

Higher-Performance R via C++

Part 4: Rcpp Gallery Examples

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Rcpp Gallery

Rcpp Gallery: Overview

- The *Rcpp Gallery* at <http://gallery.rcpp.org> provides almost one-hundred ready-to-run and documented examples.
- It is built on a blog-alike backend in a repository hosted at GitHub.
- You can clone the repository, or just download examples one-by-one.

Rcpp Gallery: Simple Examples

Cumulative Sum: vector-cumulative-sum/

A basic looped version:

```
#include <Rcpp.h>
#include <numeric>          // for std::partial_sum
using namespace Rcpp;
// [[Rcpp::export]]
NumericVector cumsum1(NumericVector x) {
    double acc = 0;        // init an accumulator var
    NumericVector res(x.size()); // init result vector
    for (int i = 0; i < x.size(); i++){
        acc += x[i];
        res[i] = acc;
    }
    return res;
}
```

Cumulative Sum: vector-cumulative-sum/

An STL variant:

```
#include <Rcpp.h>
#include <numeric>      // for std::partial_sum
using namespace Rcpp;

// [[Rcpp::export]]
NumericVector cumsum2(NumericVector x) {
    // initialize the result vector
    NumericVector res(x.size());
    std::partial_sum(x.begin(), x.end(),
                     res.begin());
    return res;
}
```

Sugar:

```
// [[Rcpp::export]]  
NumericVector cumsum3(NumericVector x) {  
    return cumsum(x); // compute + return result  
}
```


Calling an R Function: r-function-from-c++/

```
#include <Rcpp.h>

using namespace Rcpp;

// [[Rcpp::export]]
NumericVector callFunction(NumericVector x,
                           Function f) {
    NumericVector res = f(x);
    return res;
}
```

Vector Subsetting: subsetting/

```
#include <Rcpp.h>
using namespace Rcpp;

// [[Rcpp::export]]
NumericVector positives(NumericVector x) {
    return x[x > 0];
}

// [[Rcpp::export]]
List first_three(List x) {
    IntegerVector idx = IntegerVector::create(0, 1, 2);
    return x[idx];
}

// [[Rcpp::export]]
List with_names(List x, CharacterVector y) {
    return x[y];
}
```

Vector Subsetting: armadillo-subsetting/

```
#include <RcppArmadillo.h>
// [[Rcpp::depends(RcppArmadillo)]]

// [[Rcpp::export]]
arma::mat matrixSubset(arma::mat M) {
    // logical conditionL where is transpose larger?
    arma::umat a = trans(M) > M;
    arma::mat N = arma::conv_to<arma::mat>::from(a);
    return N;
}

// [[Rcpp::export]]
arma::vec matrixSubset2(arma::mat M) {
    arma::mat Z = M * M.t();
    arma::vec v = Z.elem( arma::find( Z >= 100 ) );
    return v;
}
```

Rcpp Gallery: Boost

Boost via BH: a-first-boost-example/

```
// [[Rcpp::depends(BH)]]  
#include <Rcpp.h>  
#include <boost/math/common_factor.hpp>  
  
// [[Rcpp::export]]  
int computeGCD(int a, int b) {  
    return boost::math::gcd(a, b);  
}  
  
// [[Rcpp::export]]  
int computeLCM(int a, int b) {  
    return boost::math::lcm(a, b);  
}
```

Boost via BH: a-second-boost-example/

```
// [[Rcpp::depends(BH)]]
#include <Rcpp.h>
#include <boost/lexical_cast.hpp>
using boost::lexical_cast;
using boost::bad_lexical_cast;

// [[Rcpp::export]]
std::vector<double> lexicalCast(std::vector<std::string> v) {
  std::vector<double> res(v.size());
  for (int i=0; i<v.size(); i++) {
    try {
      res[i] = lexical_cast<double>(v[i]);
    } catch(bad_lexical_cast &) {
      res[i] = NA_REAL;
    }
  }
  return res;
}

// R> lexicalCast(c("1.23", ".4", "1000", "foo", "42", "pi/4"))
// [1] 1.23 0.40 1000.00 NA 42.00 NA
```

Boost via BH: using-boost-with-bh/

```
// [[Rcpp::depends(BH)]]
#include <Rcpp.h>

// One include file from Boost
#include <boost/date_time/gregorian/gregorian_types.hpp>

using namespace boost::gregorian;

// [[Rcpp::export]]
Rcpp::Date getIMMDate(int mon, int year) {
    // compute third Wednesday of given month / year
    date d = nth_day_of_the_week_in_month(
        nth_day_of_the_week_in_month::third,
        Wednesday, mon).get_date(year);
    date::ymd_type ymd = d.year_month_day();
    return Rcpp::Date(ymd.year, ymd.month, ymd.day);
}
```

Boost via BH: boost-foreach/

```
#include <Rcpp.h>
#include <boost/foreach.hpp>
using namespace Rcpp;
// [[Rcpp::depends(BH)]]

// the C-style upper-case macro name is a bit ugly
#define foreach BOOST_FOREACH

// [[Rcpp::export]]
NumericVector square( NumericVector x ) {

    // elem is a reference to each element in x
    // we can re-assign to these elements as well
    foreach( double& elem, x ) {
        elem = elem*elem;
    }
    return x;
}
```


Boost via BH: boost-regular-expressions/

NB: Use `Sys.setenv("PKG_LIBS"="-lboost_regex")`

```
// boost.org/doc/libs/1_53_0/libs/regex/example/snippets/credit_card_example.cpp
```

```
#include <Rcpp.h>
```

```
#include <string>
```

```
#include <boost/regex.hpp>
```

```
bool validate_card_format(const std::string& s) {  
    static const boost::regex e("(\\d{4}[- ]){3}\\d{4}");  
    return boost::regex_match(s, e);  
}
```

```
// [[Rcpp::export]]
```

```
std::vector<bool> regexDemo(std::vector<std::string> s) {  
    int n = s.size();  
    std::vector<bool> v(n);  
    for (int i=0; i<n; i++)  
        v[i] = validate_card_format(s[i]);  
    return v;  
}
```

Rcpp Gallery: XPtr

Passing an XPtr: passing-cpp-function-pointers/

Consider two functions modifying a given Armadillo vector:

```
// [[Rcpp::depends(RcppArmadillo)]]  
#include <RcppArmadillo.h>  
  
using namespace arma;  
using namespace Rcpp;  
  
vec fun1_cpp(const vec& x) {    // a first function  
    vec y = x + x;  
    return (y);  
}  
  
vec fun2_cpp(const vec& x) {    // and a second function  
    vec y = 10*x;  
    return (y);  
}
```

Passing an XPtr: passing-cpp-function-pointers/

Using typedef to declare funcPtr as an interface to a function taking and returning a vector — and defining a function returning a function pointer given a string argument

```
typedef vec (*funcPtr)(const vec& x);

// [[Rcpp::export]]
XPtr<funcPtr> putFunPtrInXPtr(std::string fstr) {
    if (fstr == "fun1")
        return(XPtr<funcPtr>(new funcPtr(&fun1_cpp)));
    else if (fstr == "fun2")
        return(XPtr<funcPtr>(new funcPtr(&fun2_cpp)));
    else
        // runtime err.: NULL no XPtr
        return XPtr<funcPtr>(R_NilValue);
}
```

Next we create a function calling the supplied function on a given vector by ‘unpacking’ the function pointer:

```
// [[Rcpp::export]]  
vec callViaXPtr(const vec x, SEXP xpsexp) {  
    XPtr<funcPtr> xpfun(xpsexp);  
    funcPtr fun = *xpfun;  
    vec y = fun(x);  
    return (y);  
}
```

Putting it together:

```
# this gets us a function  
fun <- putFunPtrInXPtr("fun1")  
# and pass it down to C++ to  
# have it applied on given vector  
callViaXPtr(1:4, fun)
```

This mechanism is generic and can be used for objective functions, gradients, samplers, ... to operate at C++ speed on user-supplied C++ functions.

Rcpp Gallery: Plugins

Plugin support in Rcpp

```
# setup plugins environment
.plugins <- new.env()
# built-in C++11 plugin
.plugins[["cpp11"]] <- function() {
  if (getRversion() >= "3.1")
    list(env = list(USE_CXX1X = "yes"))
  else if (.Platform$OS.type == "windows")
    list(env = list(PKG_CXXFLAGS = "-std=c++0x"))
  else
    list(env = list(PKG_CXXFLAGS = "-std=c++11"))
}
# built-in OpenMP++11 plugin
.plugins[["openmp"]] <- function() {
  list(env = list(PKG_CXXFLAGS="-fopenmp", PKG_LIBS="-fopenmp"))
}

# register a plugin
registerPlugin <- function(name, plugin) {
  .plugins[[name]] <- plugin
}
```


C++11 auto: first-steps-with-C++11/

```
#include <Rcpp.h>

// Enable C++11 via this plugin
// [[Rcpp::plugins("cpp11")]]

// [[Rcpp::export]]
int useAuto() {
    auto val = 42;      // val will be of type int
    return val;
}
```

```
#include <Rcpp.h>

// [[Rcpp::plugins("cpp11")]]

// [[Rcpp::export]]
std::vector<std::string> useInitLists() {
    std::vector<std::string> vec =
        {"larry", "curly", "moe"};
    return vec;
}
```

C++11 range: first-steps-with-C++11/

```
#include <Rcpp.h>
```

```
// [[Rcpp::plugins("cpp11")]]
```

```
// [[Rcpp::export]]
```

```
int simpleProd(std::vector<int> vec) {
```

```
    int prod = 1;
```

```
    for (int &x : vec) {
```

```
        prod *= x;
```

```
    }
```

```
    return prod;
```

```
}
```

```
// loop over all values of vec
```

```
// access each elem., compute prod
```

```
#include <Rcpp.h>

// [[Rcpp::plugins("cpp11")]]

// [[Rcpp::export]]
std::vector<double>
transformEx(const std::vector<double>& x) {
    std::vector<double> y(x.size());
    std::transform(x.begin(), x.end(), y.begin(),
        [](double x) { return x*x; } );
    return y;
}
```

OpenMP: using-rcppprogress/

We start we with (somewhat boring/made-up) slow double-loop:

```
#include <Rcpp.h>

// [[Rcpp::export]]
double long_computation(int nb) {
    double sum = 0;
    for (int i = 0; i < nb; ++i) {
        for (int j = 0; j < nb; ++j) {
            sum += R::dlnorm(i+j, 0.0, 1.0, 0);
        }
    }
    return sum + nb;
}
```

OpenMP: using-rcppprogress/

```
// [[Rcpp::plugins("openmp")]]
#include <Rcpp.h>

// [[Rcpp::export]]
double long_computation_omp(int nb, int threads=1) {
#ifdef _OPENMP
    if (threads > 0) omp_set_num_threads( threads );
    Rprintf("Number of threads=%i\n", omp_get_max_threads());
#endif

    double sum = 0;
#pragma omp parallel for schedule(dynamic)
    for (int i = 0; i < nb; ++i) {
        double thread_sum = 0;
        for (int j = 0; j < nb; ++j) {
            thread_sum += R::dlnorm(i+j, 0.0, 1.0, 0);
        }
        sum += thread_sum;
    }
    return sum + nb;
}
```

Even on my laptop gains can be seen:

```
R> sourceCpp("code/openmpEx.cpp")
R> system.time(long_computation(1e4))
  user  system elapsed 
22.436   0.000  22.432 
R> system.time(long_computation_omp(1e4,4))
Number of threads=4
  user  system elapsed 
25.432   0.076   7.046 
R>
```

Rcpp Gallery: RcppParallel

Parallel Matrix Transform: parallel-matrix-transform

```
#include <Rcpp.h>
using namespace Rcpp;

#include <cmath>
#include <algorithm>

// [[Rcpp::export]]
NumericMatrix matrixSqrt(NumericMatrix orig) {
    // allocate the matrix we will return
    NumericMatrix mat(orig.nrow(), orig.ncol());
    // transform it
    std::transform(orig.begin(), orig.end(), mat.begin(), ::sqrt);
    // return the new matrix
    return mat;
}
```

Parallel Matrix Transform: parallel-matrix-transform

```
// [[Rcpp::depends(RcppParallel)]]
#include <RcppParallel.h>
using namespace RcppParallel;

struct SquareRoot : public Worker {
    const RMatrix<double> input;      // source matrix

    RMatrix<double> output;          // destination matrix

    // initialize with source and destination
    SquareRoot(const NumericMatrix input, NumericMatrix output)
        : input(input), output(output) {}

    // take the square root of the range of elements requested
    void operator()(std::size_t begin, std::size_t end) {
        std::transform(input.begin() + begin,
                        input.begin() + end,
                        output.begin() + begin,
                        ::sqrt);
    }
};
```

Parallel Matrix Transform: parallel-matrix-transform

```
// [[Rcpp::export]]  
NumericMatrix parallelMatrixSqrt(NumericMatrix x) {  
  
    // allocate the output matrix  
    NumericMatrix output(x.nrow(), x.ncol());  
  
    // SquareRoot functor (pass input and output matrixes)  
    SquareRoot squareRoot(x, output);  
  
    // call parallelFor to do the work  
    parallelFor(0, x.length(), squareRoot);  
  
    // return the output matrix  
    return output;  
}
```