This note provides an overview of the steps programmers should follow to extend Rcpp (Eddelbuettel et al., 2018a; Eddelbuettel and François, 2011) for use with their own classes. This document is based on our experience in extending Rcpp to work with the Armadillo (Sanderson, 2010) classes, available in the separate package RcppArmadillo (Eddelbuettel et al., 2018b). This document assumes knowledge of Rcpp as well as some knowledge of C++ templates (Abrahams and Gurtovoy, 2004).

1. Introduction

Rcpp facilitates data interchange between R and C++ through the templated functions Rcpp::as (for conversion of objects from R to C++) and Rcpp::wrap (for conversion from C++ to R). In other words, we convert between the so-called S-expression pointers (in type SEXP) to a templated C++ type, and vice versa. The corresponding function declarations are as follows:

```cpp
// conversion from R to C++
template <typename T> T as(SEXP x);
// conversion from C++ to R
template <typename T> SEXP wrap(const T& object);
```

These converters are often used implicitly, as in the following code chunk:

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

// [[Rcpp::export]]
List fx(List input) { // we get a list from R
    // pull std::vector<double> from R list
    // this is achieved through an implicit
call to Rcpp::as
    std::vector<double> x = input["x"];

    // return an R list; this is achieved
    // through an implicit call to Rcpp::wrap
    return List::create(_["front"] = x.front(),
                        _["back"] = x.back());
}
```

Example:

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

class Foo {
    public:
        Foo();
        // this operator enables implicit Rcpp::wrap
        operator SEXP() {
            // this operator enables implicit Rcpp::wrap
            return List::create(_["front"] = x.front(),
                                _["back"] = x.back());
        }
};
```

The Rcpp converter function Rcpp::as and Rcpp::wrap have been designed to be extensible to user-defined types and third-party types.

2. Extending Rcpp::wrap

The Rcpp::wrap converter is extensible in essentially two ways: intrusive and non-intrusive.

2.1. Intrusive extension.

When extending Rcpp with your own data type, the recommended way is to implement a conversion to SEXP. This lets Rcpp::wrap know about the new data type. The template meta programming (or TMP) dispatch is able to recognize that a type is convertible to a SEXP and Rcpp::wrap will use that conversion.

The caveat is that the type must be declared before the main header file Rcpp.h is included.

```cpp
#include <RcppCommon.h>

class Foo {
    public:
        Foo();
        operator SEXP() {
            // this operator enables implicit Rcpp::wrap
            return List::create(_["front"] = x.front(),
                                _["back"] = x.back());
        }
};
```

This is called intrusive because the conversion to SEXP operator has to be declared within the class.

2.2. Non-intrusive extension.

It is often desirable to offer automatic conversion to third-party types, over which the developer has no control and can therefore not include a conversion to SEXP operator in the class definition.

To provide automatic conversion from C++ to R, one must declare a specialization of the Rcpp::wrap template between the includes of RcppCommon.h and Rcpp.h.

```cpp
#include <RcppCommon.h>

namespace Rcpp {
    template <> SEXP wrap(const Bar&);
}
```

This must appear after the specialization, otherwise the specialization will not be
It should be noted that only the declaration is required. The implementation can appear after the Rcpp.h file is included, and therefore take full advantage of the Rcpp type system.

Another non-intrusive option is to expose an external pointer. The macro RCPP_EXPORT_WRAP provides an easy way to expose a C++ class to R as an external pointer. It can be used instead of specializing Rcpp::wrap, and should not be used simultaneously.

```cpp
#include RcppCommon.h
#include foobar.h
RCPP_EXPORT_WRAP(Bar);
```

### 2.3. Templates and partial specialization

It is perfectly valid to declare a partial specialization for the Rcpp::wrap template. The compiler will identify the appropriate overload:

```cpp
#include <RcppCommon.h>
#include foobar.h

// third party library that declares a template class Bling<T>
#include <foobar.h>

// declaring the partial specialization
namespace Rcpp {
    template <typename T>
    SEXP wrap(const Bling<T>&);
}

// this must appear after the specialization, or
// specialization will not be seen by Rcpp types
#include <Rcpp.h>
```

Furthermore, another non-intrusive option is to opt for sharing an R external pointer. The macro RCPP_EXPORT_AS provides an easy way to expose Rcpp::as to expose R external pointers to C++. It can be used instead of specializing Rcpp::as, and should not be used simultaneously.

```cpp
#include RcppCommon.h
#include foobar.h
RCPP_EXPORT_AS(Bar);
```

With this being said, there is one additional macro that can be used to simultaneously define both Rcpp::wrap and Rcpp::as specialization for an external pointer. The macro RCPP_EXPORTED_CLASS can be used to transparently exchange a class between R and C++ as an external pointer. Do not simultaneously use it alongside RCPP_EXPORTED_WRAP, RCPP_EXPORTED_AS, or Rcpp::as.

### 3. Extending Rcpp::as

Conversion from R to C++ is also possible in both intrusive and non-intrusive ways.

#### 3.1. Intrusive extension

As part of its template meta programming dispatch logic, Rcpp::as will attempt to use the constructor of the target class taking a SEXP.

```cpp
#include <RcppCommon.h>

class Foo{
    public:
        Foo();
        // this ctor enables implicit Rcpp::as
        Foo(SEXP);
    }

    // this must appear after the specialization, or
    // specialization will not be seen by Rcpp types
    #include <Rcpp.h>
```

This is the reason why the default behavior of Rcpp::as is to invoke the constructor of the type T taking a SEXP.
Since partial specialization of class templates is allowed, we can expose a set of classes as follows:

```cpp
#include <RcppCommon.h>

// third party library that declares
// a template class Bling<T>
#include <foobar.h>

// declaring the partial specialization
namespace Rcpp {
    namespace traits {
        template <typename T>
        class Exporter< Bling<T> >;
    }
}

// this must appear after the specialization, or
// specialization will not be seen by Rcpp types
#include <Rcpp.h>
```

Using this approach, the requirements for the `Exporter< Bling<T> >` class are:

- it should have a constructor taking a SEXP
- it should have a methods called get that returns an instance of the `Bling<T>` type.

4. Summary

The Rcpp package greatly facilitates the transfer of objects between R and C++. This note has shown how to extend Rcpp to either user-defined or third-party classes via the `Rcpp::as` and `Rcpp::wrap` template functions. Both intrusive and non-intrusive approaches were discussed.

References