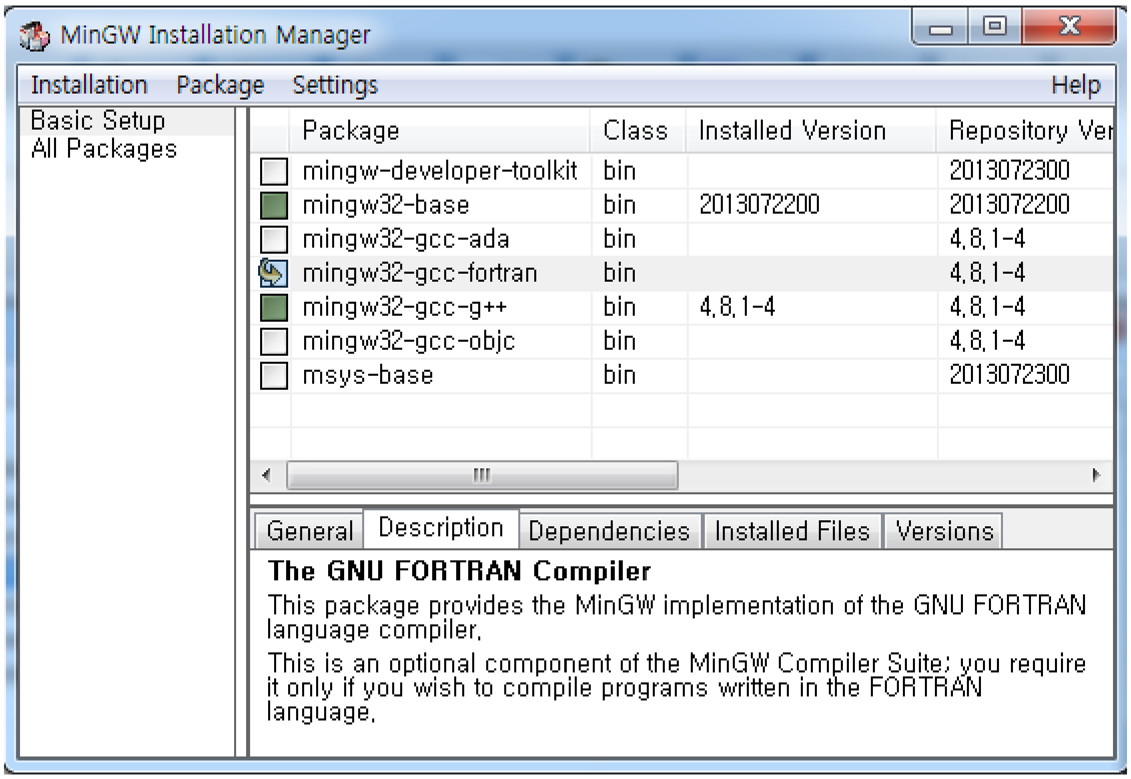
# R Extention Test Note for Windows

## Fortran Compiler and Usage

### `MinGW` Installation

A contraction of "Minimalist GNU for Windows", is a minimalist development environment for native Microsoft Windows applications.

- `MinGW`: http://www.mingw.org/
- Provides a complete Open Source programming tool set which is suitable for the development of native MS-Windows applications, and which do not depend on any 3rd-party C-Runtime DLLs.
- A port of the GNU Compiler Collection (GCC), including C, C++, ADA and Fortran compilers;
- ...
- Download: http://sourceforge.net/projects/mingw/files/latest/download?source=files
- Install: check to install Fortran GNU Compiler



| | Package | Class | Installed Version | Repository Ver |
|---|---|---|---|---|
| ☐ | mingw-developer-toolkit | bin | | 2013072300 |
| 🟩 | mingw32-base | bin | 2013072200 | 2013072200 |
| ☐ | mingw32-gcc-ada | bin | | 4.8.1-4 |
| ⟳ | mingw32-gcc-fortran | bin | | 4.8.1-4 |
| 🟩 | mingw32-gcc-g++ | bin | 4.8.1-4 | 4.8.1-4 |
| ☐ | mingw32-gcc-objc | bin | | 4.8.1-4 |
| ☐ | msys-base | bin | | 2013072300 |

**The GNU FORTRAN Compiler**

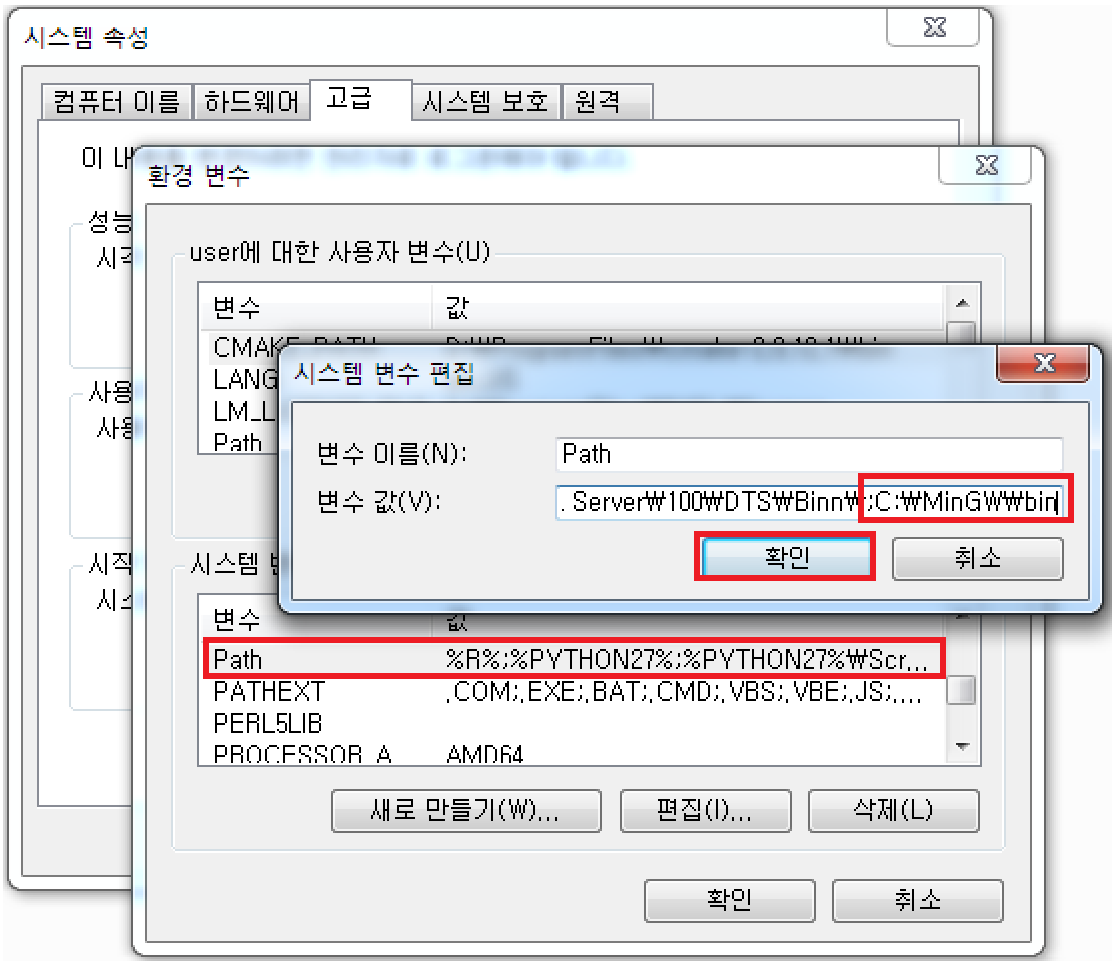
This package provides the MinGW implementation of the GNU FORTRAN language compiler.

This is an optional component of the MinGW Compiler Suite; you require it only if you wish to compile programs written in the FORTRAN language.

Figure 1: gfortran compiler

- Set System PATH

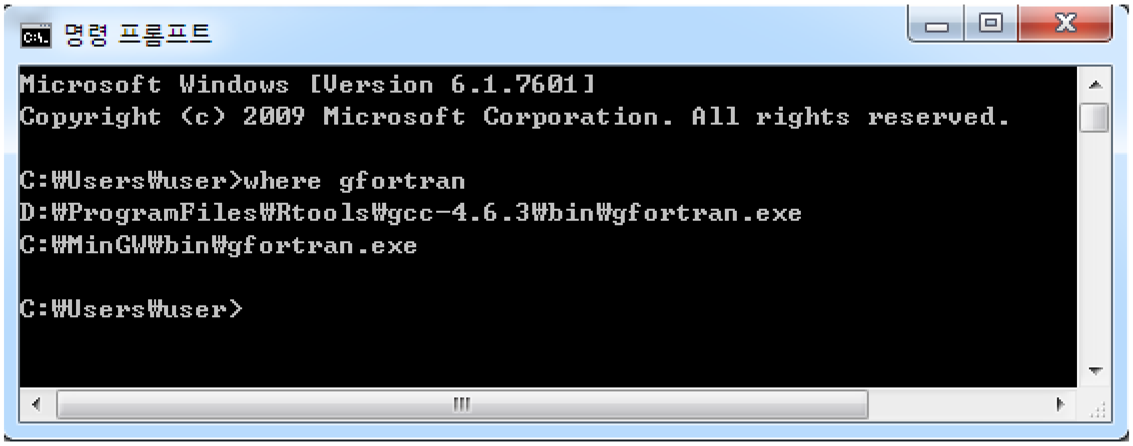
- Confirm: in windows CMD command line, `where` is the equivalent of `which` in Linux. As shown in the following figure, there are two `gfortran` executable file in my system path, the first one will be used by default.



변수 이름(N): Path
변수 값(V): . Server₩100₩DTS₩Binn₩;C:₩MinGW₩bin

| 변수 | 값 |
|---|---|
| Path | %R%;%PYTHON27%;%PYTHON27%₩Scr... |
| PATHEXT | .COM;.EXE;.BAT;.CMD;.VBS;.VBE;.JS;.... |
| PERL5LIB | |
| PROCESSOR_A | AMD64 |

Figure 2: system path



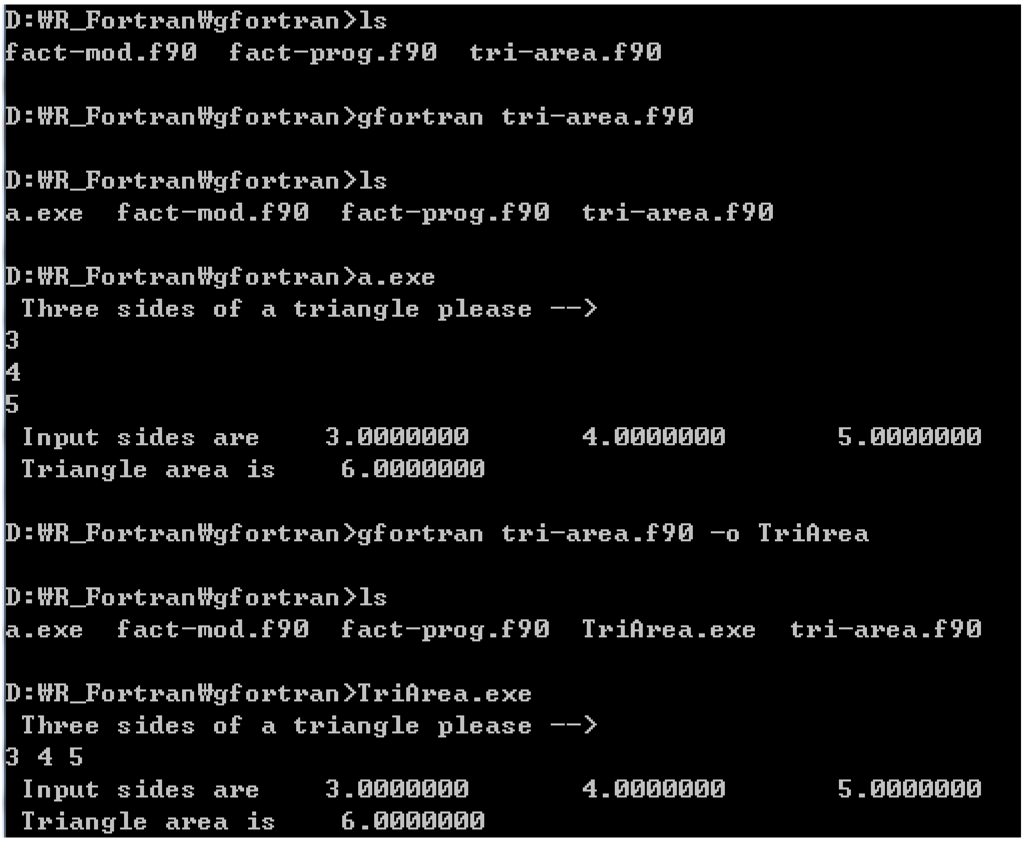
```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation. All rights reserved.

C:₩Users₩user>where gfortran
D:₩ProgramFiles₩Rtools₩gcc-4.6.3₩bin₩gfortran.exe
C:₩MinGW₩bin₩gfortran.exe

C:₩Users₩user>
```

Figure 3: cmd where

## `gfortran` Usage

- The GNU Fortran Compiler: http://gcc.gnu.org/onlinedocs/gfortran/
- Getting started with gfortran: http://gcc.gnu.org/wiki/GFortranGettingStarted
- Example1
- Compile one file. This program is used to calculate the area of a triangle given side lengths.
- Source location: `gfortran/tri-area.f90`, from: http://www.cs.mtu.edu/~shene/COURSES/cs201/NOTES/chap06/area-2.html

```
## The simplest way, default output is `a.exe`
gfortran tri-area.f90
## -o: specify the output name
gfortran tri-area.f90 -o TriArea
```

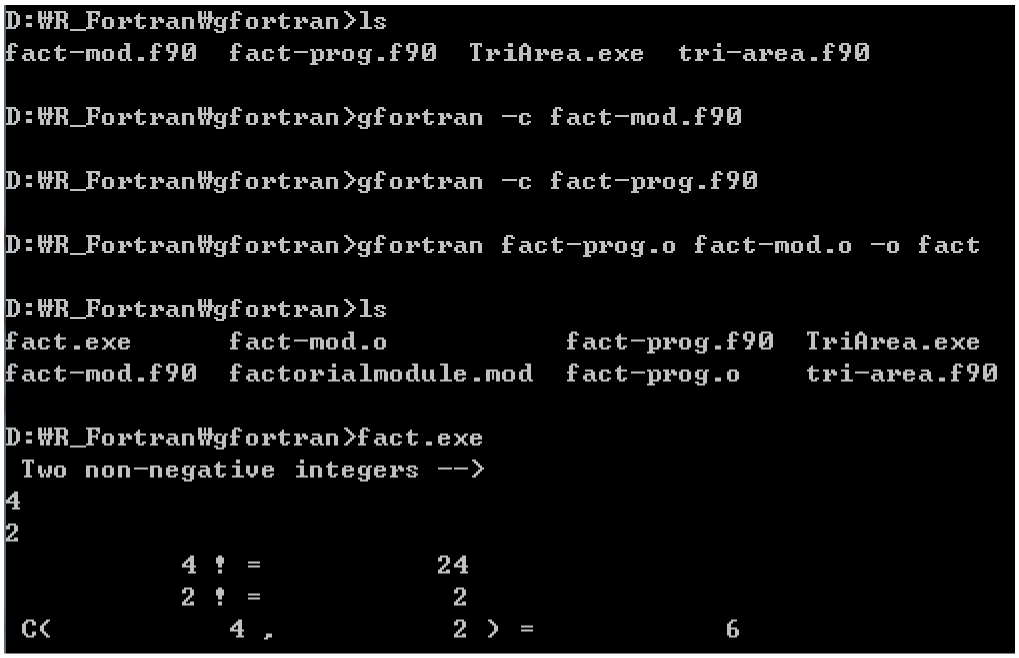


```
D:₩R_Fortran₩gfortran>ls
fact-mod.f90  fact-prog.f90  tri-area.f90

D:₩R_Fortran₩gfortran>gfortran tri-area.f90

D:₩R_Fortran₩gfortran>ls
a.exe  fact-mod.f90  fact-prog.f90  tri-area.f90

D:₩R_Fortran₩gfortran>a.exe
 Three sides of a triangle please -->
3
4
5
 Input sides are    3.0000000       4.0000000       5.0000000
 Triangle area is    6.0000000

D:₩R_Fortran₩gfortran>gfortran tri-area.f90 -o TriArea

D:₩R_Fortran₩gfortran>ls
a.exe  fact-mod.f90  fact-prog.f90  TriArea.exe  tri-area.f90

D:₩R_Fortran₩gfortran>TriArea.exe
 Three sides of a triangle please -->
3 4 5
 Input sides are    3.0000000       4.0000000       5.0000000
 Triangle area is    6.0000000
```

Figure 4: tri-area

- Example2
- Compile two files, one of which defines a module. This program is used to calculate the factorial $n!$ and combinatorial coefficient $C_n^r$ given $n$ and $r$.
- Source location: `gfortran/fact-mod.f90`, `gfortran/fact-prog.f90`, from http://www.cs.mtu.edu/~shene/COURSES/cs201/
2.html

```
## 1. Straight forward
gfortran fact-prog.f90 fact-mod.f90 -o fact
## 2. Step by step
gfortran -c fact-mod.f90
gfortran -c fact-prog.f90
gfortran fact-prog.o fact-prog.o -o fact
```



```
D:₩R_Fortran₩gfortran>ls
fact-mod.f90  fact-prog.f90  TriArea.exe  tri-area.f90

D:₩R_Fortran₩gfortran>gfortran -c fact-mod.f90

D:₩R_Fortran₩gfortran>gfortran -c fact-prog.f90

D:₩R_Fortran₩gfortran>gfortran fact-prog.o fact-mod.o -o fact

D:₩R_Fortran₩gfortran>ls
fact.exe      fact-mod.o           fact-prog.f90  TriArea.exe
fact-mod.f90  factorialmodule.mod  fact-prog.o    tri-area.f90

D:₩R_Fortran₩gfortran>fact.exe
 Two non-negative integers -->
4
2
           4 ! =           24
           2 ! =            2
 C(           4 ,           2 ) =           6
```

Figure 5: fact

**Note1:** In the *step by step* method, a `factorialmodule.mod` file is generated together with the `fact-mod.o` file. The former file is associated with the latter one, so if you delete the mod file, the last step will fail.

**Note2:** If you want to be an advanced developer, you should learn how to use command line and avoid using IDE if possible.

**Note3:** There are also some other popular Fortran compilers in Windows, such as `Absoft Pro Fortran` and `Intel Fortran Compiler`, which are all proprietary software. Since `R` uses `gcc` to build package and R itself in Windows, we only introduce `gfortran` compiler here.

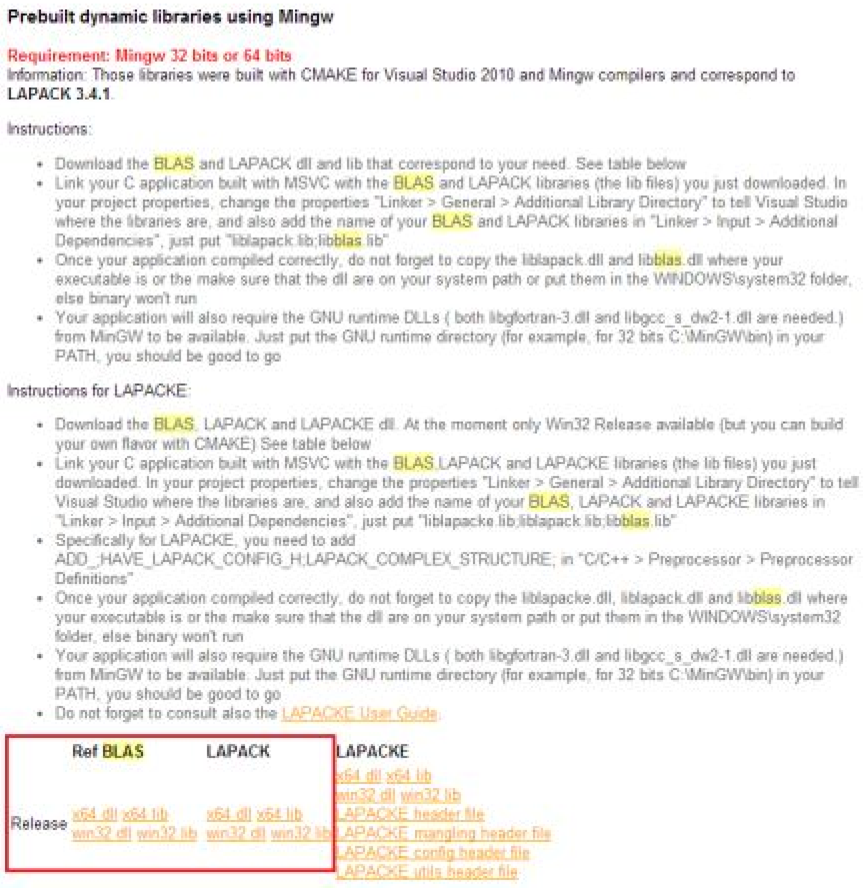
## BLAS & LAPACK & ATLAS

### BLAS (Basic Linear Algebra Subprograms)

> The Basic Linear Algebra Subprograms (BLAS) define a set of fundamental operations on vectors and matrices which can be used to create optimized higher-level linear algebra functionality.

- There are three levels of BLAS operations,
- The Level 1 BLAS perform scalar, vector and vector-vector operations;
- The Level 2 BLAS perform matrix-vector operations;
- The Level 3 BLAS perform matrix-matrix operations.
- Quick Reference Guide to the BLAS: http://www.netlib.org/lapack/lug/node145.html
- Reference Card: http://www.netlib.org/blas/blasqr.pdf
- Homepage: http://www.netlib.org/blas/
- Installation for Windows: http://icl.cs.utk.edu/lapack-for-windows/lapack/

**Note:** In this manual, we use the 'Prebuilt libraries'(check the 'Prebuilt dynamic libraries using Mingw' section described in Installation for Windows' above). Download the 32-bit dll files for both BLAS and LAPACK: `libblas.dll` and `liblapack.dll`. Of course, you can also build BLAS and LAPACK manually by yourself.



**Prebuilt dynamic libraries using Mingw**

**Requirement: Mingw 32 bits or 64 bits**
Information: Those libraries were built with CMAKE for Visual Studio 2010 and Mingw compilers and correspond to **LAPACK 3.4.1**.

Instructions:

- Download the BLAS and LAPACK dll and lib that correspond to your need. See table below
- Link your C application built with MSVC with the BLAS and LAPACK libraries (the lib files) you just downloaded. In your project properties, change the properties "Linker > General > Additional Library Directory" to tell Visual Studio where the libraries are, and also add the name of your BLAS and LAPACK libraries in "Linker > Input > Additional Dependencies", just put "liblapack.lib;libblas.lib"
- Once your application compiled correctly, do not forget to copy the liblapack.dll and libblas.dll where your executable is or the make sure that the dll are on your system path or put them in the WINDOWS\system32 folder, else binary won't run
- Your application will also require the GNU runtime DLLs ( both libgfortran-3.dll and libgcc_s_dw2-1.dll are needed.) from MinGW to be available. Just put the GNU runtime directory (for example, for 32 bits C:\MinGW\bin) in your PATH, you should be good to go

Instructions for LAPACKE:

- Download the BLAS, LAPACK and LAPACKE dll. At the moment only Win32 Release available (but you can build your own flavor with CMAKE) See table below
- Link your C application built with MSVC with the BLAS,LAPACK and LAPACKE libraries (the lib files) you just downloaded. In your project properties, change the properties "Linker > General > Additional Library Directory" to tell Visual Studio where the libraries are, and also add the name of your BLAS, LAPACK and LAPACKE libraries in "Linker > Input > Additional Dependencies", just put "liblapacke.lib;liblapack.lib;libblas.lib"
- Specifically for LAPACKE, you need to add ADD_;HAVE_LAPACK_CONFIG_H;LAPACK_COMPLEX_STRUCTURE; in "C/C++ > Preprocessor > Preprocessor Definitions"
- Once your application compiled correctly, do not forget to copy the liblapacke.dll, liblapack.dll and libblas.dll where your executable is or the make sure that the dll are on your system path or put them in the WINDOWS\system32 folder, else binary won't run
- Your application will also require the GNU runtime DLLs ( both libgfortran-3.dll and libgcc_s_dw2-1.dll are needed.) from MinGW to be available. Just put the GNU runtime directory (for example, for 32 bits C:\MinGW\bin) in your PATH, you should be good to go
- Do not forget to consult also the LAPACKE User Guide.

| | Ref BLAS | LAPACK | LAPACKE |
|---|---|---|---|
| Release | x64 dll x64 lib<br>win32 dll win32 lib | x64 dll x64 lib<br>win32 dll win32 lib | x64 dll x64 lib<br>win32 dll win32 lib<br>LAPACKE header file<br>LAPACKE mangling header file<br>LAPACKE config header file<br>LAPACKE utils header file |

Figure 6: BLAS and LAPACK install

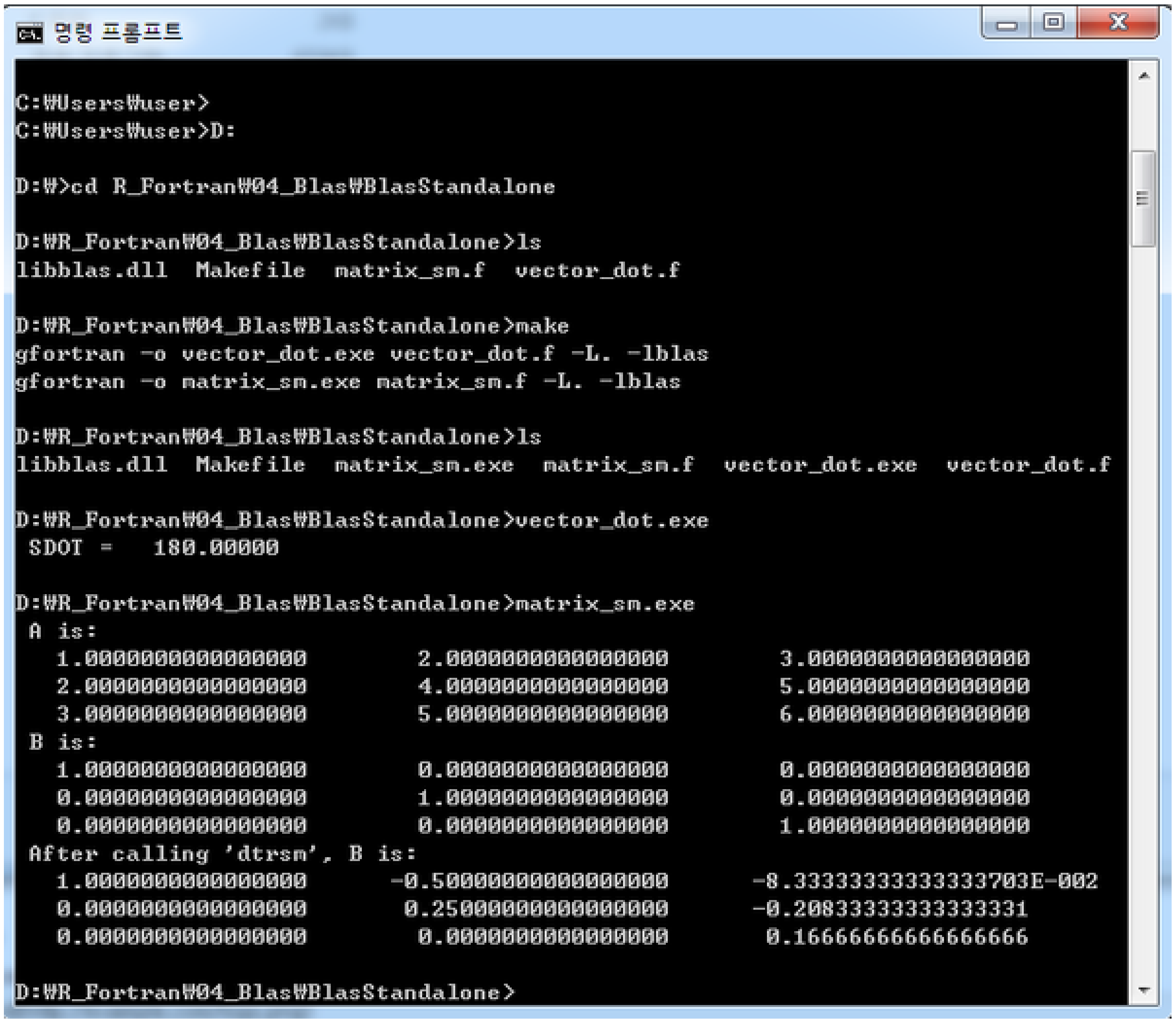
- Examples: vector-vector calculation $x^T x$; matrix-matrix calculation $A^{-1}B$
- Source location: `gfortran/BlasStandalone/vector_dot.f` and `gfortran/BlasStandalone/matrix_sm.f`
- Usage: Copy the downloaded `libblas.dll` to the `BlasStandalone` folder. Then, in the CMD command line, input `make` and enter, two executable files `matrix_sm.exe` and `vector_dot.exe` will be generated. Or you can input directly in the command line `gfortran -o xxx.exe xxx.f -L. -lblas`, where the `-L. -lblas` option means linking the `libblas.dll` file in the current directory to the program.
- Reference: `sdot`: http://www.netlib.org/blas/sdot.f; `dtrsm`: http://www.netlib.org/blas/dtrsm.f

**Note:** The `gfortran` compiler installed by Rtools lacks of some component for compiling standalone fortran program with BLAS and LAPACK, so you need to install `MinGW` first.

```
c vector_dot.f
c Example. Using BLAS Level 1 Routine
c vector-vector dot product
c Compute (1, 3, 5, 7, 9) * (10, 9, 8, 7, 6)
      program dot_main
      real x(10), y(10), sdot, res
      integer n, incx, incy, i
      n=5
      incx=2
      incy=1
      do i = 1, 10
         x(i) = i
         y(i) = 11-i
      end do
      res = sdot(n, x, incx, y, incy)
      print*,'SDOT =', res
      end
```

```
c matrix_sm.f
c Example. Using BLAS Level 3 Routine
c matrix-matrix solve, solve(A)%*%B, where A is mxm, B is mxn
c          [1, 2, 3]       [1, 4]
c     A =  [2, 4, 5], B = [2, 5]
c          [3, 5, 6]       [3, 6]
c Function:
c     DTRSM (SIDE, UPLO, TRANSA, DIAG, M, N, ALPHA, A, LDA, B, LDB)
      program dot_main
      double precision a(3,3), b(3,2), alpha
      integer i, j, m, n, lda, ldb
      character side, uplo, transa, diag
      side='l'
      uplo='u'
      transa='n'
      diag='n'
      data A/1.0, 2.0, 3.0, 2.0, 4.0, 5.0, 3.0, 5.0, 6.0/
      data B/1.0, 2.0, 3.0, 4.0, 5.0, 6.0/
      alpha=1.0
      m=3
      n=2
      lda=3
      ldb=3
      write(*,*) "A is:"
      do i=1, m
         print*, (A(i,j), j=1,m)
      enddo
```

```
write(*,*) "B is:"
do i=1, m
   print*, (B(i,j), j=1,n)
enddo
call dtrsm(side, uplo, transa, diag, m, n, alpha, a, lda, b, ldb)

write(*,*) "After calling 'dtrsm', B is:"
do i=1, m
   print*, (B(i,j), j=1,n)
enddo
end
```



```
C:₩Users₩user>
C:₩Users₩user>D:

D:₩>cd R_Fortran₩04_Blas₩BlasStandalone

D:₩R_Fortran₩04_Blas₩BlasStandalone>ls
libblas.dll  Makefile  matrix_sm.f  vector_dot.f

D:₩R_Fortran₩04_Blas₩BlasStandalone>make
gfortran -o vector_dot.exe vector_dot.f -L. -lblas
gfortran -o matrix_sm.exe matrix_sm.f -L. -lblas

D:₩R_Fortran₩04_Blas₩BlasStandalone>ls
libblas.dll  Makefile  matrix_sm.exe  matrix_sm.f  vector_dot.exe  vector_dot.f

D:₩R_Fortran₩04_Blas₩BlasStandalone>vector_dot.exe
 SDOT =   180.00000

D:₩R_Fortran₩04_Blas₩BlasStandalone>matrix_sm.exe
 A is:
   1.0000000000000000        2.0000000000000000        3.0000000000000000
   2.0000000000000000        4.0000000000000000        5.0000000000000000
   3.0000000000000000        5.0000000000000000        6.0000000000000000
 B is:
   1.0000000000000000        0.0000000000000000        0.0000000000000000
   0.0000000000000000        1.0000000000000000        0.0000000000000000
   0.0000000000000000        0.0000000000000000        1.0000000000000000
 After calling 'dtrsm', B is:
   1.0000000000000000      -0.50000000000000000      -8.3333333333333703E-002
   0.0000000000000000       0.25000000000000000      -0.20833333333333331
   0.0000000000000000        0.0000000000000000       0.16666666666666666

D:₩R_Fortran₩04_Blas₩BlasStandalone>
```

Figure 7: BLAS example

## LAPACK (Linear Algebra PACKage)

LAPACK is written in Fortran 90 and provides routines for solving systems of simultaneous linear equations, least-squares solutions of linear systems of equations, eigenvalue problems, and singular value problems. The associated matrix factorizations (LU, Cholesky, QR, SVD, Schur, generalized Schur) are also provided, as are related computations such as reordering of the Schur factorizations and estimating condition numbers. Dense and banded matrices are handled, but not general sparse matrices. In all areas, similar functionality is provided for real and complex matrices, in both single and double precision.

- Homepage: http://www.netlib.org/lapack/
- Users' Guide: http://www.netlib.org/lapack/#*users*guide
- Routines: http://www.netlib.org/lapack/individualroutines.html
- Examples: http://www.physics.orst.edu/~rubin/nacphy/lapack/fortran.html
- Installation for Windows: http://icl.cs.utk.edu/lapack-for-windows/lapack/

**Note:** Check the *Note* information in BLAS section.

- Examples: Solving $Ax = B$
- Source location: `gfortran/LapackStandalone/linear_equ.f`
- Usage: Copy the downloaded `libblas.dll` and `liblapack.dll` to the `R_Fortran/05_Lapack/LapackStandalone` folder. In the CMD command line input `make` or directly input `gfortran linear_equ.f -L. -llapack -o linear_equ.exe` in the command line. The `-L. -llapack` option means link the `liblapack.dll` file in the current directory to the program. `liblapack.dll` depends on `libblas.dll`, so `libblas.dll` is also necessary.
- Reference: `SGESV`: http://www.netlib.org/lapack/single/sgesv.f

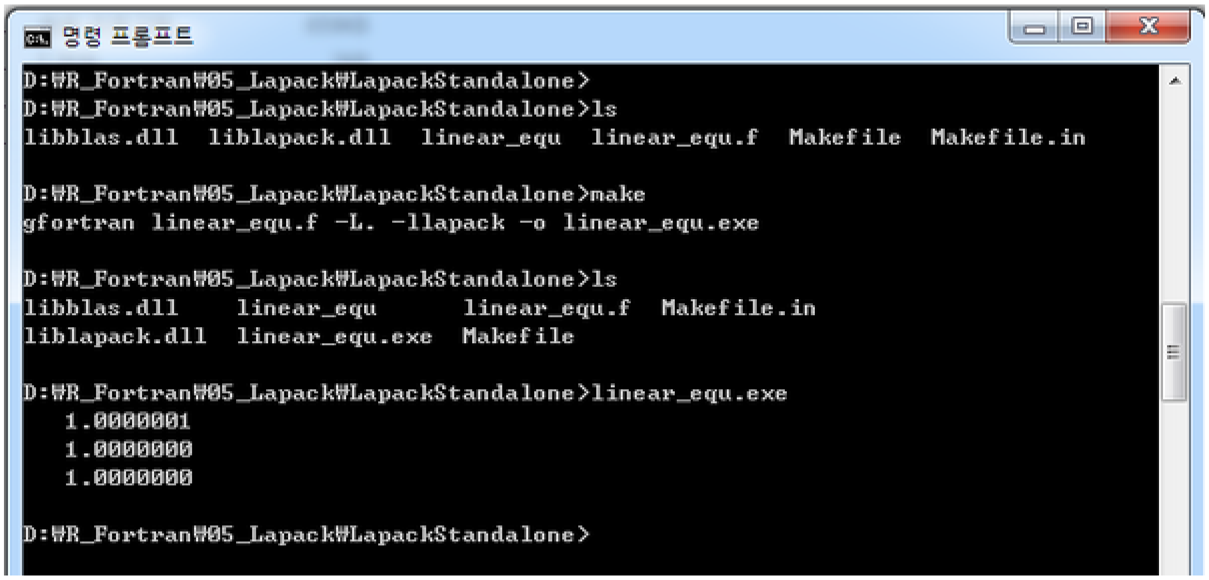
```
c     linear_equ.f
c     Example of solving linear equations
c     solving the matrix equation A*x=b using LAPACK
c     From: http://www.physics.orst.edu/~rubin/nacphy/lapack/codes/linear-f.html
      Program LinearEquations
      Implicit none
c     declarations, notice single precision
      Real*4 A(3,3), b(3)
      integer i, j, pivot(3), ok
c     define matrix A
      data A/3.1, 1.0, 3.4, 1.3, -6.9, 7.2, -5.7, 5.8, -8.8/
c     define vector b, make b a matrix and you can solve multiple
c     equations with the same A but different b
      data b/-1.3, -0.1, 1.8/
c     find the solution using the LAPACK routine SGESV
      call SGESV(3, 1, A, 3, pivot, b, 3, ok)
c     parameters in the order as they appear in the function call
c     order of matrix A, number of right hand sides (b), matrix A,
c     leading dimension of A, array that records pivoting,
c     result vector b on entry, x on exit, leading dimension of b
c     return value
c
c     print the vector x
      do i=1, 3
         write(*,*) b(i)
      end do
      end
```

## ATLAS (Automatically Tuned Linear Algebra Software)

ATLAS stands for Automatically Tuned Linear Algebra Software. ATLAS is both a research project and a software package. ATLAS's purpose is to provide portably optimal linear algebra software. The current version provides a complete BLAS API (for both C and Fortran77), and a very small subset of the LAPACK API. For all supported operations, ATLAS achieves performance on par with machine-specific tuned libraries.

- Homepage: http://math-atlas.sourceforge.net/
- Use ATLAS in R

1. Download the `Rblas.dll` file frome http://cran.r-project.org/bin/windows/contrib/ATLAS/
2. Replace the `Rblas.dll` file in the `R-x.x.x\bin\x32` directory.



```
D:₩R_Fortran₩05_Lapack₩LapackStandalone>
D:₩R_Fortran₩05_Lapack₩LapackStandalone>ls
libblas.dll  liblapack.dll  linear_equ  linear_equ.f  Makefile  Makefile.in

D:₩R_Fortran₩05_Lapack₩LapackStandalone>make
gfortran linear_equ.f -L. -llapack -o linear_equ.exe

D:₩R_Fortran₩05_Lapack₩LapackStandalone>ls
libblas.dll    linear_equ      linear_equ.f  Makefile.in
liblapack.dll  linear_equ.exe  Makefile

D:₩R_Fortran₩05_Lapack₩LapackStandalone>linear_equ.exe
   1.0000001
   1.0000000
   1.0000000

D:₩R_Fortran₩05_Lapack₩LapackStandalone>
```

Figure 8: LAPACK example

## R foreign language interfaces

**When to use?** When a task requires explicit loops that can't be vectorized away. If a task can be vectorized or has no more than one loop, using R only would be a better choice, since in such situation, converting R code to C or Fortran doesn't improve much implementation efficient.

**Tools?** In linux system, if R has been installed, the developing environment is already prepared. In MS Windows system, after installing R, you also need to install the `Rtools`.

### `Rtools`

> The standard toolchain for building R packages under Microsoft Windows, or for building R itself. It contains the command line tools, MinGW compilers, etc.

- Download: http://cran.r-project.org/bin/windows/Rtools/
- Install
- Add `path\to\Rtools\bin;path\to\Rtools\gcc-x.x.x\bin;` to the system `PATH` variable
- For more details, read the `Rtools.txt` and `README.txt` file in the main Rtools directory.

## R and Fortran Interface

### .Fortran interface

### General procedure

1. Writting Fortran subroutines, say `xxx(arg1, arg2)`, and saving it in the `foo.f` file.
2. Compling Fortran code to Dynamic Link Library or shared objects(`.dll`/`.so`) with `R CMD SHLIB foo.f` command.
3. In R, loading `foo.dll`/`foo.so` to R with `dyn.load('foo.dll')`
4. In R, calling subroutines defined in `foo.f` with `.Fortran` function: `.Fortran('xxx', arg1, arg2)`

### Notice

- The Fortran code to be called **MUST** be a subroutines.

- Lengths of the vectors passed to Fortran subroutine should be given.
- When invoking `.Fortran` function, argument types should be matched by explicit coersions with `as.integer` or `as.double` or by creating vectors of an explicit storage mode and length using the constructors `integer(n)` and `double(n)`.
- The return value from `.Fortran` is a list with the same number of components (and names, if given) as the argument list.

### Comparison of R and Fortran data types

| R storage mode | FORTRAN type |
|---|---|
| logical | INTEGER |
| integer | INTEGER |
| double | DOUBLE PRECISION |
| complex | DOUBLE COMPLEX |
| character | CHARACTER*255 raw unsigned \| none |

**Example1: convolve** This is the canonical example introduced in Writting R Extensions.

The convolution of two sequences $x_1, ..., x_n$ and $y_1, ...y_m$ is defined as: $z_k = \sum_{i+j=k} x_i y_j$

**The Fortran part**

```
c A subroutine to convole two finite sequences
      subroutine convolvef(a, na, b, nb, ab)
      integer na, nb, nab, i, j
      double precision a(na), b(nb), ab(na+nb-1)
      nab = na + nb - 1

      do 10 i = 1, nab
         ab(i) = 0.0
 10   continue
      do 20 i = 1, na
         do 30 j = 1, nb
            ab(i+j-1) = ab(i+j) + a(i)*b(j)
 30      continue
 20   continue
      end
```

**The R part**

```
# Load Shared Objects (*.so) / Dynamic-Link Library (*.DLL)
# dyn.load('01_convolve/convolve.so') # Linux
# dyn.load('01_convolve/convolve.dll') # Windows
dyn.load(file.path("R_Fortran", "01_Convolve", paste0("convolve", .Platform$dynlib.ext)))  # Platform indepen
# Check whether Fortran subroutine `convolvef` is available
is.loaded("convolvef")
```

```
## [1] TRUE
```

```
x = 1:5
y = 6:10
```

```
#
.Fortran("convolvef", as.double(x), as.integer(length(x)), as.double(y), as.integer(length(y)),
    double(length(x) + length(y) - 1))
```

```
## [[1]]
## [1] 1 2 3 4 5
##
## [[2]]
## [1] 5
##
## [[3]]
## [1]  6  7  8  9 10
##
## [[4]]
## [1] 5
##
## [[5]]
## [1]   6  19  40  70 110 114 106  85  50
```

```
.Fortran("convolvef", as.double(x), as.integer(length(x)), as.double(y), as.integer(length(y)),
    xy = double(length(x) + length(y) - 1))$xy
```

```
## [1]   6  19  40  70 110 114 106  85  50
```

```
# R wrapper
conv_f <- function(x, y) {
    if (!(is.numeric(x) && is.numeric(y)))
        stop("x and y should be both numeric vector")
    .Fortran("convolvef", as.double(x), as.integer(length(x)), as.double(y),
        as.integer(length(y)), double(length(x) + length(y) - 1))
}

conv_f(1:5, 6:10)
```

```
## [[1]]
## [1] 1 2 3 4 5
##
## [[2]]
## [1] 5
##
## [[3]]
## [1]  6  7  8  9 10
##
## [[4]]
## [1] 5
##
## [[5]]
## [1]   6  19  40  70 110 114 106  85  50
```

```
conv_f(1:5, 6:7)
```

```
## [[1]]
## [1] 1 2 3 4 5
##
## [[2]]
## [1] 5
##
## [[3]]
## [1] 6 7
##
## [[4]]
## [1] 2
##
## [[5]]
## [1]  6 19 32 45 58 35
```

```
dyn.unload(file.path("R_Fortran", "01_Convolve", paste0("convolve", .Platform$dynlib.ext)))  # Platform indep
```

**Example2: swap & Reverse** We'll study more details about the `.Fortran` interface though this example.

**The Fortran part**

```
c     swap two integer number
      subroutine ISWAPF (a, b)
      integer a, b, tmp
      tmp = a
      a = b
      b = tmp
      end

c     swap two double number
      subroutine DSWAPF (a, b)
      double precision a, b, tmp
      tmp = a
      a = b
      b = tmp
      end

c     Subroutine Reverse:
c     reverses the order of the input array
      subroutine Reversef(a, n)
      integer n, i
      double precision a(n)
      do 10 i = 1, INT(n/2)
         call DSWAPF(a(i), a(n - i + 1))
 10   continue
      end
```

**The R part**

```
# ?.Fortran All Fortran compilers known to be usable to compile R map symbol
# names to lower case.  Symbol names containing underscores are not valid
# Fortran 77 (although they are valid in Fortran 9x). Portable code should
# not use Fortran names containing underscores.  `gfortran` transforms names
# of entities specified in the Fortran source file by appending underscores
# to them.
dyn.load(file.path("R_Fortran", "02_Swap", paste0("swap", .Platform$dynlib.ext)))
is.loaded("iswapf")
```

```
## [1] TRUE
```

```
x = 10
y = 20
# a and b are a copy of x and y, x and y doesn't change a and b are called
# by reference
.Fortran("iswapf", a = as.integer(x), b = as.integer(y))

## $a
## [1] 20
##
## $b
## [1] 10

x

## [1] 10

y

## [1] 20

# The arguments are not meaningful
.Fortran("iswapf", p = as.integer(x), q = as.integer(y))

## $p
## [1] 20
##
## $q
## [1] 10

# With 'DUP = FALSE', your compiled code can alter the local variable
# DEP=FALSE can speed up the program by avoiding pssing hudge matrix
# Oops..., didn't swap! Why?
.Fortran("iswapf", as.integer(x), as.integer(y), DUP = FALSE)

## [[1]]
## [1] 20
##
## [[2]]
## [1] 10

x

## [1] 10

y

## [1] 20

# Use `dswapf`. Wow!
.Fortran("dswapf", as.double(x), as.double(y), DUP = FALSE)
```

```
## [[1]]
## [1] 20
##
## [[2]]
## [1] 10
```

```
x
```

```
## [1] 20
```

```
y
```

```
## [1] 10
```

```
# Mhm...
is.double(x)
```

```
## [1] TRUE
```

```
x = as.integer(10)
y = as.integer(20)
.Fortran("iswapf", x, y, DUP = FALSE)
```

```
## [[1]]
## [1] 20
##
## [[2]]
## [1] 10
```

```
x
```

```
## [1] 20
```

```
y
```

```
## [1] 10
```

```
# Reverse a vector x, y are vectors of lenth n, exchange x[i] and y[i] if
# x[i] is bigger than y[i], i=1,...,n ivswapf subroutine invokes the iswapf
# subroutine Again, what's the problem here?
x = 1:10
if (is.loaded("reversef")) .Fortran("reversef", as.double(x), as.integer(length(x)),
    DUP = FALSE)
```

```
## [[1]]
##  [1] 10  9  8  7  6  5  4  3  2  1
##
## [[2]]
## [1] 10
```

```
# So, always be careful about the dat type
is.integer(x)
```

```
## [1] TRUE
```

```
x = as.double(1:10)
if (is.loaded("reversef")) .Fortran("reversef", x, as.integer(length(x)), DUP = FALSE)
```

```
## [[1]]
##  [1] 10  9  8  7  6  5  4  3  2  1
##
## [[2]]
## [1] 10
```

```
x
```

```
##  [1] 10  9  8  7  6  5  4  3  2  1
```

```
dyn.unload(file.path("R_Fortran", "02_Swap", paste0("swap", .Platform$dynlib.ext)))
```

**Concepts & Conclusions** - `symbol name` vs `transformed symbol name` - the arguments are a copy of the passed variables - the arguments are 'meaningless' - passing the R variables' real address via `DUP=FALSE` - do coerce the data type before passing to Fortran

**Example3: array** An example of using Fortran90 to calculate the summation and multiplication of matrix.

**Intrinsic functions in Fortran 90:** http://www.nsc.liu.se/~boein/f77to90/a5.html

**The Fortran part**

```
! subroutine of matrix summation with fortran90
subroutine arraysumf90(a, b, c, nrow, ncol)
  implicit none
  integer nrow, ncol, i, j
  double precision a(nrow, ncol), b(nrow, ncol), c(nrow, ncol)
  c = a + b
end subroutine arraysumf90

! subroutine of matrix inner product with fortran90
subroutine arraymulf90(a, b, c, nrow, ncol)
  implicit none
  integer nrow, ncol, i, j
  double precision a(nrow, ncol), b(nrow, ncol), c(nrow, ncol)
  c = matmul(a, b)
end subroutine arraymulf90
```

**The R part**

```
# Fortran90
x = y = z = matrix(1:9, 3)
dyn.load(file.path("R_Fortran", "03_Array", paste0("array90", .Platform$dynlib.ext)))
# matrix summation
is.loaded("arraysumf90")
```

```
## [1] TRUE
```

```
.Fortran("arraysumf90", as.double(x), as.double(y), as.double(z), as.integer(nrow(x)),
    as.integer(ncol(x)))[[3]]
```

```
## [1]  2  4  6  8 10 12 14 16 18
```

```
# matrix multiplication
is.loaded("arraymulf90")
```

```
## [1] TRUE
```

```
.Fortran("arraymulf90", as.double(x), as.double(y), as.double(z), as.integer(nrow(x)),
    as.integer(ncol(x)))[[3]]
```

```
## [1]  30  36  42  66  81  96 102 126 150
```

```
x %*% y
```

```
##      [,1] [,2] [,3]
## [1,]   30   66  102
## [2,]   36   81  126
## [3,]   42   96  150
```

```
dyn.unload(file.path("R_Fortran", "03_Array", paste0("array90", .Platform$dynlib.ext)))
```

**Example4: BLAS** **Working principle** R uses the BLAS and LAPACK libraries to do basic linear algebra calculations, and the BLAS and LAPACK is used via Dynamic Link Library. On Windows, these DLL files, named `Rblas.dll` and `Rlapack.dll`, maybe exist in the `bin` folder under R home directory, such as `R-x.xx/bin/x64`.

Fortran can use R's BLAS and Lapack library directly by linking to the DLLs, so you don't need to install BLAS and Lapack seperately on your system. To link your Fortran code to the DLLs, you need to use the `-lblas` and `-llapack` option whlie compiling your code to DLLs. Usually it would be convenient to write a `Makevars` file with the content:

```
PKG_LIBS = $(LAPACK_LIBS) $(BLAS_LIBS)
```

Then when you run the `R CMD SHLIB` command, R can link your code to BLAS and Lapack properly.

---

In this example, we'll make a fortran subroutine called `idamaxf` by using the IDAMAX function in BLAS library to calculate the first occurrence of the maximum absolute value of a double precision vector. Then compile it to DLL and invoke it in R.

**The Fortran part**

```
c     IDAMAX searches a double precision vector for the first occurrence
c     of the the maximum absolute value.
c     Arguments:
c       n: Number of elements to process in the vector to be searched.
c       x: Array of dimension (n-1) * |incx| + 1.
c       incx: Increment between elements of x.
      subroutine idamaxf(n, x, incx, y)
      integer n, incx, y, idamax
      double precision x(*)
      y = idamax(n, x, incx)
      return
      end
```

**The R part**

```
dyn.load(file.path("R_Fortran", "04_Blas", paste0("blas_idamax", .Platform$dynlib.ext)))
# Test
is.loaded("idamaxf")

## [1] TRUE

n = 10
# PROBLEM: when incx < 0, return value is always 0!
incx = 1
x = sample((n - 1) * abs(incx) + 1)
x

##  [1]  5  4 10  9  3  8  6  7  1  2

.Fortran("idamaxf", as.integer(n), as.double(x), as.integer(incx), as.integer(1))[[4]]

## [1] 3

# R wrapper
idamax <- function(x, n, by = 1) {
    if (length(x) < ((n - 1) * abs(by) + 1))
        stop("x is too short!")
    .Fortran("idamaxf", as.integer(n), as.double(x), as.integer(by), as.integer(1))[[4]]
}
(x = sample(10))

##  [1] 10  6  3  1  7  4  5  2  8  9

# which(x[1:5]==max(x[1:5]))
idamax(x, 5)

## [1] 1

# which(x[seq(1,10,2)]==max(x[seq(1,10,2)]))
idamax(x, 5, by = 2)

## [1] 1

dyn.unload(file.path("R_Fortran", "04_Blas", paste0("blas_idamax", .Platform$dynlib.ext)))
```

**Example5: LAPACK** **Working principle** is the same with BLAS introduced in previous section.

In this example, we'll make a subroutine called `Lineareq` to solve the equation $Ax = b$, where $A$ is a $nxn$ matrix and $b$ is a vector of length $n$, by using the `DGESV` subroutine in LAPACK library.

**The Fortran part**

```
c     Example of solving linear equations
c     From: http://www.physics.orst.edu/~rubin/nacphy/lapack/codes/linear-f.html
c     SUBROUTINE: DGESV( N, NRHS, A, LDA, IPIV, B, LDB, INFO )
c     http://www.netlib.org/lapack/single/sgesv.f
c     Solving the matrix equation A*x=b using LAPACK
      Subroutine Lineareq(A, b, n, info)
      Implicit none
      integer n, info
      integer ipiv(n)
      double precision A(n, n), b(n)
      call DGESV(n, 1, A, n, ipiv, b, n, info)
      end
```

**The R part**

```
# Solving the matrix equation A*x=b using LAPACK
dyn.load(file.path("R_Fortran", "05_Lapack", paste0("linear_equ", .Platform$dynlib.ext)))
is.loaded("lineareq")

## [1] TRUE

A = matrix(c(3.1, 1.3, -5.7, 1, -6.9, 5.8, 3.4, 7.2, -8.8), 3, byrow = TRUE)
b = c(-1.3, -0.1, 1.8)
solve(A) %*% b

##      [,1]
## [1,]    1
## [2,]    1
## [3,]    1

.Fortran("lineareq", A = as.double(A), b = as.double(b), n = as.integer(nrow(A)),
    info = as.integer(1))

## $A
## [1]  3.4000  0.2941  0.9118  7.2000 -9.0176  0.5838 -8.8000  8.3882 -2.5737
##
## $b
## [1] 1 1 1
##
## $n
## [1] 3
##
## $info
## [1] 0

# R wrapper
lineareq <- function(A, b) {
    if (!is.matrix(A))
        stop("A must be a matrix")
    if (nrow(A) != ncol(A))
        stop("A must be a symmetic matrix")
    if (nrow(A) != length(b))
        stop("The row number of matrix 'A' is different with the length of vector 'b'")
    res = .Fortran("lineareq", A = as.double(A), b = as.double(b), n = as.integer(nrow(A)),
        info = as.integer(1))
    if (res$info < 0)
        stop("Arguments error!") else if (res$info > 0)
        stop("Singular!") else res$b
}
lineareq(A, b)

## [1] 1 1 1

dyn.unload(file.path("R_Fortran", "05_Lapack", paste0("linear_equ", .Platform$dynlib.ext)))
```

**Example6: R API**

> There are a large number of entry points in the R executable/DLL that can be called from C code (and some that can be called from FORTRAN code)

Check Writting R Extension Chapter 6 for more information

**The Fortran part**

**normal distribution pdf (version 1)**

```
c     dnorm defined in R: dnorm(x, mean = 0, sd = 1, log = FALSE)
      subroutine dnormf(x, mean, sd, log, re)
      double precision x, mean, sd, re
      integer log
      call dnormwrap(x, mean, sd, log, re)
      return
      end
```

**The corresponding C wrapper**

```
#include <R.h>
#include <Rmath.h>
// DO NOT USE `dnorm` as the wrap function name.
void F77_SUB(dnormwrap)(double *x, double *mean, double *sd, int *log, double *re)
{
  *re = Rf_dnorm4(*x, *mean, *sd, *log);
}
```

---

**normal distribution pdf (version 2)**

```
c     dnorm defined in R: dnorm(x, mean = 0, sd = 1, log = FALSE)
      subroutine dnormf1(x, mean, sd, log, re)
      double precision x, mean, sd, re, dnormwrap
      integer log
      re = dnormwrap(x, mean, sd, log)
      return
      end
```

**The corresponding C wrapper**

```
#include <R.h>
#include <Rmath.h>
// DO NOT USE `dnorm` as the wrap function name, since it is a kind of key words
double F77_SUB(dnormwrap)(double *x, double *mean, double *sd, int *log)
 {
   return Rf_dnorm4(*x, *mean, *sd, *log);
 }
```

**The R part**

```
# fortran using R's dnorm function C wrapper version 1: void type, no return
# value
dyn.load(file.path("R_Fortran", "06_Rapi", "dnorm", paste0("dnorm", .Platform$dynlib.ext)))
is.loaded("dnormf")
```

```
## [1] TRUE
```

```
.Fortran("dnormf", as.double(0), as.double(0), as.double(1), as.integer(0),
    as.double(0))[[5]]
```

```
## [1] 0.3989
```

```
dyn.unload(file.path("R_Fortran", "06_Rapi", "dnorm", paste0("dnorm", .Platform$dynlib.ext)))

# C wrapper version 2: double type, has return value
dyn.load(file.path("R_Fortran", "06_Rapi", "dnorm", paste0("dnorm1", .Platform$dynlib.ext)))
is.loaded("dnormf1")
```

```
## [1] TRUE
```

```
.Fortran("dnormf1", as.double(0), as.double(0), as.double(1), as.integer(0),
    as.double(0))[[5]]
```

```
## [1] 0.3989
```

```
dyn.unload(file.path("R_Fortran", "06_Rapi", "dnorm", paste0("dnorm1", .Platform$dynlib.ext)))
```

---

**The Fortran part**

**random number generation**

```
c A subroutine generating normal & uniform random numbers
      subroutine nurnd(x, y)
      real*8 normrnd, unifrnd, x, y

      call rndstart()
      x = normrnd()
      y = unifrnd()
      call rndend()

      return
      end
```

**The corresponding C wrapper**

```
#include <R.h>
#include <Rmath.h>

void F77_SUB(rndstart)(void) { GetRNGstate(); }
void F77_SUB(rndend)(void) { PutRNGstate(); }
double F77_SUB(normrnd)(void) { return rnorm(0, 1); }
double F77_SUB(unifrnd)(void) { return runif(0, 1); }
```

**The R part**

```
# fortran using R's random number generation
dyn.load(file.path("R_Fortran", "06_Rapi", "random_number", paste0("random",
    .Platform$dynlib.ext)))
is.loaded("nurnd")
```

```
## [1] TRUE
```

```
.Fortran("nurnd", as.double(1), as.double(1))
```

```
## [[1]]
## [1] 1.546
##
## [[2]]
## [1] 0.09605
```

```
dyn.unload(file.path("R_Fortran", "06_Rapi", "random_number", paste0("random",
    .Platform$dynlib.ext)))
```

## R and C Interface

**Why?** - R itself is mainly written in C, consequently, C extensions fit perfectly with R. - C is standardized, portable, and has good-quality free compilers on effectively all platforms.

There are two interfaces for C, `.C` and `.Call`

### .C interface

#### General procedure

1. Writting `void` type C functions, say `xxx(arg1, arg2)`, and saving it in the `foo.c` file.
2. Compling C code to Dynamic Link Library or shared objects(`.dll`/`.so`) with `R CMD SHLIB foo.c` command.
3. In R, loading `foo.dll`/`foo.so` to R with `dyn.load('foo.dll')`
4. In R, calling subroutines defined in `foo.c` with `.C` function: `.C('xxx', arg1, arg2)`

#### Notice

- The C function should be `void` type and all values should be returned via arguments.
- All arguments should be passed as pointers, since all R data types are vectors.
- Lengths of the vectors passed to C function should be given.
- When invoking `.C` function, argument types should be matched by explicit coersions with `as.integer` or `as.double` or by creating vectors of an explicit storage mode and length using the constructors `integer(n)` and `double(n)`.
- The return value from `.C` is a list with the same number of components (and names, if given) as the argument list.

#### Comparison of R and C data types

| R storage mode | C type |
|---|---|
| logical<br>integer | int * |
| double<br>complex | double * |

#### Example1: convolve  The C part

```
void convolveC(double *a, int *na, double *b, int *nb, double *ab)
{
  int i, j, nab = *na + *nb - 1;
  for(i = 0; i < nab; i++)
    ab[i] = 0.0;
  for( i = 0; i < *na; i++)
    for(j = 0; j < *nb; j++)
      ab[i + j] += a[i]*b[j];
}
```

### The R part

```
dyn.load(file.path("R_C", "01_convolve", paste0("convolveC", .Platform$dynlib.ext)))
is.loaded("convolveC")
```

```
## [1] TRUE
```

```
x = 1:5
y = 6:10
.C("convolveC", as.double(x), as.integer(length(x)), as.double(y), as.integer(length(y)),
    double(length(x) + length(y) - 1))
```

```
## [[1]]
## [1] 1 2 3 4 5
##
## [[2]]
## [1] 5
##
## [[3]]
## [1]  6  7  8  9 10
##
## [[4]]
## [1] 5
##
## [[5]]
## [1]   6  19  40  70 110 114 106  85  50
```

```
# R wrapper
conv_C <- function(x, y) {
    if (!(is.numeric(x) && is.numeric(y)))
        stop("x and y should be both numeric vector")
    .C("convolveC", as.double(x), as.integer(length(x)), as.double(y), as.integer(length(y)),
        double(length(x) + length(y) - 1))[[5]]
}
conv_C(1:5, 6:10)
```

```
## [1]   6  19  40  70 110 114 106  85  50
```

```
conv_C(1:5, 6:7)
```

```
## [1]  6 19 32 45 58 35
```

```
dyn.unload(file.path("R_C", "01_convolve", paste0("convolveC", .Platform$dynlib.ext)))
```

### .Call

**Features** - Passing R objects to C - Creating R objects in C - Manipulating R objects in C - Returning R objects from C

**syntax** SEXP FunctionName(SEXP arg1, SEXP arg2, . . . ) - SEXP standing for S expression, is a pointer to a C struct. - The returned value from C is also a SEXP type. - If new SEXP objects are created within the C function, they should be protected with `PROTECT` to keep them from being cleaned by R as garbage. - Header file "Rinternals.h" should be included.

**Example1: convolve** **The C part**

```
#include <Rinternals.h>

SEXP convolveCall(SEXP a, SEXP b)
{
    int na, nb, nab;
    double *xa, *xb, *xab;
    SEXP ab;

    a = PROTECT(coerceVector(a, REALSXP));
    b = PROTECT(coerceVector(b, REALSXP));
    na = length(a); nb = length(b); nab = na + nb - 1;
    ab = PROTECT(allocVector(REALSXP, nab));
    xa = REAL(a); xb = REAL(b); xab = REAL(ab);
    for(int i = 0; i < nab; i++) xab[i] = 0.0;
    for(int i = 0; i < na; i++)
        for(int j = 0; j < nb; j++) xab[i + j] += xa[i] * xb[j];
    UNPROTECT(3);
    return ab;
}
```

**The R part**

```
dyn.load(file.path("R_C", "01_convolve", paste0("convolveCall", .Platform$dynlib.ext)))
is.loaded("convolveCall")
```

```
## [1] TRUE
```

```
x = 1:5
y = 6:10
.Call("convolveCall", x, y)
```

```
## [1]   6  19  40  70 110 114 106  85  50
```

```
dyn.unload(file.path("R_C", "01_convolve", paste0("convolveCall", .Platform$dynlib.ext)))
```

## Speed comparison

We use the `convolve` example to compare the speed of all the R interfaces.

```
## Compare the speed of C and Fortran interfaces with R
dyn.load(file.path("R_Fortran", "01_convolve", paste0("convolve", .Platform$dynlib.ext)))  # Platform indepen
dyn.load(file.path("R_C", "01_convolve", paste0("convolveC", .Platform$dynlib.ext)))
dyn.load(file.path("R_C", "01_convolve", paste0("convolveCall", .Platform$dynlib.ext)))

convolveR <- function(x, y) {
    nx <- length(x)
    ny <- length(y)
    z <- double(nx + ny - 1)
    for (i in 1:nx) for (j in 1:ny) z[i + j - 1] = z[i + j - 1] + x[i] * y[j]
    z
}

convolveF <- function(x, nx, y, ny) {
    .Fortran("convolvef", as.double(x), as.integer(nx), as.double(y), as.integer(ny),
        double(nx + ny - 1))
}

convolveC <- function(x, nx, y, ny) {
    .C("convolveC", as.double(x), as.integer(nx), as.double(y), as.integer(ny),
        double(nx + ny - 1))
}

convolveCall <- function(x, y) {
    .Call("convolveCall", x, y)
}

library(rbenchmark)
set.seed(1204)
x = rnorm(1000)
y = rnorm(1000)
nx = length(x)
ny = length(y)
benchmark(convolveF = convolveF(x, nx, y, ny), convolveC = convolveC(x, nx,
    y, ny), convolveCall = convolveCall(x, y), replications = 1000, columns = c("test",
    "replications", "elapsed", "relative"))
```

```
##           test replications elapsed relative
## 2    convolveC         1000    1.00    1.471
## 3 convolveCall         1000    1.00    1.471
## 1    convolveF         1000    0.68    1.000
```

```
system.time(convolveR(x, y))
```

```
##    user  system elapsed
##    4.05    0.00    4.06
```

```
dyn.unload(file.path("R_Fortran", "01_convolve", paste0("convolve", .Platform$dynlib.ext)))  # Platform indep
dyn.unload(file.path("R_C", "01_convolve", paste0("convolveC", .Platform$dynlib.ext)))
dyn.unload(file.path("R_C", "01_convolve", paste0("convolveCall", .Platform$dynlib.ext)))
```

## R and C++ Interface

### Rcpp

Selected Sources: - Rcpp Homepage: http://www.rcpp.org/ - Rcpp: Seamless R and C++ Integration: http://www.jstatsoft.org/v40/i0
- Rcpp vignettes included in the package: `library/Rcpp/doc/` - Hadley's guide to high performance R with Rcpp: http://adv-r.had.co.nz/Rcpp.html - Rcpp Tutorial Part I, II: Introduction: http://dirk.eddelbuettel.com/papers/rcpp_workshop_intro
- Rcpp Tutorial Part III, IV: Advanced Rcpp: http://dirk.eddelbuettel.com/papers/rcpp_workshop_advanced_user2012.pdf

### Fibonacci example

```
## basic R function
fibR <- function(n) {
    if (n == 0)
```

```
        return(0)
    if (n == 1)
        return(1)
    return(fibR(n - 1) + fibR(n - 2))
}

library(Rcpp)
library(inline)
## we need a pure C/C++ function here
incltxt <- "\nint fibonacci(const int x) {\n  if (x == 0) return(0);\n  if (x == 1) return(1);\n  return (fib
## Rcpp version of Fibonacci
fibRcpp <- cxxfunction(signature(xs = "int"), plugin = "Rcpp", incl = incltxt,
    body = "\n                       int x = Rcpp::as<int>(xs);\n                       return Rcpp::wrap( fi
```

```
## cygwin warning:
##   MS-DOS style path detected: D:/PROGRA~1/R-30~1.2/etc/x64/Makeconf
##   Preferred POSIX equivalent is: /cygdrive/d/PROGRA~1/R-30~1.2/etc/x64/Makeconf
##   CYGWIN environment variable option "nodosfilewarning" turns off this warning.
##   Consult the user's guide for more details about POSIX paths:
##     http://cygwin.com/cygwin-ug-net/using.html#using-pathnames
```

```
library(rbenchmark)
N = 20
res <- benchmark(fibR(N), fibRcpp(N), columns = c("test", "replications", "elapsed",
    "relative", "user.self", "sys.self"), order = "relative", replications = 100)
res
```

```
##         test replications elapsed relative user.self sys.self
## 1    fibR(N)          100    6.04       NA      6.03        0
## 2 fibRcpp(N)          100    0.00       NA      0.00        0
```

### RcppArmadillo

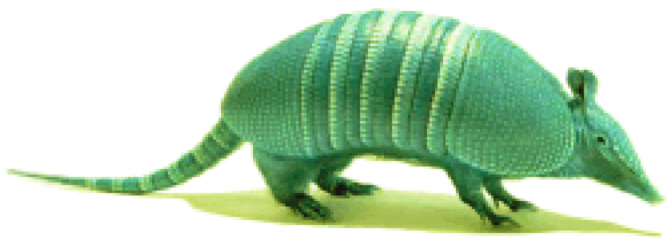


Figure 9: armadillo_logo

### Armadillo

> Armadillo is a C++ linear algebra library (matrix maths) aiming towards a good balance between speed and ease of use.

API: http://arma.sourceforge.net/docs.html

# Building R packages

## Tools for Windows

#### `Rtools`

See the `R foreign language interfaces/Rtools` section for details.

#### `MiKTex` (optional)

> A LaTeX and pdftex package used to build .pdf forms of documentation.

- Download: http://miktex.org/download
- The PATH is automatically set during the installation. Use `pdflatex --version` in the command line to test whether MiKTeX is installed successfully.

## R package structure

The simplest package structure is:

```
pkg (the package name)
|
|--DESCRIPTION (contains basic information about the package)
|--NAMESPACE (controls which variables to export, import, etc.)
|--R (R source files)
   |--function1.R
   |--function2.R
   |--...
|--man (help documents)
   |--function1.Rd
   |--function2.Rd
   |--...
|--...
```

Optional subdirectories are `data`, `demo`, `exec`, `inst`, `po`, `src`, `tests`, `tools` and `vignettes`.

For more information, read **1.1 Package structure** of the Writting R extensions

## Example

In the traditional way of making package, you need to write R functions (say `myfun`) first and then add the correponding help files (`myfun.Rd`) to the `man` directory. However, it is an error-prone process. Here I'll introduce a more advanced process using `Roxygen2` package.

As an example, we'll make a package called `MyPkg` here.

1. Make a folder called `Mypkg`
2. Make a file called `DESCRIPTION`, with the following content:

   Package: MyPkg Type: Package Title: A package demo Version: 1.0 Date: 2013-12-06 Author: Weicheng Zhu Maintainer: Weicheng weicheng@dreamhunter.me Description: More about what it does (maybe more than one line) License: GPL
3. Make a folder named `R` under `Mypkg`
4. Make a file named `myFun.R` under `Mypkg`

5. Add the `convolvR` function to `myFun.R`:

```
##' A description of this function
##'
##' Details about this function
##' @title Convolution of two vector
##' @param x numeric vector
##' @param y numeric vector
##' @return numeric vector of length (nx+ny-1)
##' @author weicheng
##' @export
convolveR <- function(x, y) {
    nx <- length(x)
    ny <- length(y)
    z <- double(nx + ny - 1)
    for (i in 1:nx) for (j in 1:ny) z[i + j - 1] = z[i + j - 1] + x[i] * y[j]
    z
}
```

Now, your directory structure would be like this:

```
MyPkg
  |--DESCRIPTION
  |--R
     |--myFun.R
```

6. Run `R` and set the working direcotry to the parent direcotry of `MyPkg`, then run the following command:

```
library(roxygen2)
roxygenize("MyPkg")
```

After running this commands, the directory structure of the `MyPkg` would be like this:

```
MyPkg
  |--DESCRIPTION
  |--man
      |--convolveR.Rd
  |--NAMESPACE
  |--R
     |--myFun.R
```

7. In the system command line, go the parent directory of `MyPkg` and run `R CMD build MyPkg`, then a file named `MyPkg_1.0.tar.gz` will be made. Then run `R CMD check MyPkg_1.0.tar.gz`, if no error occurs this R package is made successfully and can be installed with the command `R CMD INSTALL MyPkg_1.0.tar.gz`.
8. Test `MyPkg` in R:

```
library(MyPkg)
help(package = "MyPkg")
convolveR(1:5, 1:5)
```

## Building R package using Rcpp and RcppArmadillo

Rcpp and RcppArmadillo both provide a package skeleton function, which makes building R packages more easier.

```
library(Rcpp)
Rcpp.package.skeleton()

library(RcppArmadillo)
RcppArmadillo.package.skeleton
```