Calling C from R

Stat 580: Statistical Computing

- Theme: Black - White
- Printable version

References

- "Advanced R", by Hadley Wickham.
- "Writing R Extensions", by R Core Team.

R's C interface

- `.C()`, `.Call()` `.External()` (support variable number of arguments)
- `.Call()` allows
  - inputing R objects to C
  - creation of R objects in C
  - manipulation of R objects in C
  - usage of R functions in C
  - returning R objects
- variables are passed by reference by `.Call()`
- "Writing R Extensions" is a good reference of `.Call()`

R's C interface

- Some setup required:
  - Windows: Rtools
  - Mac: Xcode command line tools
  - (Most) Linux distributions: usually comes with the required compilers

Hello world (again?!)

- C code:

```c
/* Rhello.c */

#include <R.h>

#include <Rinternals.h>
/* alternative: Rdefines.h, which includes Rinternals */

SEXP sayhello(){
  Rprintf("Hello world\n");
  return R_NilValue;
}
```

- in command line:

```
R CMD SHLIB Rhello.c
```

  - you will get a shared object (.so) (.dll in Windows)

Hello world (again?!)

- in R: (change to the right directory)

```
dyn.load("Rhello.so")
out <- .Call("sayhello")
```

- we usually write a wrapper function for ease of calling:

```
hello <- function(){
.Call("sayhello")
}
```

Hello world (again?!)

```
/* Rhello.c */

#include <R.h>

#include <Rinternals.h>
/* alternative: Rdefines.h, which includes Rinternals */

SEXP sayhello(){
  Rprintf("Hello world\n");
  return R_NilValue;
}
```

- commonly used header files: R.h, Rinternals.h, Rdefines.h, Rmath.h
    - check here
- function input and output are both of type `SEXP`
    - `SEXP` standards for S Expression
    - `SEXP` is actually a pointer to `SEXPREC`
    - this can be treated as the R object in C

Hello world (again?!)

```c
/* Rhello.c */

#include <R.h>

#include <Rinternals.h>
/* alternative: Rdefines.h, which includes Rinternals */

SEXP sayhello(){
  Rprintf("Hello world\n");
  return R_NilValue;
}
```

- `Rprintf()` is defined in `R_ext/Print.h` which is included in `R.h`
  - customized `printf()` for R output
- `R_NilValue` is the `NULL` in R
  - `R_NilValue` is of type `NILSXP`, a subtype of `SEXP`

`SEXP`

In C, R objects are stored in a common data type, `SEXP`:

- `SEXP` is a variant type, with subtypes for all R's data structures
    - `REALSXP`: numeric vector
    - `INTSXP`: integer vector
    - `LGLSXP`: logical vector
    - `STRSXP`: character vector
    - `VECSXP`: list
    - `CLOSXP`: function (closure)
    - `ENVSXP`: environment
    - more

Example

```c
/* vecprod.c */
#include <R.h>
#include <Rinternals.h>

SEXP vecprod(SEXP Rx){
  double *x, temp=1;
  int i, n;

  x = REAL(Rx);
  n = length(Rx);

  for (i=0; i<n; i++){
    temp *= x[i];
  }

  Rprintf("The product is %f.\n", temp);
  return R_NilValue;
}
```

Example

Compile with `R CMD SHLIB`. In R, we write

```
dyn.load("vecprod.so")
.Call("vecprod", as.double(1:3))
```

- Why not `.Call("vecprod", 1:3)`?
    - wrapper function:

      ```
      vecsum <- function(x) .Call("vecprod", as.double(x))
      ```

    - To coerce objects at the C level, use `PROTECT(coerceVector(old, SEXPTYPE))`. (we will talk about `PROTECT()` later.)

Another example

```
x = REAL(Rx);
n = length(Rx);
```

- `REAL()` returns a pointer to the C array inside numeric vector `Rx` (R object)
  - if `Rx` is a vector, you can use `REAL(Rx)[1]` to refer to the second element of `Rx`.
  - other similar (commonly used) functions: `CHAR()`, `INTEGER()`, `LOGICAL()`
- `length()` returns the length of a vector

Garbage collection

- the memory allocated for R objects is not freed by the user
- the memory is freed from time to time by a process called garbage collection
- If you create R object (to be precise, `SEXPREC`) in C, you must tell R that the object is in use
    - otherwise R will destroy it during garbage collection
    - you can use the PROTECT macro (on the pointer `SEXP`) to achieve this
- you don't have to protect/unprotect R objects passed from R

`PROTECT()`

- note that it is the object (`SEXPREC`) is protected, not the pointer `SEXP`
    - if you invoke `PROTECT(p)`, it is the object that `p` is pointing to at this time get protected
    - if you change where `p` is pointing to later, this new object may not be protected
- the programmer is responsible for un-protecting the protected object by `UNPROTECT(n)`:
    - it unprotects the last `n` objects which were protected.

Example

```c
/* vecprod2.c */
#include <R.h>
#include <Rinternals.h>

SEXP vecprod(SEXP Rx){
  double *x, temp=1;
  int i, n;
  SEXP Rout = PROTECT(allocVector(REALSXP, 1));

  x = REAL(Rx);
  n = length(Rx);
  for (i=0; i<n; i++){
    temp *= x[i];
  }
  REAL(Rout)[0] = temp;
  UNPROTECT(1);
  return Rout;
}
```

- `allocVector(REALSXP, n)` creates an SEXP object corresponding to a numeric vector of length `n`
  - replace `REALSXP` by `INTSXP`, `VECSXP` to create integer vector and list

Lists

- accessing vector data: `REAL()`, `INTEGER()`, ... (use them to get a pointer; work as if dealing with a C array)
- for lists, each element is `SEXP`
- `allocVector(VECSXP, n)`: allocate a list of length `n`
- `SET_VECTOR_ELT(x, i, value)`: set the `i`-th (C indexing) of `x` to `value`
- `VECTOR_ELT(x, i)`: access the value of the `i`-th (C indexing) of `x`

Lists

```
double xsum=0, xmean, *x;
int n, i;
SEXP Rout;

/* codes for computation */

Rout = PROTECT(allocVector(VECSXP, 2));
SET_VECTOR_ELT(Rout, 0, ScalarReal(xsum));
SET_VECTOR_ELT(Rout, 1, ScalarReal(xmean));

UNPROTECT(1);
return Rout;
```

Useful functions for coercing scalars

- `asLogical(x)`: `LGLSXP` to `int`
- `asInteger(x)`: `INTSXP` to `int`
- `asReal(x)`: `REALSXP` to `double`
- `CHAR(asChar(x))`: `STRSXP` to `const char*`

- `ScalarLogical(x)`: `int` to `LGLSXP`
- `ScalarInteger(x)`: `int` to `INTSXP`
- `ScalarReal(x)`: `double` to `REALSXP`
- `mkString(x)`: `const char*` to `STRSXP`

Example

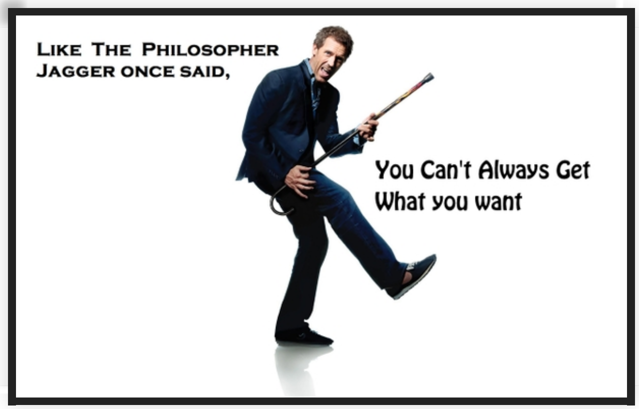
```c
#include <R.h>
#include <Rinternals.h>

SEXP myrowsum(SEXP Rmat){
  double *mat, *out;
  int n, m, i, j;
  SEXP Rout;

  /* alternative:
  n = INTEGER(getAttrib(Rmat, R_DimSymbol))[0];
  m = INTEGER(getAttrib(Rmat, R_DimSymbol))[1];
  */
  n = nrows(Rmat);
  m = ncols(Rmat);
  mat = REAL(Rmat);
  Rout = PROTECT(allocVector(REALSXP, n));
  out = REAL(Rout);
  for (i=0; i<n; i++){
    out[i] = 0;
    for (j=0; j<m; j++){
      out[i] += mat[i + n * j];
    }
  }
  UNPROTECT(1);
  return Rout;
}
```

Example

```
y <- matrix(rnorm(100), nr=10)
microbenchmark(.Call("myrowsum", y), apply(y, 1, sum), rowSums(y))
```


Like The Philosopher Jagger once said,
You Can't Always Get What you want

- "But if you try sometimes, well you might find... You get what you need!"

```
y <- matrix(rnorm(100000), nr=1000)
microbenchmark(.Call("myrowsum", y), apply(y, 1, sum), rowSums(y))
```

Picture credit: www.quotesaga.com

Example

```c
#include <R.h>
#include <Rinternals.h>

SEXP myasvec(SEXP x){
  SEXP y;
  y = PROTECT(duplicate(x));
  setAttrib(y, R_DimSymbol, ScalarReal(length(y)));
  UNPROTECT(1);
  return y;
}
```

```c
#include <R.h>
#include <Rinternals.h>

SEXP myasvec(SEXP x){
  setAttrib(x, R_DimSymbol, ScalarReal(length(x)));
  return R_NilValue;
}
```

Randomness

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

SEXP myrnorm(SEXP Rn){

  int i, n = asInteger(Rn);
  SEXP Rout = PROTECT(allocVector(REALSXP, n));
  double * out = REAL(Rout);

  GetRNGstate();

  for (i=0; i<n; i++){
    out[i] = norm_rand();
  }

  PutRNGstate();

  UNPROTECT(1);
  return Rout;
}
```

- use `GETRNGstate()` and `PutRNGstate()` to get/return the R RNG state from/to R.

Randomness

```
set.seed(1234)
.Call("myrnorm", 10)

set.seed(1234)
rnorm(10)
```

LAPACK

```
/* vecprod.c */
#include <R.h>
#include <Rinternals.h>
#include <R_ext/Lapack.h>

SEXP mysolve(SEXP RA, SEXP RB){
  double *A, *B, *A1, *B1;
  int i, j, n1, n2, info;
  SEXP Ripiv, Rout;

  A = REAL(RA);
  B = REAL(RB);
  n1 = nrows(RA);
  n2 = ncols(RB);


  Ripiv = PROTECT(allocVector(INTSXP, n1));
  Rout = PROTECT(allocMatrix(REALSXP, n1, n2));
  A1 = (double*)malloc(sizeof(double)*(n1*n1));
  B1 = REAL(Rout);
```

LAPACK

```
  for (i=0; i<(n1*n1); i++)
    A1[i] = A[i];

  for (i=0; i<(n1*n2); i++)
    B1[i] = B[i];

  dgesv_(&n1, &n2, A1, &n1, INTEGER(Ripiv), B1, &n1, &info);

  UNPROTECT(2);
  free(A1);
  return Rout;
}
```