the array (such as `obj(0)` or `matval(0)`), with a subscript .

The example Visual Basic project vbexamp1.vbp uses frontmip.bas and C-style arrays; it can be opened and run in Visual Basic 4.0 (16-bit or 32-bit) or in Visual Basic 5.0 and above (32-bit only). The example project vbexamp2.vbp uses safrontmip.bas and SAFEARRAYs; it can be opened and run only in Visual Basic 5.0 and above.

You can pass array arguments as C-style arrays in Visual Basic 5.0 or above, if you wish. However, any callback function *funceval()* that you write for use with the nonlinear or nonsmooth Solver "engines" will only be able to access the first element of the array arguments passed to it – which means that you can solve at most a nonlinear problem with one variable and one constraint.

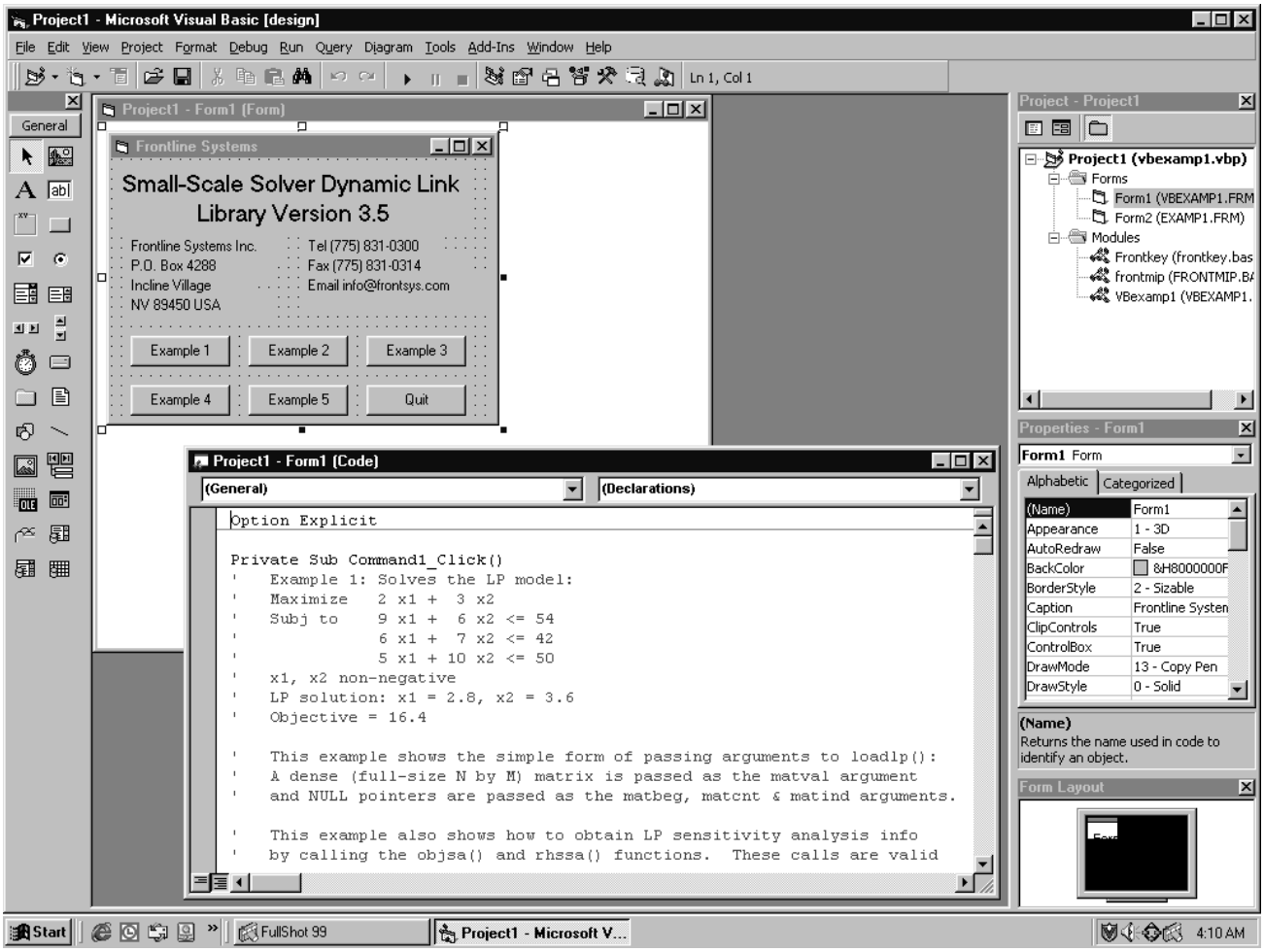
Building a 32-Bit Visual Basic Program

You can run the compiled versions of the Visual Basic examples vbexamp1.exe and vbexamp2.exe using **Start Run**. These programs, like all Visual Basic applications, rely on the Visual Basic runtime system DLLs; if you have installed either the Visual Basic programming system or some other Visual Basic program, these DLLs should already be present in your Windows system directory.

You can edit, build and test the source code of vbexamp1.exe (vbexamp2.exe is similar) as follows:

1. Start the Visual Basic programming system. In the New Project dialog, click on the Existing tab, navigate to the Visual Basic example subdirectory (for example **c:\frontmip\examples\vbexamp**), select **vbexamp1.vbp** and click Open.
2. The Visual Basic system will load the project file, the related form files (vbexamp1.frm and examp1.frm) and the related module file (vbexamp1.bas) as well as the header files frontmip.bas and frontkey.bas. (*Note:* Since the form files in this project were saved in a format compatible with Visual Basic 4.0, you may see the message "This file was saved in a previous version of Visual Basic" – just click OK (or OK For All) in response to this message.)

3. By selecting these files in the project list and clicking on **View Form** or **View Code**, you can examine and (if desired) modify the elements of this application. After opening vbexamp1.vbp and clicking on View Form and View Code, your screen should resemble the picture below.

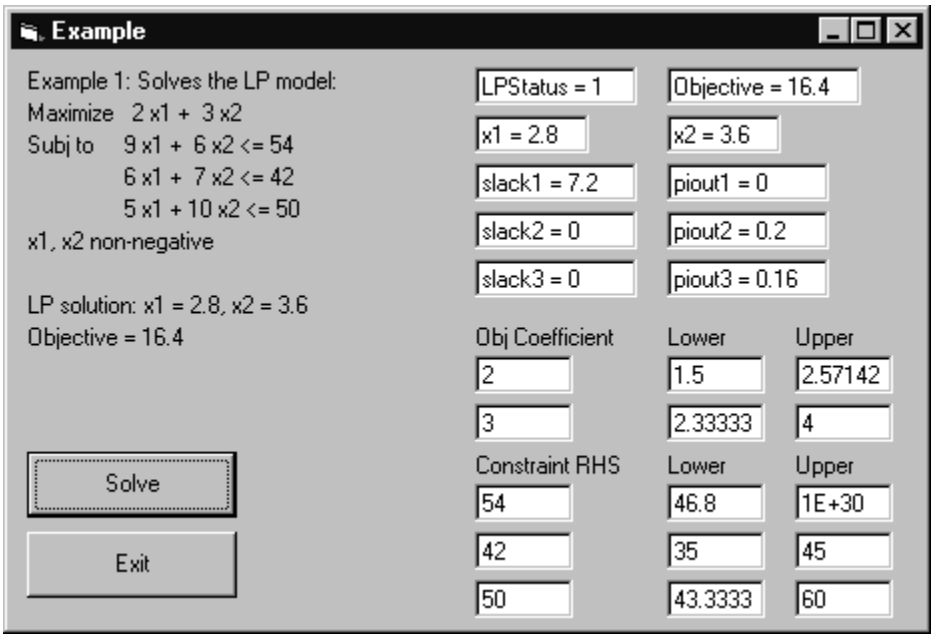


3. To test-run the program within the Visual Basic programming system, select **Run Start** and then click on one of the buttons labeled “Example 1” through “Example 5.” This will display a form with comments, output fields, and “Solve” and “Exit” buttons. If you click the button “Example 1” and then click “Solve,” for example, the output fields will appear filled with values, as shown on the following page.

4. Example 2 uses the *lpwrite()* function to create a file vbexamp1, containing an algebraic statement of its problem, in the Visual Basic program directory (for example C:\DevStudio\VB). Example 5 uses the *lpread()* function to read this file and define and solve the same problem, without setting up all of the array arguments normally required. To end execution of the program, click the Exit button on the Example Problem form, and the Quit button on the main form.

5. To trace execution of this program, select **Debug Step Into** and press the F8 key to execute one Visual Basic statement at a time. You will see that the routine *Sub Command1_Click()* that is executed when you click the “Example 1” button sets up the various array arguments needed to call the Solver DLL, then loads the form examp1.frm. The routine *Sub Command1_Click()* on this form that is

executed when you click "Solve" calls the various Solver DLL routines such as *loadlp()*, *optimize()* and *solution()*.



6. To produce a binary executable version of your Visual Basic application, select **File Make vbexamp1.exe** Note that this executable version still requires the Visual Basic runtime system DLLs, as well as the Solver DLL frontmip.dll.

Building a 16-Bit Visual Basic Program

In 16-bit Visual Basic 4.0, you may open the same project file vbexamp1.vbp illustrated above for 32-bit Visual Basic 5.0. To do so:

1. Start the Visual Basic programming system. Select **File Open Project…** and navigate to the Visual Basic example subdirectory (for example **c:\frontmip\examples\vbexamp**), select **vbexamp1.vbp** and click OK.
2. The Visual Basic system will load the project file, the related form and module files, and the header files frontmip.bas and frontkey.bas. Because this project (i) was saved in Visual Basic 4.0 format and (ii) uses frontmip.bas and C-style arrays, it is backward compatible with the 16-bit Visual Basic system.
3. When you run the program, the forms and buttons look and behave in the same way. You simply need to ensure that your program finds and loads the 16-bit version of frontmip.dll instead of the 32-bit version, by placing it in the current directory, or a directory in your PATH.

However, you cannot open and run the project file vbexamp2.vbp. This project was saved in Visual Basic 5.0 format, and it uses safrontmip.bas, SAFEARRAYs, and the AddressOf operator, which are not compatible with the 16-bit Visual Basic system. Most new Visual Basic applications are targeted for 32-bit systems such as Windows 95/98 and Windows NT/2000, and new features of the Solver DLL are likely to be targeted to these platforms as well.

Visual Basic Source Code: Linear / Quadratic Problems

The Visual Basic source code from the files vbexamp1.bas, vbexamp1.frm and examp1.frm is listed below. It includes five example problems for the Solver DLL, which are set up and solved when you click on the appropriate buttons. The first example is a simple two-variable LP problem. The second example – for which source code in Delphi Pascal and FORTRAN is also included – is a MIP problem, identical to the previous LP problem except that the decision variables are required to have integer values. The third example attempts to solve an LP problem that is infeasible, then it uses the IIS finder to diagnose the infeasibility. The fourth example is a quadratic programming problem, using the classic Markowitz method to find an efficient portfolio of five securities. The fifth example uses the *lpread()* function to read in a problem in "algebraic notation" from a text file that was created by the *lpwrite()* function in the second example.

You are encouraged to study this source code (or the C/C++ source code) and the comments in each problem, even if you plan to use a language other than Visual Basic for most of your work. The C/C++ and Visual Basic example code is more extensive than the examples for the other languages, and illustrates most of the features of the Solver DLL including the Quadratic Solver, the Evolutionary Solver, automatic diagnosis of infeasible problems, and use of the *lpread()* and *lpwrite()* functions.

```
VBEXAMP1.BAS
------------

Global obj() As Double
Global rhs() As Double
Global sense() As Byte
Global ctype() As Byte
Global matbeg() As Long
Global matcnt() As Long
Global matind() As Long
Global matval() As Double
Global qmatbeg() As Long
Global qmatcnt() As Long
Global qmatind() As Long
Global qmatval() As Double
Global lb() As Double
Global ub() As Double
Global stat As Long
Global objval As Double
Global x() As Double
Global piout() As Double
Global slack() As Double
Global dj() As Double
Global varlow() As Double
Global varupp() As Double
Global conlow() As Double
Global conupp() As Double
Global lp As Long

'  The call to lpcallback in EXAMP1.FRM is commented out for compatibility
'  with 16-bit Visual Basic 4.0.


Function lpcallback(ByVal lpinfo As Long, ByVal wherefrom As Long) As Long
   Dim iters As Long
   Dim obj As Double
   Dim ret As Long
   ret = getcallbackinfo(lpinfo, wherefrom, CBINFO_ITCOUNT, iters)
   ret = getcallbackinfo(lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, obj)
```

```
   MsgBox "Iteration: " & Trim(Str(iters)) & "  Obj = " & Trim(Str(obj))
   lpcallback = PSTAT_CONTINUE
End Function

Sub AdjustFormforExample2()
   [detail omitted]
End Sub

Sub AdjustFormforExample3()
   [detail omitted]
End Sub

Sub AdjustFormforExample4()
   [detail omitted]
End Sub

Sub AdjustFormforExample5()
   [detail omitted]
End Sub


VBEXAMP1.FRM
------------

Private Sub Command1_Click()
'  Example 1: Solves the LP model:
'  Maximize   2 x1 +  3 x2
'  Subj to    9 x1 +  6 x2 <= 54
'             6 x1 +  7 x2 <= 42
'             5 x1 + 10 x2 <= 50
'  x1, x2 non-negative
'  LP solution: x1 = 2.8, x2 = 3.6
'  Objective = 16.4

'  This example shows the simple form of passing arguments to loadlp():
'  A dense (full-size N by M) matrix is passed as the matval argument
'  and NULL pointers are passed as the matbeg, matcnt & matind arguments.

'  This example also shows how to obtain LP sensitivity analysis info
'  by calling the objsa() and rhssa() functions.  These calls are valid
'  only for LP problems.  For QP problems, only dual values (the piout
'  and dj arguments of solution()) are available; for MIP problems, no
'  sensitivity analysis info is available (none would be meaningful).
'
'  This example uses a callback function to display the LP iterations.

   ReDim obj(0 To 1) As Double
   obj(0) = 2
   obj(1) = 3
   ReDim rhs(0 To 2) As Double
   rhs(0) = 54
   rhs(1) = 42
   rhs(2) = 50
   ReDim sense(0 To 2) As Byte
   ' L's for <=, E's for =, G's for >=
   sense(0) = Asc("L")
   sense(1) = Asc("L")
   sense(2) = Asc("L")
   ReDim matval(0 To 5) As Double
   matval(0) = 9
   matval(1) = 6
   matval(2) = 5
   matval(3) = 6
   matval(4) = 7
   matval(5) = 10
   ReDim lb(0 To 1) As Double
   lb(0) = 0
```

```
   lb(1) = 0
   ReDim ub(0 To 1) As Double
   ub(0) = INFBOUND
   ub(1) = INFBOUND
   ReDim x(0 To 1) As Double
   ReDim piout(0 To 2) As Double
   ReDim slack(0 To 2) As Double
   ReDim dj(0 To 1) As Double
   ReDim varlow(0 To 1) As Double
   ReDim varupp(0 To 1) As Double
   ReDim conlow(0 To 2) As Double
   ReDim conupp(0 To 2) As Double

   Form2.Show
End Sub


Private Sub Command2_Click()

'  Example 2: Solves the MIP model:
'  Maximize   2 x1 +  3 x2
'  Subj to    9 x1 +  6 x2 <= 54
'             6 x1 +  7 x2 <= 42
'             5 x1 + 10 x2 <= 50
'  x1, x2 non-negative, integer
'  MIP solution: x1 = 2, x2 = 4
'  Objective = 16

'  This example illustrates the full set of arguments, used to pass a
'  potentially sparse matrix to loadlp.  For each variable (column) i,
'  matbeg[i] and matcnt[i] are the beginning index and count of non-
'  zero coefficients in the matind and matval arrays.  For each such
'  coefficient, matind[k] is the constraint (row) index and matval[i]
'  is the coefficient value.  See the documentation for more details.

'  In this example, we also use two debugging features of the Solver
'  DLL:  (1) We call setintparam() to enable the display of error
'  MessageBoxes by the DLL routines if they detect an invalid value
'  in one of the arguments we pass (since there are no errors, none
'  will appear).  (2) We call lpwrite() to write out a file which
'  summarizes the LP/MIP problem in algebraic form.  This can help
'  us verify that the arguments we pass have defined the right problem.
'
   ReDim obj(0 To 1) As Double
   obj(0) = 2
   obj(1) = 3
   ReDim rhs(0 To 2) As Double
   rhs(0) = 54
   rhs(1) = 42
   rhs(2) = 50
   ReDim sense(0 To 2) As Byte
   ' L's for <=, E's for =, G's for >=
   sense(0) = Asc("L")
   sense(1) = Asc("L")
   sense(2) = Asc("L")
   ReDim ctype(0 To 1) As Byte
   ' I = integer, B = binary, C = continuous
   ctype(0) = Asc("I")
   ctype(1) = Asc("I")
   ReDim matbeg(0 To 1) As Long
   matbeg(0) = 0
   matbeg(1) = 3
   ReDim matcnt(0 To 1) As Long
   matcnt(0) = 3
   matcnt(1) = 3
   ReDim matind(0 To 5) As Long
   matind(0) = 0
```

```
   matind(1) = 1
   matind(2) = 2
   matind(3) = 0
   matind(4) = 1
   matind(5) = 2
   ReDim matval(0 To 5) As Double
   matval(0) = 9
   matval(1) = 6
   matval(2) = 5
   matval(3) = 6
   matval(4) = 7
   matval(5) = 10
   ReDim lb(0 To 1) As Double
   lb(0) = 0
   lb(1) = 0
   ReDim ub(0 To 1) As Double
   ub(0) = INFBOUND
   ub(1) = INFBOUND
   ReDim x(0 To 1) As Double

   AdjustFormforExample2
   Form2.Show
End Sub


Private Sub Command3_Click()

'  Example 3: Attempt to solve the LP model:
'  Maximize   2 x1 +  3 x2
'  Subj to    9 x1 +  6 x2 <= 54
'             6 x1 +  7 x2 <= 42
'             5 x1 + 10 x2 <= -50
'  x1, x2 non-negative
'  Infeasible (due to non-negative variables and negative RHS)

'  When solution() returns stat = PSTAT_INFEASIBLE, ask Solver DLL
'  to find an Irreducibly Infeasible Subset (IIS) of the constraints:
'  Row 2 (with the negative RHS) and lower bounds on both variables

'  The constraint matrix is passed in simple (dense) form in matval[].

   ReDim obj(0 To 1) As Double
   obj(0) = 2
   obj(1) = 3
   ReDim rhs(0 To 2) As Double
   rhs(0) = 54
   rhs(1) = 42
   rhs(2) = -50
   ReDim sense(0 To 2) As Byte
   ' L's for <=, E's for =, G's for >=
   sense(0) = Asc("L")
   sense(1) = Asc("L")
   sense(2) = Asc("L")
   ReDim matval(0 To 5) As Double
   matval(0) = 9
   matval(1) = 6
   matval(2) = 5
   matval(3) = 6
   matval(4) = 7
   matval(5) = 10
   ReDim lb(0 To 1) As Double
   lb(0) = 0
   lb(1) = 0
   ReDim ub(0 To 1) As Double
   ub(0) = INFBOUND
   ub(1) = INFBOUND
   ReDim x(0 To 1) As Double
```

```
   AdjustFormforExample3
   Form2.Show
End Sub


Private Sub Command4_Click()

'  Example 4: Use the QP solver to perform
'  Markowitz-style portfolio optimization.
'  Variables are the percentages to be allocated
'  to each investment or asset class:
'     0 <= x1, x2, x3, x4 x5 <= 1
'  Minimize portfolio variance: [xi] Q [xi]
'  Subj to allocations: Sum (xi) = 1
'     and portfolio return: Sum (Ri xi) >= 0.085

'  The efficient portfolio is the QP solution (approx):
'     x1 = 0.462  x2 = 0  x3 = 0.313  x4 = 0  x5 = 0.225
'  The objective = approx. 0.00014 (minimum variance)

'  Both the constraint matrix and the Q matrix are passed
'  using the full set of arguments for sparse matrices.

   Dim i As Long
   ReDim obj(0 To 4) As Double
   For i = 0 To 4
      obj(i) = 0
   Next
   ReDim rhs(0 To 1) As Double
   rhs(0) = 1#
   rhs(1) = 0.085
   ReDim sense(0 To 1) As Byte
   sense(0) = Asc("E")
   sense(1) = Asc("G")
   ReDim matbeg(0 To 4) As Long
   ReDim matcnt(0 To 4) As Long
   ReDim matind(0 To 9) As Long
   ReDim lb(0 To 4) As Double
   ReDim ub(0 To 4) As Double
   For i = 0 To 4
      matbeg(i) = 2 * i
      matcnt(i) = 2
      matind(2 * i) = 0
      matind(2 * i + 1) = 1
      lb(i) = 0
      ub(i) = 1
   Next
   ReDim matval(0 To 9) As Double
   matval(0) = 1
   matval(1) = 0.086
   matval(2) = 1
   matval(3) = 0.071
   matval(4) = 1
   matval(5) = 0.095
   matval(6) = 1
   matval(7) = 0.107
   matval(8) = 1
   matval(9) = 0.069

   ReDim qmatbeg(0 To 4) As Long
   ReDim qmatcnt(0 To 4) As Long
   ReDim qmatind(0 To 24) As Long
   For i = 0 To 4
       qmatbeg(i) = 5 * i
       qmatcnt(i) = 5
       qmatind(i) = i
```

```
        qmatind(i + 5) = i
        qmatind(i + 10) = i
        qmatind(i + 15) = i
        qmatind(i + 20) = i
    Next
    ReDim qmatval(0 To 24) As Double
    ' The Q matrix specifies the covariance between each pair of assets
    qmatval(0) = 0.000204
    qmatval(1) = 0.000424
    qmatval(2) = 0.00017
    qmatval(3) = 0.000448
    qmatval(4) = -0.000014
    qmatval(5) = 0.000424
    qmatval(6) = 0.012329
    qmatval(7) = 0.001785
    qmatval(8) = 0.001633
    qmatval(9) = -0.000539
    qmatval(10) = 0.00017
    qmatval(11) = 0.001785
    qmatval(12) = 0.000365
    qmatval(13) = 0.000425
    qmatval(14) = -0.000075
    qmatval(15) = 0.000448
    qmatval(16) = 0.001633
    qmatval(17) = 0.000425
    qmatval(18) = 0.005141
    qmatval(19) = 0.000237
    qmatval(20) = -0.000014
    qmatval(21) = -0.000539
    qmatval(22) = -0.000075
    qmatval(23) = 0.000237
    qmatval(24) = 0.000509
    ReDim x(0 To 4) As Double

    AdjustFormforExample4
    Form2.Show
End Sub


Private Sub Command5_Click()
    End
End Sub


Private Sub Command6_Click()

'  Here we use the lpread() function to read in the model.

'  First, we assume that the dimensions of the problem
'  are known.  We call loadlp(), passing array arguments
'  of the proper dimension.  Since the sense[] and ctype[]
'  arrays are checked for validity, we initialize them.

    ReDim obj(0 To 1) As Double
    ReDim rhs(0 To 2) As Double
    ReDim sense(0 To 2) As Byte
    ReDim ctype(0 To 1) As Byte
    ReDim matbeg(0 To 1) As Long
    ReDim matcnt(0 To 1) As Long
    ReDim matind(0 To 5) As Long
    ReDim matval(0 To 5) As Double
    ReDim lb(0 To 1) As Double
    ReDim ub(0 To 1) As Double
    ReDim x(0 To 1) As Double

    AdjustFormforExample5
    Form2.Show
```

```
End Sub


EXAMP1.FRM
----------

Private Sub Command1_Click()

   ' set up the LP problem

   Select Case Left(Form2.Label1, 9)

   Case "Example 1"
       lp = loadlp(PROBNAME, 2, 3, -1, obj(0), rhs(0), sense(0), _
             -1, -1, -1, matval(0), lb(0), ub(0), -1, 2, 3, 6)

       If (lp = 0) Then Exit Sub

       ' set up the callback
       ' setlpcallbackfunc lp, AddressOf lpcallback

       ' solve the problem
       optimize lp

       ' obtain the solution: display objective and variables
       solution lp, stat, objval, x(0), piout(0), slack(0), dj(0)
       Form2.Text3 = "LPStatus = " & Trim(Str(stat))
       Form2.Text4 = "Objective = " & Trim(Str(objval))

       ' display constraint slacks and dual values
       Form2.Text1 = "x1 = " & x(0)
       Form2.Text2 = "x2 = " & x(1)

       Form2.Text5 = "slack1 = " & slack(0)
       Form2.Text6 = "piout1 = " & piout(0)
       Form2.Text7 = "slack2 = " & slack(1)
       Form2.Text8 = "piout2 = " & piout(1)
       Form2.Text24 = "slack3 = " & slack(2)
       Form2.Text25 = "piout3 = " & piout(2)

       ' obtain and display sensitivity analysis information
       objsa lp, 0, 1, varlow(0), varupp(0)
       Form2.Text9 = obj(0)
       Form2.Text10 = varlow(0)
       Form2.Text11 = varupp(0)
       Form2.Text12 = obj(1)
       Form2.Text13 = varlow(1)
       Form2.Text14 = varupp(1)

       rhssa lp, 0, 2, conlow(0), conupp(0)

       Form2.Text15 = rhs(0)
       Form2.Text16 = conlow(0)
       Form2.Text17 = conupp(0)
       Form2.Text18 = rhs(1)
       Form2.Text19 = conlow(1)
       Form2.Text20 = conupp(1)
       Form2.Text21 = rhs(2)
       Form2.Text22 = conlow(2)
       Form2.Text23 = conupp(2)

       ' remove the callback function
       setlpcallbackfunc lp, 0

       ' call unloadprob() to release memory
       unloadprob lp
```

```
Case "Example 2"
    lp = loadlp(PROBNAME, 2, 3, -1, obj(0), rhs(0), sense(0), _
          matbeg(0), matcnt(0), matind(0), matval(0), lb(0), ub(0), _
          -1, 2, 3, 6)

    If (lp = 0) Then Exit Sub

    loadctype lp, ctype(0)

    ' lpwrite() can be called anytime after the problem
    ' is defined, and before unloadprob() is called.  It
    ' will write out the following text in file vbexamp1:
    ' Maximize LP / MIP
    ' obj: 2.0 x1 + 3.0 x2
    ' Subject To
    ' c1:  9.0 x1 + 6.0 x2 <= 54.0
    ' c2:  6.0 x1 + 7.0 x2 <= 42.0
    ' c3:  5.0 x1 + 10.0 x2 <= 50.0
    ' Bounds
    ' 0.0 <= x1 <= +infinity
    ' 0.0 <= x2 <= +infinity
    ' Integers
    ' x1
    ' x2
    ' End
    lpwrite lp, "vbexamp1"

    'solve the problem
    mipoptimize lp

    ' obtain the solution: display objective and variables
    solution lp, stat, objval, x(0), -1, -1, -1
    Form2.Text3 = "LPStatus = " & Trim(Str(stat))
    Form2.Text4 = "Objective = " & Trim(Str(objval))

    Form2.Text1 = "x1 = " & x(0)
    Form2.Text2 = "x2 = " & x(1)

    ' call unloadprob() to release memory
    unloadprob lp


 Case "Example 3"
    Dim iisrows As Long
    Dim iiscols As Long
    lp = loadlp(PROBNAME, 2, 3, -1, obj(0), rhs(0), sense(0), _
          -1, -1, -1, matval(0), lb(0), ub(0), -1, 2, 3, 6)

    If (lp = 0) Then Exit Sub

    ' solve the problem
    optimize lp

    ' obtain the solution: display objective and variables
    solution lp, stat, objval, x(0), -1, -1, -1
    Form2.Text3 = "LPStatus = " & Trim(Str(stat))
    Form2.Text4 = "Objective = " & Trim(Str(objval))

    ' if infeasible, find and display an Irreducibly
    ' Infeasible Subset (IIS) of the constraints

    If stat = PSTAT_INFEASIBLE Then
       findiis lp, iisrows, iiscols
       MsgBox "Findiis: iisrows = " & Trim(Str(iisrows)) _
          & " iiscols = " & Trim(Str(iiscols))
       Form2.Text1 = "iisrows = " & Trim(Str(iisrows))
```

```
      Form2.Text2 = "iiscols = " & Trim(Str(iiscols))

      ReDim rowbdstat(iisrows - 1) As Long
      ReDim colbdstat(iiscols - 1) As Long
      ReDim rowind(iisrows - 1) As Long
      ReDim colind(iiscols - 1) As Long
      getiis lp, stat, rowind(0), rowbdstat(0), iisrows, _
         colind(0), colbdstat(0), iiscols
      Form2.Text5 = "rowind1 = " & rowind(0)
      Form2.Text6 = "rowbdstat1 = " & rowbdstat(0)
      Form2.Text7 = "colind1 = " & colind(0)
      Form2.Text8 = "colbdstat1 = " & colbdstat(0)
      Form2.Text24 = "colind2 = " & colind(1)
      Form2.Text25 = "colbdstat2 = " & colbdstat(1)

      iiswrite lp, "iisexamp.txt"
   End If

   ' call unloadprob() to release memory
   unloadprob lp


Case "Example Q"
   ' set up the LP portion of the problem.  The LP portion
   ' of the objective is all 0's here; it could be elaborated
   ' to include transaction costs or other factors.

   lp = loadlp(PROBNAME, 5, 2, 1, obj(0), rhs(0), sense(0), _
         matbeg(0), matcnt(0), matind(0), matval(0), lb(0), ub(0), _
         -1, 5, 2, 10)

   If (lp = 0) Then Exit Sub

   ' now set up the Q matrix to define the quadratic objective
   loadquad lp, qmatbeg(0), qmatcnt(0), qmatind(0), qmatval(0), _
         25, x(0)

   ' solve the problem; obtain and display the solution
   optimize lp
   solution lp, stat, objval, x(0), -1, -1, -1

   Form2.Text3 = "LPStatus = " & Trim(Str(stat))
   Form2.Text4 = "Obj = " & Trim(Format(objval, "0.0####"))

   Form2.Text1 = "x1 = " & x(0)
   Form2.Text2 = "x2 = " & x(1)
   Form2.Text5 = "x3 = " & x(2)
   Form2.Text6 = "x4 = " & x(3)
   Form2.Text7 = "x5 = " & x(4)

   ' call unloadprob() to release memory
   unloadprob lp


Case "Example 5"
   ' we merely pass the right sizes on. Since "sense" and "ctype" get
   ' checked for validity, we do initialize them

   sense(0) = Asc("L")
   sense(1) = Asc("L")
   sense(2) = Asc("L")
   ctype(0) = Asc("C")
   ctype(1) = Asc("C")

   lp = loadlp(PROBNAME, 2, 3, -1, obj(0), rhs(0), sense(0), _
         -1, -1, -1, matval(0), lb(0), ub(0), -1, 2, 3, 6)
```

```
        If (lp = 0) Then Exit Sub
        loadctype lp, ctype(0)

        ' Now we read in the textfile "vbexamp1", and all arrays
        ' are filled in automatically

        ret = lpread(lp, "vbexamp1", -1, -1, -1, -1, -1, -1)

        If (ret <> 0) Then
           MsgBox "Please run Example 2 first to create a textfile containing
the problem."
           unloadprob lp
           Exit Sub
        End If

        ' we can immediately solve the problem.
        mipoptimize lp

        ' obtain the solution: display objective and variables
        solution lp, stat, objval, x(0), -1, -1, -1
        Form2.Text3 = "LPStatus = " & Trim(Str(stat))
        Form2.Text4 = "Objective = " & Trim(Str(objval))

        Form2.Text1 = "x1 = " & x(0)
        Form2.Text2 = "x2 = " & x(1)

        ' call unloadprob() to release memory
        unloadprob lp


        ' Next, we assume that the dimensions of the problem are
        ' not known in advance.  We can call lpread() with a NULL
        ' first argument to read the file and obtain the actual
        ' problem dimensions.  Then, we would allocate arrays of
        ' appropriate size (to keep this example simple, we'll
        ' re-use the arrays from the first example above).  We call
        ' loadlp() to define a problem and return a pointer to it.
        ' Next, we call lpread() again to read in the actual array
        ' values.  Then we'll be ready to call mipoptimize().

        ' Call lpread() to obtain the problem dimensions.  If
        ' the matcnt argument is passed (needed only for sparse
        ' problems), it must have at least as many elements as the
        ' number of variables in the largest problem to be handled.
        ' (If necessary, you can call lpread() twice, the first
        ' time to get this size via the numcols argument.)

        Dim objsen As Long
        Dim numcols As Long
        Dim numrows As Long
        Dim numints As Long
        Dim nzspace As Long
        Dim i As Long

        MsgBox "Read problem of unknown size"
        Form2.Text1 = ""
        Form2.Text2 = ""
        Form2.Text3 = ""
        Form2.Text4 = ""

        lpread 0, "vbexamp1", objsen, numcols, numrows, numints, _
           matcnt(0), -1

        ' We would now allocate the x[], obj[], lb[], ub[], and
        ' (if used) ctype[] and matbeg[] arrays to have numcols
        ' elements, and the rhs[] and sense[] arrays to have
        ' numrows elements.  For a dense problem, matval[] should
```

```
        ' be allocated to have numcols * numrows elements.  For a
        ' sparse problem, the matind[] and matval[] arrays should
        ' be allocated to have nzspace elements, where nzspace is
        ' the sum of the counts in matcnt[] as returned by lpread().
        ' (To keep this example simple, we'll re-use the arrays
        ' from the first example above).

        nzspace = 0
        For i = 0 To numcols - 1
           nzspace = nzspace + matcnt(i)
        Next
        ' (we could now allocate matind[] and matval[] based on nzspace)
        For i = 0 To nzspace - 1
           matval(i) = 0
           matind(i) = 0
        Next
        ' matval[] and matind[] will be filled in by our next call to
        ' lpread(); we need only initialize matbeg[] based on matcnt[]
        matbeg(0) = 0
        For i = 1 To numcols - 1
           matbeg(i) = matbeg(i - 1) + matcnt(i - 1)
        Next
        ' Next, call loadlp() and loadctype() to define the problem
        ' and pass in arrays of appropriate dimension.

        lp = loadlp(PROBNAME, numcols, numrows, objsen, obj(0), rhs(0),
           sense(0), -1, -1, -1, matval(0), lb(0), ub(0), -1, _
           numcols, numrows, nzspace)

        If (lp = 0) Then Exit Sub
        loadctype lp, ctype(0)

        ' Now we call lpread() to read in the actual array values.

        lpread lp, "vbexamp1", -1, -1, -1, -1, -1, -1

        'Finally, we call mipoptimize() and display the solution.

        mipoptimize lp

        ' obtain the solution: display objective and variables
        solution lp, stat, objval, x(0), -1, -1, -1
        Form2.Text3 = "LPStatus = " & Trim(Str(stat))
        Form2.Text4 = "Objective = " & Trim(Str(objval))

        Form2.Text1 = "x1 = " & x(0)
        Form2.Text2 = "x2 = " & x(1)

        ' call unloadprob() to release memory
        unloadprob lp
    End Select
End Sub

Private Sub Command2_Click()
    Unload Form2
End Sub

Private Sub Form_Activate()
    Form2.Command1.SetFocus
End Sub
```

Visual Basic Source Code: Nonlinear / Nonsmooth Problems

The Visual Basic source code from the files vbexamp2.frm, examp2.frm and vbexamp2.bas is listed below. It includes four example problems for the nonlinear GRG Solver, which are set up and solved when you click on the appropriate buttons. The first example is a simple two-variable nonlinear optimization problem, which defines a *funceval()* routine to evaluate the problem functions. The second example is identical to the first one, except that a *jacobian()* routine is also defined, to give the Solver faster and more accurate partial derivatives of the problem functions. The third example attempts to solve a nonlinear problem that is infeasible, then it uses the IIS finder to diagnose the infeasibility. The fourth example illustrates how you can solve a series of linear and nonlinear problems, using the *testnltype()* function to determine whether the problem defined by your *funceval()* routine is linear, and how you can switch to the LP Solver engine if *testnltype()* finds that a problem is entirely linear.

Also included in vbexamp2.frm, examp2.frm and vbexamp2.bas are two example problems using the Evolutionary Solver. The first of these finds the global optimum of a classic two-variable problem, the Branin function, which has three local optima. The second one finds the optimal solution of a three-variable problem where the objective function involves an "IF statement," which is nonsmooth (in fact discontinuous) in the variable X.

You are encouraged to study this source code (or the C/C++ source code) and the comments in each problem, even if you plan to use a language other than Visual Basic for most of your work. Like the example source code for linear and quadratic problems, these example files are more extensive than the ones for the other languages.

```
VBEXAMP2.BAS
------------

Global Nonlinear As Boolean
Global Example As Long


Function funceval1(lp As Long, ByVal numcols As Integer, _
    ByVal numrows As Integer, ByRef objval As Double, _
    ByRef lhs() As Double, ByRef var() As Double, _
    ByVal varone As Integer, ByVal vartwo As Integer) As Long
    Err = 0
    On Error Resume Next
    ' The use of the addressof operator can crash VB. We never return
    ' an error value to the DLL.  Therefore, use on error resume next
    objval = var(0) * var(0) + var(1) * var(1) ' objective
    lhs(0) = var(0) + var(1) ' constraint left hand side
    lhs(1) = var(0) * var(1) ' constraint left hand side
    funceval = 0
End Function


Function showiter1(ByVal lp As Long, ByVal wherefrom As Long) As Long
   Dim itercount As Long
   Dim objval As Double
   Dim ret As Long
   ret = getcallbackinfo(lpinfo, wherefrom, CBINFO_ITCOUNT, itercount)
   ret = getcallbackinfo(lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, objval)
   MsgBox "Iteration :" & itercount & "  Objective = " & objval
```

```
   showiter1 = 0
End Function


Function funceval3(lp As Long, ByVal numcols As Integer, _
   ByVal numrows As Integer, ByRef objval As Double, _
   ByRef lhs() As Double, ByRef var() As Double, _
   ByVal varone As Integer, ByVal vartwo As Integer) As Long
    Err = 0
    On Error Resume Next
    ' The use of the addressof operator can crash VB. We never return
    ' an error value to the DLL.  Therefore, use on error resume next
    objval = var(0) * var(0) + var(1) * var(1) ' objective
    lhs(0) = var(0) * var(1) ' constraint left hand side
    lhs(1) = var(0) * var(1) ' constraint left hand side
    funceval3 = 0
End Function


Function funceval4(lp As Long, ByVal numcols As Integer, _
   ByVal numrows As Integer, ByRef objval As Double, _
   ByRef lhs() As Double, ByRef var() As Double, _
   ByVal varone As Integer, ByVal vartwo As Integer) As Long
    Err = 0
    On Error Resume Next
    ' The use of the addressof operator can crash VB. We never return
    ' an error value to the DLL.  Therefore, use on error resume next
    If Nonlinear Then
        objval = var(0) * var(0) + var(1) * var(1) ' objective
        lhs(0) = var(0) + var(1) ' constraint left hand side
        lhs(1) = var(0) * var(1) ' constraint left hand side
    Else
        objval = 2 * var(0) + var(1) ' objective
        lhs(0) = var(0) + var(1) ' constraint left hand side
        lhs(1) = 3 * var(0) - var(1) ' constraint left hand side
    End If
    funceval4 = 0
End Function


Function funceval5(lp As Long, ByVal numcols As Integer, _
   ByVal numrows As Integer, ByRef objval As Double, _
   ByRef lhs() As Double, ByRef var() As Double, _
   ByVal varone As Integer, ByVal vartwo As Integer) As Long
    Err = 0
    On Error Resume Next
    Dim term1 As Double, term2 As Double, term3 As Double
    Dim PI As Double
    PI = 3.141593
    ' The use of the addressof operator can crash VB. We never return
    ' an error value to the DLL.  Therefore, use on error resume next
    term1 = var(0) / PI * (5.1 * var(0) / PI / 4# - 5#)
    term2 = (var(1) - term1 - 6) * (var(1) - term1 - 6)
    term3 = 10# * (1# - 1# / PI / 8#) * Cos(var(0)) + 10#
    objval = term2 + term3
    funceval5 = 0
End Function


Function funceval6(lp As Long, ByVal numcols As Integer, _
   ByVal numrows As Integer, ByRef objval As Double, _
   ByRef lhs() As Double, ByRef var() As Double, _
   ByVal varone As Integer, ByVal vartwo As Integer) As Long
    Err = 0
    On Error Resume Next
    If var(0) > 10 Then
       objval = var(1) + var(2)
```

```
    Else
       objval = var(1) - var(2)
    End If
    funceval6 = 0
End Function


Function jacobian1(lp As Long, ByVal numcols As Integer, _
    ByVal numrows As Integer, ByVal nzspace As Integer, _
    ByRef objval As Double, ByRef obj() As Double, _
    ByRef matbeg() As Long, ByRef matcnt() As Long, _
    ByRef matind() As Long, ByRef matval() As Double, _
    ByRef var() As Double,  ByRef objtype() As Byte, _
    ByRef matvaltype() As Byte) As Long

    Err = 0
    On Error Resume Next
    MsgBox "jacobian evaluated at: x1 = " & var(0) & " x2 = " & var(1)
    ' Value of the objective function
    objval = var(0) * var(0) + var(1) * var(1)
    ' Partial derivatives of the objective
    obj(0) = 2 * var(0)
    obj(1) = 2 * var(1)
    ' Partial derivatives of X + Y (constant)
    matval(0) = 1
    matval(2) = 1
    ' Partial derivatives of X * Y (variable)
    matval(1) = var(1)
    matval(3) = var(0)
    jacobian1 = 0
End Function


Function jacobian3(lp As Long, ByVal numcols As Integer, _
    ByVal numrows As Integer, ByVal nzspace As Integer, _
    ByRef objval As Double, ByRef obj() As Double, _
    ByRef matbeg() As Long, ByRef matcnt() As Long, _
    ByRef matind() As Long, ByRef matval() As Double, _
    ByRef var() As Double,  ByRef objtype() As Byte, _
    ByRef matvaltype() As Byte) As Long

    Err = 0
    On Error Resume Next
    ' Value of the objective function
    objval = var(0) * var(0) + var(1) * var(1)
    ' Partial derivatives of the objective
    obj(0) = 2 * var(0)
    obj(1) = 2 * var(1)
    ' Partial derivatives of X * Y (variable)
    matval(0) = var(1)
    matval(2) = var(0)
    ' Partial derivatives of X * Y (variable)
    matval(1) = var(1)
    matval(3) = var(0)
    jacobian3 = 0
End Function


Sub Showlimits()
   Dim cols As Long, rows As Long, ints As Long

   ret = getproblimits(PROB_LP, cols, rows, ints)
   MsgBox "LP limits: " & Trim(Str(cols)) & " variables, " _
      & Trim(Str(rows)) & " constraints, " & Trim(Str(ints)) & " integers"

   ret = getproblimits(PROB_QP, cols, rows, ints)
   MsgBox "QP limits: " & Trim(Str(cols)) & " variables, " _
```

```
      & Trim(Str(rows)) & " constraints, " & Trim(Str(ints)) & " integers"

   ret = getproblimits(PROB_NLP, cols, rows, ints)
   MsgBox "NLP limits: " & Trim(Str(cols)) & " variables, " _
      & Trim(Str(rows)) & " constraints, " & Trim(Str(ints)) & " integers"

   ret = getproblimits(PROB_NSP, cols, rows, ints)
   MsgBox "NSP limits: " & Trim(Str(cols)) & " variables, " _
      & Trim(Str(rows)) & " constraints, " & Trim(Str(ints)) & " integers"

End Sub


Sub AdjustFormforExample2()
   [detail omitted]
End Sub

Sub AdjustFormforExample3()
   [detail omitted]
End Sub

Sub AdjustFormforExample4()
   [detail omitted]
End Sub

Sub Adjustfor4a()
   [detail omitted]
End Sub

Sub AdjustFormforExample5()
   [detail omitted]
End Sub

Sub AdjustFormforExample6()
   [detail omitted]
End Sub

Sub AdjustFormforExample1()
   [detail omitted]
End Sub



EXAMP2.FRM
------------

Private Sub Command1_Click()

   Dim obj(0 To 1) As Double    ' Dim obj(0 To number_of_variables - 1)
   Dim rhs(0 To 1) As Double    ' Dim rhs(0 To number_of_constraints - 1)
   Dim sense(0 To 1) As Byte    ' Dim sense(0 To number_of_constraints - 1)
   Dim matbeg(0 To 1) As Long   ' Dim matbeg(0 To number_of_variables - 1)
   Dim matcnt(0 To 1) As Long   ' Dim matcnt(0 To number_of_variables - 1)

   Dim matind(0 To 3) As Long
   Dim matval(0 To 3) As Double
   ' The size of the arrays of matind and matval depends on the
   ' number of nonzero elements in the LP matrix for linear problems.
   ' For nonlinear problems, it is easiest to take the number of
   ' constraints times the number of variables. See documentation
   ' for details.  In this case 2 constraints x 2 variables = 4

   Dim lb(0 To 1) As Double      ' Dim lb(0 To number_of_variables - 1)
   Dim ub(0 To 1) As Double      ' Dim lb(0 To number_of_variables - 1)
   Dim rngval(0 To 1) As Double  ' Dim rngval(0 To number constraints - 1)
   ' Note that rngval can only be used with the Large Scale DLL
```

```
Dim ctype(0 To 1) As Byte     ' Dim ctype(0 To number_of_variables - 1)
Dim stat As Long, objval As Double
Dim x(0 To 1) As Double       ' Dim x(0 To number_of_variables - 1)
Dim piout(0 To 1) As Double  ' Dim piout(0 To number_of_constraints - 1)
Dim slack(0 To 1) As Double  ' Dim slack(0 To number_of_constraints - 1)
Dim dj(0 To 1) As Double      ' Dim dj(0 To number_of_variables - 1)

Dim varlow(0 To 1) As Double, varupp(0 To 1) As Double
' Dim varlow and varupp(0 to number_of_variables - 1)
Dim conlow(0 To 1) As Double, conupp(0 To 1) As Double
' Dim conlow and conupp(0 to number of constraints - 1)
Dim objtype(0 To 1) As Byte, matvaltype(0 To 3) As Byte
' Dim objtype(0 to number_of_variables - 1)
' Dim matvaltype(same as matval)
Dim iisrows As Long, iiscols As Long
Dim rowbdstat() As Long, colbdstat() As Long
Dim rowind() As Long, colind() As Long
Dim lp As Long
Dim ret As Long
Dim nlstat As Long

' set up the LP problem

' use Safearrays:
setintparam 0, PARAM_ARRAY, 1

' Note that in VB we can not use NULL as in C.
' Therefor we define an array of size 1 with element -1
' This is recognized by the DLL as NULL

Dim NullL(0) As Long, NullD(0) As Double, NullB(0) As Byte
NullL(0) = -1
NullD(0) = -1
NullB(0) = 0


Select Case Example


Case 1

'Example program calling the nonlinear Solver DLL.
'Solves the problem:

'Minimize x ^ 2 + Y ^ 2
'Subject to:
'   X + Y = 1
'   X * Y >= 0

'(Solution is X = Y = 0.5, Objective = 0.5)

    rhs(0) = 1
    rhs(1) = 0
    sense(0) = Asc("E")
    sense(1) = Asc("G")
    lb(0) = -INFBOUND
    lb(1) = -INFBOUND
    ub(0) = INFBOUND
    ub(1) = INFBOUND
    x(0) = 0
    x(1) = 1

    setintparam 0, PARAM_ARGCK, 1

    lp = loadnlp(PROBNAME, 2, 2, 1, obj, rhs, sense, _
            NullL, NullL, NullL, matval, x, lb, ub, NullD, 4, _
            AddressOf funceval1, 0)
```

```
    If lp = 0 Then Exit Sub

    setlpcallbackfunc lp, AddressOf showiter1

    optimize lp

    solution lp, stat, objval, x, piout, slack, dj
    Form2.Text3 = "Status = " & stat
    Form2.Text4 = "Objective = " & objval
    Form2.Text1 = "x1 = " & x(0)
    Form2.Text2 = "x2 = " & x(1)
    Form2.Text5 = "slack1 = " & slack(0)
    Form2.Text7 = "slack2 = " & slack(1)
    Form2.Text6 = "piout1 = " & piout(0)
    Form2.Text8 = "piout2 = " & piout(1)

    setlpcallbackfunc lp, 0
    ' call unloadprob() to release memory
    unloadprob lp


Case 2

'Example program calling the nonlinear Solver DLL.
'Solves the problem:

'Minimize x ^ 2 + Y ^ 2
'Subject to:
'   X + Y = 1
'   X * Y >= 0

'(Solution is X = Y = 0.5, Objective = 0.5)

    rhs(0) = 1
    rhs(1) = 0
    sense(0) = Asc("E")
    sense(1) = Asc("G")
    lb(0) = -INFBOUND
    lb(1) = -INFBOUND
    ub(0) = INFBOUND
    ub(1) = INFBOUND
    x(0) = 0
    x(1) = 1

    setintparam 0, PARAM_ARGCK, 1

    lp = loadnlp(PROBNAME, 2, 2, 1, obj, rhs, sense, _
            NullL, NullL, NullL, matval, x, lb, ub, NullD, 4, _
            AddressOf funceval1, AddressOf jacobian1)
    If lp = 0 Then Exit Sub

    ' Ask the Solver DLL to call our jacobian() routine, and *check*
    ' the partial derivatives we supply against its own "rise over run"
    ' derivative calculations
    setintparam lp, PARAM_DERIV, 3

    optimize lp

    solution lp, stat, objval, x, piout, slack, dj
    Form2.Text3 = "Status = " & stat
    Form2.Text4 = "Objective = " & objval
    Form2.Text1 = "x1 = " & x(0)
    Form2.Text2 = "x2 = " & x(1)
    Form2.Text5 = "slack1 = " & slack(0)
    Form2.Text7 = "slack2 = " & slack(1)
    Form2.Text6 = "piout1 = " & piout(0)
    Form2.Text8 = "piout2 = " & piout(1)
```

```
   ' call unloadprob() to release memory
   unloadprob lp


Case 3

'Example program calling the nonlinear Solver DLL.
'Attempt to solve the problem:

'Minimize x ^ 2 + Y ^ 2
'Subject to:
'   X * Y = 1
'   X * Y = 0

'This problem is infeasible, because the two constraints conflict.
'We will call findiis() and getiis() to help isolate the source
'of the infeasibility.

   rhs(0) = 1
   rhs(1) = 0
   sense(0) = Asc("E")
   sense(1) = Asc("E")
   lb(0) = -INFBOUND
   lb(1) = -INFBOUND
   ub(0) = INFBOUND
   ub(1) = INFBOUND
   x(0) = 0.25
   x(1) = 0.25

   setintparam 0, PARAM_ARGCK, 1

   lp = loadnlp(PROBNAME, 2, 2, 1, obj, rhs, sense, _
        NullL, NullL, NullL, matval, x, lb, ub, NullD, 4, _
        AddressOf funceval3, 0)
   If lp = 0 Then Exit Sub

   optimize lp

   solution lp, stat, objval, x, piout, slack, dj
   Form2.Text3 = "Status = " & stat
   Form2.Text4 = "Objective = " & objval

   If stat = PSTAT_INFEASIBLE Then
      setlpcallbackfunc lp, 0
      findiis lp, iisrows, iiscols
      MsgBox "Findiis: iisrows = " & Trim(Str(iisrows)) _
         & " iiscols = " & Trim(Str(iiscols))
      Form2.Text1 = "iisrows = " & Trim(Str(iisrows))
      Form2.Text2 = "iiscols = " & Trim(Str(iiscols))

      ReDim rowbdstat(iisrows - 1) As Long
      ReDim rowind(iisrows - 1) As Long
      getiis lp, stat, rowind, rowbdstat, iisrows, _
         NullL, NullL, iiscols
      Form2.Text5 = "rowind1 = " & rowind(0)
      Form2.Text6 = "rowbdstat1 = " & rowbdstat(0)
      Form2.Text7 = "rowind1 = " & rowind(1)
      Form2.Text8 = "rowbdstat1 = " & rowbdstat(1)
   End If

   ' call unloadprob() to release memory
   unloadprob lp
```

```
Case 4

'Example program calling the nonlinear Solver DLL for a series of
'problems which may be linear or nonlinear.  This situation might
'arise if you are calling some external program, or using your own
'interpreter, to evaluate the problem functions.  We will define and
'solve two example problems:

'Nonlinear problem:

'Minimize x ^ 2 + Y ^ 2
'Subject to:
'   X + Y = 1
'   X * Y >= 0

'(Solution is X = Y = 0.5, Objective = 0.5)

'Alternate linear problem:

'Minimize 2 * X + Y
'Subject to:
'   X + Y = 1
'   3 * X - Y >= 0

'(Solution is X = 0.25, Y = 0.75, Objective = 1.25)

'In this example, we call testnltype() to determine whether
'the problem is linear or nonlinear.  If it is linear, we
'solve it first with the nonlinear Solver engine, then solve
'it again with the linear (Simplex) Solver engine.

   rhs(0) = 1
   rhs(1) = 0
   sense(0) = Asc("E")
   sense(1) = Asc("G")
   lb(0) = -10
   lb(1) = -10
   ub(0) = 10
   ub(1) = 10
   x(0) = 0
   x(1) = 0

   setintparam 0, PARAM_ARGCK, 1

   lp = loadnlp(PROBNAME, 2, 2, 1, obj, rhs, sense, _
        NullL, NullL, NullL, matval, x, lb, ub, NullD, 4, _
        AddressOf funceval4, 0)
   If lp = 0 Then Exit Sub

   ' Test the problem to determine linearity / nonlinearity

   testnltype lp, 1, NullD, nlstat, NullB, NullB
   If nlstat Then
      MsgBox "Testnltype: NONLINEAR"
   Else
      MsgBox "Testnltype: LINEAR"
   End If

   ' Solve the problem (using the NLP Solver)
   optimize lp
   solution lp, stat, objval, x, piout, slack, dj
   Form2.Text3 = "Status = " & stat
   Form2.Text4 = "Obj = " & objval
   Form2.Text1 = "x1 = " & x(0)
   Form2.Text2 = "x2 = " & x(1)
   If nlstat Then Exit Sub
```

```
   unloadprob lp

   ' Re-solve the problem using the LP Solver
   Form2.Label6 = "First solution via loadnlp, second via loadlp"
   Form2.Label6.Visible = True

   lp = loadlp(PROBNAME, 2, 2, 1, obj, rhs, sense, _
           NullL, NullL, NullL, matval, lb, ub, NullD, 2, 2, 4)
   optimize lp
   solution lp, stat, objval, x, piout, slack, dj
   Form2.Text5 = "Status = " & stat
   Form2.Text6 = "Obj = " & objval
   Form2.Text7 = "x1 = " & x(0)
   Form2.Text8 = "x2 = " & x(1)

   ' call unloadprob() to release memory
   unloadprob lp


Case 5

'Example program calling the Evolutionary Solver DLL.
'Minimize the Branin function:
'term1 = X/PI * (5.1 * X/PI/4 - 5)
'term2 = (Y - term1 - 6)^2
'term3 = 10 * (1 - 1/PI/8) * cos X + 10
'objective = term2 + term3
'-5 <= X, Y <= 10
'(3 local optima; 1 global optimum = approx 0.3978)

   Dim mid(0 To 1) As Double
   Dim disp(0 To 1) As Double
   Dim lower(0 To 1) As Double
   Dim upper(0 To 1) As Double

   lb(0) = -5
   lb(1) = -5
   ub(0) = 10
   ub(1) = 10
   x(0) = 1
   x(1) = 1

   setintparam 0, PARAM_ARGCK, 1
   lp = loadnlp(PROBNAME, 2, 0, 1, obj, NullD, NullB, _
        NullL, NullL, NullL, NullD, x, lb, ub, NullD, 0, _
        AddressOf funceval5, 0)
   If lp = 0 Then Exit Sub
   loadnltype lp, NullB, NullB ' indicate nonsmooth

   setintparam lp, PARAM_NOIMP, 1 ' 1 second

   setlpcallbackfunc lp, AddressOf showiter1
   optimize lp

   solution lp, stat, objval, x, NullD, NullD, NullD

   varstat lp, 0, 1, mid, disp, lower, upper

   Form2.Text3 = "Status = " & stat
   Form2.Text4 = "Objective = " & objval
   Form2.Text1 = "x1 = " & x(0)
   Form2.Text2 = "x2 = " & x(1)
   Form2.Text5 = "mid1 = " & mid(0)
   Form2.Text7 = "mid2 = " & mid(1)
   Form2.Text6 = "disp1 = " & disp(0)
   Form2.Text8 = "disp2 = " & disp(1)
   Form2.Text10 = "lower1 = " & lower(0)
```

```
        Form2.Text11 = "lower2 = " & lower(1)
        Form2.Text24 = "upper1 = " & upper(0)
        Form2.Text25 = "upper2 = " & upper(1)

        setlpcallbackfunc lp, 0
        ' call unloadprob() to release memory
        unloadprob lp


    Case 6
    'Example C program calling the Evolutionary Solver DLL.
    'Solves the problem:

    'Maximize (if X > 10 then Y + Z else Y - Z)
    '0 <= X, Y, Z <= 20

    '(Solution is X > 10, Y = Z = 20, objective = 40)

        Dim lb2(0 To 2) As Double
        Dim ub2(0 To 2) As Double
        Dim x2(0 To 2) As Double
        Dim obj2(0 To 2) As Double
        lb2(0) = 0
        lb2(1) = 0
        lb2(2) = 0
        ub2(0) = 20
        ub2(1) = 20
        ub2(2) = 20
        x2(0) = 5
        x2(1) = 5
        x2(2) = 5

        setintparam 0, PARAM_ARGCK, 1
        lp = loadnlp(PROBNAME, 3, 0, -1, obj2, NullD, NullB, _
             NullL, NullL, NullL, NullD, x2, lb2, ub2, NullD, 0, _
             AddressOf funceval6, 0)
        If lp = 0 Then Exit Sub
        loadnltype lp, NullB, NullB ' indicate nonsmooth

        setintparam lp, PARAM_NOIMP, 1 ' 1 second

        setlpcallbackfunc lp, 0
        optimize lp

        solution lp, stat, objval, x2, NullD, NullD, NullD

        Form2.Text3 = "Status = " & stat
        Form2.Text4 = "Objective = " & objval
        Form2.Text1 = "X = " & x2(0)
        Form2.Text2 = "Y = " & x2(1)
        Form2.Text5 = "Z = " & x2(1)

        ' call unloadprob() to release memory
        unloadprob lp

    End Select
End Sub

Private Sub Command2_Click()
    Unload Form2
End Sub

Private Sub Form_Activate()
   Form2.Command1.SetFocus
End Sub
```

Limitations of 16-Bit Visual Basic

Visual Basic 4.0 is the last version of Visual Basic offered in a 16-bit version; newer versions of Visual Basic support only 32-bit applications and operating systems such as Windows 95/98 and Windows NT/2000. Support for 16-bit applications in the Solver DLL will be limited in the future. If you need to build applications for older 16-bit operating systems such as Windows 3.1, you will need to take into account the issues discussed in this section.

Callback Functions

Because Visual Basic 4.0 does not support the *AddressOf* operator, you cannot write callback functions in this version of Visual Basic and pass their addresses to the Solver DLL routines *loadnlp()*, *setlpcallbackfunc()* and *setmipcallbackfunc()*.

You can, however, write your callback functions in C/C++, and use a few more lines of C/C++ code to pass these function addresses to the Solver DLL routines. Then your main program can still be written in Visual Basic, and the Solver DLL will call your C/C++ callback functions at the appropriate times. These callback functions would be written independently of the rest of your Visual Basic program, but could display a message or dialog box using direct calls to the Windows API.

You should not use the header file safrontmip.bas with Visual Basic 4.0. Because of the different representation of SAFEARRAYs in 16-bits, Visual Basic 4.0 will not accept array names passed as arguments to the Solver DLL routines. Instead, use frontmip.bas and pass the first element of each array argument (e.g. `obj(0)`) to the Solver DLL routines.

Array Size Limitations

The 16-bit version of Visual Basic has limitations on the size of data objects it can handle. In particular, the maximum array subscript value is 32,767. Although this is larger than any array you might use with the Small-Scale Solver DLL, in exceptional cases it can be a limiting factor when using the Large-Scale Solver DLL. For example, if you were trying to solve a problem with 8,192 decision variables and 8,192 constraints, you might have more than 32,767 nonzero coefficients in the LP matrix (depending on the sparsity of the problem); but you could not construct the *matind[]* and *matval[]* arrays that you would need in 16-bit Visual Basic.

The most straightforward solution is, of course, to use the 32-bit version of Visual Basic. Another approach is to write the part of your application which calls the Large-Scale Solver DLL in C/C++, where you can declare *matind[]* and *matval[]* as "huge" arrays, while writing the rest of the application (including the user interface) in Visual Basic. Your Visual Basic code would then declare your own C/C++ routine and call *it* as a DLL. Your DLL, in turn, would call the Solver DLL.

Calling the Solver DLL from Delphi Pascal

You can use Version 3.5 of the Solver DLL in Pascal programs created in Borland Delphi – either the 32-bit versions (Delphi 2.0 and above) under Windows 95/98 and Windows NT/2000, or the 16-bit version (Delphi 1.0) under Windows 3.x.

It is straightforward to use the Solver DLL with Delphi. You need only include the header file frontmip.pas (which defines a Pascal "unit") in your Delphi project, and make calls to the Solver DLL entry points at the appropriate points in your code.

Basic Steps

To create a Delphi application that calls the Solver DLL, you must perform the following steps:

1. Include the header file **frontmip.pas** in your Delphi project, and ensure that the unit Frontmip appears in your Use statement(s). (You should also include the directive {$I frontkey} to obtain a license key string from **frontkey.pas**.)
2. Call at least the routines *loadlp()* or *loadnlp()*, *optimize()*, *solution()* and *unloadprob()* in that order.

You can use the example code in psunit.pas as a guide for getting the arguments right. This source file, in combination with the form file psunit.dfm, defines a simple form, with four edit boxes to display results, and two buttons that call the Solver DLL routines to solve a mixed-integer linear (MIP) and a nonlinear (NLP) problem, respectively, when they are pressed. In the Pascal source code, the arrays and other variables used as Solver DLL arguments are declared as **public**. The argument values are set up, and the appropriate DLL routines are called in the procedures TForm1.LPButtonClick and TForm1.NLPButtonClick, which run when the appropriate button is pressed.

Passing Array and Function Arguments

Delphi Pascal imposes "strong type checking" on arguments to the Solver DLL functions – requiring, for example, an exact match in the number of elements between actual array arguments and array parameters. To permit flexibility in the Solver DLL's array arguments, the header file **frontmip.pas** declares array

parameters as (for example) `var obj:Double`. For the corresponding array argument, you should pass the first element of the array (for example `obj[0]`).

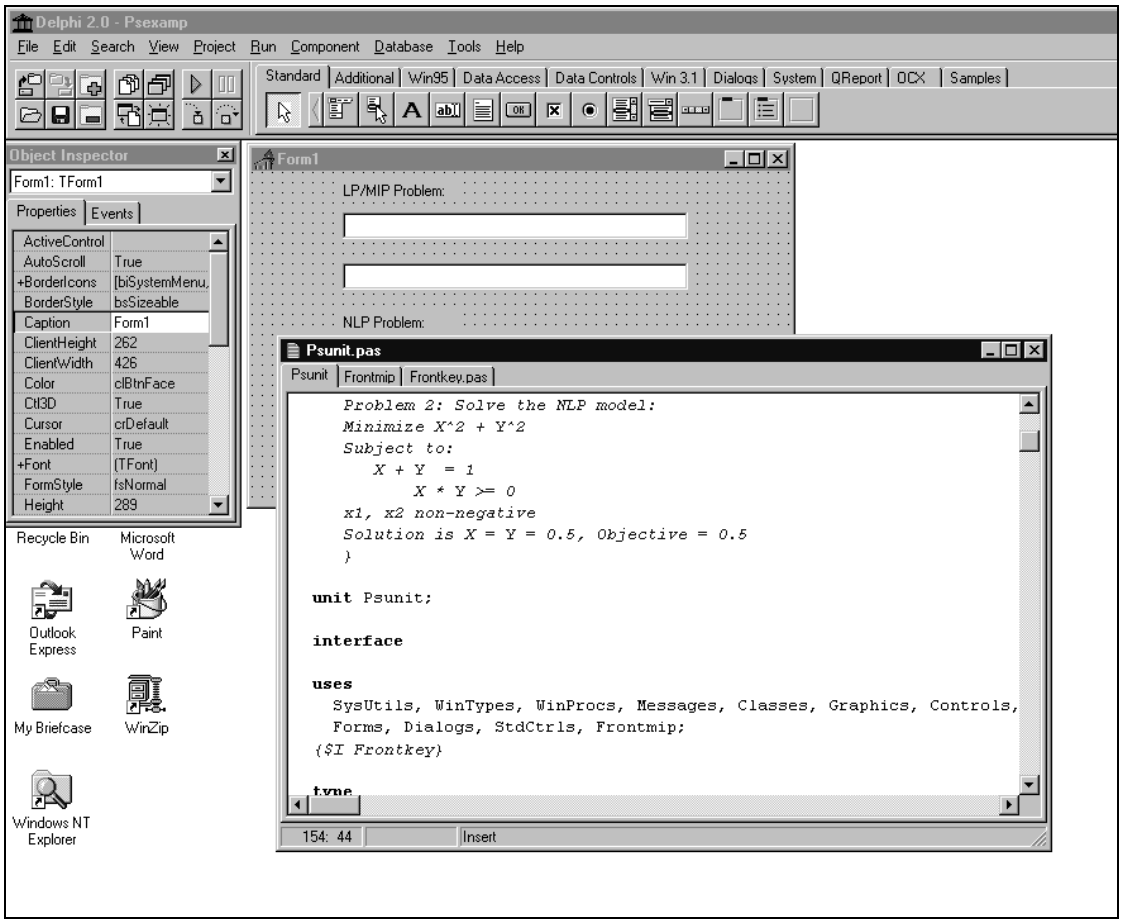
In many Solver DLL routines, certain array arguments are optional – you can instead pass a "NULL value," as described in "NULL Values for Arrays" in the chapter "Solver API Reference." The most convenient such value to use in Delphi Pascal is a variable of the appropriate type (Longint or Double) initialized to –1. (You cannot pass the constant –1 because the corresponding parameters have the `var` attribute.)

In *loadnlp()*, *setlpcallbackfunc()* and *setmipcallbackfunc()*, you pass procedure pointers as actual arguments. There are types defined for these arguments (FUNCEVAL and JACOBIAN for *loadnlp()*, and CCPROC for *setlpcallbackfunc()* and *setmipcallbackfunc()*) in the header file **frontmip.pas**. As long as your procedures have "signatures" that match these types, Delphi will allow you to pass the procedure name as the actual argument. To pass a NULL or empty pointer for a procedure argument (e.g. to omit a *jacobian* function in *loadnlp()*, or to reset the callback function in *setlpcallbackfunc()*), use the special constant **Nil**.

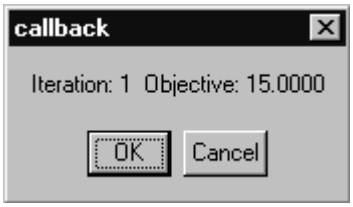
Building a 32-Bit Delphi Pascal Program

You can run the compiled version of the Delphi example psexamp.exe using **Start Run**... You can edit, compile and test the source code of this example as follows:

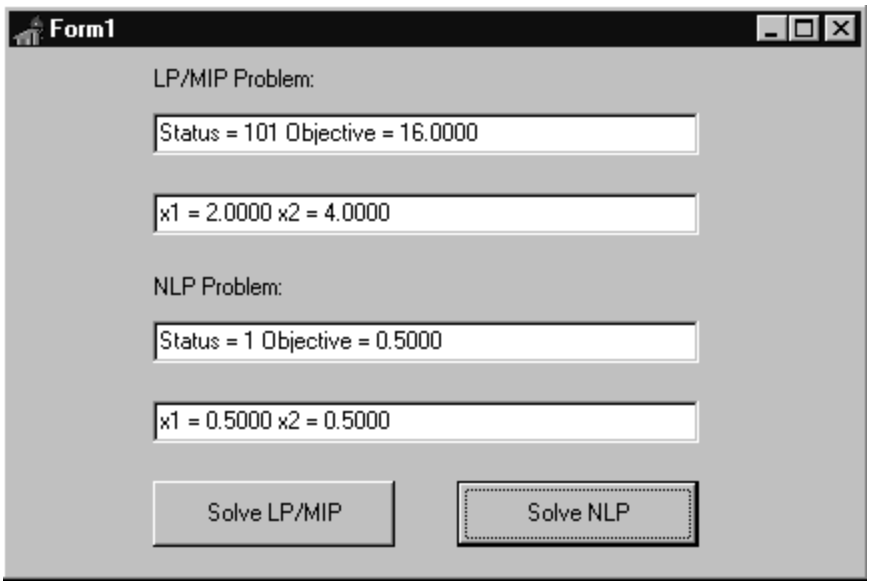
1. Start the Delphi programming system. Select **File Open Project...**, navigate to the Delphi example subdirectory (**c:\frontmip\examples\psexamp**), select **psexamp.dpr** and click OK.
2. The Delphi system will load the project's form and related code (found in psunit.pas). Select **View Units…** or **View Forms…** (**View Project Source** in earlier versions of Delphi) to examine and, if desired, modify the elements of this application. Delphi doesn't automatically display the header file frontmip.pas (which is referenced in the project's Use statements), but you can add it to the project source display with **File Open...** After you open psexamp.dpr, select View Project Source and open frontmip.pas, your screen should resemble the picture on the next page.



3. To test-run the program within the Delphi programming system, select **Run Run** and then click on the button labeled "Solve LP/MIP." This will execute the statements found in procedure TForm1.LPButtonClick, calling *loadlp()*, *loadctype()*, *lpwrite()*,*setlpcallbackfunc(), optimize()*, *solution()* and *unloadprob()*. During the execution of *optimize()*, the Solver DLL will call the callback function, which displays a MessageBox like the one shown below.



After *optimize()* returns, the Pascal code calls *solution()* and places the solution values in the first pair of text edit fields. Clicking on the button "Solve NLP" will execute the statements found in procedure TForm1.NLPButtonClick, calling *loadnlp()*, *setlpcallbackfunc(), optimize()*, *solution()* and *unloadprob()*. This will display the iterations of the nonlinear Solver (assuming that your version of the Solver DLL includes the nonlinear Solver engine). In this case, the Pascal code will call *solution()* and place the solution values in the second pair of text edit fields. At this point, the Delphi Pascal form should look like the one shown on the next page.



4. To end execution of the program, click on the Close button in the upper right hand corner of the window. If you now look in the Delphi example directory, you should find a new file named psexamp, which was written by the call to *lpwrite()*. You can examine this file in Notepad or another text editor; it contains an algebraic statement of the LP/MIP problem that you have solved.

5. Delphi compiles and links your application into a binary executable before running it. The file psexamp.exe can be run by itself, outside the Delphi environment, as long as it can find and load the Solver DLL frontmip.dll.

Building a 16-Bit Delphi Pascal Program

The 16-bit Delphi 1.0 programming system is quite similar to the 32-bit Delphi 2.0 version. Although there are minor differences in the menus, toolbars, palettes and other features, you can open and use the same project file (psexamp.dpr), example program (psunit.pas), and header file (frontmip.pas) as in the 32-bit system. The step-by-step instructions outlined above for the 32-bit Delphi system can be used as-is with the 16-bit system, with only minor differences (for example, Delphi 1.0 displays the project source code by default, so you don't have to select **View Units…, View Forms…** or **View Project Source**). The on-screen appearance of Delphi 1.0 is very similar to Delphi 2.0. You simply need to ensure that your program finds and loads the correct (16-bit) version of frontmip.dll.

When you run the program as compiled by 16-bit Delphi 1.0, you will see the solution of the LP/MIP problem, but you will also find that the MessageBoxes displaying the iterations of the LP Solver engine don't appear, and pressing the "Solve NLP" button doesn't seem to have any effect. This is explained below.

Delphi Pascal Example Source Code

The Delphi Pascal source code for the example problems is shown below. This source code can be used in both the 32-bit and 16-bit Delphi systems, but you will notice conditional compilation directives *{$IFDEF WIN32}* and *{$ENDIF}* around the definition of the callback functions and the code to call the nonlinear Solver.

This is also done in the C/C++ example file vcexamp1.c in an earlier chapter, for similar reasons: The 16-bit version would have to take special steps to ensure that the callback function's local data is addressable in each application instance – and this complication was left out of this simple example. This topic is more fully explored in the chapter "Special Considerations for Windows 3.x."

The header file frontmip.pas can also be used in both the 32-bit and 16-bit Delphi systems; however, it makes extensive use of conditional compilation directives in order to declare the proper calling conventions (*far pascal* versus *stdcall*) for 16-bit and 32-bit DLL routines.

```
   {
   Problem 1: Solve the MIP model:
   Maximize   2 x1 +  3 x2
   Subj to    9 x1 +  6 x2 <= 54
              6 x1 +  7 x2 <= 42
              5 x1 + 10 x2 <= 50
   x1, x2 non-negative, integer
   MIP solution: x1 = 2, x2 = 4
   Objective = 16.0

   Problem 2: Solve the NLP model:
   Minimize X^2 + Y^2
   Subject to:
      X + Y  = 1
      X * Y >= 0
   x1, x2 non-negative
   Solution is X = Y = 0.5, Objective = 0.5
   }

unit Psunit;

interface

uses
  SysUtils, WinTypes, WinProcs, Messages, Classes, Graphics, Controls,
  Forms, Dialogs, StdCtrls, Frontmip;
{$I Frontkey}

type
  TForm1 = class(TForm)
    LPLabel: TLabel;
    LPEdit1: TEdit;
    LPEdit2: TEdit;
    LPButton: TButton;
    NLPLabel: TLabel;
    NLPEdit1: TEdit;
    NLPEdit2: TEdit;
    NLPButton: TButton;
    procedure LPButtonClick(Sender: TObject);
    procedure NLPButtonClick(Sender: TObject);

  private
    { Private declarations }
  public
     obj: array[0..1] of double;
     rhs: array[0..2] of double;
     sense: array[0..2] of char;
     matbeg: array[0..1] of Longint;
     matcnt: array[0..1] of Longint;
     matind: array[0..5] of Longint;
     matval: array[0..5] of double;
     lb: array[0..1] of double;
     ub: array[0..1] of double;
```

```
     ctype: array[0..1] of char;
     stat: Longint;
     objval: double;
     x: array[0..1] of double;
     NullL: Longint;
     NullD: Double;
     lp: Longint;
     ret: Longint;
  end;

var
  Form1: TForm1;

implementation

{$R *.DFM}

{$IFDEF WIN32}

{ Define a "callback" function that displays the iteration number
  and current objective value }

function callback(lpinfo: Longint; wherefrom: Longint): Longint;
stdcall;
var
   iters: Longint;
   obj: Double;
   objtext, Msg: String;
begin
   getcallbackinfo (lpinfo, wherefrom, CBINFO_ITCOUNT, iters);
   getcallbackinfo (lpinfo, wherefrom, CBINFO_PRIMAL_OBJ, obj);
   str (obj:4:4,objtext);
   Msg := 'Iteration: ' + inttostr(iters) + '  Objective: ' + objtext;
   Application.MessageBox (PChar(Msg), 'callback', IDOK);
   Result := PSTAT_CONTINUE;
end;

{ Define a "callback" function that computes the objective and constraint
  left hand sides, for any supplied values of the decision variables. }

function funceval1(lp: Longint; numcols: Longint; numrows: Longint;
   var objval: Double; var lhs: DimD; var pvar: DimD;
   varone: Longint; vartwo: Longint): Longint;
stdcall;
begin
   objval := pvar[0] * pvar[0] + pvar[1] * pvar[1] ; { objective }
   lhs[0] := pvar[0] + pvar[1]; { constraint left hand side }
   lhs[1] := pvar[0] * pvar[1]; { constraint left hand side }
   Result := 0;
end;

{$ENDIF}

{ Define and solve the example LP/MIP problem }

procedure TForm1.LPButtonClick(Sender: TObject);
var
   objtext:string;
   x0:string;
   x1:string;
begin
     { objective coefficients }
     obj[0]:=2;
     obj[1]:=3;
     { right hand sides of constraints }
     rhs[0]:=54;
     rhs[1]:=42;
```

```
     rhs[2]:=50;
     { sense of constraints: 'L' is <= }
     sense[0]:='L';
     sense[1]:='L';
     sense[2]:='L';
     { define constraint coefficients using the "sparse
       matrix" form -- See Solver User Guide for details }
     matbeg[0]:=0;
     matbeg[1]:=3;
     matcnt[0]:=3;
     matcnt[1]:=3;
     matind[0]:=0;
     matind[1]:=1;
     matind[2]:=2;
     matind[3]:=0;
     matind[4]:=1;
     matind[5]:=2;
     matval[0]:=9;
     matval[1]:=6;
     matval[2]:=5;
     matval[3]:=6;
     matval[4]:=7;
     matval[5]:=10;
     { bounds on variables }
     lb[0]:=0;
     lb[1]:=0;
     ub[0]:=INFBOUND;
     ub[1]:=INFBOUND;
     { integer variables }
     ctype[0]:='I';
     ctype[1]:='I';
     { to pass a NULL or empty array }
     NullL := -1;
     NullD := -1;

     setintparam (NullL, PARAM_ARGCK, 1);
     lp := loadlp (PROBNAME, 2, 3, -1, obj[0], rhs[0], sense, matbeg[0],
          matcnt[0], matind[0], matval[0], lb[0], ub[0], NullD, 2, 3, 6);
     if (lp = 0) then Exit;
     ret := loadctype (lp, ctype);
     ret := lpwrite (lp, 'psexamp');
{$IFDEF WIN32}
     setlpcallbackfunc (lp, callback);
{$ENDIF}
     ret := optimize (lp);
     ret := solution (lp, stat, objval, x[0], NullD, NullD, NullD);
     str (objval:4:4,objtext);
     LPEdit1.text := 'Status = ' + inttostr(stat)
          + ' Objective = ' + objtext;
     str (x[0]:4:4, x0);
     str (x[1]:4:4, x1);
     LPEdit2.text := 'x1 = ' + x0 + ' x2 = ' + x1;
end;

{ Define and solve the example NLP problem.
  This works only in 32-bit Delphi 2.0 or above. }

procedure TForm1.NLPButtonClick(Sender: TObject);
var
   objtext:string;
   x0:string;
   x1:string;
begin
     { right hand sides of constraints }
     rhs[0]:=1;
     rhs[1]:=0;
     { sense of constraints: 'E' is =, 'G' is >= }
```

```
     sense[0]:='E';
     sense[1]:='G';
     { bounds on variables }
     lb[0]:=-INFBOUND;
     lb[1]:=-INFBOUND;
     ub[0]:=INFBOUND;
     ub[1]:=INFBOUND;
     { to pass NULL or empty arrays }
     NullL := -1;
     NullD := -1;
{$IFDEF WIN32}
     setintparam (NullL, PARAM_ARGCK, 1);
     lp := loadnlp (PROBNAME, 2, 2, 1, obj[0], rhs[0], sense, NullL,
           NullL, NullL, matval[0], x[0], lb[0], ub[0], NullD,
           4, funceval1, nil);
     if (lp = 0) then Exit;
     setlpcallbackfunc (lp, callback);
     ret := optimize (lp);
     ret := solution (lp, stat, objval, x[0], NullD, NullD, NullD);
     str (objval:4:4,objtext);
     NLPEdit1.text := 'Status = ' + inttostr(stat)
          + ' Objective = ' + objtext;
     str (x[0]:4:4, x0);
     str (x[1]:4:4, x1);
     NLPEdit2.text := 'x1 = ' + x0 + ' x2 = ' + x1;
{$ENDIF}
end;

end.
```

Calling the Solver DLL from FORTRAN

FORTRAN Compilers

To use the Solver DLL from FORTRAN, you must have an appropriate compiler capable of building 32-bit or 16-bit Windows applications and calling DLLs. This Guide will give explicit instructions for use with Microsoft FORTRAN PowerStation 4.0 (32-bit) and Microsoft FORTRAN 5.1 (16-bit), but use with other compilers should be similar.

Microsoft FORTRAN PowerStation 4.0 and FORTRAN 5.1 both allow you to easily "port" applications written for DOS, UNIX or other systems to Windows, displaying WRITE statement output in a window and entering keyboard input in response to READ statements. To simplify the input/output and focus on the Solver DLL routines and arguments, the example application in this chapter uses simple WRITE statements for output and will be built as a "QuickWin" application in FORTRAN PowerStation, and with equivalent options in FORTRAN 5.1.

Basic Steps

To create a FORTRAN application that calls the Solver DLL, you must perform the three following steps:

1. Include the header file **frontmip.for** in your FORTRAN source program. (You must also include – or copy and paste – the one-line declaration in **frontkey.for**, to define your license key string.)
2. Include the import library file **frontmip.lib** in your project or your linker response file.
3. Call at least the routines *loadlp()* or *loadnlp()*, *optimize()*, *solution()* and *unloadprob()* in that order.

You can use the example code in **flexamp.for** as a guide for getting the arguments right. It calls the Solver DLL routines to solve both a simple mixed-integer linear (MIP) problem and a simple nonlinear (NLP) problem.

Bear in mind that **the Solver DLL uses the C convention for array indices, starting from 0 rather than 1**; to make your FORTRAN arrays compatible with this

convention, it is easiest to use lower and upper bounds in your DIMENSION statements, as shown in the example below.

If you call the Solver DLL routine *getcallbackinfo()* in your own callback routine, you should include the file **frontcbi.for** in your source code, immediately after you declare your own callback routine arguments – as shown in the example **flexamp.for**.

Building a 32-Bit FORTRAN Program

This section will outline the steps required to compile, link and run the example Solver DLL application flexamp.exe, using 32-bit Microsoft FORTRAN Power-Station 4.0 under Windows 95/98 or Windows NT/2000. The steps involved in using other FORTRAN compilers should be similar. First, follow the steps in the "Installation" chapter, which will copy the example programs into the **examples** subdirectory of the **frontmip** directory on your hard disk. If you wish, you can run the pre-built version of flexamp.exe (by simply double-clicking on its name), before you try to compile and link it from the source code.

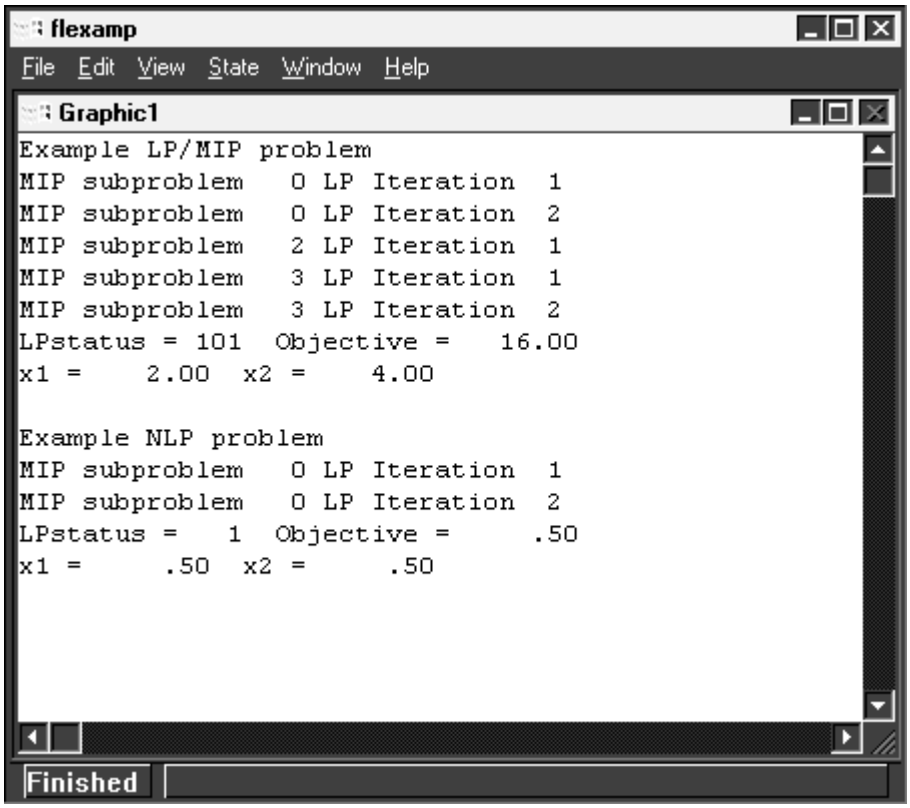
1. **Create a Project.** Start the Microsoft Developer Studio. Select File New... and in the resulting dialog, select Project Workspace and click OK. In the New Project Workspace dialog, select QuickWin Application in the Type list box, type **flexamp** in the Name edit box, and type **c:\frontmip\examples\flexamp** (or another path of your choosing) in the Location edit box. Then click Create.

2. **Add Files.** Select Insert Files into Project... In the resulting dialog, navigate if necessary to the proper directory, select the file **flexamp.for**, and click Add.

   Now select Insert Files into Project... again. In the dialog, open the Files of type dropdown list and select Library Files (*.lib). Navigate to the Win32 subdirectory that contains the 32-bit version of the import library frontmip.lib. Select **frontmip.lib** and click Add.

3. **Check Build Settings.** Before compiling flexamp.for, you must ensure that the preprocessor symbol WIN32 is defined. Select Build Settings..., click on the Fortran tab, open the Category dropdown list, and select Preprocessor. The Predefined Preprocessor Variables edit box should contain the symbol WIN32; if not, type WIN32 in this box and then click OK.

4. **Build and Run the Application.** To compile and link flexamp.for and produce flexamp.exe, select Build Rebuild All. Then select Build Execute flexamp.exe to run the program. An output window like the one on the next page should appear.

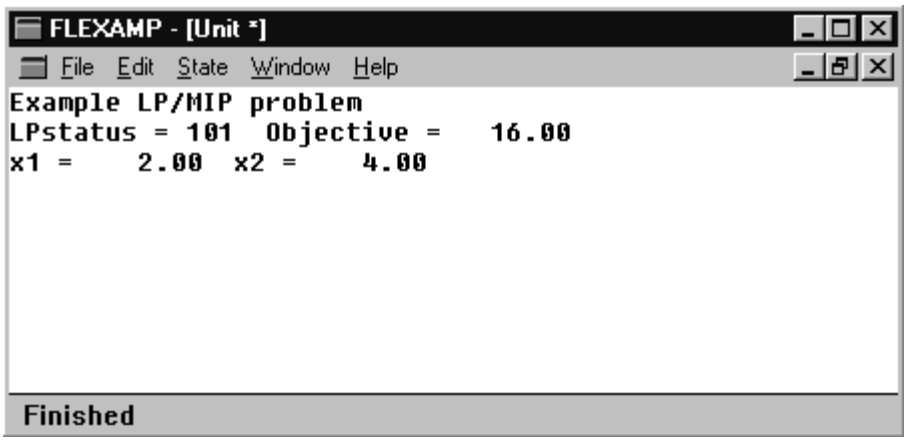


Building a 16-Bit FORTRAN Program

A 16-bit version of the example Solver DLL application flexamp.exe, which runs under Windows 3.x, may be built using the Microsoft FORTRAN 5.1 Programmer's Workbench as follows. Note that the FORTRAN Programmer's Workbench is a DOS application.

1. Start the Programmer's Workbench. Select File Open..., navigate to the appropriate directory and select the file **flexamp.for**.
2. Select Options Environment..., and add the path to the import library (for example, **c:\frontmip\win16**) to the Library Files Search Path.
3. Select Options Build Options.... Set the Main Language to FORTRAN and the Initial Build Options to Windows EXE.
4. Select Options LINK Options.... In the Additional Libraries field, enter **frontmip.lib**.
5. Select Options FORTRAN Compiler Options... and check that the choice for FORTRAN Libraries is Windows, and that the Windows Entry/Exit Code box is checked.
6. Select Rebuild All to compile flexamp.for and produce the program flexamp.exe.

You may run the program from the Windows Program Manager or File Manager using File Run..., or from the Programmer's Workbench. (The latter option starts up Windows automatically.) The result should be a window display like the one shown on the next page.



As you can see, the 16-bit version of the example program solves the same LP/MIP problem as the 32-bit version, but the output from the callback function lpcallback does not appear, and the nonlinear Solver example (which uses the funceval1 and jacobian1 callback routines) is not solved. This is explained below.

FORTRAN Example Source Code

The FORTRAN source code for the example problems is shown below. This source code can be used with both the 32-bit and 16-bit FORTRAN compilers, but you will notice conditional compilation directives *$IF DEFINED(WIN32)* and *$ENDIF* around the definition of the callback functions and the code to call the nonlinear Solver. This is also done in the Delphi Pascal example file psunit.pas and the C/C++ example file vcexamp1.c in earlier chapters, for similar reasons: The 16-bit version would have to take special steps to ensure that the callback function's local data is addressable in each application instance – and this complication was left out of this simple example. This topic is more fully explored in the chapter "Special Considerations for Windows 3.x."

The header file frontmip.for can also be used with both the 32-bit and 16-bit FORTRAN compilers; however, it makes extensive use of conditional compilation directives in order to declare the proper calling for 16-bit and 32-bit DLL routines.

```
C ************************************************************************
C     Frontline Systems Solver DLL (Dynamic Link Library) Version 3.5
C     Frontline Systems Inc., P.O. Box 4288, Incline Village, NV 89450 USA
C     Tel (775) 831-0300 ** Fax (775) 831-0314 ** Email info@frontsys.com
C
C     Example LP/MIP problem in FORTRAN: Build as QuickWin project contain-
C     ing files FLEXAMP.FOR and FRONTMIP.LIB (the import library).  Use
C     FORTRAN Powerstation 4.0 with WIN32 defined, or FORTRAN 5.1 (16-bit).
C ************************************************************************

$IF DEFINED( WIN32)
C     Define a "callback" function that displays the iteration number
C     and current objective value
      INTEGER*4 FUNCTION lpcallback[STDCALL] (lp, wherefrom)
      INTEGER*4 lp[VALUE], wherefrom[VALUE]
      INCLUDE 'frontcbi.for'
      INTEGER*4 ret, iter, mip

      ret = getcallbackinfo (lp, wherefrom, CBINFO_MIP_ITERATIONS, mip)
      ret = getcallbackinfo (lp, wherefrom, CBINFO_ITCOUNT, iter)
      WRITE (*, 10) mip, iter
```

```
10    FORMAT (' MIP subproblem 'I3' LP Iteration'I3)
      lpcallback = 0
      END FUNCTION

C     Define a "callback" function that computes the objective and
C     constraint left hand sides, for any supplied values of the variables.

      INTEGER*4 FUNCTION funceval1[STDCALL] (lp, numcols, numrows,
     +  objval, lhs, var, varone, vartwo)
      INTEGER*4 lp[VALUE], numcols[VALUE], numrows[VALUE]
      REAL*8 objval[REFERENCE]
      REAL*8 lhs(0:1), var(0:1)
      INTEGER*4 varone[VALUE], vartwo[VALUE]

      objval = var(0) * var(0) + var(1) * var(1)
      lhs(0) = var(0) + var(1)
      lhs(1) = var(0) * var(1)
      funceval1 = 0
      END FUNCTION

C     Define a "callback" function that computes the objective gradient and
C     Jacobian of the constraints for any supplied values of the variables.

      INTEGER*4 FUNCTION jacobian1[STDCALL] (lp, numcols, numrows,
     +  nzspace, objval, obj, matbeg, matcnt, matind, matval, var,
     +  objtype, matvaltype)
      INTEGER*4 lp[VALUE], numcols[VALUE], numrows[VALUE]
      INTEGER*4 nzspace[VALUE]
      REAL*8 objval[REFERENCE], obj(0:1)
      INTEGER*4 matbeg(0:1), matcnt(0:1), matind(0:1)
      REAL*8 matval(0:1), var(0:1)
      CHARACTER*2 objtype[REFERENCE]
      CHARACTER*2 matvaltype[REFERENCE]

      WRITE (*, 20) var(0), var(1)
20    FORMAT (' Jacobian evaluated at: x1 = 'F7.2'  x2 = 'F7.2)
C     Value of the objective function
      objval = var(0) * var(0) + var(1) * var(1)
C     Partial derivatives of the objective
      obj(0) = 2.0 * var(0);
      obj(1) = 2.0 * var(1);
C     Partial derivatives of X + Y (constant)
      matval(0) = 1.0;
      matval(2) = 1.0;
C     Partial derivatives of X * Y (variable)
      matval(1) = var(1);
      matval(3) = var(0);
      jacobian1 = 0
      END FUNCTION
$ENDIF

      INCLUDE 'frontmip.for'
C     You must initialize PROBNAME with your own license key string!
      INCLUDE 'frontkey.for'
$IF (.NOT.DEFINED( WIN32))
      INTEGER*4 setintparam, loadlp, loadctype, optimize, solution
      INTEGER*4 lpwrite
$ENDIF
      EXTERNAL lpcallback, funceval1, jacobian1
      INTEGER*4 lpcallback, funceval1, jacobian1

      REAL*8 obj(0:1) / 2.0, 3.0 /
      REAL*8 rhs(0:2) /  54.0, 42.0, 50.0 /
      CHARACTER*3 sense /'LLL'/
      INTEGER*4 matbeg(0:1) / 0, 3 /
      INTEGER*4 matcnt(0:1) / 3, 3 /
      INTEGER*4 matind(0:5) / 0, 1, 2, 0, 1, 2 /
```

```
      REAL*8 matval(0:5) / 9.0, 6.0, 5.0, 6.0, 7.0, 10.0 /
      REAL*8 lb(0:1) / 0.0, 0.0 /
      REAL*8 ub(0:1) / 1.0e30, 1.0e30 /
      CHARACTER*2 ctype /'II'/
      INTEGER*4 stat, ret
      REAL*8 objval, x(0:1)
      INTEGER*4 lp
      INTEGER*4 NullL(0:1) / -1, -1 /
      REAL*8 NullD(0:1) / -1.0, -1.0 /

C     Display MessageBoxes on invalid arguments, for both problems
      ret = setintparam (0, PARAM_ARGCK, 1 )

      WRITE (*, 100)
100   FORMAT (' Example LP/MIP problem')
C     Set up the LP portion of the problem
      lp = loadlp (PROBNAME, 2, 3, -1, obj, rhs, sense,
     + matbeg, matcnt, matind, matval, lb, ub, NullD, 2, 3, 6)
C     Now define the integer variables
      ret = loadctype (lp, ctype)
C     Write out the problem as a text file, in "algebraic" format
      ret = lpwrite (lp, 'flexamp')
$IF DEFINED( WIN32)
C     Set up the callback function to display iteration # and objective
      ret = setlpcallbackfunc (lp, lpcallback )
$ENDIF
C     Solve the mixed-integer problem
      ret = optimize (lp)
C     Obtain and write out the solution
      ret = solution (lp, stat, objval, x, NullD, NullD, NullD)
      WRITE (*, 110) stat, objval
110   FORMAT (' LPstatus = 'I3,'  Objective = 'F7.2)
      WRITE (*, 120) x(0), x(1)
120   FORMAT (' x1 = 'F7.2,'  x2 = 'F7.2)

$IF DEFINED( WIN32)
      WRITE (*, 200)
200   FORMAT (/' Example NLP problem')
C     Re-initialize the values of the rhs, sense, and lb arrays
      rhs(0) = 1.0
      rhs(1) = 0.0
      sense = 'EG'
      lb(0) = -INFBOUND
      lb(1) = -INFBOUND
C     Initialize the values of the variables
      x(0) = 0.25
      x(1) = 0.25
C     Set up the NLP problem
      lp = loadnlp (PROBNAME, 2, 2, 1, obj, rhs, sense,
     + NullL, NullL, NullL, matval, x, lb, ub, NullD, 4,
     +    funceval1, jacobian1)
C     Set up the callback function to display iteration # and objective
      ret = setlpcallbackfunc (lp, lpcallback )
C     Solve the nonlinear problem
      ret = optimize (lp)
C     Obtain and write out the solution
      ret = solution (lp, stat, objval, x, NullD, NullD, NullD)
      WRITE (*, 110) stat, objval
      WRITE (*, 120) x(0), x(1)
$ENDIF
END
```

The Microsoft compilers also support various extensions to FORTRAN that you can use to add Windows user interface features to your FORTRAN application. Consult the Microsoft FORTRAN PowerStation or FORTRAN 5.1 manuals for details.

Solver API Reference

Overview

In this section, we present the detailed arguments and return values of each of the Solver DLL's callable routines. The declaration syntax used is that of C; you will find prototypes and symbolic constants for all of the callable routines in the C/C++ header file `frontmip.h`. To see the corresponding declaration syntax in Visual Basic, Delphi Pascal and FORTRAN, examine the header files `frontmip.bas` or `safrontmip.bas`, `frontmip.pas`, and `frontmip.for` respectively.

Linking may be accomplished with the supplied import library, via entries in the IMPORTS section of a module definition file, or at runtime with calls to the Windows routines *LoadLibrary()* and *GetProcAddress()*. The Visual Basic and Delphi Pascal systems do not require the import library or a module definition file; they use run-time dynamic linking and implicitly call *LoadLibrary()* and *GetProcAddress()* for you.

A typical program to solve a linear programming problem consists of the following calls:

```
main()
{
/* Get data and set up an LP problem */
...
loadlp(..., matval, ...);       /* Load the problem */
optimize(...);                  /* Solve it         */
solution(...);                  /* Get the solution */
unloadprob(...);                /* Free memory      */
...
}
```

In linear and quadratic problems, you pass an array or matrix of coefficients (called *matval* above); the Solver DLL can determine values for the objective and constraints by computing the sums of products of the variables with the supplied coefficients. In nonlinear and nonsmooth problems, however, the problem functions cannot be described this way. Instead, you must write a "callback" function (called *funceval* below) which computes values for the problem functions (objective and constraints) for any given values of the variables. The Solver DLL will call this function repeatedly during the solution process. You supply the address of this callback function as an argument to *loadnlp()*.

A typical program to solve a nonlinear or nonsmooth optimization problem consists of the following calls:

```
funceval(...)
{
/* Receive values for the variables, compute values */
/* for the constraints and the objective function   */
}

main()
{
/* Get data and set up an LP problem */
...
loadnlp(..., funceval, ...);    /* Load the problem */
optimize(...);                  /* Solve it         */
solution(...);                  /* Get the solution */
unloadprob(...);                /* Free memory      */
...
}
```

For more information, consult the chapter "Designing Your Application."

Argument Types

In the Solver DLL, all integer arguments (including array arguments such as *matbeg*, *matcnt* and *matind*) are defined as `long`, or 32-bit integers. In Visual Basic, variables of this type must be declared as `Long` rather than `Integer`. The corresponding type in Delphi Pascal is `Longint`, and in FORTRAN it is `INTEGER*4`. In C/C++, type `int` is the same as type `long` in 32-bit compilers, but we recommend that such variables be declared as `long`.

The *sense* argument of *loadlp()* and *loadnlp()*, the *ctype* argument of *loadctype()*, and the *objtype* and *matvaltype* arguments of *loadnltype()* and *testnltype()* are defined as arrays of unsigned characters. Visual Basic (Version 4.0 and above) treats these arguments as arrays of type `Byte`, whereas it treats ordinary (signed) character array arguments as type `String`. (`String` variables in Visual Basic are actually BSTRs (OLE strings) which may be reallocated at any time – this would cause problems for the Solver DLL). Hence, *Visual Basic programs should define these arguments as arrays of* `Byte`*, and initialize them element by element*.

In the C/C++ header file `frontmip.h`, the name `INTARG` (a typedef for `long`) is used for integer arguments, and `LPINTARG` is used for integer array arguments. The name `REALARG` is used for double arguments, and `LPREALARG` is used for double array arguments. The names `HPINTARG` and `HPREALARG` are used for the *matind* and *matval* arrays in *loadlp()* so that these array arguments can be "huge" arrays (greater than 64K bytes) in 16-bit Windows; they are simply arrays of long and double in the 32-bit versions. And the name `LPBYTEARG` (a typedef for pointer to `unsigned char`) is used for the *sense*, *ctype*, *objtype* and *matvaltype* arguments, for the reasons outlined above.

NULL Values for Arrays

Many of the Solver DLL routines accept arrays as arguments. In a number of cases, these arrays are optional, and you may pass a "NULL value" in lieu of an array. In order to support multiple programming languages, including those that use OLE SAFEARRAYs, the Solver DLL accepts any of the following as a "NULL value:"

- A NULL pointer (i.e. an integer value of 0)

- A pointer to an integer value of –1
- A pointer to a pointer to a SAFEARRAY containing exactly one element whose value is –1
- For Byte arrays only (e.g. the *sense* argument of *loadnlp()* for an unconstrained nonlinear problem), a pointer to a Byte value of 0, or a pointer to a pointer to a SAFEARRAY containing exactly one Byte element whose value is 0

In the first two cases, the integer value must be 4 bytes long. In the third case, the single element of the SAFEARRAY may be a 4-byte integer or an 8-byte double as required by array's normal data type. An example declaration and initialization in Visual Basic would be:

```
Dim NullL(0) As Long
NullL(0) = -1
```

or for an argument which is a Byte array:

```
Dim NullB(0) As Byte
NullB(0) = 0
```

In languages such as C/C++ which can easily manipulate NULL pointers, you can use the symbolic name NULL which is defined as 0. In Visual Basic using C-style arrays (header file `frontmip.bas`), you would use –1 (which will be passed by reference). In Visual Basic when using SAFEARRAYs (and including header file `safrontmip.bas`), you would declare an array of one element, such as *NullL* or *NullB* above, and pass the array name as the argument. In Delphi Pascal, use a variable of the appropriate type (Longint or Double) initialized to –1.

Problem Definition Routines

The following Solver DLL routines are used to define an optimization problem. The definition of every problem starts with a call to either *loadlp()* or *loadnlp()*.

A call to *loadlp()* may be followed by a call to *loadquad()*, for a quadratic problem, and/or a call to *loadctype()*, for a mixed-integer problem.

A call to *loadnlp()* may be followed by a call to *loadnltype(),* for a nonsmooth problem, a call to *loadnltype()* or *testnltype(),* to specify linearly occurring variables, and/or a call to *loadctype(),* for a mixed-integer problem. If your call to *testnltype()* reveals that a problem is entirely linear, you may call *unloadprob()* and then call *loadlp()* with the same arguments, to solve your problem with the faster and more reliable Simplex method.

After calling the appropriate solution routines and/or diagnostic routines, you must call *unloadprob()* to free memory allocated by your calls to other routines.

loadlp

```
HPROBLEM loadlp (probname, numcols, numrows, objsen, obj,
   rhs, sense, matbeg, matcnt, matind, matval, lb, ub,
   rngval, colspace, rowspace, nzspace)

LPSTR probname;
INTARG numcols, numrows, objsen;
LPREALARG obj, rhs;
LPBYTEARG sense;
LPINTARG matbeg, matcnt;
```

```
HPINTARG matind;
HPREALARG matval;
LPREALARG lb, ub, rngval;
INTARG colspace, rowspace, nzspace;
```

`probname` A character string (currently 16 characters plus a 0 terminator byte) containing a unique "key" which is assigned to you when you license the Solver DLL from Frontline Systems. The DLL that is licensed to you recognizes your specific key string; if it is not supplied when *loadlp()* or *loadnlp()* is called, these routines will return NULL, and calls to these and other routines will not be successful.

`numcols` The number of columns in the constraint matrix (i.e. the number of variables).

`numrows` The number of rows in the constraint matrix, not including the objective function or bounds on the variables.

`objsen` Indicates minimization or maximization: 1 = minimize, -1 = maximize.

`obj` An array (of dimension *numcols*) containing the objective function coefficients.

`rhs` An array (of dimension *numrows*) containing the constant or "right hand side" term for each row in the constraint matrix. See also the *rngval* argument below.

`sense` An array (of dimension *numrows*) containing the sense of each constraint (row):
sense[i] = 'L' <= constraint
sense[i] = 'E' = constraint
sense[i] = 'G' >= constraint
sense[i] = 'R' ranged constraint
Note that the value 'R' cannot be used with the Small-Scale Solver DLL.

`matbeg`
`matcnt`
`matind`
`matval` These four arguments describe the nonzero elements of the constraint matrix. You may pass "NULL values" for *matbeg*, *matcnt*, and *matind* if your *matval* array is a full-size dense matrix, i.e. consisting of *numcols* * *numrows* elements (where the elements for each column are consecutive).

If *matbeg*, *matcnt* and *matind* are not NULL values, the array *matval* contains the nonzero coefficients grouped by column (i.e. all coefficients for the same variable are consecutive). *matbeg[i]* contains the index in *matval* of the first coefficient for column i. *matcnt[i]* contains the number of coefficients in column i. Note that the indices in *matbeg* must be in ascending order. Each entry *matind[i]* is the row number of the corresponding coefficient in *matval[i]*. The entries in *matind* are not required to be in ascending row order. The coefficient M[i,j] in the full constraint matrix (if it is nonzero) would be stored in *matval[matbeg[j]+k]* where k is between 0 and *matcnt[j]*-1 (inclusive) and the corresponding entry *matind[matbeg[j]+k]* = i, the row index.

`lb` An array (of dimension *numcols*) containing the lower bound on each variable. A lower bound less than or equal to -INFBOUND will be treated as "minus infinity."

`ub` An array (of dimension *numcols*) containing the upper bound on each variable. A upper bound greater than or equal to +INFBOUND will be treated as "plus infinity."

`rngval` An array (of dimension *rows*) containing the range value of each constraint right hand side. Ranged rows are specified in the *sense* array. If the row is not ranged, the corresponding *rngval* element should be 0.0. A range value for row i means that the constraint left hand side must be between *rhs[i]* and *rhs[i]+rngval[i]*. *rngval[i]* may be positive or negative. If there are no ranged rows at all, *rngval* may be NULL (it is *ignored* when the Small-Scale Solver DLL is used).

`colspace`
`rowspace`
`nzspace`

These three arguments are included for compatibility with the Large-Scale Solver DLL. In the Small-Scale Solver DLL, *colspace* should be equal to *cols*; *rowspace* should be equal to *rows*; and *nzspace* should be equal to the number of entries in *matval*. When PARAM_ARRAY is 1, the actual size of the *matval* SAFEARRAY is checked and must match the value of *nzspace*.

Loadlp() returns NULL if there is an error in its arguments, if linear problems are not supported by this version of the Solver DLL, if the *probname* key string is not recognized, or in the single-threaded version of the DLL, if another problem is still active (i.e. if *loadlp()* or *loadnlp()* has been called without a corresponding call to *unloadprob()*.). You should not change or free the memory for arguments passed to *loadlp()* until after you make the corresponding call to *unloadprob()*.

loadquad

```
INTARG loadquad (lp, qmatbeg, qmatcnt, qmatind, qmatval,
   qnzspace, var)

HPROBLEM lp;
LPINTARG qmatbeg, qmatcnt;
HPINTARG qmatind;
HPREALARG qmatval;
INTARG qnzspace;
LPREALARG var;
```

This routine is called only for quadratic programming problems. The first argument must be the value returned by a previous call to *loadlp()*.

`qmatbeg`
`qmatcnt`
`qmatind`
`qmatval`

These four arguments describe the nonzero elements of the Q matrix, which provides the coefficients of the quadratic portion of the objective function. (The coefficients of the linear portion of the objective are still specified with the *obj* argument of *loadlp*.) They are analogous to the *matxxx* arguments of *loadlp*; however both the row and column indices refer to decision variables, which are multiplied together and by the coefficient, then summed to form the objective.

You may pass "NULL values" for *qmatbeg*, *qmatcnt*, and *qmatind* if your *qmatval* array is a full-size dense matrix, i.e. consisting of *numcols* * *numcols* elements – which is often the case for quadratic problems. In this case, the elements for each matrix column should be consecutive.

If *qmatbeg*, *qmatcnt* and *qmatind* are not NULL values, the array *qmatval* contains the nonzero coefficients grouped by column (i.e. all coefficients for the same variable are consecutive). *qmatbeg[i]* contains the index in *qmatval* of the first coefficient for column i. *qmatcnt[i]* contains the number of coefficients in column i. Note that the indices in *qmatbeg[]* must be in ascending order. Each entry *qmatind[i]* is the row number of the corresponding coefficient in *qmatval[i]*. The entries in *qmatind[]* are not required to be in ascending row order. The coefficient M[i,j] in the Q matrix (if it is nonzero) would be stored in *qmatval[qmatbeg[j]+k]* where k is between 0 and *qmatcnt[j]*-1 (inclusive) and the corresponding entry *qmatind[qmatbeg[j]+k]* = i, the row index.

`qnzspace`

This argument should be equal to the number of elements in the arrays *qmatind* and *qmatval*. IF PARAM_ARRAY is 1, the actual sizes of the arrays are checked against this value.

`var`

This argument should be an array of *numcols* elements, containing initial values for the decision variables. These initial values are relevant only if the Q matrix is semi-

definite or indefinite, in which case they will influence the path that the Solver DLL takes, and the final solution to which it will converge.

Loadquad() returns 0 unless there is an error in its arguments, in which case it returns an integer value indicating the ordinal position of the first argument found to be in error. *Note: objsa()* and *rhssa()* (which return LP range information) may not be used when *loadquad()* has been called.

Loadquad() uses a numerical test to determine whether the Q matrix is at least positive semi-definite (for minimization problems) or negative semi-definite (for maximization problems). If the Q matrix is indefinite, *loadquad()* will return 5 (the ordinal position of the *qmatval* argument) and, if PARAM_ARGCK is 1, it will display an error message dialog indicating this condition. See the section "Solution Properties of Quadratic Problems" in the chapter "Designing Your Application."

loadctype

```
INTARG loadctype (lp, ctype)

HPROBLEM lp;
LPBYTEARG ctype;
```

This routine is called only for mixed-integer problems. The first argument must be the value returned by a previous call to *loadlp()* or *loadnlp()*.

`ctype` An array (of dimension *numcols*) indicating the types of variables in MIP problems. The element ctype[i] indicates the type of variable i as follows:

ctype[i] = 'C' Continuous variable
ctype[i] = 'I' General integer variable
ctype[i] = 'B' Binary (0-1) integer variable

loadctype() returns 0 unless there is an error in its arguments, in which case it returns 1 or 2 to indicate the ordinal position of the argument found to be in error.

loadnlp

```
HPROBLEM loadnlp (probname, numcols, numrows, objsen,
   obj, rhs, sense, matbeg, matcnt, matind, matval,
   var, lb, ub, rngval, nzspace, funceval, jacobian)

LPSTR probname;
INTARG numcols, numrows, objsen;
LPREALARG obj, rhs;
LPBYTEARG sense;
LPINTARG matbeg, matcnt;
HPINTARG matind;
HPREALARG matval;
LPREALARG var, lb, ub, rngval;
INTARG nzspace;
_FUNCEVAL funceval;
_JACOBIAN jacobian;
```

`probname` A character string (currently 16 characters plus a 0 terminator byte) containing a unique "key" which is assigned to you when you license the Solver DLL from Frontline Systems. The DLL that is licensed to you recognizes your specific key string; if it is not supplied when *loadlp()* or *loadnlp()* is called, these routines will return NULL, and calls to these and other routines will not be successful.

`numcols` The number of columns in the constraint matrix (i.e. the number of variables).

`numrows` The number of rows in the constraint matrix, not including the objective function or bounds on the variables.

`objsen` Indicates minimization or maximization: 1 = minimize, -1 = maximize.

`obj` An array (of dimension *numcols*) containing the objective function gradient. This array must be present and of the appropriate size, but its contents need be initialized only if you are calling *loadnltype()* to specify that some or all of objective gradient elements are constant. Otherwise, the Solver DLL will fill in this array when it calls your *funceval()* and/or *jacobian()* routines.

`rhs` An array (of dimension *numrows*) containing the constant or "right hand side" term for each row in the constraint matrix. See also the *rngval* argument below.

`sense` An array (of dimension *numrows*) containing the sense of each constraint (row):
sense[i] = 'L' <= constraint
sense[i] = 'E' = constraint
sense[i] = 'G' >= constraint
sense[i] = 'R' ranged constraint
Note that the value 'R' cannot be used with the Small-Scale Solver DLL.

`matbeg`
`matcnt`
`matind`
`matval`
These four arguments describe the nonzero elements of the Jacobian matrix. If the problem has no constraints, you may pass "NULL values" for all of these arguments. Otherwise, the *matval* array, at a minimum, must be present and must be of the appropriate size, but its contents need be initialized only if you are calling *loadnltype()* to specify that some or all of Jacobian matrix elements are constant. Otherwise, the Solver DLL will fill in this array when it calls your *funceval()* and/or *jacobian()* routines. If the *matbeg*, *matcnt*, and *matind* arrays are present, these arrays and the *matval* array must account for all of the partial derivatives which *could become nonzero at any time* during the solution process.

You may pass "NULL values" for *matbeg*, *matcnt*, and *matind* if your *matval* array is a full-size dense matrix, i.e. consisting of *numcols* * *numrows* elements (and the elements of each column are consecutive).

If *matbeg*, *matcnt* and *matind* are not NULL values, the array *matval* contains the nonzero coefficients grouped by column (i.e. all coefficients for the same variable are consecutive). *matbeg[i]* contains the index in *matval* of the first coefficient for column i. *matcnt[i]* contains the number of coefficients in column i. Note that the indices in *matbeg* must be in ascending order. Each entry *matind[i]* is the row number of the corresponding coefficient in *matval[i]*. The entries in *matind* are not required to be in ascending row order. The coefficient M[i,j] in the full constraint matrix (if it is nonzero) would be stored in *matval[matbeg[j]+k]* where k is between 0 and *matcnt[j]*-1 (inclusive) and the corresponding entry *matind[matbeg[j]+k]* = i, the row index.

`var` An array (of dimension *numcols*) containing initial values for the variables. These values may influence the progress of the nonlinear Solver "engine" and determine which of several locally optimal points are found during the solution process.

`lb` An array (of dimension *numcols*) containing the lower bound on each variable. A lower bound less than or equal to -INFBOUND will be treated as "minus infinity."

`ub` An array (of dimension *numcols*) containing the upper bound on each variable. A upper bound greater than or equal to +INFBOUND will be treated as "plus infinity."

`rngval` An array (of dimension *rows*) containing the range value of each constraint right hand side. Ranged rows are specified in the *sense* array. If the row is not ranged, the

corresponding *rngval* element should be 0.0. A range value for row i means that the constraint left hand side must be between *rhs[i]* and *rhs[i]+rngval[i]*. *rngval[i]* may be positive or negative. If there are no ranged rows at all, *rngval* may be NULL (it is *ignored* when the Small-Scale Solver DLL is used).

`nzspace` This argument should be equal to the number of entries in *matval*. When PARAM_ARRAY is 1, the actual size of the *matval* SAFEARRAY is checked and must match the value of *nzspace*.

`funceval` The address of a user-written callback routine which computes the values of your objective function and constraints (i.e. a *procedure pointer*), declared as shown in the section "Callback Routines" below.

`jacobian` The address of a user-written callback routine which computes a gradient for your objective function and a Jacobian matrix for your constraints (i.e. a *procedure pointer*), declared as shown in the section "Callback Routines" below

Loadnlp() returns NULL if there is an error in its arguments, if nonlinear problems are not supported by this version of the Solver DLL, if the *probname* key string is not recognized, or in the single-threaded version of the DLL, if another problem is still active (i.e. if *loadlp()* or *loadnlp()* has been called without a corresponding call to *unloadprob()*.). You should not change or free the memory for arguments passed to *loadnlp()* until after you make the corresponding call to *unloadprob()*.

loadnltype

```
INTARG loadnltype (lp, objtype, matvaltype)

HPROBLEM lp;
LPBYTEARG objtype, matvaltype;
```

This routine is optional. If called, it gives the Solver DLL information about whether each variable occurs in a linear, nonlinear, or nonsmooth/discontinuous way in each problem function. The Solver can use this information to choose the appropriate Solver "engine" and/or to speed up the solution process. The argument *lp* must be the value returned by a previous call to *loadnlp()*.

You may pass "NULL values" for *objtype*, *matvaltype*, or both to indicate that the objective or the constraints are, in general, nonsmooth or discontinuous functions of the variables. In Version 3.5 of the Solver DLL, if either of these arguments is NULL, or if *any* variable occurs in a nonsmooth/discontinuous way in the objective or in *any* constraint, the Evolutionary Solver "engine" is used to solve the problem.

`objtype` An array (of dimension *numcols*) indicating whether the variables occur in a linear, smooth nonlinear, or nonsmooth/discontinuous way in the objective function:

objtype[i] = 'L' Variable occurs linearly (or not at all) in the objective
objtype[i] = 'N' Variable is (smooth) nonlinear in the objective
objtype[i] = 'D' Variable is nonsmooth/discontinuous in the objective

`matvaltype` An array (of dimension *nzspace*) indicating whether the variables occur in a linear, smooth nonlinear, or nonsmooth/discontinuous way in the constraint functions:

matvaltype[i] = 'L' Matval[i] represents a linear occurrence of a variable
matvaltype[i] = 'N' Matval[i] represents a (smooth) nonlinear occurrence
matvaltype[i] = 'D' Matval[i] represents a nonsmooth/discontinuous occurrence

The relevant variable and constraint are identified by the corresponding elements of the *matbeg*, *matcnt* and *matind* arrays.

testnltype

```
INTARG testnltype (lp, numtests, testvals, pstat,
   objtype, matvaltype)

HPROBLEM lp;
INTARG numtests;
LPREALARG testvals;
LPINTARG pstat;
LPBYTEARG objtype, matvaltype;
```

This routine is optional. It can be called to compute information about whether each variable occurs linearly or nonlinearly in each problem function, through a numerical test. The lp argument is the "problem handle" returned by *loadnlp()*.

Testnltype() computes the gradient for your objective function and Jacobian values for your constraints at the origin, storing them in the *obj* and *matval* arrays that you supplied in your call to *loadnlp()*. It then tests whether these gradient and Jacobian values remain constant over a range around the origin. Your *matval* array must be of appropriate size, and if they are used, your *matbeg*, *matcnt* and *matind* arrays must be correctly initialized to indicate which elements of the Jacobian matrix can be nonzero *for any variable values over the domain of your functions*. *Testnltype()* will ignore elements of the Jacobian that you have indicated are zero (through your *matbeg*, *matcnt* and *matind* arrays); hence it will not diagnose linearity correctly if you have "missed" some Jacobian entries which can be nonzero for certain variable values. (Remember that you can always pass "NULL values" for *matbeg*, *matcnt* and *matind* and pass a *matval* array of size *numcols* * *numrows*.)

`numtests` Indicates the number of tests performed to validate the gradient and Jacobian values. Each test is performed by choosing test values for each variable, computing the objective and constraint values using the gradient and Jacobian just determined, computing the objective and constraint values by calling your *funceval()* routine, and comparing the results. If you supply a "NULL value" for *testvals*, the test values for the variables are chosen randomly. If you supply an array for *testvals*, the test values are drawn from this array.

`testvals` An array (of dimension *numtests* * *numcols*) containing test values for the variables to be used in validating the gradient and Jacobian determined by *testnltype()*, as described above. If you supply a "NULL value", the Solver DLL will choose test values at random between the bounds you supply in the *lb* and *ub* arrays.

`pstat` A pointer to a (long) integer indicating whether the entire problem was diagnosed as nonlinear or linear:

pstat = 1	Problem was diagnosed as (smooth) nonlinear
pstat = 0	Problem was diagnosed as linear
pstat = -1	Diagnosis aborted because your *funceval()* routine returned 1 (failure)

If pstat returns 1, at least one of the elements of either *objtype* or *matvaltype* will be 'N'; if pstat returns 0, all elements of both arrays will be 'L'.

`objtype` An array (of dimension *numcols*) which *testnltype()* will fill in to indicate whether the variables occur linearly or nonlinearly in the objective function:

objtype[i] = 'L'	Variable occurs linearly (or not at all) in the objective
objtype[i] = 'N'	Variable occurs nonlinearly in the objective

`matvaltype` An array (of dimension *nzspace*) which *testnltype()* will fill in to indicate whether the variables occur linearly or nonlinearly in the constraint functions:

matvaltype[i] = 'L' Matval[i] represents a linear occurrence of a variable
matvaltype[i] = 'N' Matval[i] represents a nonlinear occurrence of a variable

The relevant variable and constraint are identified by the corresponding elements of the *matbeg*, *matcnt* and *matind* arrays. You may pass a "NULL value" for *objtype* and/or *matvaltype* if you are not interested in this information.

The numerical test used by *testnltype()* is effective on a broad range of problems, but since it samples function values returned by the *funceval()* routine, it is not foolproof. An all-linear problem which is reasonably well-scaled will always return 0 (linear model) in *pstat*; but a very poorly scaled linear problem could return 1 (nonlinear model), and a nonlinear problem which behaves linearly over a significant region around the origin could return 0 (linear model). Given the nature of the numerical test, *testnltype()* cannot determine whether any of the variables occur in a nonsmooth/discontinuous way in your problem.

The information used to compute function values in your *funceval()* routine may provide a more certain way to determine the linearity or nonlinearity of your model. If you have this information, it is better to make the decision to call *loadnlp()* or *loadlp()* based on your own test, and optionally call *loadnltype()* to supply the information to the Solver DLL.

If *testnltype()* returns 0 in pstat, the *matval* array will contain the (constant) Jacobian values which make up the LP coefficient matrix for the Simplex method. You may switch to the Simplex method and solve the problem by calling *unloadprob()*, then calling *loadlp()* with the same arguments (including *matval*) you supplied in your call to *loadnlp()*.

unloadprob

```
INTARG unloadprob (lp)

HPROBLEM *lp;
```

This routine "erases" the current problem from the Solver DLL's memory. The argument *lp* must be a *pointer to* the value returned by a previous call to *loadlp()* or *loadnlp()*. After this call, the value of *lp* is invalid and should no longer be used. As noted above, after calling *unloadprob()* you may change or free the memory for the arguments passed to *loadlp()* or *loadnlp()*.

Note: The single-threaded version of the Solver DLL handles only one problem at a time. Hence, you may call *loadlp()* or *loadnlp()* for a second problem only after you have called *unloadprob()* for the first problem. The multi-threaded version of the Solver DLL supports multiple concurrent or recursive calls to these routines.

Unloadprob() returns 0 unless its *lp* argument is invalid, in which case it returns 1.

Solution Routines

The following Solver DLL routines are used to solve an optimization problem, which has been previously defined by a call to either *loadlp()* or *loadnlp()*.

You should call *optimize()* to find the solution to a linear, quadratic or nonlinear problem without integer variables (i.e. one where you have not called *loadctype()*). You should call *mipoptimize()* if the problem includes integer variables.

During the call to *optimize()* or *mipoptimize()*, the Solver DLL may make repeated calls to one or more callback routines that you have written and passed as arguments to *loadnlp()*, *setlpcallbackfunc()* or *setmipcallbackfunc()*. These routines are discussed below under "Callback Routines for Nonlinear Problems" and "Other Callback Routines."

Call *solution()* to retrieve the final status of the optimization, the final value of the decision variables and the objective function, and if appropriate, dual values (basic sensitivity analysis information) for the variables and constraints. For linear programming problems (only), you may call *objsa()* and/or *rhssa()* to obtain the ranges of values over which the sensitivity analysis information is valid. For nonsmooth optimization problems (only), you may call *varstat()* and/or *constat()* to obtain statistical information about the final population of candidate solutions.

optimize

```
INTARG optimize (lp)
HPROBLEM lp;
```

The argument *lp* of *optimize()* must be the value returned by a previous call to *loadlp()* or *loadnlp()*. When this function is called, the Solver DLL will solve the specified linear, quadratic, nonlinear, or nonsmooth optimization problem. *Optimize()* returns a value of 0 if successful (i.e. the solution process ran to completion, though it may or may not have found an optimal solution – see *solution()* for details). If the solution process cannot be carried out, *optimize()* returns a nonzero value.

mipoptimize

```
INTARG mipoptimize (lp)
HPROBLEM lp;
```

This routine is called in lieu of *optimize()* to solve a mixed-integer programming problem. The argument *lp* of *mipoptimize()* must be the value returned by a previous call to *loadlp()* or *loadnlp()*. When this function is called, the Solver DLL will solve the specified optimization problem. *Mipoptimize()* returns a value of 0 if successful (i.e. the solution process ran to completion, though it may or may not have found an optimal solution – see *solution()* for details). If the solution process cannot be carried out, *mipoptimize()* returns a nonzero value.

solution

```
INTARG solution (lp, pstat, pobj, x, piout, slack, dj)

HPROBLEM lp;
LPINTARG pstat;
LPREALARG pobj, x, piout, slack, dj;
```

The argument *lp* of *solution()* must be the value returned by a previous call to *loadlp()* or *loadnlp()*. The other arguments are pointers to locations where data may be written. This data may include the status of the optimization, the value of the

objective function, the values of the (primal) variables, the dual values, the slacks and the reduced costs. If some of the data is not required, a "NULL value" may be passed for that argument. If there is no optimal solution, sensitivity analysis information is not available, so the *piout*, *slack* and *dj* arguments will be ignored. If you are solving a MIP problem, sensitivity analysis information is not meaningful and the *piout*, *slack* and *dj* arguments must be "NULL values."

Solution() returns 0 unless its *lp* argument is invalid, in which case it returns 1.

`pstat` A pointer to a (long) integer where the result of the optimization will be stored. The specific values which *stat* (pointed to by *pstat)* can take and their meanings are:

stat = 1 = PSTAT_OPTIMAL	optimal solution found
stat = 2 = PSTAT_INFEASIBLE	no feasible solution
stat = 3 = PSTAT_UNBOUNDED	objective unbounded
stat = 5 = PSTAT_IT_LIM_FEAS	iteration limit exceeded, feasible
stat = 6 = PSTAT_IT_LIM_INFEAS	iteration limit exceeded, not yet feas.
stat = 7 = TIME_LIM_FEAS	time limit exceeded, feasible
stat = 8 = TIME_LIM_INFEAS	time limit exceeded, not yet feasible
stat = 12 = PSTAT_ABORT_FEAS	user interrupted solution, feasible
stat = 13 = PSTAT_ABORT_INFEAS	user interrupted solution, not yet feas.
stat = 65 = PSTAT_FRACT_CHANGE	objective function changing too slowly
stat = 66 = PSTAT_NO_REMEDIES	all remedies failed to find a better point
stat = 67 = PSTAT_FLOAT_ERROR	error in evaluating problem functions
stat = 68 = PSTAT_MEM_LIM	could not allocate enough memory
stat = 69 = PSTAT_ENTRY_ERROR	attempt to re-enter DLL during solution
stat = 101 = PSTAT_MIP_OPTIMAL	MIP optimal solution found
stat = 102 = PSTAT_MIP_OPTIMAL_TOL	MIP solution within epgap tolerance
stat = 103 = PSTAT_MIP_INFEASIBLE	no feasible integer solution
stat = 104 = PSTAT_MIP_SOL_LIM	integer solution limit exceeded
stat = 105 = PSTAT_MIP_NODE_LIM_FEAS	node limit exceeded, feasible
stat = 106 = PSTAT_MIP_NODE_LIM_INFEAS	node limit exceeded, not feas.
stat = 107 = PSTAT_MIP_TIME_LIM_FEAS	time limit exceeded, feasible
stat = 108 = PSTAT_MIP_TIME_LIM_INFEAS	time limit exceeded, not feas.

A *pstat* value of 69 (PSTAT_ENTRY_ERROR) is returned only by the single-threaded version of the Solver DLL, and only if *optimize()* or *mipoptimize()* is called, directly or indirectly, from a callback function that the Solver DLL called during execution of an earlier *optimize()* or *mipoptimize()* call. In the multi-threaded version of the Solver DLL, these types of recursive calls are permitted.

`pobj` A pointer to a double variable where the optimal objective function value will be stored.

`x` A array of dimension equal to the number of columns (variables) in which the optimal values of the (primal) variables will be stored.

`piout` An array of dimension equal to the number of rows (constraints) in which the dual values (shadow prices) of the constraints will be stored. The *piout* values are available only if an optimal solution to an LP or QP problem has been found.

`slack` An array of dimension equal to the number of rows (constraints) in which the optimal slack or surplus values for the constraints will be stored. The *slack* values are available only if an optimal solution to an LP or QP problem has been found.

`dj` An array of dimension equal to the number of columns (variables) in which the dual values (reduced costs) of the variables will be stored. The *dj* values are available only if an optimal solution to an LP or QP problem has been found.

objsa

```
INTARG objsa (lp, begidx, endidx, lower, upper)

HPROBLEM lp;
INTARG begidx, endidx;
LPREALARG lower, upper;
```

This routine need be called only if sensitivity ranges for the objective function coefficients are desired. The argument *lp* of *objsa()* must be the value returned by a previous call to *loadlp()*. The arguments *begidx* and *endidx* are used to limit the set of columns (variables) for which the range information is computed. Since range information is not meaningful for NSP, NLP, QP and MIP problems, *objsa* should not be called for them. *objsa* returns 0 unless there is an error in its arguments, in which case it returns an integer value indicating the ordinal position of the first argument found to be in error.

`begidx` The first column number (index as in *loadlp* arguments) for which sensitivity range information should be returned.

`endidx` The last column number (index as in *loadlp* arguments) for which sensitivity range information should be returned.

`lower` An array of dimension *endidx* - *begidx* + 1 where the objective function coefficient lower range values will be returned.

`upper` An array of dimension *endidx* - *begidx* + 1 where the objective function coefficient upper range values will be returned.

rhssa

```
INTARG rhssa (lp, begidx, endidx, lower, upper)

HPROBLEM lp;
INTARG begidx, endidx;
LPREALARG lower, upper;
```

This routine need be called only if sensitivity ranges for the constraint right hand sides are desired. The argument *lp* of *rhssa()* must be the value returned by a previous call to *loadlp()*. The arguments *begidx* and *endidx* are used to limit the set of rows (constraints) for which the range information is computed. Since range information is not meaningful for NSP, NLP, QP and MIP problems, *rhssa* should not be called for them. *rhssa* returns 0 unless there is an error in its arguments, in which case it returns an integer value indicating the ordinal position of the first argument found to be in error.

`begidx` The first row number (index as in *loadlp* arguments) for which sensitivity range information should be returned.

`endidx` The last row number (index as in *loadlp* arguments) for which sensitivity range information should be returned.

`lower` An array of dimension *endidx* - *begidx* + 1 where the constraint right hand side lower range values will be returned.

`upper` An array of dimension *endidx* - *begidx* + 1 where the constraint right hand side upper range values will be returned.

varstat

```
INTARG varstat (lp, begidx, endidx, mid, disp,
   lower, upper)

HPROBLEM lp;
INTARG begidx, endidx;
LPREALARG mid, disp, lower, upper;
```

This routine need be called only if statistical information about the variable values in the final population of candidate solutions (found by the Evolutionary Solver "engine") is desired. The argument *lp* of *varstat()* must be the value returned by a previous call to *loadnlp()*. The arguments *begidx* and *endidx* are used to limit the set of columns (variables) for which the statistical information is computed. Since this information is meaningful only for NSP (nonsmooth optimization) problems, *varstat()* should not be called for other types of problems. *Varstat()* returns 0 unless there is an error in its arguments, in which case it returns an integer value indicating the ordinal position of the first argument found to be in error.

`begidx` The first column number (index as in *loadnlp* arguments) for which statistical information should be returned.

`endidx` The last column number (index as in *loadnlp* arguments) for which statistical information should be returned.

`mid` An array of dimension *endidx* - *begidx* + 1 where the mean of each variable's values in the final population of candidate solutions will be returned.

`disp` An array of dimension *endidx* - *begidx* + 1 where the standard deviation of each variable's values in the final population of candidate solutions will be returned.

`lower` An array of dimension *endidx* - *begidx* + 1 where the minimum of each variable's values in the final population of candidate solutions will be returned.

`upper` An array of dimension *endidx* - *begidx* + 1 where the maximum of each variable's values in the final population of candidate solutions will be returned.

constat

```
INTARG constat (lp, begidx, endidx, mid, disp,
   lower, upper)

HPROBLEM lp;
INTARG begidx, endidx;
LPREALARG mid, disp, lower, upper;
```

This routine need be called only if statistical information about the constraint values in the final population of candidate solutions (found by the Evolutionary Solver "engine") is desired. The argument *lp* of *constat()* must be the value returned by a previous call to *loadnlp()*. The arguments *begidx* and *endidx* are used to limit the set of rows (constraints) for which the statistical information is computed. Since this information is meaningful only for NSP (nonsmooth optimization) problems, *constat()* should not be called for other types of problems. *Constat()* returns 0 unless there is an error in its arguments, in which case it returns an integer value indicating the ordinal position of the first argument found to be in error.

`begidx` The first row number (index as in *loadnlp* arguments) for which statistical information should be returned.

`endidx`	The last row number (index as in *loadnlp* arguments) for which statistical information should be returned.
`mid`	An array of dimension *endidx* - *begidx* + 1 where the mean of each constraint's values in the final population of candidate solutions will be returned.
`disp`	An array of dimension *endidx* - *begidx* + 1 where the standard deviation of each constraint's values in the final population of candidate solutions will be returned.
`lower`	An array of dimension *endidx* - *begidx* + 1 where the minimum of each constraint's values in the final population of candidate solutions will be returned.
`upper`	An array of dimension *endidx* - *begidx* + 1 where the maximum of each constraint's values in the final population of candidate solutions will be returned.

Diagnostic Routines

The following Solver DLL routines may be called to diagnose a problem when the linear, quadratic or nonlinear Solver "engine" has reported that no feasible solution could be found; to validate that your calls to *loadlp()*, *loadquad()* and/or *loadctype()* have programmatically defined the problem as you intended; or to read in a problem previously saved to disk or generated by another program.

You may call *findiis()* or (for linear and quadratic problems) *iiswrite()* at any time after *solution()* has reported that a problem is infeasible (and before you've called *unloadprob()*. These routines compute an Irreducibly Infeasible Subset (IIS) of the constraints, such that your problem, with just those constraints, is still infeasible, but if any one constraint is dropped from the subset, the problem becomes feasible. Call *getiis()* to programmatically examine the IIS.

You may *call lpwrite()* (for linear and quadratic problems only) to write out a text file containing an algebraic description of the problem you have defined by calling to *loadlp()*, *loadquad()* and/or *loadctype()* and passing the necessary parameters and arrays. If you are not getting the solution you expect, calling *lpwrite()* may reveal that you haven't defined the problem you expected. (For compatibility with previous versions of the Solver DLL, *lprewrite()* is a synonym for *lpwrite()*.)

You may call *lpread()* to read in a text file – previously written by *lpwrite()*, or perhaps hand-edited or generated by another program – containing an algebraic description of a linear, quadratic or mixed-integer programming problem. This can save you the effort of writing and debugging your own code to set up the contents of the arrays needed by the *loadlp()*, *loadquad()* and/or *loadctype()* routines.

findiis

```
INTARG findiis (lp, pnumrows, pnumcols)

HPROBLEM lp;
LPINTARG pnumrows, pnumcols;
```

Findiis() computes an Irreducibly Infeasible Subset (IIS) of the constraints, to help you identify problems in your constraint formulation which make the problem infeasible. You may call this routine when the *pstat* argument value returned by *solution()* is 2 (PSTAT_INFEASIBLE). The argument *lp* must be the value returned by a previous call to *loadlp()* or *loadnlp()*. If the parameter PARAM_IISBND is 0 (the default), both constraints and variable bounds will be considered and eliminated

from the IIS if possible. If PARAM_IISBND is 1, only the constraints will be considered for elimination from the IIS, leaving all variable bounds in force.

`pnumrows` On return, the variable pointed to by *pnumrows* will contain the number of constraints (rows) in the IIS.

`pnumcols` On return, the variable pointed to by *pnumcols* will contain the number of variable bounds (columns) in the IIS.

To obtain details of the IIS, call the routine *getiis()*. The routine *iiswrite()* calls *findiis()* automatically, if it has not already been called

getiis

```
INTARG getiis (lp, pstat,
   rowind, rowbdstat, pnumrows,
   colind, colbdstat, pnumcols)

HPROBLEM lp;
LPINTARG pstat;
LPINTARG rowind, rowbdstat, pnumrows;
LPINTARG colind, colbdstat, pnumcols;
```

You may call this routine after calling *findiis()*, which returns the information you need to properly dimension the arrays *rowind*, *rowbdstat*, *colind* and *colbdstat* passed to *getiis()*. *Getiis()* returns information about the specific constraints (rows) and variable bounds (columns) included in the IIS.

`pstat` On return, the variable pointed to *pstat* will contain 1 if a complete IIS was found, or 2 if the IIS finder stopped prior to completing the isolation of an IIS (normally due to exceeding the time limit set by the PARAM_TILIM parameter)..

`rowind`
`rowbdstat`
`pnumrows`

The arguments *rowind* and *rowbdstat* should be arrays of integers with dimension at least equal to the *pnumrows* argument value returned by *findiis()*. On return, *rowind* contains the indices (same as those used in the *sense* and *rhs* arguments of *loadlp()* and *loadnlp()*) of the constraints (rows) included in the IIS. The corresponding elements of *rowbdstat* will contain 0 if the constraint (normally with sense 'G') is at its lower bound; 1 if the constraint (normally with sense 'E') is fixed at one value; and 2 if the constraint (normally with sense 'L') is at its upper bound.

`colind`
`colbdstat`
`pnumcols`

The arguments *colind* and *colbdstat* should be arrays of integers with dimension at least equal to the *pnumcols* argument value returned by *findiis()*. On return, *colind* contains the indices (same as those used in the *lb* and *ub* arguments of *loadlp()* and *loadnlp()*) of the variable bounds (columns) included in the IIS. The corresponding elements of *colbdstat* will contain 0 if the variable is at its lower bound; 1 if the variable is fixed at one value; and 2 if the variable is at its upper bound.

If the value returned via *pstat* is 2 – meaning that a complete IIS was not found – the information returned by *getiis()* may still be useful: It will identify a subset of the constraints and variable bounds containing the source of infeasibility, even though this subset may contain more rows and columns than would be included in an IIS.

iiswrite

```
INTARG iiswrite (lp, filename)

HPROBLEM lp;
LPSTR filename;
```

You may call this routine (for linear or quadratic programming problems only) when the *pstat* argument value returned by *solution()* is 2 (PSTAT_INFEASIBLE). The *iiswrite()* routine calls *findiis()*, if necessary, to compute an Irreducibly Infeasible Set of constraints and bounds, as described above. It then writes an ASCII text file to disk, named *filename*, which lists the objective, the constraints included in the IIS, and the variable bounds included in the IIS, in the same "algebraic" format used by *lpwrite()*. This file is designed to be quickly readable in a text editor, and you can use it to identify the problem(s) in your constraints which are causing the overall model to be infeasible.

lpwrite

```
INTARG lpwrite (lp, filename)
```

```
HPROBLEM lp;
LPSTR filename;
```

This routine may be called at any time after *loadlp*, *loadquad* and/or *loadctype* have been called (and before *unloadprob* is called). It cannot be called for a nonlinear problem, defined via *loadnlp()*. *Lpwrite()* will write an output text file *filename*, containing an algebraic statement of the problem you have defined. By calling *lpwrite* and examining the resulting file, you can verify that the problem defined by your arguments is the one you intended. You can also use *lpwrite()* to save a problem to disk, and *lpread()* to read it in and solve it later. (For compatibility with previous versions of the Solver DLL, *lprewrite()* is a synonym for *lpwrite()*.)

Lpwrite() returns 0 unless there is an error in its arguments, in which case it returns 1 for an invalid *lp* argument, or 2 for any I/O error related to opening and writing the contents of *filename*.

`filename` The name (or complete path) of the output text file. *Lpwrite()* will create this file, which will replace any existing file of the same name. If *filename* does not include an explicit path, the file will be created in the current directory.

As an example, the following text appears in *filename* when *lpwrite()* is called for Example 2 in the sample source programs supplied with the Solver DLL:

```
Maximize LP/MIP
  obj: 2.0 x1 + 3.0 x2
Subject To
  c1:  9.0 x1 + 6.0 x2 <= 54.0
  c2:  6.0 x1 + 7.0 x2 <= 42.0
  c3:  5.0 x1 + 10.0 x2 <= 50.0
Bounds
  0.0 <= x1 <= +infinity
  0.0 <= x2 <= +infinity
Integers
  x1
  x2
End
```

lpread

```
INTARG lpread (lp, filename, objsen_p, numcols_p,
   numrows_p, numints_p, matcnt, qmatcnt)
```

```
HPROBLEM lp;
LPSTR filename;
```

```
LPINTARG objsen_p, numcols_p, numrows_p, numints_p;
LPINTARG matcnt, qmatcnt;
```

This routine can be used to read in the definition of a linear, quadratic, or mixed-integer problem, in algebraic format, from a text file. The file may be previously written by the *lpwrite()* routine, created by hand, or generated by another program. As long as the problem definition follows the format and syntax described here (and illustrated above under *lpwrite()*) and is within the size limits of your version of the Solver DLL, you can read it in through *lpread()* and solve it.

The text file should consist of lines ending in a newline (linefeed) or a carriage return/linefeed combination. The keywords `Maximize` or `Minimize`, `Subject To`, `Bounds`, `Integers` and `End` should appear on separate lines. The objective expression must be preceded by `obj:` and each constraint expression preceded by `c1:`, `c2:`, etc., but otherwise the expressions may be split across multiple lines. Each variable occurrence must have a form such as `x1`, `x123`, etc.; the highest variable index found in the file is returned in the variable pointed to by *numcols_p*. Lower and upper bounds on variables should either be numbers, `-infinity` or `+infinity`. The quadratic part of the objective (if used) must be surrounded by brackets, and each term should consist of a number followed by either two variable names separated by `*`, or one variable name followed by `^2`. For example:

```
[ x1^2 - x1*x2 + x2^2 ]
```

`lp` — Either NULL, or a pointer to a problem previously returned by *loadlp()*. If this argument is NULL, *lpread()* will scan the input text file and return values for the *objsen_p*, *numcols_p*, *numrows_p*, *numints_p*, *matcnt* and *qmatcnt* arguments (if they are specified), but it will not store any of the coefficient, bound or integer variable information. If lp is non-NULL, *lpread()* will scan the file, return values for the other arguments mentioned above, and fill in values for all of the arguments previously passed to *loadlp()*, *loadquad()* and/or *loadctype()* when the problem was defined, except for *matbeg* and *matcnt* (if used) and *qmatbeg* and *qmatcnt* (if used). It is your responsibility to ensure that the arrays previously passed to these routines are of the correct dimensions for the problem being read.

`filename` — The name (or complete path) of the input text file.

`objsen_p` — On return, the variable pointed to by *objsen_p* will contain the "sense" of the optimization problem (1 for minimize, -1 for maximize), as used by *loadlp()*. You may pass a "NULL value" for this argument if you don't need this information.

`numcols_p`
`numrows_p`
`numints_p` — On return, the variable pointed to by *numcols_p* will contain the number of columns (variables) in the problem defined by the input file; the variable pointed to by *numrows_p* will contain the number of rows (constraints) in the problem; and the variable pointed to by *numints_p* will contain the number of integer variables in the problem. You may pass "NULL values" for any of these arguments if you don't need the corresponding information.

`matcnt` — If used, this argument must be an integer array of dimension at least equal to the number of columns (variables) in the problem. On return, each element of the array will contain the number of nonzero coefficients of the corresponding variable found in the constraints of the problem. The resulting array has the same meaning as, and may be passed as, the *matcnt* argument of the *loadlp()* routine. You may pass a "NULL value" for this argument if you don't need this information, for example if you are using a dense matrix for the *matval* array of coefficients passed to *loadlp()*.

`qmatcnt` — If used, this argument must be an integer array of dimension at least equal to the number of columns (variables) in the problem. On return, each element of the array will contain the number of nonzero coefficients of the corresponding variable found

in the quadratic objective (if any) of the problem. The resulting array has the same meaning as, and may be passed as, the *qmatcnt* argument of the *loadquad()* routine. You may pass a "NULL value" for this argument if you don't need this information, for example if you are using a dense matrix for the *qmatval* array of coefficients passed to *loadquad()*.

If you know the sense and dimensions (number of variables, constraints and integers) of the problem you are going to read in and solve, you can simply call *loadlp()* (plus *loadquad()* and/or *loadctype()*) to define the problem with arrays of the correct dimension, then call *lpread()* once to fill in the coefficient, bound and integer variable information.

If you do not know the sense and/or dimensions of the problem in advance, you can call *lpread()* with a NULL first argument to obtain this information; then allocate arrays of the appropriate size, and call *loadlp()* (plus *loadquad()* and/or *loadctype()*) to define the problem; and finally call *lpread()* again – this time with a non-NULL first argument – to fill in the coefficient, bound and integer variable information.

To satisfy the Solver DLL's checks for argument validity, you must initialize the *sense* array – say, with all elements equal to 'E', the *ctype* array (if used for integer problems) – say, with all elements equal to 'C', and the *matbeg*, *matcnt* and *matind* arrays (if used for sparse problems). *Matbeg* and *matcnt* may be initialized as described below, and *matind* may be initialized with all elements equal to zero. (*Qmatbeg*, *qmatcnt* and *qmatind* should be treated similarly.)

If you are using sparse arrays to define *matval* or *qmatval*, and you do not know the dimensions or sparsity pattern in advance, you will need to call *lpread()* twice as outlined above, passing the *matcnt* and/or *qmatcnt* array arguments on the first call. These arrays must be of dimension at least equal to the number of columns (variables) in the problem being read; to create them, you can either use the maximum number of columns returned by the *getproblimits()* routine, or you can call *lpread()* one more time in advance to obtain the actual number of columns defined in the text file. The number of nonzeroes in the constraint matrix (the *nzspace* argument passed to *loadlp()*) is equal to the sum of the counts returned in the elements of *matcnt* (similarly for *qmatcnt* and *qnzspace*). You can initialize the *matbeg* array based on the counts in *matcnt* (similarly for *qmatbeg* and *qmatcnt*). For example, in C/C++:

```
for (nzspace = i = 0; i < numcols; i++) nzspace += matcnt[i];
for (i = 0; i < nzspace; i++) matind[i] = 0;
for (i = 0; i < numcols; i++)
   matbeg[i] = (i == 0 ? 0 : matbeg[i-1] + matcnt[i-1]);
```

Use Control Routines

The multi-threaded version of the Solver DLL can be distributed under a license based either on the number of users ("seats") or on the number of uses (calls to the *optimize()* or *mipoptimize()* routines.) Use-based licensing is advantageous in situations, such as public Web server applications, where the number of users is not known, or is so large that user-based licensing would be potentially too expensive. To facilitate use-based licensing, the Solver DLL includes routines that can be called to determine the number of uses to date, write this information to a text file, or automatically email this information to Frontline Systems, all under the control of the application program.

The Solver DLL is shipped in multiple configurations that include only the Solver "engines" that you need for your application, and that place specific upper limits on

problem sizes. By calling *getproblimits()*, you can find out at runtime which Solver "engines" are available and how many decision variables, constraints and integer variables you can specify in calls to each "engine."

getuse

```
INTARG getuse (lp, loadprob_p, optimize_p, verify_p,
   reload_p, repopt_p, repdate_p)

HPROBLEM lp;
LPINTARG loadprob_p, optimize_p, verify_p;
LPINTARG reload_p, repopt_p, repdate_p;
```

This function returns information to your application about the number of uses (calls to *loadlp()* or *loadnlp()*, and calls to *optimize()* or *mipoptimize()*) since the Solver DLL was placed in service. The *lp* argument is ignored and may be NULL. You may also pass NULL for any of the other arguments, if you do not need the corresponding information.

`loadprob_p` A pointer to a variable of type `long`, where *getuse()* will store the cumulative number of calls to *loadlp()* or *loadnlp()* to date.

`optimize_p` A pointer to a variable of type `long`, where *getuse()* will store the cumulative number of calls to *optimize()* or *mipoptimize()* to date.

`verify_p` A pointer to a variable of type `long`, where *getuse()* will store an encrypted form of the cumulative number of uses to date.

`reload_p` A pointer to a variable of type `long`, where *getuse()* will store the number of calls to *loadlp()* or *loadnlp()* previously reported to Frontline Systems (via an earlier call to *reportuse()*, or automatically as determined by the PARAM_USERP setting).

`repopt_p` A pointer to a variable of type `long`, where *getuse()* will store the number of calls to *optimize()* / *mipoptimize()* previously reported to Frontline Systems (via an earlier call to *reportuse()*, or automatically as determined by the PARAM_USERP setting).

`repdate_p` A pointer to a variable of type `long`, where *getuse()* will store the date of the last report to Frontline Systems, as an integer of the form YYYYMMDD.

The Solver DLL stores the information returned by *getuse()* in the system Registry, under the key:

`HKEY_LOCAL_MACHINE\SOFTWARE\FrontlineSystems\SolverDLL\3.5`

Under this key are six values – `UseLoadProb`, `UseOptimize`, `UseVerify`, `UseRepLoad`, `UseRepOpt` and `UseRepDate` – corresponding to *loadprob_p*, *optimize_p*, *verify_p*, *reload_p*, *repopt_p* and *repdate_p* respectively.

Frontline's use-based licensing terms can take into account the number of calls to *loadlp()* or *loadnlp()*, the number of calls to *optimize()* or *mipoptimize()*, or both counts. In many Solver DLL applications these counts may be the same. However, in some applications, one count or the other may correspond more closely to the number of "sessions" with individual users served by the application.

reportuse

```
INTARG reportuse (lp, probname, filename,
   profilename, password)
```

```
HPROBLEM lp;
LPSTR probname, filename, profilename, password;
```

This function will either write a text file to disk, or automatically send an email message to Frontline Systems (info@frontsys.com), containing the use information returned by *getuse()*, plus your application-specific "key" string and the Windows name of the computer on which the application is running. The email message, if used, is sent via the Win32 Messaging API (MAPI) which is normally available on the Windows system where the Solver DLL is running. The *lp* argument is ignored and may be NULL.

`probname` A character string (currently 16 characters plus a 0 terminator byte) containing a unique "key" which is assigned to you when you license the Solver DLL from Frontline Systems – the same as the argument you supply to *loadlp()* or *loadnlp()*.

`filename` If used, the name (or complete path) of the output text file that will contain the use information. *Reportuse()* will create this file, which will replace any existing file of the same name. If *filename* does not include an explicit path, the file will be created in the current directory. If this argument is NULL or an empty string, *reportuse()* will send an email message instead.

`profilename` This argument is optional. If *reportuse()* is sending an email message (i.e. the *filename* argument is NULL), this is the profile name (typically, the user name) of the email account used to send the message. If this argument is NULL or an empty string, *reportuse()* uses the MAPI "shared session" to send the email message.

`password` This argument is optional. If *reportuse()* is sending an email message (i.e. the *filename* argument is NULL), this is the password of the email account used to send the message. If this argument is NULL or an empty string, *reportuse()* uses the MAPI "shared session" to send the email message.

getproblimits

```
INTARG getproblimits (lp, type, pnumcols, pnumrows,
   pnumints)
```

```
HPROBLEM lp;
INTARG type;
LPINTARG pnumcols, pnumrows, pnumints;
```

This function allows you to determine the capabilities of the Solver DLL version you are using, at runtime. The Solver DLL V3.5 can be configured to include or exclude the nonlinear GRG and Evolutionary Solver "engines," the linear Solver "engine," or the quadratic Solver "engine," and the maximum number of decision variables (columns) and constraints (rows) supported by each "engine" can also be configured. *Getproblimits()* returns information about these characteristics of the Solver DLL. The *lp* argument is ignored and may be NULL

`type` This should be one of the following integer codes (the corresponding symbolic names are defined by the PROBTYPE enum in the header file FRONTMIP.H):

type = 0 = PROB_LP	Linear (Simplex) Solver
type = 4 = PROB_QP	Quadratic extension to Simplex Solver
type = 12 = PROB_NLP	Nonlinear (GRG) Solver
type = 20 = PROB_NSP	Nonsmooth (Evolutionary) Solver

(The mixed-integer variants of these codes return the same results as their corresponding codes listed here.).

`pnumcols`
`pnumrows`
`pnumints`

These three arguments should be pointers to variables of type `long`, where *getproblimits()* will store the maximum number of decision variables (columns), constraints (rows), and integer variables supported by the Solver "engine" specified by the *type* argument. If the number returned is zero, the corresponding "engine" is not supported in this configuration of the Solver DLL.

Callback Routines for Nonlinear Problems

For nonlinear and nonsmooth optimization problems, you must write a "callback" function (called *funceval* below) that computes values for the problem functions (objective and constraints) for any given values of the variables. The Solver DLL will call this function repeatedly during the solution process. You supply the address of this callback function as an argument to *loadnlp()*, which defines the overall nonlinear optimization problem. In 16-bit Windows 3.x, the address you pass must be obtained from the Windows routine *MakeProcInstance* – for example: *lpFuncEval = (_FUNCEVAL)MakeProcInstance ((FARPROC)MyFuncEval, hInst);* where *hInst* is the "instance handle" of the currently running application.

The nonlinear GRG Solver "engine" uses the callback function *funceval()* in two different ways: (i) to compute values for the problem functions at specific trial points as it seeks an optimum, and (ii) to compute estimates of the partial derivatives of the objective (the gradient) and the constraints (the Jacobian). The partial derivatives are estimated by a "rise over run" calculation, in which the value of each variable in turn is perturbed, and the change in the problem function values is observed. For a problem with N variables, the Solver DLL will call *funceval()* N times on each occasion when it needs new estimates of the partial derivatives (2*N times if the "central differencing" option is used). This often accounts for 50% or more of the calls to *funceval()* during the solution process.

The Evolutionary Solver "engine" does not assume that the problem functions are smooth or differentiable, and it does not attempt to estimate partial derivatives. However, it may make even more calls to *funceval()*, in total, than the nonlinear GRG Solver would make for a problem of a given size.

To speed up the solution process (for smooth nonlinear problems only), and to give the Solver DLL more accurate estimates of the partial derivatives, you can supply a second callback function *jacobian()* which returns values for all elements of the objective gradient and constraint Jacobian matrix in one call. The callback function is optional – you can supply NULL instead of a function address – but if it is present, the nonlinear GRG Solver "engine" will call it instead of making repeated calls to *funceval()* to evaluate partial derivatives.

funceval

```
INTARG funceval (lp, numcols, numrows, objval,
   lhs, var, varone, vartwo)

HPROBLEM lp;
INTARG numcols, numrows;
LPREALARG objval, lhs, var;
INTARG varone, vartwo;
```

The *funceval()* routine computes values for the problem functions. It is passed a vector of variable values, and a vector of function values (including the objective) to

be computed. It uses the variables to compute the functions, stores these into the vector of function values, and returns an integer indicating success or failure.

The *numcols* and *numrows* arguments are the same values you supplied to *loadnlp()*. The *var* array has dimension *numcols*, and the *lhs* array has dimension *numrows*. The *objval* argument is a pointer to a location where the (scalar) objective value should be stored. The routine should compute and store the objective value, compute constraint left hand side values and store them in *lhs*, and return 0 for success or 1 for failure (1 will cause the Solver DLL to stop and return from its *optimize()* call).

The *varone* and *vartwo* arguments may be ignored unless your function evaluation process is designed to take advantage of information about which elements of the *var* array have changed since the last call to *funceval()*. When the Solver is supplying entirely new variable values (i.e. exploring a new trial point), *varone* and *vartwo* will both be –1.

When the Solver is computing partial derivatives on its own via finite differencing (in the absence of the *jacobian()* callback function), it calls *funceval()* repeatedly, perturbing one variable at a time (and resetting the previously perturbed variable). On these calls (usually about *half* of all *funceval()* calls), *varone* and *vartwo* are the indices (0 to numcols-1) of the (only) variables whose values have changed since the last call. Your *funceval()* routine must still compute values for *objval* and all elements of the *lhs* array, but you may be able to do less work based on knowledge of which variables have changed.

jacobian

```
INTARG jacobian (lp, numcols, numrows, nzspace,
   objval, obj, matbeg, matcnt, matind, matval,
   var, objtype, matvaltype)

HPROBLEM lp;
INTARG numcols, numrows, nzspace;
LPREALARG objval, obj;
LPINTARG matbeg, matcnt;
HPINTARG matind;
HPREALARG matval;
LPREALARG var;
LPBYTEARG objtype, matvaltype;
```

The *jacobian()* routine, if supplied, is called in preference to *funceval()* – but only by the nonlinear GRG Solver "engine" – to compute the objective gradient and the Jacobian matrix of partial derivatives of the problem functions, at a specific trial point found by the Solver. (Each row of the Jacobian is the gradient of the corresponding constraint function.) Note that if *jacobian()* is supplied, *funceval()* will still be called, but its *varone* and *vartwo* arguments will always be -1.

The *jacobian()* routine should compute the value and gradient of the objective and the Jacobian at the trial point represented by the values in the *var* argument. The *numcols*, *numrows* and *nzspace* values and the *matbeg*, *matcnt* and *matind* arrays are the same ones (possibly NULL pointers) that you supplied to *loadnlp()*. *Objtype* and *matvaltype* are the arrays of characters you supplied to *loadnltype()*; otherwise they will be NULL pointers. The *objval* argument is a pointer to a location where the (scalar) objective value should be stored. You should store the objective value in *objval*, the gradient of the objective in the *obj* array, and the partial derivative values in the appropriate elements of the *matval* array (taking care not to exceed the dimension *nzspace* for *matind* and *matval*). If all elements of the *objtype* array are `'L'`, you can skip computing and storing the objective value and gradient; if all

elements of the *matvaltype* array are `'L'`, you can skip computing the partial derivatives of the problem functions. Your routine should return 0 for success or 1 for failure (1 will cause the Solver DLL to stop and return from its *optimize()* call).

Other Callback Routines

For all types of problems – nonlinear, linear, quadratic, and mixed integer – you can arrange to have the Solver DLL periodically call a routine which you specify. In this routine, you can access information about the progress of the optimization, check for external conditions such as a user interaction, etc. Your routine can return a value to the Solver DLL signalling that it should continue, or halt the optimization and return to your program. For LP problems, you can specify a callback routine which will obtain control on each "pivot" or Simplex iteration. For MIP problems, you can also specify a routine which will obtain control on each "branch" or Branch & Bound LP subproblem.

Both callback routines should be declared as follows:

```
INTARG _CC MyCallback (lpinfo, wherefrom)

HPROBLEM lpinfo;
INTARG wherefrom;
```

_CC ("calling convention") is a typedef for callback routines under Windows: It is *export far pascal* in 16-bit Windows 3.x, and *stdcall* in 32-bit Windows 95/98 and NT. _CCPROC is a typedef for the address of a routine with this signature. Both of these symbols are defined in `frontmip.h`. You pass the address of your callback routine to the Solver DLL via a call to *setlpcallbackfunc* or *setmipcallbackfunc*.

In 16-bit Windows 3.x, the address you pass should be obtained from the Windows routine *MakeProcInstance.* An example would be: *_CCPROC lpCallback = (_CCPROC)MakeProcInstance ((FARPROC)MyCallback, hInst);* where *hInst* is the "instance handle" of the currently running application.

The *lpinfo* argument is a "problem handle" identifying the current LP or MIP problem, but its only use should be as the first argument in calls to *getcallbackinfo* (see below). The *wherefrom* argument indicates whether this is an LP pivot (*wherefrom* = CALLBACK_PRIMAL = 1) or a MIP branch (*wherefrom* = CALLBACK_MIP = 101); this makes it easy to use a single routine for both types of callbacks.

In the body of your callback routine, you can obtain information about the progress of the optimization by calling *getcallbackinfo* with arguments specifying exactly the information you want. You return a zero value to indicate that the optimization process should continue, or a nonzero value to indicate that the optimization should be halted and the Solver DLL should return to its caller.

There is a typedef enum PSTAT in `frontmip.h`, which can be used to return values from your callback routine, or to test the *pstat* values returned by *solution*. PSTAT_CONTINUE (which equals 0) means "continue the solution process;" PSTAT_USER_ABORT signals that the user wants to interrupt the solution process.

setlpcallbackfunc

```
INTARG setlpcallbackfunc (lp, callback)
```

```
HPROBLEM lp;
_CCPROC callback;
```

Your program should call this function, prior to calling *optimize* or *mipoptimize*, to specify the callback function which the Solver DLL should call on each "pivot" or Simplex iteration.

`callback` The address of a user-written callback routine (i.e. a *procedure pointer*), declared as shown above. To eliminate use of the callback function, pass an argument value of NULL to *setlpcallbackfunc*.

getlpcallbackfunc

```
void getlpcallbackfunc (lp, callback_p)
```

```
HPROBLEM lp;
_CCPROC *callback_p;
```

`callback_p` The *address* of a *procedure pointer variable* which will be set to the address of the current LP pivot callback routine. Before you set the callback with *setlpcallbackfunc*, *getlpcallbackfunc* will store NULL in this variable.

setmipcallbackfunc

```
INTARG setmipcallbackfunc (lp, callback)
```

```
HPROBLEM lp;
_CCPROC callback;
```

Your program should call this function, prior to calling *mipoptimize*, to specify the callback function which the Solver DLL should call on each "branch" or LP subproblem in a MIP problem.

`callback` The address of a user-written callback routine (i.e. a *procedure pointer*), declared as shown above. To eliminate use of the callback function, pass an argument value of NULL to *setmipcallbackfunc()*.

getmipcallbackfunc

```
void getmipcallbackfunc (lp, callback_p)
```

```
HPROBLEM lp;
_CCPROC *callback_p;
```

`callback_p` The *address* of a *procedure pointer variable* which will be set to the address of the current MIP callback routine. Before you set the callback with *setmipcallbackfunc()*, *getmipcallbackfunc()* will store NULL in this variable.

getcallbackinfo

```
INTARG getcallbackinfo (lpinfo, wherefrom, infonumber,
result_p)
```

```
HPROBLEM lpinfo;
INTARG wherefrom, infonumber;
void *result_p;
```

`lpinfo` This argument identifies the problem; it ***must*** be the value of the *lpinfo* argument passed to your callback routine.

`wherefrom` This argument identifies the callback type; it ***must*** be the value of the *wherefrom* argument passed to your callback routine.

`infonumber` This selects the specific information to be returned in the *result_p* argument:

CBINFO_PRIMAL_OBJ	The current objective function value (double)
CBINFO_PRIMAL_INFMEAS	The sum of the current infeasibilities (double)
CBINFO_PRIMAL_FEAS	= 1 if current solution is feasible, = 0 if not (long)
CBINFO_ITCOUNT	Number of iterations so far in the LP problem (long)
CBINFO_NODE_COUNT	Number of branches so far in the MIP problem (long)
CBINFO_MIP_ITERATIONS	Total number of LP pivots/iterations so far (long)
CBINFO_BEST_INTEGER	Objective value of the "incumbent," the best integer solution found so far (double)

`result_p` The address of a variable to receive the requested information; this variable must be of the data type implied by the *infonumber* argument, e.g. a pointer to a double for a call with *infonumber* = CBINFO_PRIMAL_OBJ, or a pointer to a long integer for *infonumber* = CBINFO_PRIMAL_ITCOUNT.

Solver Parameters

The Solver DLL has a number of options and tolerances which you can control to influence the behavior of the LP, QP and MIP solution algorithms. These are collectively called "parameters," and may be of either integer or double type. Integer parameters are used to select algorithmic options and to set "countable" limits, such as the maximum number of iterations. Double parameters are used to set tolerances, such as how small an LP matrix pivot element can be.

All integer parameters are manipulated with one set of routines (*setintparam*, *getintparam*, and *infointparam*), and all double parameters are manipulated with a similar set of routines (*setdblparam*, *getdblparam* and *infodblparam*). You can set all parameters to their default values by calling *setdefaults*.

Each parameter is identified by a numeric code, for which a symbolic name is defined in the C/C++ and Pascal header files. The parameters are summarized in this section, and then each parameter manipulation routine is described in detail.

Integer Parameters (General)

The following parameters have (long) integer values. They control general features of the Solver DLL such as array argument passing conventions and the IIS finder.

Symbolic Name	***Code***	***Usage in Solver DLLs***
PARAM_ARGCK	990	on argument errors: 1-MsgBox, 0-retval only
PARAM_ARRAY	995	0 - Use C-style arrays, 1 - Use VB-style OLE SAFEARRAYs
PARAM_USERP	997	0 - Eval/Test mode, 1 - automatic reports, 2 – user-controlled reports
PARAM_IISBND	999	0 - Eliminate bounds, 1 - Don't eliminate bounds in finding IIS
PARAM_ITLIM	1020	limit on Solver "engine" iterations

PARAM_ARGCK This parameter is unique to the Solver DLL and is used for debugging: When it is set to 1, if your program calls a Solver DLL routine which detects an invalid argument, that routine will display a Windows MessageBox describing the error. This allows you to see the problem immediately, without having to write code to test the value returned by the DLL routine.

PARAM_ARRAY This parameter affects *all* of the Solver DLL routines which take arrays as arguments. If this parameter is 0 (the default), all array arguments supplied to the Solver, and all array arguments of callback functions (i.e. *funceval()* and *jacobian()*) are C-style arrays: The actual arguments are pointers to the base of the block of memory holding array values. If this parameter is 1, all array arguments are Visual Basic or OLE-style SAFEARRAYs: The actual arguments are pointers to pointers to SAFEARRAY descriptors, which contain pointers to the base of the block of memory holding array values.

PARAM_USERP This parameter controls the reporting of "use" information in certain licensed versions of the Solver DLL. The default setting is 0, which means that the Solver DLL operates in "Evaluation/Test mode:" It will not keep track of the number of uses, or store anything in the Registry, but once every 10 minutes, it will display a MessageBox on the system console. Once the DLL is placed into service, this parameter should be set to 1 or 2: In this case the Solver DLL will count uses (calls to *optimize()* or *mipoptimize()*) and will store this information in the Registry. When PARAM_USERP is 1, the DLL will automatically send an updated report of the cumulative number of uses by email to Frontline Systems (info@frontsys.com) each time it is run in a new calendar month. When PARAM_USERP is 2, the DLL will not send any reports automatically, but reports may be generated and written to a text file or emailed to Frontline Systems, under control of the user's application, through calls to the *reportuse()* routine.

PARAM_IISBND Setting this parameter to 1 causes the Solver DLL's IIS finder to skip the steps (and computing time) required to eliminate variable bounds from an Irreducibly Infeasible Set of constraints. When PARAM_IISBND is 1, any IIS which is found will include all of the variable bounds defined (in the lb and ub arrays) for the problem. When this parameter is 0 (the default), as many variable bounds as possible will be eliminated from the IIS.

PARAM_ITLIM This is the maximum number of iterations (pivots) that the Solver will perform on an NLP, LP or QP problem (or a subproblem of a MIP problem). When this limit is exceeded, the *optimize* routine will return and the *solution* routine's *pstat* argument will be set to PSTAT_IT_LIM_FEAS or PSTAT_IT_LIM_INFEAS, depending on whether a feasible solution has been found.

Integer Parameters (Solver Engines)

The following parameters have (long) integer values. They control various features of the Nonlinear, Linear and Quadratic Solver "engines."

Symbolic Name	*Code*	*Usage in Solver DLLs*
PARAM_SCAIND	1033	scaling: -1-none, 0-normal, 1-aggressive
PARAM_CRAIND	1007	crashing: 0-none, 1-crash initial basis
PARAM_LINVAR	5010	NLP linear variables: 0 - ignore, 1 - recognize linear variables
PARAM_DERIV	5011	NLP derivatives: 0 - Forward, 1 - Central differencing; 2 - Use supplied jacobian function, 3 - Use and *check* supplied jacobian

PARAM_ESTIM	5012	NLP estimates of basic variables: 0 - Tangent, 1 - Quadratic
PARAM_DIREC	5013	NLP search direction: 0 - Quasi-Newton, 1 - Conjugate Gradient
PARAM_SAMPSZ	6001	Evolutionary Solver population (sample) size
PARAM_NOIMP	6002	Evol. Solver max time with no improvement

`PARAM_SCAIND` The scaling option determines how the LP matrix, variable and constraint bounds are (re)scaled during the solution process. A value of -1 means no scaling, 0 means "normal" scaling, and 1 means "aggressive" scaling (used only by the Large-Scale LP/MIP Solver DLL). The default value of 0 will usually yield good results, including more accurate solutions and fewer total iterations.

`PARAM_CRAIND` The "crashing" option is used only by the Large-Scale LP/MIP Solver DLL. A value of 1 indicates that the Solver should start by constructing an advanced basis, in which so-called "artificial" variables are eliminated in favor of "structural" variables wherever possible. This often results in fewer total iterations. A value of 0 means that the Solver should start from a "normal" basis.

`PARAM_LINVAR` This parameter determines whether the nonlinear Solver "engine" will attempt to recognize variables occurring linearly in all of the problem functions, and then save time by assuming that first partial derivatives with respect to these variables are constant and need not be recomputed. This is an "aggressive" strategy which should be used only when you know that the nonlinearly occurring variables will not appear to change linearly over the intervals around their starting values.

`PARAM_DERIV` This parameter controls the method used by the Solver to compute approximate first partial derivatives. 0 means that "forward differencing" will be used, perturbing variable values in one direction from the current point. 1 means that "central differencing" will be used, perturbing variable values in two opposing directions from the current point. Central differencing takes more computing time, but can yield better results and fewer total iterations, especially if the Solver's path to the solution lies close to one or more constraint boundaries.

2 means that the *jacobian()* function, which must be supplied as an argument to *loadnlp()*, will be called to compute partial derivatives. 3 may be used for debugging purposes: It means that the Solver will compute partial derivatives via forward differencing, then call the *jacobian()* function and compare the results. If the derivatives do not match within a small tolerance, the Solver will stop and return PSTAT_FLOAT_ERROR; however if PARAM_ARGCK is 1, the Solver will display Windows MessageBoxes reporting each mismatching derivative, and will return PSTAT_FLOAT_ERROR only if you click Cancel in a MessageBox.

`PARAM_ESTIM` This parameter controls the method used to estimate initial values for the basic variables at the beginning of each one-dimensional line search. 0 means that the Solver will use linear extrapolation from the line tangent to the reduced objective function. 1 means that the Solver will extrapolate to the minimum (or maximum) of a quadratic fitted to the reduced objective at its current point.

`PARAM_DIREC` This parameter controls the method used by the Solver to determine a direction vector for the variables being changed on a given iteration. 0 means that the Solver will use a Quasi-Newton method, maintaining an approximate Hessian matrix for the reduced objective function. 1 means that the Solver will use a Conjugate Gradient method, which does not require the Hessian matrix.

`PARAM_SAMPSZ` This parameter determines the number of points in the Evolutionary Solver's population of candidate solutions. The default value is 0, which instructs the

Evolutionary Solver to select a "reasonable" population size for the problem (currently 10 times the number of variables in the problem, but no more than 200). In general, a larger population size will permit more diversity among candidate solutions, but may slow down convergence towards an accepted solution.

`PARAM_NOIMP` This parameter controls one of the stopping criteria used by the Evolutionary Solver "engine:" If the Solver does not find an improved solution within the time (in seconds) specified by this parameter, it will stop and return from the call to *optimize()* with the best solution found so far. An "improved solution" is a feasible solution where the relative improvement in the objective, compared to the best solution found previously, exceeds the PARAM_EPGAP setting.

Integer Parameters (Mixed-Integer Problems)

Symbolic Name	*Code*	*Usage in Solver DLLs*
PARAM_NDLIM	2017	limit on Branch & Bound nodes explored
PARAM_MIPLIM	2015	limit on Branch & Bound IP solutions found
PARAM_RELAX	2501	Solve relaxation: 0 - normal problem, 1 - ignore integer variables
PARAM_PREPRO	2502	P&P Probing: 0 - Off, 1 - On
PARAM_OPTFIX	2503	P&P Optimality Fixing: 0 - Off, 1 - On
PARAM_REORDR	2504	P&P Branch Var Reordering: 0 - Off, 1 - On
PARAM_IMPBND	2505	P&P Bounds Improvement: 0 - Off, 1 - On

`PARAM_NDLIM` This is the maximum number of nodes, or LP subproblems, that the Branch & Bound algorithm will fathom on a MIP problem. When this limit is exceeded, the *mipoptimize* routine will return and the *solution* routine's *pstat* argument will be set to PSTAT_MIP_NODE_LIM_FEAS or PSTAT_MIP_NODE_LIM_INFEAS, depending on whether a feasible integer solution has been found.

`PARAM_MIPLIM` This is the maximum number of feasible integer solutions that the Branch & Bound algorithm will find on a MIP problem. When this limit is exceeded, the *mipoptimize* routine will return and the *solution* routine's *pstat* argument will be set to PSTAT_MIP_SOL_LIM (there is always a feasible integer solution at this point).

`PARAM_RELAX` Setting this parameter to 1 causes the Solver DLL to *ignore* any integer variables defined by a call to *loadctype()*, and instead to solve the "relaxation" of the mixed-integer programming problem. It is effective for both linear and nonlinear problems. When this parameter is set to 0 (the default), the integer variables are taken into account and the Branch & Bound algorithm is used to find an integer optimal solution.

`PARAM_PREPRO` Setting this parameter to 1 activates the Probing strategy for MIP problems (in the Solver DLL Plus). The Probing strategy allows the Solver to derive values for certain binary integer variables based on the settings of others, prior to actually solving the problem. When the Branch & Bound method creates a subproblem with an additional (tighter) bound on a binary integer variable, this causes the variable to be fixed at 0 or 1. In many problems, this has implications for the values of other binary integer variables which can be discovered through Probing. For example, your model may have a constraint such as $x_1 + x_2 + x_3 + x_4 + x_5 \leq 1$ where x_1 through x_5 are all binary integer variables. Whenever one of these variables is fixed at 1, all of the others are forced to be 0; Probing allows the Solver to determine this *before* solving the problem. In some cases, the Feasibility tests performed as part of Probing will determine that the subproblem is infeasible, so it is unnecessary to solve it at all. (This is a special case of a "clique" or "Special Ordered Set" (SOS) constraint; the Solver recognizes these constraints in their most general form.)

`PARAM_OPTFIX` Setting this parameter to 1 activates the Optimality Fixing strategy for MIP problems (in the Solver DLL Plus). The Optimality Fixing strategy is another way to fix the values of binary integer variables before the subproblem is solved, based on the signs of the coefficients of these variables in the objective and the constraints. Optimality Fixing can lead to further opportunities for Probing and Bounds Improvement, and vice versa.

`PARAM_REORDR` Setting this parameter to 1 activates the Variable Reordering strategy for MIP problems (in the Solver DLL Plus). The Variable Reordering strategy attempts to improve the order in which the Branch & Bound algorithm chooses integer variables

to "branch" upon, based on the relative magnitudes of their coefficients in the objective and constraints. The goal is to choose integer variables to "branch" upon which have a large impact on the values which may be assumed by other variables in the problem. For example, you might have a binary integer variable which indicates whether or not a new plant will be built, and other variables which then determine whether certain manufacturing lines will be started up. You would like the Solver to "branch" upon the plant-building variable as early as possible, since its setting will eliminate many other possibilities which would otherwise have to be considered during the solution of each subproblem. If this parameter is set to 0, the selection of integer variables to branch upon is guided by the order of the variables in the arrays defining your problem.

`PARAM_IMPBND` Setting this parameter to 1 activates the Bounds Improvement strategy for MIP problems (in the Solver DLL Plus). The Bounds Improvement strategy allows the Solver to tighten the bounds on variables which are *not* 0-1 or binary integer variables, based on the values which have been derived for the binary variables, before the problem is solved. Tightening the bounds usually reduces the effort required by the Simplex or other Solver engine to find the optimal solution, and it some cases it leads to an immediate determination that the subproblem is infeasible and need not be solved.

Double Parameters

The following parameters have double values. Parameters whose names begin with EP are used to set tolerances in the LP, QP and MIP solution algorithms.

Symbolic Name	***Code***	***Usage in Solver DLLs***
PARAM_TILIM	1038	time limit for *optimize*/*mipoptimize*
PARAM_EPOPT	1014	LP optimality tolerance
PARAM_EPPIV	1091	LP pivot tolerance
PARAM_EPSOL	1092	Large-Scale LP solution tolerance
PARAM_EPRHS	1016	LP feasibility tolerance
PARAM_EPGAP	2009	integer tolerance/MIP gap
PARAM_CUTLO	2006	known incumbent for max MIP
PARAM_CUTHI	2007	known incumbent for min MIP
PARAM_EPNEWT	5001	NLP constraint satisfaction tolerance
PARAM_EPCONV	5002	NLP tolerance for slowly changing objective
PARAM_MUTATE	6010	Evolutionary Solver mutation probability

`PARAM_TILIM` This is the maximum number of seconds that the Solver spend on the overall LP or MIP problem. When this limit is exceeded, the *optimize* routine will return and the *solution* routine's *pstat* argument will be set to PSTAT_TIME_LIM_FEAS or PSTAT_TIME_LIM_INFEAS for an LP problem, depending on whether a feasible solution has been found. On a MIP problem, the pstat argument will be set to PSTAT_MIP_TIME_LIM_FEAS or PSTAT_MIP_TIME_LIM_FEAS, depending on whether a feasible integer solution has been found.

`PARAM_EPOPT` This is the "optimality tolerance" or "reduced cost tolerance" for LP problems. Variables whose reduced cost is less than the negative of this tolerance are candidates for entering the basis.

`PARAM_EPPIV` This is the "pivot tolerance" for LP problems. LP matrix elements must have an absolute value greater than or equal to this tolerance to be candidates for pivoting.

PARAM_EPSOL This is the "solution tolerance" in the Large-Scale LP/MIP Solver DLL. Any calculated basic variable whose absolute value is less than this tolerance is treated as zero.

PARAM_EPRHS This is the "feasibility tolerance," within which constraints are considered satisfied and values for decision variables are treated as integer in MIP problems.

PARAM_EPGAP This is the (relative) integer objective "gap tolerance" for MIP problems. On such problems, it often happens that the Branch & Bound algorithm will find a good solution fairly quickly, but will require a great deal of time to find (or verify that it has found) the optimal integer solution. The integer gap tolerance setting may be used to tell the Solver to stop if the best solution so far is "close enough."

The Solver computes the absolute value of the difference between the objective value for the best *integer solution* so far (the "incumbent") and the "best bound" on the objective value found so far by the Branch & Bound process, divided by the best bound's objective value. If this relative difference is less than the integer gap tolerance, the Solver stops and returns the incumbent as the solution.

Initially, the objective value of the LP "relaxation" of the problem (ignoring the integer constraints) serves as the best bound, since the all-integer solution can be no better than this. During the Branch & Bound process, the best bound is updated based on the subproblems that have already been explored.

By default, the integer gap tolerance is zero, which means that the Solver will continue searching until all alternatives have been explored and the optimal integer solution has been found. You can often save significant solution time by setting an integer gap tolerance, greater than zero, which is sufficient for your application.

PARAM_CUTLO This is the "integer objective cutoff value" for MIP maximization problems. In the Branch & Bound algorithm, any subproblem whose objective is less than this value will not be fathomed. If you have an objective value for a known integer solution to this problem, for example from a previous call to the Solver, you can use it to set this parameter and save on solution time.

PARAM_CUTHI This is the "integer objective cutoff value" for MIP minimization problems. In the Branch & Bound algorithm, any subproblem whose objective is greater than this value will not be fathomed. If you have an objective value for a known integer solution to this problem, for example from a previous call to the Solver, you can use it to set this parameter and save on solution time.

PARAM_EPNEWT This is the tolerance within which constraints will be considered "binding," or satisfied with equality, during the solution process.

PARAM_EPCONV This is the tolerance used in the nonlinear GRG Solver's and the Evolutionary Solver's test for a "slowly changing objective:" In the GRG Solver, if the relative change in the objective function is less than this value for the last five iterations, the Solver stops and returns PSTAT_FRAC_CHANGE in the *pstat* argument of the *solution()* function. In the Evolutionary Solver, if 99% of the population members have "fitness values" that differ by less than this value, the Solver stops and returns PSTAT_FRAC_CHANGE.

PARAM_MUTATE This is the probability that the Evolutionary Solver "engine," on one of its major iterations, will attempt to generate a new trial point by "mutating" or altering one or more variable values of a current point in the population of candidate solutions.

setintparam

```
INTARG setintparam (lp, whichparam, newvalue)
```

```
HPROBLEM lp;
INTARG whichparam;
INTARG newvalue;
```

This routine is called to set the current value of one of the integer parameters in a specified problem. It returns 0 if successful, 1 if *whichparam* isn't one of the valid codes for integer parameters, or 2 if *newvalue* is outside the range of valid values for the chosen parameter.

`whichparam` One of the symbolic names or codes for integer parameters: PARAM_ARGCK, PARAM_ARRAY, PARAM_USERP, PARAM_IISBND, PARAM_ITLIM, PARAM_NDLIM, PARAM_MIPLIM, PARAM_SAMPSZ, PARAM_NOIMP, PARAM_SCAIND, PARAM_CRAIND, PARAM_LINVAR, PARAM_DERIV, PARAM_ESTIM, PARAM_DIREC, PARAM_RELAX, PARAM_PREPRO, PARAM_OPTFIX, PARAM_REORDR, PARAM_IMPBND, PARAM_REQBND.

`newvalue` The desired new value for the chosen parameter.

getintparam

```
INTARG getintparam (lp, whichparam, value_p)
```

```
HPROBLEM lp;
INTARG whichparam;
LPINTARG value_p;
```

This routine is called to get the current value of one of the integer parameters in a specified problem. It returns 0 if successful, or 1 if *whichparam* isn't one of the valid codes for integer parameters.

`whichparam` One of the symbolic names or codes for integer parameters: PARAM_ARGCK, PARAM_ARRAY, PARAM_USERP, PARAM_IISBND, PARAM_ITLIM, PARAM_NDLIM, PARAM_MIPLIM, PARAM_SAMPSZ, PARAM_NOIMP, PARAM_SCAIND, PARAM_CRAIND, PARAM_LINVAR, PARAM_DERIV, PARAM_ESTIM, PARAM_DIREC, PARAM_RELAX, PARAM_PREPRO, PARAM_OPTFIX, PARAM_REORDR, PARAM_IMPBND, PARAM_REQBND.

`value_p` A pointer to the location where the current value of the parameter will be stored.

infointparam

```
INTARG infointparam (lp, whichparam, defvalue_p,
   minvalue_p, maxvalue_p)
```

```
HPROBLEM lp;
INTARG whichparam;
LPINTARG defvalue_p, minvalue_p, maxvalue_p;
```

This routine is called to get the minimum, maximum, and default values of one of the integer parameters. It returns 0 if successful, or 1 if *whichparam* isn't one of the valid codes for integer parameters. The *lp* argument is ignored and may be NULL.

`whichparam` One of the symbolic names or codes for integer parameters: PARAM_ARGCK, PARAM_ARRAY, PARAM_USERP, PARAM_IISBND, PARAM_ITLIM,

PARAM_NDLIM, PARAM_MIPLIM, PARAM_SAMPSZ, PARAM_NOIMP, PARAM_SCAIND, PARAM_CRAIND, PARAM_LINVAR, PARAM_DERIV, PARAM_ESTIM, PARAM_DIREC, PARAM_RELAX, PARAM_PREPRO, PARAM_OPTFIX, PARAM_REORDR, PARAM_IMPBND, PARAM_REQBND.

`defvalue_p` A pointer to the location where the default value of the parameter will be stored.

`minvalue_p` A pointer to the location where the minimum value of the parameter will be stored.

`maxvalue_p` A pointer to the location where the maximum value of the parameter will be stored.

Below is a list of the default, minimum and maximum values of each of the integer parameters.

Symbolic Name	*Default*	*Minimum*	*Maximum*
PARAM_ARGCK	0	0	1
PARAM_ARRAY	0	0	1
PARAM_USERP	0	0	2
PARAM_IISBND	0	0	1
PARAM_ITLIM	2147483647	0	2147483647
PARAM_NDLIM	2147483647	0	2147483647
PARAM_MIPLIM	2147483647	0	2147483647
PARAM_SAMPSZ	0	0	2147483647
PARAM_NOIMP	30	0	2147483647
PARAM_SCAIND	0	-1	1
PARAM_CRAIND	0	0	1
PARAM_LINVAR	0	0	1
PARAM_DERIV	0	0	3
PARAM_ESTIM	0	0	1
PARAM_DIREC	0	0	1
PARAM_RELAX	0	0	1
PARAM_PREPRO	0	0	1
PARAM_OPTFIX	0	0	1
PARAM_REORDR	0	0	1
PARAM_IMPBND	0	0	1
PARAM_REQBND	1	0	1

setdblparam

```
INTARG setdblparam (lp, whichparam, newvalue)

HPROBLEM lp;
INTARG whichparam;
REALARG newvalue;
```

This routine is called to set the current value of one of the double parameters in a specified problem. It returns 0 if successful, 1 if *whichparam* isn't one of the valid codes for integer parameters, or 2 if *newvalue* is outside the range of valid values for the chosen parameter.

`whichparam` One of the symbolic names or codes for double parameters: PARAM_TILIM, PARAM_EPOPT, PARAM_EPPIV, PARAM_EPSOL, PARAM_EPRHS, PARAM_EPGAP, PARAM_CUTLO, PARAM_CUTHI, PARAM_EPNEWT, PARAM_EPCONV or PARAM_MUTATE.

`newvalue` The desired new value for the chosen parameter.

getdblparam

```
INTARG getdblparam (lp, whichparam, value_p)
```

```
HPROBLEM lp;
INTARG whichparam;
LPREALARG value_p;
```

This routine is called to get the current value of one of the double parameters in a specified problem. It returns 0 if successful, or 1 if *whichparam* isn't one of the valid codes for double parameters.

`whichparam` One of the symbolic names or codes for double parameters: PARAM_TILIM, PARAM_EPOPT, PARAM_EPPIV, PARAM_EPSOL, PARAM_EPRHS, PARAM_EPGAP, PARAM_CUTLO, PARAM_CUTHI, PARAM_EPNEWT, PARAM_EPCONV or PARAM_MUTATE THI.

`value_p` A pointer to the location where the current value of the parameter will be stored.

infodblparam

```
INTARG infodblparam (lp, whichparam, defvalue_p,
   minvalue_p, maxvalue_p)
```

```
HPROBLEM lp;
INTARG whichparam;
LPREALARG defvalue_p, minvalue_p, maxvalue_p;
```

This routine is called to get the minimum, maximum, and default values of one of the double parameters. It returns 0 if successful, or 1 if *whichparam* isn't one of the valid codes for double parameters. The *lp* argument is ignored and may be NULL.

`whichparam` One of the symbolic names or codes for double parameters: PARAM_TILIM, PARAM_EPOPT, PARAM_EPPIV, PARAM_EPSOL, PARAM_EPRHS, PARAM_EPGAP, PARAM_CUTLO, PARAM_CUTHI, PARAM_EPNEWT, PARAM_EPCONV or PARAM_MUTATE.

`defvalue_p` A pointer to the location where the default value of the parameter will be stored.

`minvalue_p` A pointer to the location where the minimum value of the parameter will be stored.

`maxvalue_p` A pointer to the location where the maximum value of the parameter will be stored.

A list of the default, minimum and maximum values of each of the double parameters is shown on the next page.

Symbolic Name	*Default*	*Minimum*	*Maximum*
PARAM_TILIM	65535.0	0.0	65535.0
PARAM_EPOPT	1.0E-5	1.0E-9	1.0E-4
PARAM_EPPIV	1.0E-6	1.0E-9	1.0E-4
PARAM_EPSOL	1.0E-4	1.0E-9	1.0E-4
PARAM_EPRHS	1.0E-8	1.0E-9	1.0E-4
PARAM_EPGAP	0.0	0.0	1.0
PARAM_CUTLO	-2.0E+30	-2.0E+30	2.0E+30
PARAM_CUTHI	2.0E+30	-2.0E+30	2.0E+30
PARAM_EPNEWT	1.0E-6	1.0E-9	1.0E-4
PARAM_EPCONV	1.0E-4	0.0	1.0
PARAM_MUTATE	0.075	0.0	1.0

setdefaults

```
INTARG setdefaults (lp)
HPROBLEM lp;
```

This routine is called to set each of the integer and double parameters for a specified problem to their default values, as shown in the tables above for *infointparam* and *infodblparam*. The return value is always 0.