

Intro to Rcpp: Connecting C++ to R

Kevin Lee

Department of Statistics
Western Michigan University

January 25, 2019

- 1 List of Useful R Packages
- 2 Introduction to Rcpp

List of Useful R Packages

Some of the top most downloaded R packages:

- Check <https://support.rstudio.com/hc/en-us/articles/201057987-Quick-list-of-useful-R-packages>.

- 1 List of Useful R Packages
- 2 Introduction to Rcpp

What is Rcpp?

- Sometimes R code is just not fast enough.
- We will talk about how to improve performance by rewriting key functions in C++.
- Rcpp package is a fantastic tool written by Dirk Eddelbuettel and Romain Francois.
- Rcpp makes it very simple to connect C++ to R.

Why C++?

Typical bottlenecks that C++ can address include:

- Loops that can't be easily vectorized because subsequent iterations depend on previous ones.
- Recursive functions, or problems which involve calling functions many times.

How to Install Rcpp?

Install the latest version of Rcpp from CRAN

- `install.packages("Rcpp")`

You also need a working C++ compiler. To get it:

- On Windows, install Rtools.
- On Mac, install Xcode from the app store.
- On Linux, `sudo apt-get install r-base-dev` or similar.

Key Motivation: Speed (Iteration)

Two different ways to compute $\frac{1}{1+x}$:

```
f <- function(n, x) for(i in 1:n) x <- 1/(1+x)
```

```
g <- function(n, x) for(i in 1:n) x <- (1+x)^(-1)
```

Check computing time with rbenchmark package:

```
library(rbenchmark)
```

```
N <- 10000
```

```
benchmark(f(N,1), g(N,1), order="relative")[,1:4]
```


Key Motivation: Speed (Iteration)

Rcpp to compute $\frac{1}{1+x}$:

```
cppFunction("double fcpp(int n, double x){  
  for (int i=0; i<n; i++){  
    x = 1/(1+x);  
  }  
  return x;  
}")
```

Check computing time:

```
benchmark(f(N,1), g(N,1), fcpp(N,1), order="relative")[,1:4]
```

Key Motivation: Speed (Cumulative Sum)

R function to perform a cumulative sum on a vector:

```
cumsumR <- function(x){  
  for (i in 2:length(x)){  
    x[i] <- x[i-1] + x[i]  
  }  
  return(x)  
}
```

```
cumsumR(1:10)
```

```
cumsum(1:10)
```

Key Motivation: Speed (Cumulative Sum)

Rcpp function to perform a cumulative sum on a vector:

```
cppFunction("NumericVector cumsumRcpp(NumericVector x){  
  for (int i=1; i<x.length(); i++){  
    x[i] = x[i-1] + x[i];  
  }  
  return x;  
}")
```

```
cumsumRcpp(1:10)
```

Check computing time:

```
x <- c(1:10000)  
benchmark(cumsumR(x), cumsumRcpp(x), order="relative")[,1:4]
```

Key Motivation: Speed (Bootstrap)

R function to perform the bootstrap:

```
bootR <- function(x, B){  
  bootStatistic <- matrix(0, nrow = B, ncol = 2)  
  n <- length(x)  
  for(i in 1:B){  
    bootSample <- x[sample(1:n, size = n, replace = TRUE)]  
    bootStatistic[i, 1] <- mean(bootSample)  
    bootStatistic[i, 2] <- sd(bootSample)  
  }  
  return(bootStatistic)  
}
```

```
set.seed(125)  
dat <- rnorm(1000, mean = 21, sd = 10)  
resultR <- bootR(dat, 1000)  
  
sd(resultR[,1])
```

Key Motivation: Speed (Bootstrap)

Rcpp function to perform the bootstrap:

```
cppFunction("NumericMatrix bootRcpp(NumericVector x, int B){  
  NumericMatrix bootStatistic(B, 2);  
  int n = x.length();  
  for (int i=0; i<B; i++){  
    NumericVector bootSample = x[floor(runif(n, 0, n))];  
    bootStatistic(i, 0) = mean(bootSample);  
    bootStatistic(i, 1) = sd(bootSample);  
  }  
  return bootStatistic;  
}")
```

```
set.seed(125)  
resultRcpp <- bootRcpp(dat, 1000)  
all.equal(resultR, resultRcpp)
```

Key Motivation: Speed (Bootstrap)

Check computing time:

```
benchmark(bootR(dat, 1000), bootRcpp(dat, 1000),  
order="relative")[,1:4]
```

Getting Started with C++

`cppFunction()` allows you to write C++ functions in R:

```
cppFunction("int add(int x, int y, int z){  
  int sum = x + y + z;  
  return sum;  
}")  
  
add(1, 2, 3)
```

When you run the above code, Rcpp will compile the C++ code and construct an R function that connects to the compiled C++ function.

Example 1

R function:

```
one <- function(){  
  1  
}
```

Rcpp function:

```
cppFunction("int one(){  
  return 1;  
}")
```


Example 1

This function illustrates important differences between R and C++:

- The syntax to create a function looks like the syntax to call a function.
- We declare the type of output the function returns. This function returns a scalar integer.
- The scalar equivalents of numeric, integer, character, and logical vectors are: `double`, `int`, `String`, and `bool`.
- The vector equivalents are: `NumericVector`, `IntegerVector`, `CharacterVector`, and `LogicalVector`.
- We must use an explicit return statement to return a value from a function.
- Every statement is terminated by a `;`.

Example 2

R function:

```
signR <- function(x){  
  if(x > 0){  
    1  
  } else if (x == 0){  
    0  
  } else{  
    -1  
  }  
}
```

Rcpp function:

```
cppFunction("int signC(int x){  
  if(x > 0){  
    return 1;  
  } else if (x == 0){  
    return 0;  
  } else{  
    return -1;  
  }  
}")
```

Example 2

This function illustrates difference between R and C++:

- We declare the type of each input in the same way we declare the type of the output.

This function also illustrates similarity between R and C++:

- The `if` statement works the same way as R's.
- A `while` statement also works the same way as R's.

Example 3

R function:

```
sumR <- function(x){
  n <- length(x)
  total <- 0
  for(i in 1:n){
    total <- total + x[i]
  }
  total
}
```

Rcpp function:

```
cppFunction("double sumC(NumericVector x){
  int n = x.length();
  double total = 0;
  for(int i = 0; i < n; i++){
    total += x[i];
  }
  return total;
}")
```

Example 3

This function illustrates difference between R and C++:

- To find the length of the vector, we use the `.length()` method, which returns an integer.
- The `for` statement has a different syntax: `for(init; check; increment)`.
- In C++, vector indices start at 0.
- Use `=` for assignment, not `<-`
- C++ provides operators that modify in-place: `total += x[i]` is equivalent to `total = total + x[i]`.

Using `sourceCpp()`

- Use `sourceCpp()` to load a C++ file from disk in the same way you use `source()` to load a file of R code.
- We can create a C++ file using Rstudio.

- Advanced R by Hadley Wickham
- Dirk Eddelbuettel website
<http://dirk.eddelbuettel.com/>