Fortran Tools

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A Software License Agreement

Installation on Windows 1

This chapter describes how to install the Fortran compiler, Eclipse/Photran visual development environment, and related software.

1.1 Introduction

Before installing the software, please read and abide by the Software Agreement in Appendix A. Please note that most of this software is developed by third parties as open source software and is subject to the licensing agreements for the software.

1.2 Implementations Available

The implementations available are for Windows and 32-bit and 64-bit Linux. The Windows version is built with Windows XP on a Pentium D system.

1.3 Contents

The software includes a Fortran 95 compiler, the Eclipse/Photran development environment, other software (including linear algebra and plotting software), a *Fortran Tools* manual (of which this is the first section), several books in PDF format, example programs, appropriate licenses, some source code, and documentation.

The free version has an F compiler and only one version of the Atlas linear algebra libraries. The Cygwin, Photran, and JRE software are not in the distribution; they must be downloaded; they are free.

1.4 Installation

Notes:

1. You may need to have administrative privileges or be root to install the software.

2. ***Do not use or create a folder (directory) with a space in its name for any purpose related to the Fortran Tools.***
3. In order to run Photran, a Java Runtime Environment (JRE) must be installed.
4. To run Photran and other Fortran Tools, such as the plotting software, Cygwin, a collection of Unix-like tools, must be installed. Cygwin contains many tools useful to the Fortran programmer.
5. Acrobat Reader should be installed to read the documentation that is in PDF format. It is available free from `adobe.com` if it is not already installed on your system.

1.4.1 Installing the Fortran Tools Files

1.4.1.1 Installing from a CD

The Fortran Tools CD contains one directory (folder) named `FortranTools`. Copy this into a directory whose name has no spaces (i.e., ***not*** "`Program Files`"). A reasonable choice is the C (or other) drive.

1.4.1.2 Installing the Free Version

Download the Fortran Tools with the F compiler for your system and put it in a location of your choice.

Unzip the file `FortranTools_windows_f.zip` into a folder whose name has no spaces (i.e., *not* "`Program Files`"). A reasonable choices is the C (or other) drive. This should create a folder `C:\FortranTools` (for example).

1.4.2 Cygwin

Cygwin must be installed. If it is already installed, skip to Section Section 1.4.2.3, "Setting your Path Variable".

1.4.2.1 Installing from the CD

If you have the CD containing the Cygwin files, follow these directions. If not, go to section 1.4.2.2.

1. Copy the contents of the Cygwin CD into the `FortranTools` folder. Go to `cygwin` in the `FortranTools` folder.
2. Execute `setup.exe`. Select `Next`.

3. On the next page, select `Install from Local Directory`, then `Next`.

4. On the page `Select Root Install Directory`, type `C:\Cygwin` for the `Root Directory`. The Cygwin folder should be directly under a drive name, such as `C:`, `D:`, etc., so the only alternatives are to pick a disk drive other than `C:`. Defaults for the other selections on the page should be OK. Then select `Next`.

5. On the next page, use the current folder for the `Local Package Directory`, e.g., `C:\FortranTools\cygwin`. Select `Next`.

6. After a while, you should see a page titled `Cygwin Setup - Select Packages`. Change the selection after the heading `+All` to `Install` (if it says `Default`, or something else, click on the little icon between `+All` and `Default` until it says `+All Install`). Sometimes this takes a few seconds. This will install all of Cygwin. Not everything is needed, but it is not obvious what is needed. Besides, Cygwin contains lots of cool stuff, so it is not a bad idea to install everything. Select `Next`. Select `Back` to ensure that each category still indicates `Install`; in some versions of `setup.exe`, each must be selected individually. Then select `Next` again.

7. The files will be installed in `C:\Cygwin` (or wherever you indicated). This can take many minutes. When the installation is finished, you should see a page asking if you want to create icons; do so if you want to. Select `Finish`. You should see a little box indicating that the installation is complete. Click `OK`.

1.4.2.2 Installing from the Internet

Note: this is going to take a long time unless you have a high-speed connection to the internet.

1. Use your browser (e.g., Mozilla, Netscape, or Internet Explorer) to access `http://www.cygwin.com/mirrors.html`.

2. Select a mirror site near you for downloading. You should see a page titled `Index of Cygwin`. Select `setup.exe` and save it to your disk in a folder (near to where you copied the Fortran Tools) such as `C:\FortranTools\cygwin`.

3. On your computer, use `Explorer` (the file manager, not a web browser) to locate and select the file `setup.exe` that you just saved. Select it for execution (usually by double clicking). On the page `Cygwin Net Release Setup Program`, select `Next`. On the next page, select `Download Without Installing` and then `Next`.
4. On the page `Select Local Package Directory`, select `C:\FortranTools\cygwin` (or wherever you put the file `setup.exe`). Then select `Next`.
5. Select the internet connection. `Direct Connection` should be appropriate in most cases. `Next`.
6. On the `Choose A Download Site` page, you should be able to pick the same site from which you downloaded the file `setup.exe`. Just select the site and click on `Next`.
7. After some files are downloaded, you should see a page titled `Cygwin Setup - Select`. Follow the instructions in 1.4.2.1 (6) above. Select `Next`.
8. The files should be downloaded. This can take a while—at least a good part of an hour with a typical home-based high-speed broadband connection. When the download is finished, install Cygwin as described in 1.4.2.1.

1.4.2.3 Setting your Path Variable

Make sure that the Cygwin executables are in your `path` variable as follows. On XP, click *Start* → *Control Panel* → *System* → *Advanced* → *Environment Variables* → *System Variables*. Scroll down in the *System Variable* in the top window (note that the bottom window is per-user variables) until you get to *Path*. Click on *Path* and edit the value in the line at the bottom of the screen by adding

```
C:\Cygwin\bin;C:\Cygwin\usr\local\bin;
     C:\Cygwin\usr\X11R6\bin
```

(the drive may be something other than C) at the beginning of the path, followed by a semicolon to separate it from the folders already there. Select `OK` three times.

1.4.2.4 Your Home Directory

Installation of Cygwin should produce a directory (folder) named `home` and within it a directory that is your login name. E.g., `C:\Cygwin\home\joan`. When you execute the bash command, you should be taken to this, your home directory. When running `bash`, ~ is shorthand for your home directory.

1.4.3 Downloading Files for the Free Version

If you are using the free version, you need to download files for Photran and JRE.

1.4.3.1 Photran

Go to `http://www.eclipse.org/photran/` and select `downloads` in the `photran` section of the left margin. Click on `Full Photran 3.?.? for Windows`. Save the file in the directory `FortranTools/photran` (move it there if the download manager does not give you a choice).

1.4.3.2 JRE

Go to `http://www.java.com/`. Click on `Manual Download`. Select `Windows (Offline Installation)`. Save it in directory `FortranTools/java`.

1.4.4 Fortran Tools

Open a DOS Command Prompt window: *Start* → *Command Prompt*. Type `bash` to run the Bourne Again Shell.

Go to the `FortranTools` directory. E.g.,

```
cd C:/FortranTools
```

One of the files there should be a shell script `install_fortrantools`; execute it by typing

```
./install_fortrantools
```

The installed files must go into `/usr/local`. You will be asked to verify that it is OK; if not, the installation will terminate.

Also, unless you have the free version, you will be asked to select a version of the matrix libraries by typing a number. Number 0 indicates that the reference Blas and Lapack libraries are to be loaded and used with Matran. Other options are optimized versions for certain architectures. The PII (Pentium II) version probably will run on any Intel system. If there is a problem later with the one you select, simply copy a different version of the libraries into the file `/usr/local/fortran-tools/lib/libmatrix.a`. The other versions are also in `/usr/local/fortrantools/lib`, with a slightly different name, such as `libmatrixPII.a`.

Make sure that `/usr/local/bin` is in your `PATH` variable. This is taken care of by modifying the system path variable (1.4.2.3). Type `exit` to exit bash and type "`echo %path%`" in the Command Prompt window to ensure that the path is properly set even when not running `bash`. You can verify this by typing

```
which photran
```

The response should be

```
/usr/local/bin/photran
```

1.4.5 Creating a Shortcut (Optional)

If you want to be able to start Photran by clicking on an icon on the desktop, follow these steps.

1. Use `Explore` (the file manager) to locate the `FortranTools` directory which is the copy of the contents of the CD. Go into `photran`, then `eclipse`.
2. Right click on `eclipse.exe` and select `Create Shortcut`.
3. Right click on the shortcut and change the name to `Photran` (or whatever you like).
4. Move (drag) the icon to the desktop.
5. Right click on the icon and select `Properties`. Select the `Shortcut` tab. In the `Target` field, add to the end the text:

   ```
   -vmargs -Xmx512M
   ```

   This allows Eclipse/Photran to run with more memory.

1.4.6 Java Runtime Environment (JRE)

A JRE must be installed to run Photran. The JRE is not the same thing as the Java SDK.

To see whether your browser is configured to use the Java Runtime Environment (JRE) or not, first open the Windows Control Panel. From the `Start` menu button, select `Control Panel` to open the Control Panel (this may be different in different versions of Windows). You should see the Java Coffee Cup logo icon in the Control Panel. If you do not see the coffee cup icon in the Windows Control Panel, you do not have the latest version of the Sun JRE installed on your computer. Install it as follows:

1. Go to `java` in the `FortranTools` folder copied from the CD.
2. Execute the file `jre*.exe`.
3. Choose `Typical setup` and click `Accept`.
4. After installation is completed, check that all is OK as described in the first paragraph of this section.

To Java enable your browser (probably not necessary to run the Fortran Tools):

1. Double-click the Java icon in the Control Panel to open the Java Control Panel.
2. In the Java Control Panel, select the `Advanced` tab.
3. Under `Settings`, click on + icon against `<Applet>` tag support.
4. Make sure the box next to Internet Explorer, Netscape, or Mozilla is checked.
5. If it is not checked, click the checkbox to enable the JRE for your Web browser.
6. Click `Apply`.

1.5 Support

If you have any difficulties or technical queries, please send email to `info@fortran.com`.

1.6 What is Installed

A script photran is in /usr/local/bin. It starts up Photran, the graphical development environment. Photran also can be started by clicking on the shortcut icon created as described in "Creating a Shortcut (Optional)".

The Fortran compiler also is located in /usr/local/bin. It can be run from Photran or executed as a command.

The directory /usr/local/fortrantools/lib contains Fortran program libraries and some files needed by Photran.

In the directory where you copied the files from the CD, there is a subdirectory photran. It contains a subdirectory eclipse created during installation that contains the executable file eclipse.exe, which starts Eclipse/Photran. This directory must *not* be removed or Fortran Tools will not work (but the Fortran compiler can still be run from the command line).

Also in the same directory are some example programs (examples) and the Fortran Tools documentation (doc).

1.7 Licenses

1.7.1 Eclipse and Photran

Eclipse and Photran are licensed under the Eclipse Public License; it is the file epl-v10.html in the lic directory. Use is also controlled by the Eclipse Software Agreement in the file eclipse_software_ agreement.htm.

1.7.2 g95

The Fortran compiler is licensed under the Free Software Foundation General Public License; it is the file Gmu_General_Public_license.txt in the lic directory.

1.7.3 Cygwin (Windows)

Most of the Cygwin tools are covered by the GNU General Public License (GPL); it is the file gpl.txt in the doc directory. However, some are public domain, and others have a X11-style copyright. To cover the GNU GPL requirements, the basic rule is if any binaries are distributed, the source also must be made available.

The Cygwin API library found in the winsup subdirectory of the source code is also covered by the GNU GPL. By default, all executables link against this library (and in the process include GPL'd Cygwin glue code). This means that unless you modify the tools so that compiled executables do not make use of the Cygwin library, your compiled programs will also have to be free software distributed under the GPL with source code available to all.

Please also see the `-mno-cygwin` option for `g95`.

1.7.4 Java Runtime Environment

The JRE is subject to the license agreement you were required to read when installing the JRE.

1.7.5 Matran

The copyright and license information for Matran are found in the file `Matran.html` in the `doc` directory of the Fortran Tools distribution.

1.7.6 Blas, Lapack, Atlas, and Slatec

These software libraries are distributed without restrictions by Netlib: `http://www.netlib.org/`.

1.7.7 JAPI

The JAPI software is subject to the GNU Lesser Common Public License in the lic directory.

1.7.8 Other Software

Other software in the Fortran Tools may be controlled by notices in the software or documentation for that software.

1.8 Source Code

1.8.1 Eclipse and Photran

Source files for Eclipse may be found at `http://www.eclipse.org/downloads/`.

1.8.2 g95

Source files for the Fortran compiler may be found at `http://www.g95.org/g95_source.tgz`.

1.8.3 Cygwin (Windows)

The source files for Cygwin are `cygwin*.bz2` in the src directory of the distribution.

1.8.4 Matran

Source code for Matran may be found at `http://www.cs.umd.edu/~stewart/matran/Matran.html`.

1.8.5 Blas, Lapack, Atlas, and Slatec

Source code for these software libraries are found at `http://www.netlib.org/`

1.8.6 JAPI

The JAPI source code is at `http://www.japi.de`.

1.8.7 Other Software

Source code for some of the other software is in the `src` directory of the distribution.

1.9 Documentation

The doc directory copied from the CD contains the following documentation.

- The complete Fortran Tools manual, of which this is the first section. This manual describes how to run Fortran Tools and contains information about the software provided by The Fortran Company.
- `G95Manual.pdf` and `g95_docs.html` describe the Fortran compiler `g95`. Additional information may be found at the g95 website `http://www.g95.org`. This site lists lots of programs that work with `g95`. There is also information about how to suspend execution of a program and resume execution at the same place.
- Eclipse documentation may be found at the Eclipse website `http://www.eclipse.org`.
- The file `Cygwin.pdf` in the `doc` directory of the Fortran Tools distribution contains a users manual for Cygwin.
- Matran is described in *MatranWriteup* in PDF format in the doc directory of the distribution.
- Documentation for Gnuplot is in the file `Gnuplot.pdf` in the `doc` directory of the distribution.

- The manual `Japi_manual.pdf` in the `doc` directory describes the JAPI procedures.
- Copies of several books, including *Programmers Guide to Fortran 95 Using F*, *Key Features of Fortran 95*, and *Fortran Array and Pointer Techniques*.
- Documentation of several other programs provided with the Fortran Tools is in the `doc` directory of the distribution.

  For additional information about Fortran, visit

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Command Line Compilation 2

Note: If you are using the F subset compiler in the free distribution, please substitue "F" for "g95" in most places that it occurs in this and later sections.

The F subset is equivalent to invoking the g95 compiler with the `-std=F` option. However, some of the default settings and options may be different. For example, bounds checking is on by default in F and real and complex arrays are initilized to NaN, so that the use of an undefined value can be detected easily.

The syntax of F is described in the file `F_bnf.html` in the `doc` directory of the Fortran Tools distribution.

2.1 Usage

Let us go through the steps to create, compile, and run a simple Fortran program. Suppose we want to find the value of $sin(0.5)$.

The first step is to use any editor to create a file with the suffix `.f95` that contains the Fortran program to print this value. On Linux or Windows with Cygwin, the editor Emacs or Vi might be used as follows:

```
$ vi print_sin.f95
```

In a Windows command line window, Edit or Notepad might be used to create the file.

Suppose the file contains the following Fortran program:

```
program print_sin
   print *, sin(0.5)
end program print_sin
```

A nice convention is to name the file the same as the name of the program, but with the `.f95` suffix.

The next step is to compile the program. The Fortran command has the following form:

g95 [*option*] . . . [*file*] . . .

so the command for our example is:

```
$ g95 print_sin.f95
```

On a Linux or Unix system, this produces the executable program named `a.out`, which can be executed by entering:

```
$ ./a.out
```

On Windows, the executable file is named `a.exe` and can be run by entering the command `a` or `a.exe`.

2.2 Using g95 with the Fortran Tools

When using the special software that comes with the Fortran Tools, it is often necessary to add information to the command line to tell the compiler where this software is located. For example, to use the `new_unit` subroutine in the input/output module, the compiler command must look something like

```
g95 -I/usr/local/fortrantools/lib \
   the_program.f95 \
   -L/usr/local/fortrantools/lib -lfortranttols
```

which can be typed all on one line without the backslashes.

It might be convenient to create and environment variable with the value `/usr/local/fortrantools/lib` to save some typeing. This can be done using the Control Panel in Windows or by a command (possibly placed in a startup file such as `.bashrc`). In `bash`, the command would be

```
export FT_LIB=/usr/local/fortrantools/lib
```

Then the command aobe could be written

```
g95 -I$FT_LIB the_program.f95 \
    -L$FT_LIB -lfortranttols
```

Please see the individual sections describing the tools to determine which options are required.

2.3 Description

`g95` is a Fortran 95 compiler. It translates programs written in Fortran into executable programs, relocatable binary modules, assembler source files, or C source files.

The suffix of a filename determines the action `g95` performs upon it. Files with names ending in `.f90` or `.f95` are taken to be Fortran source files. Files ending in `.F90` or `.F95` are taken to be Fortran source files requiring preprocessing (Section 3.2). The file list may contain file names of any form.

Modules and include files are expected to exist in the current working directory or in a directory named by the `-I` option.

Options not recognized by g95 are passed to the link phase (`gcc`).

2.4 Some Options

`-c`

Compile only (produce `.o` file for each source file); do not link the `.o` files to produce an executable file.

`-D`*name*

Defines name as a preprocessor variable. This is equivalent to passing the `-D` option directly to `the` preprocessor.

`-fbounds-check`

Checks array and substring bounds at runtime.

`-ffixed-form`

Assumes the source file is fixed source form.

`-ffree-form`

Assumes the source file is free source form.

`--help`

Display information about the compiler.

`-i8`

Sets the default kind of integers to 8.

`-r8`

Sets the default kind of reals to 8.

`-d8`

Equivalent to both -i8 and -r8.

`-I` *pathname*

Add *pathname* to the list of directories which are to be searched for module information (`.mod`) files and include files. The current working directory is always searched first, then any directories named in `-I` options.

`-l`*x*

Load with library `lib`*x*`.a`. The loader will search for this library in the directories specified by any `-L`*dir* options followed by the normal system directories.

`-L`*dir*

Add *dir* to the list of directories for library files.

`-o` *output*

Name the output file output instead of `a.out` (`a.exe` on Windows). This also may be used to specify the name of the output file produced under the `-c` and `-S` options.

`-O`

Normal optimization.

`--version`

Print version information about the compiler.

`-std=f95`

Check that program conforms to Fortran 95 standard.

`-std=F`

Check that program conforms to the F subset.

`-S`

Produce assembler output only. Do not assemble and link.

`-Wall`

Enable most warning messages.

2.5 Pre-connected Input/Output Information

Standard error (stderr) unit number = 0
Default standard input (stdin) unit number = 5
Default standard output (stdout) unit number = 6

2.6 Error Messages

The following table gives the correspondence between runtime error numbers and the cause of the error.

–2	End of record
–1	End of file
0	Successful return
1 - 199	Operating system errno codes
200	Conflicting statement options
201	Bad statement option
202	Missing statement option
203	File already opened in another unit
204	Unattached unit
205	FORMAT error
206	Incorrect ACTION specified
207	Read past ENDFILE record
208	Corrupt unformatted sequential file
209	Bad value during read
210	Numeric overflow on read
211	Out of memory
212	Array already allocated
213	Deallocated a bad pointer
214	Bad record read on input

Preprocessors 3

Preprocessors are available with the F distribution. cpp was written as a C preprocessor, but it works for Fortran, also. fppr is a simpler preprocessor written by Michel Olagnon. coco (conditional compilation) is an ancillary Fortran standard.

3.1 cpp

cpp is invoked with the g95 -cpp option. For a description of cpp, consult Linux, Unix, or GNU documentation.

3.2 fppr

fppr is a preprocessor and “pretty printer”. Here is a simple example.

```
$define WINDOWS 0
$define FPPR_KWD_CASE FPPR_LOWER
$define FPPR_USR_CASE FPPR_LEAVE
$define FPPR_MAX_LINE 132
program test_fppr

$if WINDOWS
character(len=*), parameter :: slash = “\”
$else
character(len=*), parameter :: slash = “/”
$endif

character(len=*), parameter :: file_name = &
   “.” // slash // “fppr.f95”
integer :: ios
character(len=99) :: line

open (file=file_name, unit=35, &
      iostat=ios, status=”old”, &
      action=”read”, position=”rewind”)
if (ios == 0) then
   print *, “Successfully opened “, file_name
   read (unit=35, fmt=”(a)”) line
   print *, “First line: “, trim(line)
else
   print *, “Couldn’t open “, file_name
   print *, “IOSTAT = “, ios
end if

end program test_fppr
[walt@localhost Examples]$ fppr < fppr_in.F95 > \
                                fppr.f95
This is f90ppr: @(#) fppridnt.f90
     V-1.3 00/05/09 Michel Olagnon
( usage: f90ppr < file.F90  > file.f90 )
[walt@localhost Examples]$ F fppr.f95
[walt@localhost Examples]$ ./a.out
 Successfully opened ./fppr.f95
 First line: program test_fppr
```

Running fppr with input from fppr_in.F95 (shown above) produces an output file fppr.f95. fppr must be executed explicitly; it is not invoked by the Fortran compiler based on the suffix .F95, the way cpp is. Because the fppr variable WINDOWS is not defined to be true, the generated code will include the parameter statement that sets the variable slash to the forward slash; if WINDOWS were true, it would be the backslash. Here is the output file fppr.f95.

```
program test_fppr
!
      character (len=*), parameter :: slash = “/”
!
     character (len=*), parameter :: file_name = &
          “.” // slash // “fppr.f95”
      integer :: ios
      character (len=99) :: line
!
     open (file=file_name, unit=35, iostat=ios, &
         status=”old”, action=”read”, &
         position=”rewind”)
      if (ios == 0) then
        print *, “Successfully opened “, file_name
         read (unit=35, fmt=”(a)”) line
         print *, “First line: “, trim (line)
      else
         print *, “Couldn’t open “, file_name
         print *, “IOSTAT = “, ios
      end if
!
end program test_fppr
```

fppr does not make use of any command line argument, and the input and output files need thus to be specified with redirection, (they default to the standard input and the standard output).

3.2.1 Options

All options have to be specified through the use of directives.

3.2.2 Directives

All fppr directives start with a dollar symbol ($) as the first nonblank character in an instruction. The dollar sign was chosen because it is an element of the Fortran character set, but has no special meaning or use. The question mark, which is also an element of the Fortran character set with no special meaning, is used as a “vanishing” separator (see $define below)

`$define` *name token-string*

Replace subsequent instances of *name* with *token-string*. *name* must be identified as a token. In order to enable replacement of sub-strings embedded within tokens, ? is a special “vanishing” separator that is removed by the pre-processor.

`$define` *name* $”*token-string*”

Replace subsequent instances of *name* with *token-string* where *token-string* must not be analyzed since it may consist of multiple instructions, for instance.

`$eval` *name expression*

Replace subsequent instances of *name* with *value* where value is the result, presently of default real or integer kind, of the evaluation of *expression.*

`$undef` *name*

Remove any definition for the symbol name.

`$include` "*filename*"

Read in the contents of *filename* at this location. This data is processed by `fppr` as if it were part of the current file.

`$if` *constant-expression*

Subsequent lines up to the matching `$else`, `$elif`, or `$endif` directive, appear in the output only if *constant-expression* yields a nonzero value. All non-assignment Fortran operators, including logical ones, are legal in *constant-expression*. The logical constants are taken as 0 when false, and as 1 when true. Many intrinsic functions are also legal in *constant-expression*. The precedence of the operators is the same as that for F. Logical, integer, real constants and `$defined` identifiers for such constants are allowed in *constant-expression*.

`$ifdef` *name*

Subsequent lines up to the matching `$else`, `$elif`, or `$endif` appear in the output only if name has been defined.

`$ifndef` *name*

Subsequent lines up to the matching `$else`, `$elif`, or `$endif` appear in the output only if name has not been defined, or if its definition has been removed with an `$undef` directive.

`$elif` *constant-expression*

Any number of `$elif` directives may appear between an `$if`, `$ifdef`, or `$ifndef` directive and a matching `$else` or `$endif` directive. The lines following the `$elif` directive appear in the output only if all of the following conditions hold:

- The *constant-expression* in the preceding `$if` directive evaluated to zero, the name in the preceding `$ifdef` is not defined, or the name in the preceding `$ifndef` directive was defined.
- The constant-expression in all intervening `$elif` directives evaluated to zero.
- The current constant-expression evaluates to non-zero.

If the constant-expression evaluates to non-zero, subsequent `$elif` and `$else` directives are ignored up to the matching `$endif`. Any constant-expression allowed in an `$if` directive is allowed in an `$elif` directive.

```
$else
```

This inverts the sense of the conditional directive otherwise in effect. If the preceding conditional would indicate that lines are to be included, then lines between the `$else` and the matching `$endif` are ignored. If the preceding conditional indicates that lines would be ignored, subsequent lines are included in the output. Conditional directives and corresponding `$else` directives can be nested.

```
$endif
```

End a section of lines begun by one of the conditional directives `$if`, `$ifdef`, or `$ifndef`. Each such directive must have a matching `$endif`.

`$macro` *name* `(` *argument* [, *argument*] . . . `)` *token-string*

Replace subsequent instances of *name*, followed by a parenthesized list of arguments, with *token-string*, where each occurrence of an argument in *token-string* is replaced by the corresponding token in the comma-separated list. When a macro with arguments is expanded, the arguments are placed into the expanded *token-string* unchanged. After the entire *token-string* has been expanded, `fppr` does not re-start its scan for names to expand at the beginning of the newly created *token-string*, the opposite of the C preprocessor.

3.2.3 Macros and Defines

Macro names are not recognized within character strings during the regular scan. Thus:

```
$define abc xyz
print *, “abc”
```

does not expand abc in the second line, since it is inside a quoted string.

Macros are not expanded while processing a `$define` or `$undef`. Thus:

```
$define abc zingo
$define xyz abc
$undef abc
xyz
```

produces `abc`. The token appearing immediately after an `$ifdef` or `$ifndef` is not expanded.

Macros are not expanded during the scan which determines the actual parameters to another macro call. Thus:

```
$macro reverse(first,second) second first
$define greeting hello
reverse(greeting,       &
$define greeting goodbye &
)
```

produces

```
$define greeting goodbye greeting.
```

3.2.4 Options

A few pre-defined keywords are provided to control some features of the output code:

FPPR_FALSE_CMT !*string*

Lines beginning with !*string* should not be considered as comments, but processed. For instance, one may define:

```
$define FPPR_FALSE_CMT !HPF$
```

in order to use HPF directives in one's code.

FPPR_MAX_LINE *expression*

The current desirable maximum line length for deciding about splitting to a continuation line is set to the value resulting of evaluation of *expression*. If the value is out of the range 2-132, the directive has no effect.

FPPR_STP_INDENT *expression*

The current indentation step is set to the value resulting of evaluation of *expression*. If the value is out of a reasonable range (0-60), the directive has no effect. Note that it is recommended to use this directive when current indentation is zero, otherwise unsymmetrical back-indents would occur.

`FPPR_NMBR_LINES` *expression*

If *expression* evaluates to true, or non-zero, or is omitted, line numbering information is output in the same form as with `cpp`. If *expression* evaluates to 0, line numbering information is no longer output.

`FPPR_FXD_IN` expression

If *expression* evaluates to true, or non-zero, or is omitted, the input treated as fixed-form. If *expression* evaluates to 0, the input reverts to free-form.

`FPPR_USE_SHARP` *expression*

If *expression* evaluates to true, or non-zero, or is omitted, the sharp sign (#) may be used as well as the dollar sign as the first character of pre-processing commands. If *expression* evaluates to 0, only commands starting with dollar are processed.

`FPPR_FXD_OUT` *expression*

If *expression* evaluates to true, or non-zero, or is omitted, the output code is intended to be fixed-form compatible. If *expression* evaluates to 0, the output code reverts to free-form.

`FPPR_KWD_CASE` *expression*

If *expression* evaluates to 1, or is the keyword `FPPR_UPPER`, F keywords are output in upper case. If *expression* evaluates to 0, or is the keyword `FPPR_LEAVE`, Fortran keywords are output in mixed case. If *expression* evaluates to –1, or is the keyword `FPPR_LOWER`, F keywords are output in lower case.

`FPPR_USR_CASE` *expression*

If *expression* evaluates to 1, or is the keyword `FPPR_UPPER`, user-defined Fortran identifiers are output in upper case. If *expression* evaluates to 0, or is the keyword `FPPR_LEAVE`, user-defined Fortran identifiers are output in the same case as they were input. If *expression* evaluates to –1, or is the keyword `FPPR_LOWER`, user-defined Fortran identifiers are output in lower case.

3.2.5 Output

Output consists of a copy of the input file, with modifications, formatted with indentation, and possibly changes in the case of the identifiers according to the current active options.

3.2.6 Diagnostics

The error messages produced by `fppr` are intended to be self-explanatory. The line number and filename where the error occurred are printed along with the diagnostic.

3.2.7 Source Code

The source code is available in the `src` directory of the F distribution. It is provided by Michel Olagnon and more information about this program and others provided by Michel may be found at

```
http://www.ifremer.fr/ifremer/ditigo/molagnon/
```

3.3 COCO

The program `coco` provides preprocessing as per Part 3 of the Fortran Standard (coco stands for "conditional compilation"). It implements the auxiliary third part of ISO/IEC 1539-1:1997 (better known Fortran 95). (Part 2 is the ISO_VARYING_STRINGS standard, which is sometimes implemented as a module.) A restore program, similar to that described in the standard, is also available for download.

The Fortran source code for coco may be found at `http://users.erols.com/dnagle`..

Generally, coco programs are interpreted line by line. A line is either a coco directive or a source line. The coco directives start with the characters `??` in columns 1 and 2. Lines are continued by placing `&` as the last character of the line to be continued. Except for the `??` characters in columns 1 and 2, coco lines follow the same rules as free format lines in Fortran source code. A coco comment is any text following a `!` following the `??` characters. A coco comment may not follow the `&`.

A description of coco may be found in the file `coco.html` in the `Docs` directory. Here is a simple example.

Statement of the problem to be solved: A Fortran program needs to use full path names for file names. The separator in the file names should be / if the system is not Windows and \ if it is Windows. A file `slash.inc` contains the following, which indicates whether the system is Windows or not.

```
?? logical, parameter :: windows = .false.
```

Then the following program will produce the correct character.

```
module slash

?? include “slash.inc”

   character, parameter, public :: &
?? if (windows) then
      slash = “\”
?? else
      slash = “/”
?? end if

end module slash

program p

   use slash
   print *, “Path is usr” // slash // “local”

end program p
```

The COCO preprocessor is run with

```
coco < slash.f90 > new_slash.f95
```

which produces the file `new_slash.f95`:

```
module slash

!?>?? include “slash.inc”
!?>??! INCLUDE slash.inc
!?>?? logical, parameter :: WINDOWS = .false.
!?>??! END INCLUDE slash.inc
```

```
   character, parameter, public :: &
!?>?? if (windows) then
!?>      slash = “\”
!?>?? else
      slash = “/”
!?>?? end if

end module slash

program p

   use slash
   print *, “Path is usr” // slash // “local”

end program p
```

Compiling and running the program produces the output:

```
 Path is usr/local
```

Photran 4

Photran is a graphical interface for Fortran. It may be used to edit, compile, run, and debug Fortran programs. It is based on the Eclipse open source software (`http://www.eclipse.org`). Photran itself consists of plugins for eclipse developed at the University of Illinois (`http://www.photran.org`). Photran also is open source software. In addition, some enhancements have been provided by The Fortran Company.

4.1 Introduction to Using Photran

You can always run Fortran programs from the command line, but if you want to use the Photran graphical interface to edit, compile, run, and debug Fortran programs, follow the instructions in this section. But first a little jargon so you can read additional documentation about Eclipse and Photran.

When using Photran, your code is organized into *workspaces* and *projects*. A project usually will contain the code for one complete program, consisting of a main program and possibly some modules. These files, and others used by the Photran system, usually are stored in one directory whose name is the name of the project. A workspace consists of projects; it uses a directory whose name is the name of the workspace to store the project directories. A workspace might contain only one project.

To use Photran for Fortran programs, you create a project, which is part of some workspace. You then add source code to the project, either by copying existing files into the project or by creating new source files and typing in the code. Then, using Photran, the project can be built, run, and debugged.

4.2 Starting Photran

1. On Windows, if you created a shortcut to Photran, select it. Otherwise, type `photran`. If this does not work, in Windows, you can use `Explore` to find `eclipse.exe` and select

it for execution. In Linux, type its full path name or go to its directory and type ./`eclipse`. The Photran logo should appear and after a while Photran should be running.

2. If the screen contains only some logos, select the curved arrow labelled `Workbench` to start running some Fortran programs.

3. You will be asked to select a workspace. It is probably a good idea to select a directory different from the location of the software installed from the CD.

4.3 Creating a New Project

Here are the steps to create a new project. As with most other Photran operations, there are several ways to do it. Here is one.

1. Select the `File` tab at the upper left corner of the screen, then `New`, then `Standard Make Project.` If you see a screen asking you to select a wizard, expand the `Make` option and select `Standard Make Project`.

2. On the next screen, pick a name for the project, such as `a_simple_project`. The default workspace directory should be a good choice for this example. Select `Next` (not `Finish`).

3. On the next screen, select the `Error Parsers` tab. Check the following parsers and uncheck the rest:

```
CDT GNU Make Error Parser
CDT GNU C/C++ Error Parser
CDT GNU Assembler Error Parser
CDT GNU Linker Error Parser
Photran Error Parser for G95 Fortran
```

4. Select the `Binary Parsers` tab on the same screen. If you are using Windows, select `PE Windows Parser`. The binary parser for Linux should be `Elf Parser`. Now select `Finish`.

5. Select the + symbol to the left of the project name in the `Navigator` view and you will see files that have been put there by Photran. They contain information about the project.

If projects have been created previously, some or all of these settings may already be in place.

4.4 Importing Existing Files

Right click on the project name and select `Import` from the list of options. Select `File System` from the next screen and then `Next`. On the `File System` screen, use the `Browse` button to find the directory `/usr/local/fortrantools/lib`. Select `Makefile`. Then `Finish` to copy it to the current project. This file needs to be present in every project unless you create your own Makefile.

Or you can simply copy `Makefile` into the directory containing your project files.

4.5 Create a New Source File

To create a new source file, select `File` in the upper left corner of your screen, then `New`, then `Source File`. There are also icons to do this; determine which ones by putting your curser over the icons to see what they do. Enter a name (use `sine.f95` for example) for the source file and `Finish`.

4.6 Editing a Source File

1. Double click on the file. This will display the contents of that file in the editor view, which occupies the upper central portion of the screen.

2. If you make a change to the file (this will be indicated by an asterisk by the file name just above the edit view), save the file by selecting the save (floppy disk) icon near the upper left corner of your screen.

   To provide a simple example, enter the following program:

   ```
   program sine
      print *, “The sine of 0.5 is”, sin(0.5)
   end program sine
   ```

Note the syntax highlighting of Fortran code by Photran. Comments, character strings, and keywords appear in different colors so that they may be identified readily.

Line numbers do not appear in the edit window, but the line number and character position within the line of the cursor are displayed below the edit window.

Here is another nice feature of Photran. If you want to comment a whole block of statements, it is necessary to put the comment symbol (`!`) at the beginning of each statement. To do this using Photran, select the lines to be commented (or uncommented), right click in any open space in the `Edit View` and select `Comment` (or `Uncomment`).

4.7 Building a Project

To build the program, select the *project name* in the `Navigator View` and select `Project.` Then select `Build Project` from the pulldown menu. If the `Build Project` option cannot be selected, uncheck the `Build Automatically` option and try again. For `a_simple_project`, something like the following should appear in the `Console` view near the bottom of your screen (make sure the Console tab is highlighted).

```
make -k clean all
rm -f *.mod *.o RUN* f_Makefile
perl /usr/local/fortrantools/lib/mkmf.pl -t
/usr/local/fortrantools/lib/mkmf_args \
   -p RUN -m f_Makefile -x
make[1]: Entering directory \
   `/home/walt/FortranTools/workspace/test'
g95 -g -Wall -fbounds-check \
   -I/usr/local/fortrantools/lib \
   ./sine.f95
g95 trig_plot.o -o RUN \
  -L/usr/local/fortrantools/lib -lfortrantools \
   -lslatec -lmatrix -lg2c
make[1]: Leaving directory \
   `/home/walt/FortranTools/workspace/test'
```

If nothing happens, select the project name again in the `Navigator` view, select the `Project` pulldown menu, and select `Clean`. Select the `Clean selected projects` button and `OK`.

The important steps are those that begin with `g95`. The first of these compiles the program `sine.f95` and the second creates the executable file `RUN`. You will notice some new files appearing in the project in the Navigator view, including the file RUN.

4.8 Running a Program

A run configuration must be established before any program can be run from Photran. To check if this has been done, select the Run As tab above the edit window. If a tab showing Local Fortran Application appears, then simply click it and the program should begin execution.

If only a Run tab appears, then select it. A window in which a run configuration can be established should appear. Fortran Local Application should appear in the window to the left. Select New (lower left). Enter any name; the name of the project might be a good choice.

Select the Main tab. Enter the name of the project and enter RUN.exe (Windows) or RUN (Linux) as the Fortran Application.

On Windows, select the Environment tab and then New. Enter the name LD_LIBRARY_PATH and the value C:\Cygwin\bin.

Next select the Debugger tab and select GDB Debugger.

Then select Apply and either Run or Close.

Once the run configuration has been set up, instead of selecting Run tab and Run As, click on the Run button (the little green arrow). After the program has been run successfully, selecting the Run button may cause it to be recompiled if the source code has been changed.

The Console view is used for read * and print *; make sure that view is selected when typing.

On Linux, before each read operation from the Console view, it is necessary to force any previous output (such as a prompt) to be displayed; this is done with call flush(6)—unit 6 is the standard output unit for g95.

4.9 Make Files

When a Fortran program is complicated, it may be necessary to write your own Makefile. This can be done by simply editing the file named Makefile in your project. The Makefile that is provided executes a Perl script (mkmf.pl) which builds another make file (f_Makefile) based on the organization of modules and use statements in the project. Then that file is used to build the executable program. This is the Makefile provided.

```
FT_LIB = /usr/local/fortrantools/lib
all:
   perl $(FT_LIB)/mkmf.pl \
      -t $(FT_LIB)/mkmf_args -p RUN \
      -m f_Makefile -x
clean:
   rm -f *.mod *.o RUN* f_Makefile
```

Note that the lines executing `perl` and `rm` begin with a tab character, not spaces.

This process can be modified in a few simple ways by editing the file `mkmf_args` (make makefile arguments) located in `/usr/local/fortrantools/lib`. The one provided is:

```
FC = g95
FFLAGS = -g -Wall -fbounds-check \
   -I/usr/local/fortrantools/lib

LD = g95

LDFLAGS = -L/usr/local/fortrantools/lib \
-lfortrantools -lslatec -lmatrix -lg2c
```

The first and third lines indicate that `g95` is to be used to compile and load the program. The second line provides options to the compiler. `-g` is used for debugging, `-Wall` says to check for as many errors as possible (subscripts out of bounds, for example), and `-I` tells the compiler where to find some modules provided with Fortran Tools. When the program is ready for production use, this line might be changed to

```
FFLAGS = -O -I/usr/local/fortrantools/lib
```

to turn off error checking and turn on optimization. The `-I` option can be deleted from `FFLAGS` and the `-L` and `-l` options can be deleted from `LDFLAGS` if no Fortran Tools modules are being used.

Documentation for `mkmf.pl` is in the `doc` directory of the Fortran Tools distribution.

To see how the make file system works, let's go through an example provided by the `test_make` project.

1. Create a new project named `test_make` and import the file `Makefile` in the directory `/usr/local/fortrantools/lib`.

2. Import the files `m1.f95`, `m2.f95`, `m3.f95`, and `p.f95` from the examples directory of the distribution.
3. Look at the source files. There are three modules and a main program. Module `m1` contains declarations of the parameters `pi` and `e`. `m2` contains a subroutine `s` that uses module `m1` and prints the value of `pi`. `m3` uses `m1` and `m2` and contains a subroutine `s3` that calls `s` to print `pi` and also prints `e`. The main program `p` uses `m1` so it can print the values of `e` and `pi`. It contains a subroutine `ss` that uses `m3` and calls its module procedure `s3`.
4. Build the program. Note the compile commands that are executed and the order in which they are executed.
5. Experiment by changing one of the source files and then rebuilding the program. For example, change `m2` so that the subroutine prints `2*pi`. Don't forget to save the changed file and select the project before selecting `Build Project`. Note the compile commands when the project is rebuilt. Change the subroutine in `m2` and rebuild. Then change the value of `e` in `m1` and rebuild. In all cases, only the files that need to be recompiled are recompiled. This is not important for such a small program, but is for a big complicated one.

4.10 Deleting a Project

To delete a project, right click on the project name in the `Navigator` view and select `Delete`. The next screen gives you the option of keeping or deleting the contents of the project directory when the project is deleted.

4.11 Debugging

Programs can be debugged using the same Photran interface that is used to edit, build, and run the programs. The debugger has a lot of features, some of which take some effort to learn, but if all you use it for is a replacement for debugging by inserting `print` statements, learning just the simplest features to do that will be well worth the effort.

Let's learn about some of the features with an example.

1. Create a new project named `buggy` in your workspace.

2. Import the file `buggy.f95` in the `examples` directory of the Fortran Tools distribution. Take a look at it if you like.

3. If you are on Windows, select the project, then select the `Project` tab and select `Properties` from the pulldown menu. From the list on the left, select `Make Project`. Select the `Binary Parser` tab and check `PE Windows Parser`, if it is not already selected. Select `Apply` and then `OK`. On Linux, it should be the `Elf Parser`.

4. Build the project.

5. Run the program. There appears to be a problem; if you can figure it out, great, but if not we need to do some debugging.

6. Select the project name; select the `RUN` tab near the top of the screen; then `Debug`. If you see a window with `Create, manage, and run configurations`. Select the `Debugger` tab. Then uncheck the box labelled `Stop at main(0) on start-up`.

7. Set a breakpoint: with the source file `buggy.f95` in the edit window, place the cursor in the left margin of the edit window to the left of the statement

   ```
   j = 1
   ```

   Right click and select `Toggle Breakpoint`. Notice that a small blue circle appears in the margin to indicate the presence of the breakpoint. If you don't set a breakpoint, execution of the program may hang and you will have to terminate the program `gdb` by other means (see 4.12).

8. Select the project name; select the `RUN` tab near the top of the screen; then `Debug As`; then `Debug Local Fortran Application`. If a list pops up, select `GDB Debugger`. The arrangement of views changes significantly.

9. In the upper right corner of the screen, there is a little window that says `Debug`. This used to say `Make`. With the little icon to the left of this window you can change the perspective (the arrangement of the views) to `Debug` or `Make`. Try it.

10. With the perspective set at `Debug`, the program appears in a view near the center of the screen. The program is suspended at the breakpoint as indicated by the little arrow in the left margin pointing to the `program` statement.

11. To determine the problem, we want to execute a few statements and then see how things look. One way to do this is to use the icons above the `Debug` view. Move your cursor over them to see what they do. `Restart` begins execution of the program from the beginning. `Resume` continues execution from the current place in the program until it hits a breakpoint. `Terminate` (the red square) stops the program. `Step Into` executes one Fortran statement; if it involves a function evaluation or a subroutine call, it stops at the beginning of the procedure invoked. `Step Over` executes one statement, but does not stop inside a procedure that is invoked. Another similar operations is `Run to Line`; there is no icon for this, but can be performed by right clicking in open space in the `Debug` view and selecting it; it causes the program to run to the point where a line is selected with the cursor.

12. Use `Step Over` or `Step Into` to run to the first `if` statement. check the value of the variables `i` and `j` by examining the `Variables` view in the upper right portion of the screen.

13. Perform `Step Over` several times to watch the loop get executed three or four times. Look at the `Variables` view and notice that each time `j` changes, it turns red. In fact, since the loop exits only when `i` > `n`, and `i` never changes during the loop, that explains the problem. Fix it by changing the test to use `j` instead of `i`. Probably the easiest way to do this is to terminate the program by selecting the red square, edit the source file, and rebuild the project.

14. We have fixed the bug, but let's try a few more things with the debugger to see how they work. After rebuilding the project, set a breakpoint at the first `print` statement and start the debugger again

15. When the program stops at the breakpoint, look in the `Variables` view. `j` is 11, as it should be. To see the values of `my_array`, select the + symbol to its left. Note that the el-

ements of the array are numbered from 0. This is because the debugger is derived from a C debugger. To see the value of the character string c, do the same thing. It is treated as an array by the debugger because in C, a character string is treated as an array of characters.

16. Use Step Into until you get to the call statement. Be sure to use Step Into again (maybe a couple of times) to enter the subroutine SubA.

17. Place the cursor on the line

    ```
    zed(i) = FuncB(y)
    ```

    right click in the open space in the window and select Run To Line. Note that the variables local to the subroutine have been added to the *bottom* of the list. Also, there are variables i with two different values; one is the i declared local to the subroutine and the other is the i in the main program.

18. Step Into FuncB. Notice that the variables local to the function (e.g., xx and B_result) have been added to the Variables view.

19. Suppose we think all is OK in FuncB. Step Return to complete execution of FuncB and go back to SubA.

20. Now suppose we suspect that something goes wrong during the last iteration or two of the do loop in SubA. It would be tedious step through the loop more than 300 times. Instead we can set a conditional breakpoint. First, set a breakpoint at the line

    ```
    y = i
    ```

    Then right click on the blue circle and select Breakpoint Properties. Alternatively, select the Breakpoints tab near the upper right corner of the screen, right click on the break point just created and select Properties. In the Condition field, type

    ```
    i > 357
    ```

    Another option would be to type something like 355 in the Ignore field so that the breakpoint would be passed 355 times before the program is stopped. Select `OK`. Note the ? over the blue circle representing the breakpoint.

`Resume` to run to the breakpoint just set. Look at the `Variables` window and check to be sure that the loop was executed until the breakpoint condition was met. If this doesn't work, remove the breakpoint at the `print` statement and start the debugging process over again

21. Select the array `zed` to look at some of its values. Note that you can select portions of the array, which is very convenient if the array is large.

22. Select the red square to terminate the program. Return to the `Fortran` perspective.

4.12 Terminating a Program

Usually, an executing program can be stopped by clicking on the red square.

Sometimes, an instance of `RUN` or `gdb` may be left running when you thought everything was terminated. This happens especially during debugging. For example, the compiler may not be able to create a new version of `RUN` if the program is running. If this appears to be a problem, terminate all instances of the programs `RUN` and `gdb`. In Windows, `Ctrl-Alt-Del` to get the task manager; in Linux, use `ps` and `kill`.

4.13 Other Sources of Information

1. With Photran running, select the `Help` tab and `Help Contents`. The leads you to the *Workbench Users Guide*.

2. The *Workbench Users Guide* is also available at

   `http://www.eclipse.org/documentation/main.html`

Unfortunately, at this time, there is no additional documentation specific to Photran.

3. In the doc directory of the distribution, the file `cdt.pdf` contains the *C/C++ Development Toolkit User Guide*. Because some of the Photran software was developed from this toolkit, there is a lot of information that is applicable to Photran, particularly the debugger information.

Calling C Programs 5

Fortran programs may call C programs compiled with gcc.

5.1 Calling a C Function

Calling a C function is a little complicated because of the difference in data types, calling conventions, and other things. Fortran 2003 will make this much easier. In the meantime, here is simple example.

```
typedef struct { float r, i;} Complex;

void csub_ (i, d, a, s, c, slen)
int *i;
double *d;
float a[];
char *s;
Complex *c;
int slen;

{
printf ("The value of i is %d\n", *i);
printf ("The value of d is %f\n", *d);
printf ("The value of a[3] is %f\n", a[3]);
printf ("The value of s is %s\n", s);
printf ("The value of slen is %d\n", slen);
printf ("The value of c is (%f, %f)\n",
         c->r, c->i);
}
```

This can be compiled with the command

```
gcc -c csub.c
```

A Fortran program that calls csub is

```
program f_calls_c
   integer, parameter :: n = 4
```

```
    integer, parameter :: double = &
         selected_real_kind(9)
    real(kind=double), pointer :: dp
    integer :: i
    real, dimension(0:9) :: ra = &
          ( (/ (1.1*i, i=0,9) /) )
    character(len=3) :: s = "abc"
    complex :: c = (1.1, 2.2)

    allocate (dp)
    dp = 4.2_double
    call csub (n, dp, ra, s, c)
end program f_calls_c
```

The program can be compiled and linked by the command

```
g95 csub.o f_calls_c.f95
```

Executing the program produces the output

```
The value of i is 42
The value of d is 4.200000
The value of a[3] is 3.300000
The value of s is abc
The value of slen is 3
The value of c is (1.100000, 2.200000)
```

Note that the name of the C function has an underscore (_) appended. Also, the real and complex dummy arguments are pointers to correspond to the addresses passed for the actual argument.

These programs are in the `examples` directory of the Fortran Tools distribution.

5.2 Data Types

The following table shows the correspondence between Fortran and C data types.

where the form of Complex, DComplex, and QComplex are given by

```
typedef struct { float re, im; } Complex;
typedef struct { double re, im; } DComplex;
typedef struct { long double re, im; } QComplex;
```

Fortran data type	C data type
integer (8 bits)	signed char
integer (16 bits)	short
default integer (32bits)	int
integer (64 bits)	long long
logical (8 bits)	char
logical (16 bits)	short
default logical (32 bits)	int
logical (64 bits)	long long
real (single)	float
real (double)	double
real (quadruple)	long double
complex (single)	Complex
complex (double)	DComplex
complex (quadruple)	QComplex
character	***

***For Fortran character actual arguments, there must be two C dummy arguments: `char *` for the string and `int` for the length. The length arguments must be at the end of the dummy argument list in the correct order.

The Input/Output Module 6

The input/output module contains a few useful parameters and a subroutine that returns a unit number that exists, but is not connected.

When compiling using the command line, the following compiler options must be used.

```
-I/usr/local/fortrantools/lib prog.f95\
-L/usr/local/fortrantools/lib -lfortrantools
```

6.1 EOF and EOR Parameters

The I/O module contains parameters with the values returned by `iostat=` when encountering an end of record or end of file, respectively. The parameter names are `end_of_record` and `end_of_file`.

```
use io_module
   . . .
do
   read (iostat = ios, unit = 17) x
   if (ios == end_of_file) exit   ! End of file
      . . .
```

6.2 Standard Unit Numbers

The I/O module contains parameters with the values of the standard I/O units. The names of the parameters and their values are

```
standard_input_unit  = 5
standard_output_unit = 6
standard_error_unit  = 0
```

Example:

```
use io_module
   . . .
read (unit=standard_input_unit, fmt=*, . . .
```

6.3 Getting a New Unit Number

The I/O module provides a function new_unit that is a unit number that exists, but is not open (connected). The value –1 (an illegal unit number) is returned if none is available.

```
use io_module
integer :: unit_a, unit_b
    . . .
call new_unit(unit_a)
open (unit=unit_a, file= . . .)
call new_unit(unit_b)
open (unit=unit_b, file= . . .)
```

Without the first open statement, new_unit would return the same value both times, finding the same unit number that exists but is not open.

The Math Module 7

When using these features and compiling from the command line the following options must be used.

```
-I/usr/local/fortrantools/lib prog.f95\
-L/usr/local/fortrantools/lib -lfortrantools
```

7.1 Math Constants

The module math_module contains definitions of parameters for the constants π, e, ϕ, and γ. The names of the constants are pi, e, phi, gamma, pi_double, e_double, phi_double, and gamma_double. An example of its use is

```
program print_pi

   use math_module

   print *, pi_double

end program print_pi
```

7.2 The gcd Function

Also in the math module is the elemental function gcd that computes the greatest common divisor or two integers or two integer arrays.

```
program test_gcd
   use math_module
   print *, gcd((/432,16/),(/796,48/))
end program test_gcd
```

which prints

```
  4 16
```

The Slatec Library 8

The Slatec library is a collection of mathematical routines developed jointly by Sandia National Laboratories, Los Alamos National Laboratory, and the Air Force Phillips Laboratory, all in New Mexico.

With Fortran Tools, they may be used in a Fortran program as a "built-in" module. Invoke any of the procedures described below from any Fortran program containing the following statement:

```
use slatec_module
```

When compiling using the command line, the compiler options

```
-I/usr/local/fortrantools/lib prog.f95\
-L/usr/local/fortrantools/lib -lslatec
```

must be used.

8.1 Finding Roots in an Interval

```
find_root_in_interval(f, a, b, root, indicator)
```

is a subroutine that searches for a zero of a function *f(x)* between the given values *a* and *b*.

`f` is a function of one variable. `a` and `b` specify the interval in which to find a root of `f`. `root` is the computed root of `f` in the interval `a` to `b`. These are all type default real.

`indicator` is an optional default integer argument—if it is zero, the answer should be reliable; if it is negative, it is not.

Here is an example using the subroutine `find_root_in_interval`.

```
module function_module

   public :: f

contains
```

```
function f(x) result(r)

   real, intent(in) :: x
   real :: r

   r = x**2 - 2.0

end function f

end module function_module

program find_root

   use function_module
   use slatec_module
   real :: root
   integer :: indicator

   call find_root_in_interval&
        (f, 0.0, 2.0, root, indicator)

   if (indicator == 0) then
      print *, “A root is”, root
   else
      print *, “Root not found”
   end if

end program find_root
```

Running this program produces

```
A root is   1.4142114
```

8.2 Finding Roots of a Polynomial

The subroutine

```
find_roots_of_polynomial &
      (coefficients, roots, indicator)
```

accepts the coefficients of a polynomial and finds its roots (values where the polynomial is zero).

`coefficients` is a default real array; the element with the smallest subscript is the constant term, followed by the first degree term, etc. Thus, a reasonable choice is to make the lower bound of `coefficients` 0 so that the subscript matches the power of the coefficient.

`roots` is a complex array with at least as many elements as the degree of the polynomial. The roots of the polynomial will be found in this array after calling `find_roots_of_polynomial`.

`indicator` is a default integer optional argument; if it is negative, the solution is not reliable. In particular, if indicator is –1, a solution was not found in 30 iterations, if it is –2, the high-order coefficient is 0, if it is –3 or –4, the argument array sizes are not appropriate; if it is –5, allocation of a work array was not successful.

Here is a simple example that computes the roots of x^2 - $3x$ + 2 = 0.

```
program poly_roots

   use slatec_module

   complex, dimension(2) :: roots
   integer :: ind

   call find_roots_of_polynomial &
         ( (/ 2.0, -3.0, 1.0 /), roots, ind)
   print *, “Indicator”, ind
   print *, “Roots”, roots

end program poly_roots
```

Running the program finds the roots 1 and 2.

```
 Indicator 0
 Roots (2.00000,0.00000E+00)
(1.00000,0.00000E+00)
```

8.3 Computing a Definite Integral

```
integrate(f, a, b, value, tolerance, indicator)
```

is a general purpose subroutine for evaluation of one-dimensional integrals of user defined functions. `integrate` will pick its own points for evaluation of the integrand and these will vary from problem to problem. Thus, it is not designed to integrate over data sets.

`f` must be a function with a single argument. `a` and `b` are the limits of integration. tolerance is an optional requested error tolerance; if it is not present, 10^{-3} is used. value is the calculated integral. These are all type default real.

If the returned value of the optional default integer argument `indicator` is negative, the result is probably not correct. A positive value of `indicator` represents the number of integrand evaluations needed.

```
module sine_module

public :: sine

contains

function sine (x) result (sine_result)

   intrinsic :: sin
   real, intent (in) :: x
   real :: sine_result

   sine_result = sin (x)

end function sine

end module sine_module

program integration

use sine_module
use slatec_module
real :: answer
integer :: indicator

call integrate(sine, a=0.0, b=3.14159, &
               value=answer, tolerance=1.0e-5, &
               indicator=indicator)
```

```
print *, “Indicator is”, indicator
print *, “Value of integral is”, answer

end program integration
```

Running this program produces

```
 Indicator is 25
 Value of integral is   2.0000000
```

8.4 Special Functions

`ln_gamma(x)` is a function that returns the natural logarithm of the gamma function for positive real values of `x`. `asinh(x)`, `acosh(x)`, and `atanh(x)` return the inverse hyperbolic function values. The program

```
program test_gamma
use slatec_module
print *, “4! = “, exp(ln_gamma (5.0))
end program test_gamma
```

produces

```
 4! =   24.0000000
```

8.5 Solving Linear Equations

The Slatec linear equation solving program has bugs. Use the Matran solver or call the Lapack routines directly (see the Matrix chapter).

8.6 Differential Equations

```
solve_ode &
      (f, x0, xf, y0, yf, tolerance, indicator)
```

is a subroutine that solves an ordinary differential equation

$$\frac{du}{dx} = f(x, u)$$

using a fifth-order Runge-Kutta method.

`f` must be a function of two variables. `x0` is the initial value of x. `y0` is the initial value of y. `xf` is the final value of x. `yf` is the final solution value of `y`. `tolerance` is an optional requested tolerance; if not present 10^{-3} is used. All of these are type default real.

`indicator` is an optional default integer value—if it is negative, the solution is not reliable; a value of 2 indicates success.

Here is a simple example with $f(x, u) = -0.01y$, $x_0 = 0$, $y_0 = 100$, and $x_f = 100$.

```
module f_module

   public :: f

contains

function f(x, y) result(r)

   real, intent(in) :: x, y
   real :: r

   r = -0.01 * y

end function f

end module f_module

program test_ode

use slatec_module
use f_module

real :: x0 = 0.0, xf = 100.0, &
        y0 = 100.0, yf

call solve_ode (f, x0, xf, y0, yf)

print *, “Answer is”, yf

end program test_ode
```

Running the program produces

```
 Answer is  36.7878761
```

Defined Data Types 9

There are several modules available to the Fortran programmer that define new data types and a selection of operations on those types. The code for varying strings, big integers, rationals, quaternions, and Roman numerals all conform to the F subset; the source for each of these modules is available in the `src` directory to provide information about the modules and examples of how to build these abstract data types.

When compiling using the command line, the compiler options

```
-I/usr/local/fortrantools/lib prog.f95\
-L/usr/local/fortrantools/lib -lfortrantools
```

must be used.

9.1 Varying Length Strings

The ISO varying string module provides the type `iso_varying_string` with the operations you would expect to have for character string manipulations (concatenation, input/output, character intrinsic functions). Unlike Fortran character variables, a varying string variable has a length that changes as different values are assigned to the variable. Here is a simple program illustrating these features.

```
program string
   use iso_varying_string
   type(varying_string) :: s
   call get(string=s)
   s = s // s
   call put(string=s)
   print *, len(s)
end program string
```

The following lines show what happens when the program is compiled and run.

```
$ F string.f95
$./a.exe
A nice string.
A nice string.A nice string. 28
```

The current version of the source code is from Rich Townsend and has been modified slightly so that we have an F conformant version. This program is in the source code directory.

9.2 Big Integers

The `big_integer` data type can represent very large nonnegative integers. The representation of a big integer is a structure with one component that is an array of ordinary Fortran integers. In this version, the largest integer that can be represented is fixed, but the size is specified by a parameter that can be changed. The module may then be recompiled. The source for this module is in the `examples` directory of the distribution. All of the intrinsic operations and functions for intrinsic Fortran integers are available for big integers.

```
program factors
   use big_integer_module
   type(big_integer) :: b, n, s

   b = “9876543456789”

   n = 2
   call check_factor()
   s = sqrt(b)
   n = 3
   do
      if (n > s) exit
      call check_factor()
      n = n + 2
   end do
   if (b /= 1) then
      call print_big(b)
      print *
   end if

contains
```

```
   subroutine check_factor()
      do
         if (modulo(b, n) == 0) then
            call print_big(n)
            print *
            b = b / n
            s = sqrt(b)
         else
            exit
         end if
      end do
   end subroutine check_factor

end program factors
```

Running the program produces

```
3
3
3
3
17
97
1697
43573
```

9.3 High Precision Reals

9.3.1 The MP Module

This module provides the capability of computing with large precision real values. It was written by David Bailey of Lawrence Berkeley National Laboratory. A description of the module is in the files `mp.ps` and `mp.pdf` in the `doc` directory. More information may be found at `http://www.nersc.gov/~dhbailey/mpdist/mpdist.html`. Here is a simple example of its use.

```
program mp
   use mp_module
   type(mp_real) :: pi

   call mpinit()
   pi = 4.0 * atan(mpreal(1.0))
   call mpwrite(6, pi)
end program mp
```

The result printed consists of quite a few digits of π.

```
10 ^      0 x
3.14159265358979323846264338327950288419716939937
7510582097,
```

9.3.2 The XP Module

This module also provides the capability of computing with large precision real values. It was written by David Smith. A description of the module is in the file `xp.txt` in the `doc` directory. Here is a simple example of its use.

```
program test_xp
   use xp_real_module
   type (xp_real) :: x, y
   x = 1.0
   y = 4.0
   call xp_print(y*atan(x))
end program test_xp
```

```
 3.1415926535897932384626433832795028841971E+0
```

9.4 Rationals

A module to compute with rational numbers is provided by Dan Nagle of Purple Sage Computing Solutions, Inc. Some details are provided in the file `rationals.txt` in the `doc` directory. Here is a simple example.

```
program test_rationals
   use rationals_module
   type(rational) :: r1, r2

   r1 = (/3, 4/)
   r2 = (/5, 6/)
   r1 = r1 + r2
   print *, real(r1)
end program test_rationals
```

```
   1.583333333333333
```

9.5 Quaternions

The quaternions module was written by David Arnold of the College of the Redwoods. The only documentation is the source file `quaternions_module.f95` in the `src` directory. There is some information about quaternions in the file `quaternions.pdf` in the `doc` directory and the original article about quaternions presented by William Hamilton in 1843 can be found at `http://www.maths.tcd.ie/pub/HistMath/People/Hamilton/Quatern2/Quatern2.html`. Here is an example.

```
program Quaternions
  use Quaternions_module
  type(quaternion) :: u, v
  u=quaternion(1,2,3,4)
  v=quaternion(5,6,7,8)
  call quaternion_print(u+v)
  print *, 3+4
  print *
  call quaternion_print(u-v)
  print *, 3-4
  print *
  call quaternion_print(3.0*u)
  call quaternion_print(u*v)
  print *, 3*4
  print *
  call quaternion_print(conjg(u))
  print *, conjg((3,4))
  print *
  print *, (abs(u))
  print *, abs((3,4))
end program Quaternions
```

```
(    6.000000    8.000000   10.000000   12.000000)
 7

(   -4.000000   -4.000000   -4.000000   -4.000000)
 -1

(    3.000000    6.000000    9.000000   12.000000)
(  -60.000000   12.000000   38.000000   24.000000)
 12
```

```
(    1.000000   -2.000000   -3.000000   -4.000000)
 (3.0000000,-4.0000000)

   5.4772258
   5.0000000
```

9.6 Roman Numerals

This module to compute with Roman numbers was written by Jeanne Martin, former convenor of the international Fortran standards committee and an author of *The Fortran 95 Handbook*. The only documentation available is in the source file in the `src` directory.

```
program test_roman
use roman_numerals_module
implicit none

type(roman) :: r
integer :: i

write (unit=*, fmt=”(a)”) “Integer  Roman Number”
do i = 1900, 2000
  r = i
  write (unit=*, fmt=”(/, tr4, i4, tr2)”, &
         advance = “NO”) i
  call print_roman (r)
end do
write (unit=*, fmt=”(/)”)

end program test_roman
```

Here is the result of running the program.

```
Integer  Roman Number

    1900  MCM
    1901  MCMI
    1902  MCMII
    1903  MCMIII
    1904  MCMIV
    1905  MCMV
    1906  MCMVI
```

```
  . . .
1998  MCMXCVIII
1999  MCMXCIX
2000  MM
```

Matrix Operations 10

Fortran has extensive built-in operations on arrays, which may be used to do matrix manipulations when the matrices are represented as ordinary Fortran arrays. For example, two matrices may be added by writing

```
    A + B
```

and their matrix product may be formed as

```
    matmul(A, B)
```

because `matmul` is a standard Fortran intrinsic function.

However, more complicated operations require sophisticated programs to do the calculations effectively and efficiently. Fortunately, a lot of work has been done in this area and the results are included in the Fortran Tools. The BLAS and LAPACK libraries have been used widely for years; in addition, MATRAN (may-tran) provides a higher level interface to these routines.

When compiling using the command line, the compiler options

```
    -I/usr/local/fortrantools/lib prog.f95\
    -L/usr/local/fortrantools/lib -lmatrix -lg2c
```

must be used.

10.1 MATRAN

MATRAN is a collections of modules containing procedures that may be used to perform a variety of matrix operations, such as solving linear equations and computing eigenvalues. These procedures call BLAS and LAPACK routines.

All computations are performed with double precision real values.

MATRAN was developed by G. W. (Pete) Stewart, Department of Computer Science, Institute for Advanced Computer Studies, University of Maryland. The web site is:

```
http://www.cs.umd.edu/~stewart/
```

A few of the features of MATRAN are described here. More complete documentation may be found in *MatranWriteup* in PDF format in the `doc` directory of the Fortran Tools distribution.

10.1.1 The Rmat and Rdiag Derived Types

Most of the matrix computations in MATRAN are performed on objects of type `Rmat` (real matrix) and `Rdiag` (real diagonal matrix). These are derived types provided with MATRAN. For example, when solving a system of linear equations, objects of type `Rmat` are passed to the solver, not plain Fortran arrays. Here is a partial description of the `Rmat` type:

```
type :: Rmat
   real(wp), pointer :: a(:,:) => null()
   integer :: nrow = 0, ncol = 0
      . . .
end type Rmat
```

The first component `a` is a real array pointer. `wp` is the kind of the working precision, which is default real for the libraries provided with the Fortran Tools. The component `a` is default initialized to null, which means that it will be initialized to the null pointer for each `Rmat` object created. `nrow` and `ncol` are the number of rows and columns of the matrix, respectively.

For example if `X` is declared to be type `Rmat`

```
X % ncol
```

is the number of columns in matrix `X` and

```
X % a(nrow, :)
```

is the last row of the matrix.

Thus, `Rmat` objects may be manipulated directly (their components are not private) as well as with the procedures provided by MATRAN.

The type `Rdiag` (real diagonal matrix) represents a diagonal matrix as a one-dimensional array, consisting of the diagonal elements, and other components, such as the size of the matrix.

10.1.2 Example: Linear Equations

Let us look at some of the MATRAN operations used to construct a program to solve a set of linear equations.

Here is the program; it solves $Ax = b$.

```
program matran_linear_equations

use MatranRealCore_m

integer, parameter :: n = 3
integer :: i, j

type(Rmat) :: A, b, x

! Put some values in the matrix A
A = reshape( (/ ((real(i+j),i=1,n),j=1,n) /), &
     shape = (/ n,n /) )
A%a(n,n) = -A%a(n,n) ! Make sure A is not singular

! Put some values in the vector b
b = reshape( (/(real(i), i = 1, n)/), (/n,1/))
b = A * b

! Solve the linear equations
x = A .xiy. b

call Print(A, 15, n, "Array A", e=1)
call Print(b, 15, n, "Vector B", e=1)
print *
print *
print "(a, 3f7.4)", &
   "The solution to Ax = B is", x%a(1:n, 1)
print *

call Clean(A)
call Clean(b)
call Clean(x)

end program matran_linear_equations
```

The program could be run using Photran or from the command line by entering (on one line, if desired)

```
g95 matran_linear_equations.f95 \
  -I/usr/local/bin/FortranTools \
  -L/usr/local/bin/FortranTools -lmatrix
```

`A`, `b`, and `x` are type `Rmat` objects. All three are, in effect, representations of matrices, even though in this program we think of `b` and `x` as vectors to hold the constants of the equations and the solution to the equations, respectively. Remember that Fortran is case insensitive, but case is used in the program in the traditional way: uppercase for matrices and lowercase for vectors.

The `use` statement in the subroutine accesses a module containing many of the MATRAN features. To use other MATRAN features, additional `use` statements may be needed; see the eigenvalues example in 10.1.3.

`A` and `b` are given values using an extended assignment statement. In the statement

```
b = A * b
```

the operation is matrix multiplication, provided by MATRAN. This assigns values to `b` that will produce a solution we will recognize.

The statement

```
x = A .xiy. b
```

assigns the solution to `x` by computing `A`$^{-1}$`b` using the operator `.xiy.`, which is intended to suggest "*x* inverse times *y*". (Of course, the inverse of `A` is not actually calculated in order to solve the equations.)

The MATRAN subroutine `Print` is used to verify the values of `A` and `b` used for the equations.

The subroutine `Clean` releases allocatable storage. Note that there are other MATRAN subroutines that deal with the deallocation of dummy arguments of type `Rmat`.

Here is the output from the program.

```
 Array A
3 3 3 3 GE T 0
                 1               2               3
1        2.000E+0        3.000E+0        4.000E+0
                 1               2               3
2        3.000E+0        4.000E+0        5.000E+0
```

```
                1              2              3
3         4.000E+0       5.000E+0      -6.000E+0

Vector B
3 1 3 1 GE T 0
                1
1         2.000E+1
                1
2         2.600E+1
                1
3        -4.000E+0


The solution to Ax = B is 1.0000 2.0000 3.0000
```

10.1.3 Example: Eigenvalues

For this example, we assume that the main program uses ordinary Fortran arrays to store matrices. To compute the eigenvalues of a matrix, we want to call the subroutine `eigenvalues`, passing such an array. This subroutine will use MATRAN objects and the routine `Eig` to compute the eigenvalues.

The program could be run using Photran or from the command line by entering (on one line, if desired)

```
g95 matran_eigenvalues.f95 \
  -I/usr/local/bin/FortranTools \
  -L/usr/local/bin/FortranTools -lmatrix
```

Here is the program.

```
program matran_eigenvalues

integer, parameter :: n = 5
real, dimension(n,n) :: A
complex, dimension(n) :: e
integer :: i, j

! Put some values in the matrix A
call random_seed()
call random_number(A)
A = 10.0 * A - 5.0

call eigen_values(A, e)
```

```
print *
print *, "The eigenvalues of A are:"
print *
do i = 1, n
   print "(i3, 2(f7.2, a))", i, &
         real(e(i)), " +", &
         imag(e(i)), "i"
end do
print *
print *

contains

subroutine eigen_values (D, e)

   use MatranRealCore_m
   use RmatEig_m

   real, dimension(:, :), intent(in) :: D
   complex, dimension(:), intent(out) :: e
   type(Rmat) :: RD
   type(RmatEig) :: eigD

   RD = D
   call Print(RD, 9, 2, "Array D", e = 1)

   call Eig(eigD, RD)

   ! D is the eigenvalue component of eigD
   e = eigD % D

   call Clean(RD)
   call Clean(eigD)

end subroutine eigen_values

end program matran_eigenvalues
```

The Fortran instrinsic subroutines `random_seed` and `random_number` are used to put some values in the array `A`. The statement

```
A = 10.0 * A - 5.0
```

causes the numbers to be between –5 and +5 instead of between 0 and 1. The array `A` is passed to the subroutine `Eig` with a vector `e` to hold the eigenvalues. The dummy argument `D` is assigned to the variable `RD` of type `Rmat`. The array is printed.

The call to subroutine `Eig` computes the eigenvalues of `RD` and stores the results in `eigD`, a MATRAN object of type `RmatEig`, defined in the module `RmatEig_m`. The component `D` (not the same as the dummy array `D`) contains the eigenvalues and this is assigned to the dummy array `e`, which is returned as the value of the actual argument `e`. The eigenvalues stored in `e` are then printed.

Here is the result of one execution of the program.

```
Array D
5 5 5 5 GE T 0
          1         2         3         4         5
1  -3.54E+0 -1.88E+0  3.01E+0  2.51E+0  3.33E+0
          1         2         3         4         5
2   4.19E+0  2.04E+0 -4.80E+0 -3.19E+0  1.02E+0
          1         2         3         4         5
3  -3.99E+0  7.37E-1 -3.98E+0 -1.34E+0 -7.92E-1
          1         2         3         4         5
4  -3.44E+0  3.74E+0  1.49E-1 -3.59E+0 -1.79E+0
          1         2         3         4         5
5  -4.16E+0 -1.70E-1  1.48E+0  4.89E+0  4.46E+0

The eigenvalues of A are:

 1  -1.31 +   7.13i
 2  -1.31 +  -7.13i
 3  -3.02 +   1.91i
 4  -3.02 +  -1.91i
 5   4.05 +   0.00i
```

10.2 BLAS and LAPACK Libraries

It is possible to invoke any of the BLAS or LAPACK procedures directly in a Photran project or from the command line by using the `-lmatrix` option on the compile command.

An extensive description of LAPACK is found at

```
http://www.netlib.org/lapack/lug/index.html/
```

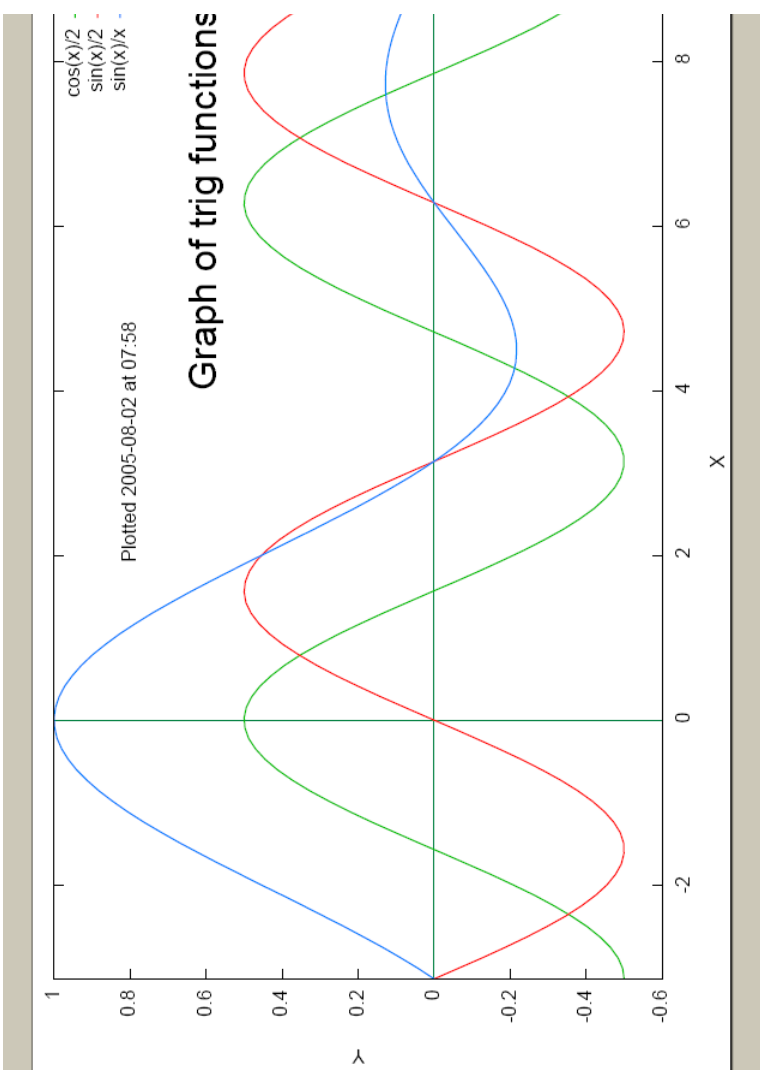
10.3 Atlas Libraries

The Atlas libraries are optimized versions of the Blas and Lapack routines. They must be built for each architecture and operating system. If, when installing, you specified the reference libraries by entering the number 0, you have not installed the Atlas libraries; you have installed the reference libraries. If you specified a different matrix library, the MATRAN programs should run considerably faster. However, if there is some problem, you can always use the reference libraries by doing one of the following:

- Use `-lmatrix0` instead of using `-lmatrix` on the command line when compiling.
- In the file `/usr/local/fortrantools/lib`, edit the file named `mkmf_args` to use `-lmatrix0` instead of `-lmatrix`.
- Reinstall the Fortran Tools and specify a different matrix library.

Conversely, if the reference libraries were installed, you can use the Atlas library be specifying `-lmatrixPII` (or the appropriate library name).

Plotting 11


Graph of trig functions
Plotted 2005-08-02 at 07:58
cos(x)/2
sin(x)/2
sin(x)/x
X
Y
-2
0
2
4
6
8
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6

The Fortran Tools use Gnuplot to do plotting. It is part of the Linux distribution and Cygwin.

11.1 Using Gnuplot

One way to use Gnuplot is to type the commands into the `gnuplot` program. On Windows, be in a Cygwin window and type `startx` to produce an X window; or in a DOS window type `bash<C:\Cygwin\usr\X11R6\bin\startx`. The default file format is x11, so this is necessary only if the default output file format is not changed. On either system, type `gnuplot`. Enter Gnuplot commands, such as

```
$ gnuplot
> plot sin(x)
> exit
```

11.2 Running Gnuplot with a Fortran Program

To run Gnuplot with a Fortran program, create a project and copy `Makefile` as usual. Then create a new file called, for example, `trig_plot.gp` containing the following Gnuplot commands, which produce the plot on page 11-1.

```
# Plot some trig functions with Gnuplot

# Draw the axes
set xzeroaxis lt 22
set yzeroaxis lt 22
set xlabel "X"
set ylabel "Y"

# Establish the time stamp
set time "Plotted 20%y-%m-%d at %H:%M" \
   45,27 "Helvetica,6"

# Provide identifying label
set label "Graph of trig functions" at 4,0.6 \
   font "Helvetica,12"

# Set plot type and output file
set terminal pdf
set output "trig_plot.pdf"
```

```
# Create the plot
plot [-pi:3*pi] cos(x)/2 lt 2 lw 2, \
                sin(x)/2 lt 1 lw 2, \
                sin(x)/x lt 3 lw 2
```

Create a Fortran program that runs `gnuplot` as follows:

```
program trig_plot

   call system ("gnuplot ""trig_plot.gp""")

end program trig_plot
```

Note that the double quotes are there so that the value of the command will be

```
gnuplot “trig_plot.gp”
```

The plot is placed in the output file `trig_plot.pdf`, which may be viewed with Acrobat Reader.

In this case, another way to run the plot is to change `Makefile` to

```
all:
	gnuplot "trig_plot.gp"
clean:
	rm -f *.mod *.o RUN* f_Makefile
```

and simply build the project, which will run `gnuplot`. Remember that the first character in the lines after `all:` and `clean:` must be a `tab`, not spaces.

11.2.1 Some Gnuplot Commands

We can use the file named `plot_heat.gp` to briefly examine some of the common Gnuplot commands. Complete descriptions of all the commands may be found in `Gnuplot.pdf` in the `docs` directory of the Fortran Tools distribution.

```
set xzeroaxis lt 22
```

indicates that the x axis is to be drawn on the plot with line type (`lt`) 22. To see the line types and point types, execute `gnuplot` and type `test`. The next three commands then do what is expected.

```
set time "Plotted 20%y-%m-%d at %H:%M" \
   45,27 "Helvetica,6"
```

puts a time stamp on the graph at a position indicated by character offsets 45 (x) and 27 (y). The format is given by the first character string and the font and size by the second.

```
set label "Graph of trig functions" at 4,0.6 \
   font "Helvetica,12"
```

places a label at coordinate position (4, 0.6) in Helvetica 12-point font.

```
set terminal pdf
set output "trig_plot.pdf"
```

indicate the format of the output file is PDF and the plot will be put in file `trig_plot.pdf`.

```
plot [-pi:3*pi] cos(x)/2 lt 2 lw 2, \
                sin(x)/2 lt 1 lw 2, \
                sin(x)/x lt 3 lw 2
```

This command generates the plot, with three curves, the label, the axes, the axis labels, and the time stamp. The notation in brackets indicates the range of x values to include in the plot. `pi` is a built-in variable. `lt` indicates the line type and `lw` means the line width is to be two times the normal size. Line types 1, 2, and 3 produce lines with color red, green, and blue, respectively.

11.3 Generating Data with a Fortran Program

The program `heat.f95` illustrates how a Fortran program can generate the data for a plot. This program generates data for many plots, in fact, and displays them sequentially. To run this program with Photran, be sure to start Photran in an X window; how to do this is explained in 11.1. If not using Photran, execute the program in an X window. Here is the program:

```
!  A simple solution to the heat equation using
!  pointers. Results are plotted with Gnuplot.

program heat
```

```
implicit none

integer, parameter   :: nn = 20, &  ! Size of grid
                         plot_frequency = 10, &
                         pause_time = 1
real, dimension(nn,nn), target :: plate
real, dimension(nn-2,nn-2)     :: temp
real, pointer, dimension(:,:) :: n,e,s,w, inside
real, parameter      :: tolerance = 1.0e-3
character(len=20)    :: filename = "heat_data."

real    :: diff
integer :: i,j, niter, ios

open(unit=11, file="heat.gp", status="replace",&
     action="write", iostat=ios)
if (ios > 0) then
   print *, "Couldn't open heat.gp"
   stop
end if

call system("rm -f head_data.*")

write(unit=11, fmt="(a)") &
      "set terminal x11", &
      "set pm3d", &
      "set palette", &
      "set ticslevel 0", &
      "set view 0,0"
write(unit=11, fmt="(a, i0)") &
      "pause_seconds=", pause_time

! Set up initial conditions
plate = 0
plate(1:nn,nn) = 1.0  ! boundary values
plate(1,1:nn) = (/ ( 1.0/nn*j, j = 1, nn ) /)

!  Point to parts of the plate
inside => plate(2:nn-1,2:nn-1)
n => plate(1:nn-2,2:nn-1)
s => plate(3:nn,2:nn-1)
e => plate(2:nn-1,3:nn)
```

```
w => plate(2:nn-1,1:nn-2)

! Iterate
niter = 0
do
   niter = niter + 1
   temp = (n + e + s + w)/4.0
   diff = maxval(abs(temp-inside))
   inside = temp
   if (modulo(niter, plot_frequency) == 0) then
      call print_data()
   end if
   if (diff < tolerance) exit
end do

if (modulo(niter, plot_frequency) /= 0) then
   call print_data()
end if

close (unit=11, status="keep")

call system("gnuplot -persist ""heat.gp""")

contains

subroutine print_data()
   write(unit=filename(11:), fmt="(i0)") niter
   open(file=trim(filename), &
        unit=22, status="replace", &
        action="write", iostat=ios)
   if (ios>0) then
      print *, "File open failed:", niter
      stop
   end if
   do i = 1,nn
      write (unit=22, fmt="(999f7.3)") &
            plate(1:nn,i)
   enddo
   close(unit=22, status="keep")
   write (unit=11, fmt="(a)") &
      "splot """ // trim(filename) // &
      """ matrix pt 0", "pause pause_seconds"
```

```
end subroutine print_data

end program heat
```

A constant heat source is placed along one edge of an nn x nn grid and a linearly diminishing heat source is placed along an adjacent edge. The steady state condition of each point in the grid is found by iteratively replacing each value in the interior of the grid (the pointer variable inside is an alias of this portion of the plate) by the average of the points (n, e, s, w) around it. If the iteration is a multiple of plot_frequency, the values in the grid are placed in a file for plotting. pause_seconds indicates the number of seconds delay between plot displays. If the largest difference between an old value and a new value in the grid is less than the parameter tolerance, no more iterations are performed and the data for the last plot is generated, if it has not been generated already.

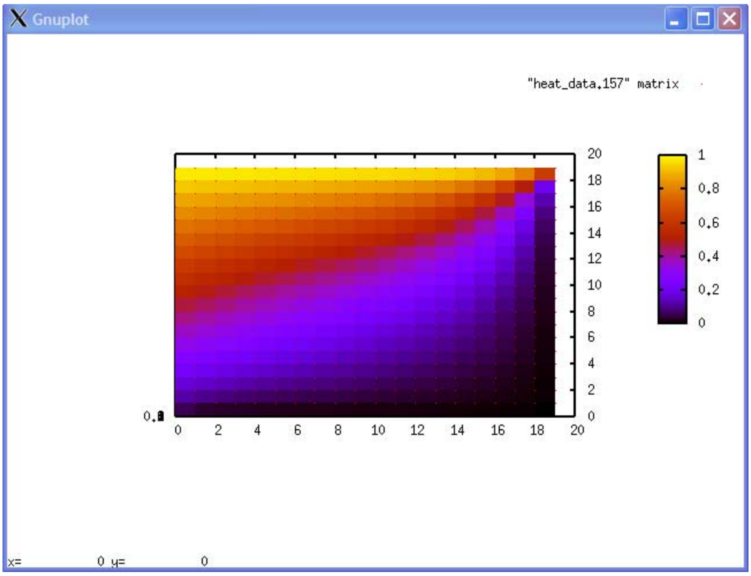
The system routine is called to execute the Gnuplot command file heat.gp generated by the program. Here is the content of the file generated in this case.

```
set terminal x11
set pm3d
set palette
set ticslevel 0
set view 0,0
pause_seconds=1
splot "heat_data.10" matrix pt 0
pause pause_seconds
splot "heat_data.20" matrix pt 0
pause pause_seconds
   . . .
splot "heat_data.150" matrix pt 0
pause pause_seconds
splot "heat_data.157" matrix pt 0
pause pause_seconds
```

This sets the file format to x11 and the style to a special three-dimensional format (pm3d). The view is from straight above the plot (0,0). It draws three-dimensional (projected on the two-dimensional screen, of course) plots (splot) for each of the data files generated by the Fortran program. matrix indicates that the data in the file is in matrix (two-dimensional array) format. `pt 0` indicates that the point style is 0. Because the command that executes this file is

```
gnuplot -persist heat.gp
```

the last plot remains displayed until closed. Here is the final plot.



GUIs in Applications 12

Photran provides a graphical user interface (GUI) for developing Fortran programs. Sometimes it is nice to provide a graphical interface for processing the input/output during execution of the Fortran program. The Fortran Tools includes a package of routines called JAPI that can be used in a Fortran program to provide this capability.

JAPI provides a set of procedures that can be called from a Fortran program. The JAPI routines themselves are written in Java and have an unusual requirement that a Java program must be running in order to run the programs that use the JAPI GUIs. This program usually runs on Linux when a program with JAPI routines is executed. On Windows, to get this program running, type `bash` to be in the Cygwin bash shell. Then

```
cd /usr/local/fortrantools/lib
java -cp JAPI.jar JAPI &
```

If the program is already running, you will get a message, but all should be OK.

All of the JAPI procedures have names that begin with `j_`. In order to have access to these procedures, a program must contain the statement

```
use japi
```

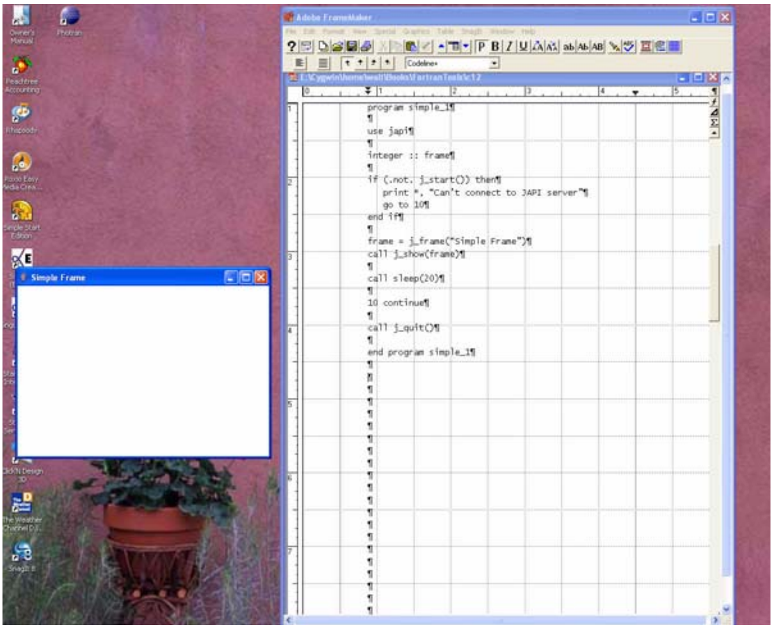
We will explore the use of JAPI with a few examples, which will provide the opportunity to discuss a few of the JAPI procedures. There are many more, which are described in the JAPI manual (`Japi_manual.pdf`) in the `doc` directory of the Fortran Tools distribution.

The idea behind JAPI is to allow the user of a Fortran program to work in a "windows" environment that is like many other applications that run on the same computer. So we begin with a very simple example that doesn't do anything useful, but shows how to create a simple window, called a ***frame*** by JAPI.

12.1 Displaying a Simple Frame

The following program produces output shown in the screen shot following the program.

```
program simple_1

use japi

integer :: frame

if (.not. j_start()) then
   print *, “Can’t connect to JAPI server”
   go to 10
end if

frame = j_frame(“Simple Frame”)
call j_show(frame)

call sleep(20)

10 continue

call j_quit()

end program simple_1
```



```
program simple_1

use japi

integer :: frame

if (.not. j_start()) then
   print *, "Can't connect to JAPI server"
   go to 10
end if

frame = j_frame("Simple Frame")
call j_show(frame)

call sleep(20)

10 continue

call j_quit()

end program simple_1
```

The small frame on the left is produced by JAPI. The screen on the right is a page of this manual that was being prepared as the program was run.

This screen is not very exciting. If you run the program (it is in the `examples` folder of the Fortran Tools distribution), it is possible to move the frame around on the screen, resize it by grabbing a corner or an edge, maximize it to fill the whole screen, and minimize it. The X icon will not close the frame, but you can stop the program running by clicking the Photran red square.

However, it was easy to produce this frame and it does have some of the properties you would expect of any window. We will see how to make things more interesting with later examples. But first, let's look at the code and see what it does.

The first block of executable code starts the JAPI process. This is where things will fail if the Java code is not running (see above).

```
if (.not. j_start()) then
   print *, "Can't connect to JAPI server"
   go to 10
end if
```

The following two statements establish `frame` as the identifier of a JAPI frame with "Simple Frame" in its title bar. `frame` is just an ordinary Fortran integer variable and it gets set to a small value determined by JAPI. This value (as the value of the variable `frame`) is used to identify this particular frame in the rest of the program. The subroutine call displays the frame.

```
frame = j_frame("Simple Frame")
call j_show(frame)
```

The rest of the program causes the program to wait 20 seconds and then terminate, at which time the frame will disappear.

12.2 Setting Frame Properties

It is possible to display more than one frame and it is possible to set many of the properties of a frame. The program `simple_2` illustrates some of these possibilities.

```
program simple_2

use japi

integer :: frame_1, frame_2

if (.not. j_start()) then
   print *, "Can't connect to JAPI server"
   go to 10
end if

frame_1 = j_frame("Frame 1")
call j_show(frame_1)

frame_2 = j_frame("Frame 2")
call j_setsize(frame_2, 500, 500)
call j_setpos(frame_2, 100, 200)
call j_setnamedcolorbg(frame_2, j_red)
call j_show(frame_2)
call sleep(10)

call j_setnamedcolorbg(frame_2, j_yellow)
call sleep(10)

10 continue

call j_quit()

end program simple_2
```

Two frames are created. Before the second one is displayed, its size, position, and color are established. After sleeping for 10 seconds, the color of the second frame is changed to yellow by executing

```
call j_setnamedcolorbg(frame_2, j_yellow)
```

`j_yellow` is simply a parameter defined in the JAPI module. Note that `j_show` is not executed a second time. The program terminates after another 10 seconds.

12.3 User Input

It is more interesting if the user can interact with the program by supplying input. The next example illustrates how the user can use a frame to provide input and how the program is written to respond to user input.

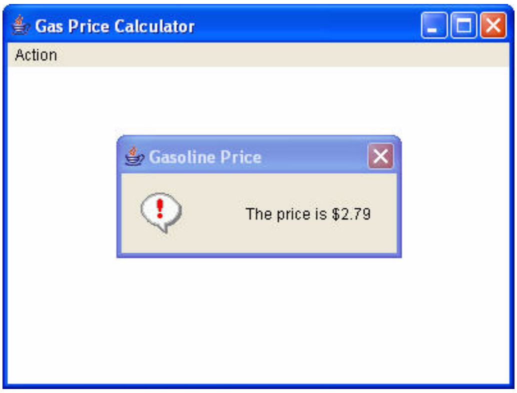
This program displays a frame and waits for user input. Here is the program.

```
module gas_price_module
   character(len=*), parameter, public :: &
         gas_price = “$2.79”
end module gas_price_module

program gas

use japi
use gas_price_module

character(len=*), parameter :: &
      title = “Gasoline Price”, &
      price = “The price is “ // gas_price
```

```
integer :: frame, menubar, quit, obj, action
integer :: cost, message

if (.not. j_start()) then
    print *, “Can’t connect to JAPI server”
    go to 10
end if

! Make a frame with a menubar
! Put on the menubar a menu with two menu items
frame   = j_frame(“Gas Price Calculator”)
menubar = j_menubar(frame)
action  = j_menu(menubar, “Action”)
cost    = j_menuitem(action, “Display price”)
quit    = j_menuitem(action, “Quit”)

call j_show(frame)

next_action: do
   obj = j_nextaction()
   if (obj==frame .or. obj==quit) then
      exit next_action
   else if (obj==cost) then
     message = j_messagebox(frame, title, price)
   else if (obj==message) then
      call j_dispose(message)
   end if
end do next_action

10 continue
call j_quit()

end program gas
```

The frame displayed by this program has a menu bar. In the menu bar is just one menu selection labelled “Action”. Here is what the frame looks like.

The menu items are displayed when the user selects Action. If Quit is selected from the Action submenu, the program will halt. Selecting the X on the Gas Price Calculator frame also will halt the program. If Display Price is selected, a message box is displayed containing information about the price of gasoline.



The price is $2.79

Selecting the X on the Gasoline Price frame will close the message box, but not the containing frame.

12.4 Event-Driven Programming

Just as your operating system sits and waits for you to type something or move the mouse, this program is waiting for somebody to interact with the frame. If Action is selected in the frame, for example, the operating system knows to pass this on to our program and the `next_action` loop then determines which event took place, handles the event, then continues to wait.

```
next_action: do
   obj = j_nextaction()
   if (obj==frame .or. obj==quit) then
      exit next_action
   else if (obj==cost) then
     message = j_messagebox(frame, title, price)
   else if (obj==message) then
      call j_dispose(message)
   end if
end do next_action
```

12.5 Selecting Colors with Buttons

This example perhaps illustrates better how a program can respond to one of multiple possible inputs without having to request which input is to occur, as must be done in a traditional Fortran program.

The frame displayed by this program contains three buttons, or *checkboxes,* one for each of the basic colors: red, green, and blue. Any of the buttons can be selected. For example, if blue and green are selected, the background color of the frame becomes turquoise and if all three are selected, the background is white.

```
program check_colors

use japi

integer :: frame, obj
integer :: blue, red, green  ! Names of checkboxes
integer :: r, g, b            ! Color values

if (.not. j_start()) then
   print *, “Can’t connect to JAPI server”
   go to 20
end if

! Make a frame with three checkboxes

frame = j_frame(“Select the color components”)

blue = j_checkbox(frame, “Blue”)
call j_setpos(blue, 150, 80)
call j_setstate(blue, .true.)
b=255

red = j_checkbox(frame, “Red”)
call j_setpos(red, 150, 120)
call j_setstate(red, .false.)
r=0

green = j_checkbox(frame, “Green”)
call j_setpos(green, 150, 160)
call j_setstate(green, .false.)
```

```
g=0

! Set the frame background color
call j_setcolorbg(frame, r, g, b)
call j_show(frame)

check_boxes: do
   obj = j_nextaction()

   if (obj == frame) then
      exit check_boxes

   ! If a color is checked, change it 0<->255
   else if (obj == red) then
      r = abs(r-255)
   else if (obj == blue) then
      b = abs(b-255)
   else if (obj == green) then
      g = abs(g-255)
   end if

   ! Make the labels readable on any background
   if (r+g+b < 256) then
      call j_setnamedcolor(red, j_white)
      call j_setnamedcolor(blue, j_white)
      call j_setnamedcolor(green, j_white)
   else
      call j_setnamedcolor(red, j_black)
      call j_setnamedcolor(blue, j_black)
      call j_setnamedcolor(green, j_black)
   end if

   call j_setcolorbg(frame, r, g, b)

end do check_boxes

20 continue
call j_quit()

end program check_colors
```

In this program, the background color is indicated by the magnitude of the three basic color components: red, green, and blue. These value range between 0 and 255. If all three components are 255, the color is white. We start with the blue button checked, the blue value `b` equal to 255, and the red and green values, `r` and `g`, equal to 0. The code to set up the blue check box is:

```
blue = j_checkbox(frame, “Blue”)
call j_setpos(blue, 150, 80)
call j_setstate(blue, .true.)
b=255
```

The other two are set up similarly.

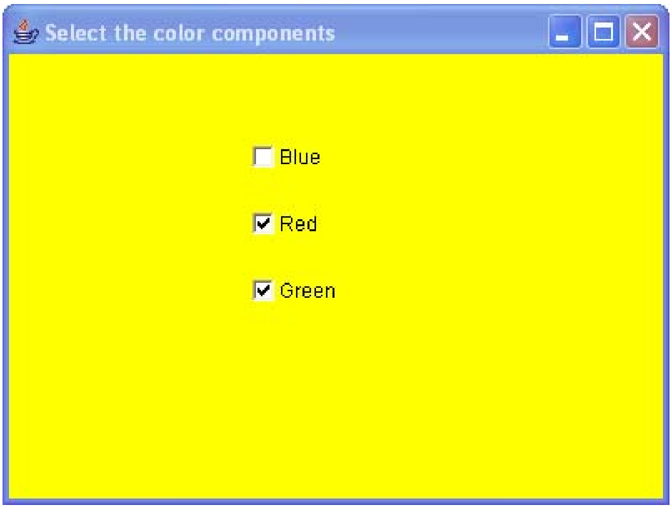
The background color is set by

```
call j_setcolorbg(frame, r, g, b)
```

The action loop is set up so that when any of the boxes is checked or unchecked, the appropriate value `r`, `g`, or `b` is changed and the background color is reset.

If `r` + `g` + `b` < 256, that means that at most one color box is checked. In this case, the text labelling the boxes is set to white to make it more readable; otherwise, it is black.

Note that abs(color–255) is 255 if color is 0 and is 0 if color is 255.



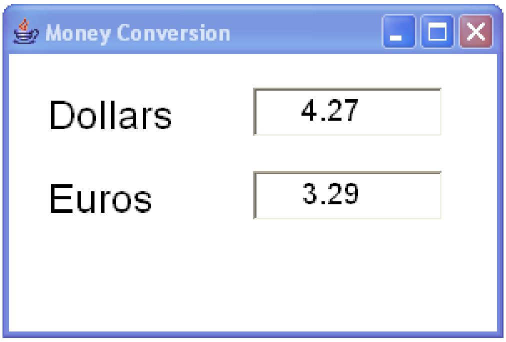
12.6 A Currency Converter

The frame in this program displays an amount of money in US dollars and the equivalent amount in Euros.

```
program change

use japi

integer :: frame, d_label, e_label
integer :: dollars, euros
integer :: action
integer, parameter :: field_length = 9
character(len=field_length) :: c_dollars, &
                               c_euros
real :: r_dollars, r_euros
real, parameter :: euros_per_dollar = 0.77

if (.not. j_start()) then
   print *, “Can’t connect to JAPI server”
   go to 10
end if

! Make a frame
frame = j_frame(“Money Conversion”)
call j_setpos(frame, 100, 200)
call j_setsize(frame, 300,200)

! Label “Dollars”
d_label = j_label(frame, “Dollars”)
call j_setpos(d_label, 20, 50)
call j_setfontsize(d_label, 24)

! Label “Euros”
e_label = j_label(frame, “Euros”)
call j_setpos(e_label, 20, 100)
call j_setfontsize(e_label, 24)

! Text field containing dollar amount
dollars = j_textfield(frame, field_length)
call j_setpos(dollars, 150, 50)
call j_setfontsize(dollars, 18)
call j_settext(dollars, “     0.00”)
```

```
     ! Text field containing euro amount
     euros = j_textfield(frame, field_length)
     call j_setpos(euros, 150, 100)
     call j_setfontsize(euros, 18)
     call j_settext(euros, “    0.00”)

     call j_show(frame)

     take_action: do

        action = j_nextaction()
        if (action==frame) then
           exit
        else if (action==dollars) then
           ! Convert dollars to euros
           call j_gettext(dollars, c_dollars)
           read (unit=c_dollars, fmt=*) r_dollars
           write (unit=c_euros, fmt=”(f9.2)”) &
                 r_dollars*euros_per_dollar
           call j_settext(euros, c_euros)
        else if (action==euros) then
           ! Convert euros to dollars
           call j_gettext(euros, c_euros)
           read (unit=c_euros, fmt=*) r_euros
           write (unit=c_dollars, fmt=”(f9.2)”) &
                 r_euros/euros_per_dollar
           call j_settext(dollars, c_dollars)
        end if

     end do take_action

     10 continue
     call j_quit()

     end program change
```

The important component of this frame is the *textfield*. It displays and accepts as input strings of characters. This means that if the Fortran program needs to do computation on values, as this one does, the character strings must be converted to and from real values. This is done with internal `read` and `write` statements. Thus, when the user types a value in the `Euros` field and hits `Enter`, the value is converted to a real number, converted to dollars, converted back to a character string, and displayed in the `Dollars` field.



Dollars 4.27

Euros 3.29

The text labels are set up with the `j_label` procedure.

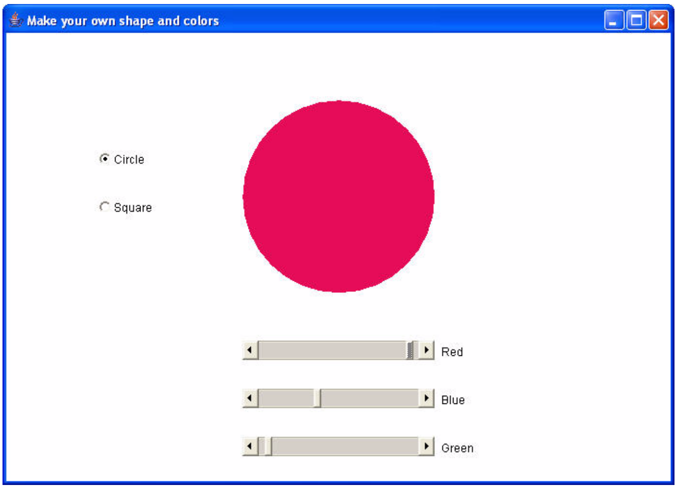
```
! Label “Dollars”
d_label = j_label(frame, “Dollars”)
call j_setpos(d_label, 20, 50)
call j_setfontsize(d_label, 24)
```

12.7 Radio Buttons and Slider Bars

In the example above that used checkboxes to select color components, any of the boxes could be checked or not checked. This example uses a set of buttons, exactly one of which must be selected at any time. That is, when one value is selected, the others are all deselected. These buttons are called *radio buttons*.

Here is an example of the frame when the circle shape is selected and a nice mixture of colors is selected. The slider bars select the size of the component for each of the three basic colors, whose values can range from 0 to 255. The program is a little long because there are more components, but the basic structure is not much different from previous examples.

```
program shape_and_color

use japi
                   implicit none
integer :: frame, canvas, obj
integer :: shape_buttons
integer :: circle, square   ! Names of shapes
integer :: red, green, blue ! Names of slider bars
integer :: r = 128, g = 128, b = 128 ! Color values
```



```
if (.not. j_start()) then
   print *, “Can’t connect to JAPI server”
   go to 20
end if

! Make a frame with radio buttons
! and three slider bars

frame = &
j_frame(“Select the shape and color components”)
call j_setsize(frame, 600, 500)
call j_setpos(frame, 100, 100)

! Radio buttons for the shapes circle and square
shape_buttons = j_radiogroup(frame)
circle = j_radiobutton(shape_buttons, “Circle”)
call j_setpos(circle, 100, 150)
call j_setstate(circle, .true.)
square = j_radiobutton(shape_buttons, “Square”)
call j_setpos(square, 100, 200)
print *,circle,square
```

```
! A canvas to draw the circle or square
canvas = j_canvas(frame, 200, 200)
call j_setpos(canvas, 200, 100)
call j_setnamedcolorbg(canvas,j_black)
call draw_circle()

! Slider bars
call slider_bar(red, 200, 350, 200, 20, &
                “Red”, 420, 350)
call slider_bar(blue, 200, 400, 200, 20, &
                “Blue”, 420, 400)
call slider_bar(green, 200, 450, 200, 20, &
                “Green”, 420, 450)

call j_show(frame)

event_loop: do
   obj = j_nextaction()
   if (obj==frame) then
      exit event_loop
   else if (obj==circle) then
      call draw_circle()
   else if (obj==square) then
      call draw_square()
   else if (obj==red) then
      r = j_getvalue(red)
      call draw_canvas()
   else if (obj==blue) then
      b = j_getvalue(blue)
      call draw_canvas()
   else if (obj==green) then
      g = j_getvalue(green)
      call draw_canvas()
   end if

end do event_loop

20 continue
call j_quit()

contains
```

```
subroutine draw_circle()
    ! First, cover up the square
    call j_setnamedcolorbg(canvas, j_white)
    call j_setcolor(canvas, r, g, b)
    call j_fillcircle(canvas, 100, 100, 100)
end subroutine draw_circle

subroutine draw_square()
    call j_setcolor(canvas, r, g, b)
    call j_fillrect(canvas, 0, 0, 200, 200)
end subroutine draw_square

subroutine draw_canvas()
   logical :: is_circle
   is_circle = j_getstate(circle)
   if (is_circle) then
      call draw_circle()
   else
      call draw_square()
   end if
end subroutine draw_canvas

subroutine slider_bar(name, xp, yp, xs, ys, &
                      title, xt, yt)
   integer, intent(out) :: name
   integer, intent(in) :: xp, yp, xs, ys, xt, yt
   character(len=*), intent(in) :: title
   integer :: label
   name = j_hscrollbar(frame)
   call j_setpos(name, xp, yp)
   call j_setsize(name, xs, ys)
   call j_setmin(name, 0)
   call j_setmax(name, 255)
   call j_setvalue(name, 128)
   label = j_label(frame, title)
   call j_setpos(label, xt, yt)
end subroutine slider_bar

end program shape_and_color
```

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