shroud Documentation

Release 0.12.2

llnl

Dec 17, 2020

Contents

Shroud is a tool for creating a Fortran or Python interface to a C or C++ library. It can also create a C API for a C++ library.

The user creates a YAML file with the C/C++ declarations to be wrapped along with some annotations to provide semantic information and code generation options. **Shroud** produces a wrapper for the library. The generated code is highly-readable and intended to be similar to code that would be hand-written to create the bindings.

verb

1. wrap or dress (a body) in a shroud for burial.
2. cover or envelop so as to conceal from view.

Contents

CHAPTER 1

Introduction

Shroud is a tool for creating a Fortran or Python interface to a C or C++ library. It can also create a C API for a C++ library.

The user creates a YAML file with the C/C++ declarations to be wrapped along with some annotations to provide semantic information and code generation options. Shroud produces a wrapper for the library. The generated code is highly-readable and intended to be similar to code that would be hand-written to create the bindings.

Input is read from the YAML file which describes the types, variables, enumerations, functions, structures and classes to wrap. This file must be created by the user. Shroud does not parse C++ code to extract the API. That was considered a large task and not needed for the size of the API of the library that inspired Shroud's development. In addition, there is a lot of semantic information which must be provided by the user that may be difficult to infer from the source alone. However, the task of creating the input file is simplified since the C++ declarations can be cut-and-pasted into the YAML file.

In some sense, Shroud can be thought of as a fancy macro processor. It takes the function declarations from the YAML file, breaks them down into a series of contexts (library, class, function, argument) and defines a dictionary of format macros of the form key=value. There are then a series of macro templates which are expanded to create the wrapper functions. The overall structure of the generated code is defined by the classes and functions in the YAML file as well as the requirements of C++ and Fortran syntax.

Each declaration can have annotations which provide semantic information. This information is used to create more idiomatic wrappers. Shroud started as a tool for creating a Fortran wrapper for a C++ library. The declarations and annotations in the input file also provide enough information to create a Python wrapper.

1.1 Goals

- Simplify the creating of wrapper for a C++ library.
- Preserves the object-oriented style of C++ classes.
- Create an idiomatic wrapper API from the C++ API.
- Generate code which is easy to understand.

- No dependent runtime library.

1.2 Fortran

The Fortran wrapper is created by using the interoperability with C features added in Fortran 2003. This includes the `iso_c_binding` module and the `bind` and `value` keywords. Fortran cannot interoperate with C++ directly and uses C as the lingua franca. C++ can communicate with C via a common heritage and the `extern "C"` keyword. A C API for the C++ API is produced as a byproduct of the Fortran wrapping.

Using a C++ API to create an object and call a method:

```
Instance * inst = new Instance;
inst->method(1);
```

In Fortran this becomes:

```
type(instance) inst
inst = instance_new()
call inst%method(1)
```

Note: The ability to generate C++ wrappers for Fortran is not supported.

1.2.1 Issues

There is a long history of ad-hoc solutions to provide C and Fortran interoperability. Any solution must address several problems:

- Name mangling of externals. This includes namespaces and operator overloading in C++.
- Call-by-reference vs call-by-value differences
- Length of string arguments.
- Blank filled vs null terminated strings.

The 2003 Fortran standard added several features for interoperability with C:

- iso_c_binding - intrinsic module which defines fortran kinds for matching with C's types.
- `BIND` keyword to control name mangling of externals.
- `VALUE` attribute to allow pass-by-value.

In addition, Fortran 2003 provides object oriented programming facilities:

- Type extension
- Procedure Polymorphism with Type-Bound Procedures
- Enumerations compatible with C

Further Interoperability of Fortran with C, Technical Specification TS 29113, now part of Fortran 2019, introduced additional features:

- assumed-type
- `ALLOCATABLE`, `OPTIONAL`, and `POINTER` attributes may be specified for a dummy argument in a procedure interface that has the `BIND` attribute.

Shroud uses the features of Fortran 2003 as well as additional generated code to solve the interoperability problem to create an idiomatic interface.

1.2.2 Requirements

Fortran wrappers are generated as free-form source and require a Fortran 2003 compiler. C code requires C99.

1.3 Python

The Python wrappers use the CPython API to create a wrapper for the library.

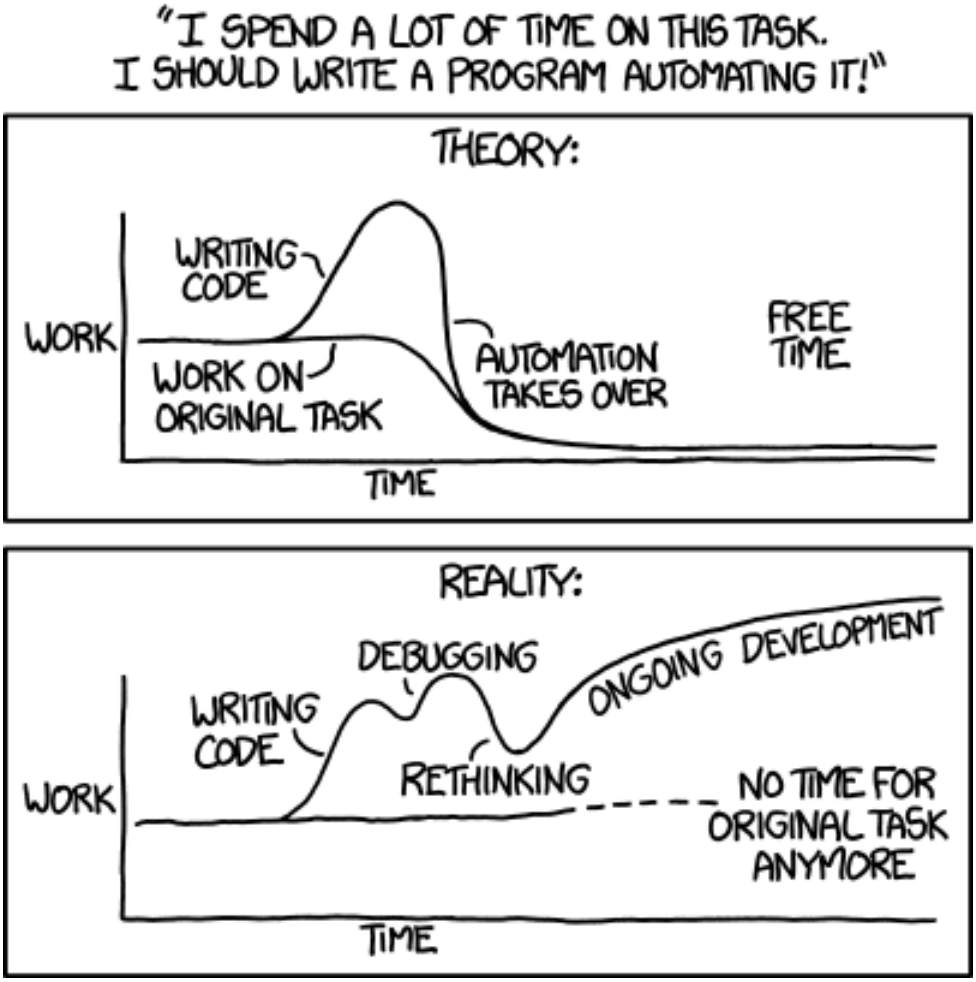
1.3.1 Requirements

The generated code will require

- Python 2.7 or Python 3.4+
- NumPy can be used when using pointers with *rank*, *dimension* or *allocatable*, attributes.

1.4 XKCD

XKCD


"I SPEND A LOT OF TIME ON THIS TASK.
I SHOULD WRITE A PROGRAM AUTOMATING IT!"
THEORY:
WORK
WRITING CODE
WORK ON ORIGINAL TASK
AUTOMATION TAKES OVER
FREE TIME
TIME
REALITY:
WORK
WRITING CODE
DEBUGGING
RETHINKING
ONGOING DEVELOPMENT
NO TIME FOR ORIGINAL TASK ANYMORE
TIME

CHAPTER 2

Installing

The easiest way to install Shroud is via pip which will fetch a file from pypi

```
pip install llnl-shroud
```

This will install Shroud into the same directory as pip. A virtual environment can be created if another destination directory is desired. For details see the python docs

The source is available from github.com/LLNL/shroud A shiv packaged executable is also available at github releases. This is an executable file which contains Shroud and PyYAML and uses the Python3 in the user's path.

Shroud is written in Python and has been tested with version 2.7 and 3.4+. It requires the module:

- PyYAML https://github.com/yaml/pyyaml

After downloading the source:

```
python setup.py install
```

This will create the script *shroud* in the same directory as Python.

Since shroud installs into Python's bin directory, it may be desirable to setup a virtual environment to try it out:

```
$ cd my_project_folder
$ virtualenv my_project
$ source my_project/bin/activate
$ cd path/to/shroud/source
$ python setup.py install
```

This will create an executable at `my_project/bin/shroud`. This version requires the virtual environment to run and may be difficult to share with others.

It's possible to create a standalone executable with shiv:

```
$ cd path/to/shroud/source
$shiv --python '/usr/bin/env python3' -c shroud -o dist/shroud.pyz .
```

A file *shroud.pyz* is created which bundles all of shroud and pyYAML into a single file. It uses the python on your path to run.

2.1 Building wrappers with CMake

Shroud can produce a CMake macro file with the option `-cmake`. This option can be incorporated into a CMakefile as:

```
if(EXISTS ${SHROUD_EXECUTABLE})
    execute_process(COMMAND ${SHROUD_EXECUTABLE}
                    --cmake ${CMAKE_CURRENT_BINARY_DIR}/SetupShroud.cmake
                    ERROR_VARIABLE SHROUD_cmake_error
                    OUTPUT_STRIP_TRAILING_WHITESPACE )
    if(${SHROUD_cmake_error})
       message(FATAL_ERROR "Error from Shroud: ${SHROUD_cmake_error}")
    endif()
    include(${CMAKE_CURRENT_BINARY_DIR}/SetupShroud.cmake)
endif()
```

The path to Shroud must be defined to CMake. It can be defined on the command line as:

```
cmake -DSHROUD_EXECUTABLE=/full/path/bin/shroud
```

The `add_shroud` macro can then be used in other `CMakeLists.txt` files as:

```
add_shroud(
    YAML_INPUT_FILE      ${YAML_INPUT_FILE}
    C_FORTRAN_OUTPUT_DIR c_fortran
)
```

`CMake` will treat all Fortran files as free format with the command:

```
set(CMAKE_Fortran_FORMAT FREE)
```

2.2 Building Python extensions

`setup.py` can be used to build the extension module from the files created by shroud. This example is drawn from the `run/tutorial` example. You must provide the paths to the input YAML file and the C++ library source files:

```
import os
from distutils.core import setup, Extension
import shroud
import numpy

outdir = 'build/source'
if not os.path.exists(outdir):
    os.makedirs(outdir)
config = shroud.create_wrapper('../../../tutorial.yaml',
                               path=['../../..'],
                               outdir=outdir)

tutorial = Extension(
    'tutorial',
```

(continues on next page)

(continued from previous page)

```
    sources = config.pyfiles + ['../tutorial.cpp'],
    include_dirs=[numpy.get_include(), '..']
)

setup(
    name='tutorial',
    version="0.0",
    description='shroud tutorial',
    author='xxx',
    author_email='yyy@zz',
    ext_modules=[tutorial],
)
```

The directory structure is layed out as:

```
tutorial.yaml
run
  tutorial
    tutorial.cpp   # C++ library to wrap
    tutorial.hpp
    python
      setup.py     # setup file shown above
      build
         source
           # create by shroud
           pyClass1type.cpp
           pySingletontype.cpp
           pyTutorialmodule.cpp
           pyTutorialmodule.hpp
           pyTutorialhelper.cpp
         lib
            tutorial.so   # generated module
```

CHAPTER 3

Tutorial

This tutorial will walk through the steps required to create a Fortran or Python wrapper for a simple C++ library.

3.1 Functions

The simplest item to wrap is a function in the file `tutorial.hpp`:

```
namespace tutorial {
  void NoReturnNoArguments(void);
}
```

This is wrapped using a YAML input file `tutorial.yaml`:

```
library: Tutorial
cxx_header: tutorial.hpp

declarations:
- decl: namespace tutorial
  declarations:
  - decl: void NoReturnNoArguments()
```

library is used to name output files and name the Fortran module. **cxx_header** is the name of a C++ header file which contains the declarations for functions to be wrapped. **declarations** is a sequence of mappings which describe the functions to wrap.

Process the file with *Shroud*:

```
% shroud tutorial.yaml
Wrote wrapTutorial.h
Wrote wrapTutorial.cpp
Wrote wrapftutorial.f

Wrote pyClass1type.cpp
```

(continues on next page)

(continued from previous page)

```
Wrote pyTutorialmodule.hpp
Wrote pyTutorialmodule.cpp
Wrote pyTutorialutil.cpp
```

The C++ code to call the function:

```
#include "tutorial.hpp"

using namespace tutorial;
NoReturnNoArguments();
```

And the Fortran version:

```
use tutorial_mod
call no_return_no_arguments
```

Note: rename module to just tutorial.

The generated code is listed at *NoReturnNoArguments*.

3.2 Arguments

3.2.1 Integer and Real

Integer and real types are handled using the `iso_c_binding` module which match them directly to the corresponding types in C++. To wrap `PassByValue`:

```
double PassByValue(double arg1, int arg2)
{
    return arg1 + arg2;
}
```

Add the declaration to the YAML file:

```
declarations:
- decl: double PassByValue(double arg1, int arg2)
```

Usage:

```
use tutorial_mod
real(C_DOUBLE) result
result = pass_by_value(1.d0, 4)
```

```
import tutorial
result = tutorial.PassByValue(1.0, 4)
```

3.3 Pointer Functions

Functions which return a pointer will create a Fortran wrapper with the `POINTER` attribute:

```
- decl: int * ReturnIntPtrDim(int *len+intent(out)+hidden) +dimension(len)
```

The C++ routine returns a pointer to an array and the length of the array in argument `len`. The Fortran API does not need to pass the argument since the returned pointer will know its length. The *hidden* attribute will cause `len` to be omitted from the Fortran API, but still passed to the C API.

It can be used as:

```
integer(C_INT), pointer :: intp(:)

intp => return_int_ptr()
```

3.4 Pointer arguments

When a C++ routine accepts a pointer argument it may mean several things

- output a scalar
- input or output an array
- pass-by-reference for a struct or class.

In this example, `len` and `values` are an input array and `result` is an output scalar:

```
void Sum(size_t len, const int *values, int *result)
{
    int sum = 0;
    for (size_t i=0; i < len; i++) {
      sum += values[i];
    }
    *result = sum;
    return;
}
```

When this function is wrapped it is necessary to give some annotations in the YAML file to describe how the variables should be mapped to Fortran:

```
- decl: void Sum(size_t len  +implied(size(values)),
                 const int *values +rank(1),
                 int *result +intent(out))
```

In the `BIND(C)` interface only *len* uses the `value` attribute. Without the attribute Fortran defaults to pass-by-reference i.e. passes a pointer. The `rank` attribute defines the variable as a one dimensional, assumed-shape array. In the C interface this maps to an assumed-length array. C pointers, like assumed-length arrays, have no idea how many values they point to. This information is passed by the *len* argument.

The *len* argument defines the `implied` attribute. This argument is not part of the Fortran API since its presence is *implied* from the expression `size(values)`. This uses the Fortran intrinsic `size` to compute the total number of elements in the array. It then passes this value to the C wrapper:

```
use tutorial_mod
integer(C_INT) result
call sum([1,2,3,4,5], result)
```

```
import tutorial
result = tutorial.Sum([1, 2, 3, 4, 5])
```

See example *Sum* for generated code.

3.4.1 String

Character variables have significant differences between C and Fortran. The Fortran interoperability with C feature treats a `character` variable of default kind as an array of `character(kind=C_CHAR,len=1)`. The wrapper then deals with the C convention of `NULL` termination to Fortran's blank filled.

C++ routine:

```
const std::string ConcatenateStrings(
    const std::string& arg1,
    const std::string& arg2)
{
    return arg1 + arg2;
}
```

YAML input:

```
declarations:
- decl: const std::string ConcatenateStrings(
    const std::string& arg1,
    const std::string& arg2 )
```

The function is called as:

```
character(len=:), allocatable :: rv4c

rv4c = concatenate_strings("one", "two")
```

Note: This function is just for demonstration purposes. Any reasonable person would just use the concatenation operator in Fortran.

3.5 Default Value Arguments

Each function with default value arguments will create a C and Fortran wrapper for each possible prototype. For Fortran, these functions are then wrapped in a generic statement which allows them to be called by the original name. A header files contains:

```
double UseDefaultArguments(double arg1 = 3.1415, bool arg2 = true)
```

and the function is defined as:

```
double UseDefaultArguments(double arg1, bool arg2)
{
    if (arg2) {
        return arg1 + 10.0;
    } else {
        return arg1;
    }
 }
```

Creating a wrapper for each possible way of calling the C++ function allows C++ to provide the default values:

```
declarations:
- decl: double UseDefaultArguments(double arg1 = 3.1415, bool arg2 = true)
  default_arg_suffix:
  -
  -  _arg1
  -  _arg1_arg2
```

The *default_arg_suffix* provides a list of values of *function_suffix* for each possible set of arguments for the function. In this case 0, 1, or 2 arguments.

Fortran usage:

```
use tutorial_mod
print *, use_default_arguments()
print *, use_default_arguments(1.d0)
print *, use_default_arguments(1.d0, .false.)
```

Python usage:

```
>>> import tutorial
>>> tutorial.UseDefaultArguments()
13.1415
>>> tutorial.UseDefaultArguments(1.0)
11.0
>>> tutorial.UseDefaultArguments(1.0, False)
1.0
```

The generated code is listed at *UseDefaultArguments*.

Note: Fortran's `OPTIONAL` attribute provides similar but different semantics. Creating wrappers for each set of arguments allows C++ to supply the default value. This is important when the default value does not map directly to Fortran. For example, `bool` type or when the default value is created by calling a C++ function.

Using the `OPTIONAL` keyword creates the possibility to call the C++ function in a way which is not supported by the C++ compilers. For example, `function5(arg2=.false.)`

Fortran has nothing similar to variadic functions.

3.6 Overloaded Functions

C++ allows function names to be overloaded. Fortran supports this by using a `generic` interface. The C and Fortran wrappers will generated a wrapper for each C++ function but must mangle the name to distinguish the names.

C++:

```
void OverloadedFunction(const std::string &name);
void OverloadedFunction(int indx);
```

By default the names are mangled by adding an index to the end. This can be controlled by setting **function_suffix** in the YAML file:

```
declarations:
- decl: void OverloadedFunction(const std::string& name)
  function_suffix: _from_name
```

(continues on next page)

(continued from previous page)

```
- decl: void OverloadedFunction(int indx)
  function_suffix: _from_index
```

```
call overloaded_function_from_name("name")
call overloaded_function_from_index(1)
call overloaded_function("name")
call overloaded_function(1)
```

```
tutorial.OverloadedFunction("name")
tutorial.OverloadedFunction(1)
```

3.7 Optional arguments and overloaded functions

Overloaded function that have optional arguments can also be wrapped:

```
- decl: int UseDefaultOverload(int num,
          int offset = 0, int stride = 1)
- decl: int UseDefaultOverload(double type, int num,
          int offset = 0, int stride = 1)
```

These routines can then be called as:

```
rv = use_default_overload(10)
rv = use_default_overload(1d0, 10)

rv = use_default_overload(10, 11, 12)
rv = use_default_overload(1d0, 10, 11, 12)
```

3.8 Templates

C++ template are handled by creating a wrapper for each instantiation of the function defined by the **cxx_template** field. The C and Fortran names are mangled by adding a type suffix to the function name.

C++:

```
template<typename ArgType>
void TemplateArgument(ArgType arg)
{
    return;
}
```

YAML:

```
- decl: |
      template<typename ArgType>
      void TemplateArgument(ArgType arg)
  cxx_template:
  - instantiation: <int>
  - instantiation: <double>
```

Fortran usage:

```
call template_argument(1)
call template_argument(10.d0)
```

Python usage:

```
tutorial.TemplateArgument(1)
tutorial.TemplateArgument(10.0)
```

Likewise, the return type can be templated but in this case no interface block will be generated since generic function cannot vary only by return type.

C++:

```
template<typename RetType>
RetType TemplateReturn()
{
    return 0;
}
```

YAML:

```
- decl: template<typename RetType> RetType TemplateReturn()
  cxx_template:
  - instantiation: <int>
  - instantiation: <double>
```

Fortran usage:

```
integer(C_INT) rv_integer
real(C_DOUBLE) rv_double
rv_integer = template_return_int()
rv_double = template_return_double()
```

Python usage:

```
rv_integer = TemplateReturn_int()
rv_double = TemplateReturn_double()
```

3.9 Generic Functions

C and C++ provide a type promotion feature when calling functions which Fortran does not support:

```
void FortranGeneric(double arg);

FortranGeneric(1.0f);
FortranGeneric(2.0);
```

When `FortranGeneric` is wrapped in Fortran it may only be used with the correct arguments:

```
call fortran_generic(1.)
                     1
Error: Type mismatch in argument 'arg' at (1); passed REAL(4) to REAL(8)
```

It would be possible to create a version of the routine in C++ which accepts floats, but that would require changes to the library being wrapped. Instead it is possible to create a generic interface to the routine by defining which variables

need their types changed. This is similar to templates in C++ but will only impact the Fortran wrapper. Instead of specify the Type which changes, you specify the argument which changes:

```
- decl: void FortranGeneric(double arg)
  fortran_generic:
  - decl: (float arg)
    function_suffix: float
  - decl: (double arg)
    function_suffix: double
```

It may now be used with single or double precision arguments:

```
call fortran_generic(1.0)
call fortran_generic(1.0d0)
```

A full example is at *GenericReal*.

3.10 Types

3.10.1 Typedef

Sometimes a library will use a `typedef` to identify a specific use of a type:

```
typedef int TypeID;

int typefunc(TypeID arg);
```

Shroud must be told about user defined types in the YAML file:

```
declarations:
- decl: typedef int TypeID;
```

This will map the C++ type `TypeID` to the predefined type `int`. The C wrapper will use `int`:

```
int TUT_typefunc(int arg)
{
    tutorial::TypeID SHC_rv = tutorial::typefunc(arg);
    return SHC_rv;
}
```

3.10.2 Enumerations

Enumeration types can also be supported by describing the type to shroud. For example:

```
namespace tutorial
{

enum EnumTypeID {
    ENUM0,
    ENUM1,
    ENUM2
};
```

(continues on next page)

(continued from previous page)

```
EnumTypeID enumfunc(EnumTypeID arg);

} /* end namespace tutorial */
```

This enumeration is within a namespace so it is not available to C. For C and Fortran the type can be describe as an `int` similar to how the `typedef` is defined. But in addition we describe how to convert between C and C++:

```
declarations:
- decl: typedef int EnumTypeID
  fields:
    c_to_cxx : static_cast<tutorial::EnumTypeID>({c_var})
    cxx_to_c : static_cast<int>({cxx_var})
```

The typename must be fully qualified (use `tutorial::EnumTypeId` instead of `EnumTypeId`). The C argument is explicitly converted to a C++ type, then the return type is explicitly converted to a C type in the generated wrapper:

```
int TUT_enumfunc(int arg)
{
    tutorial::EnumTypeID SHCXX_arg = static_cast<tutorial::EnumTypeID>(arg);
    tutorial::EnumTypeID SHCXX_rv = tutorial::enumfunc(SHCXX_arg);
    int SHC_rv = static_cast<int>(SHCXX_rv);
    return SHC_rv;
}
```

Without the explicit conversion you're likely to get an error such as:

```
error: invalid conversion from 'int' to 'tutorial::EnumTypeID'
```

A enum can also be fully defined to Fortran:

```
declarations:
- decl: |
      enum Color {
        RED,
        BLUE,
        WHITE
      };
```

In this case the type is implicitly defined so there is no need to add it to the *types* list. The C header duplicates the enumeration, but within an `extern "C"` block:

```
//  tutorial::Color
enum TUT_Color {
    TUT_tutorial_Color_RED,
    TUT_tutorial_Color_BLUE,
    TUT_tutorial_Color_WHITE
};
```

Fortran creates integer parameters for each value:

```
!  enum tutorial::Color
integer(C_INT), parameter :: tutorial_color_red = 0
integer(C_INT), parameter :: tutorial_color_blue = 1
integer(C_INT), parameter :: tutorial_color_white = 2
```

Note: Fortran's `ENUM, BIND(C)` provides a way of matching the size and values of enumerations. However, it

doesn't seem to buy you too much in this case. Defining enumeration values as `INTEGER, PARAMETER` seems more straightforward.

3.10.3 Structure

A structure in C++ can be mapped directly to a Fortran derived type using the `bind(C)` attribute provided by Fortran 2003. For example, the C++ code:

```
struct struct1 {
  int ifield;
  double dfield;
};
```

can be defined to Shroud with the YAML input:

```
- decl: |
    struct struct1 {
      int ifield;
      double dfield;
    };
```

This will generate a C struct which is compatible with C++:

```
struct s_TUT_struct1 {
    int ifield;
    double dfield;
};
typedef struct s_TUT_struct1 TUT_struct1;
```

A C++ struct is compatible with C; however, its name may not be accessible to C since it may be defined within a namespace. By creating an identical struct in the C wrapper, we're guaranteed visibility for the C API.

Note: All fields must be defined in the YAML file in order to ensure that `sizeof` operator will return the same value for the C and C++ structs.

This will generate a Fortran derived type which is compatible with C++:

```
type, bind(C) :: struct1
    integer(C_INT) :: ifield
    real(C_DOUBLE) :: dfield
end type struct1
```

A function which returns a struct value can have its value copied into a Fortran variable where the fields can be accessed directly by Fortran. A C++ function which initialized a struct can be written as:

```
- decl: struct1 returnStructByValue(int i, double d);
```

The C wrapper casts the C++ struct to the C struct by using pointers to the struct then returns the value by dereferencing the C struct pointer.

```
TUT_struct1 TUT_return_struct_by_value(int i, double d)
{
    Cstruct1 SHCXX_rv = returnStructByValue(i, d);
```

(continues on next page)

(continued from previous page)

```
    TUT_cstruct1 * SHC_rv = static_cast<TUT_cstruct1 *>(
        static_cast<void *>(&SHCXX_rv));
    return *SHC_rv;
}
```

This function can be called directly by Fortran using the generated interface:

```
function return_struct_by_value(i, d) &
        result(SHT_rv) &
        bind(C, name="TUT_return_struct_by_value")
    use iso_c_binding, only : C_DOUBLE, C_INT
    import :: struct1
    implicit none
    integer(C_INT), value, intent(IN) :: i
    real(C_DOUBLE), value, intent(IN) :: d
    type(struct1) :: SHT_rv
end function return_struct
```

To use the function:

```
type(struct1) var

var = return_struct(1, 2.5)
print *, var%ifield, var%dfield
```

3.11 Classes

Each class is wrapped in a Fortran derived type which shadows the C++ class by holding a `type(C_PTR)` pointer to an C++ instance. Class methods are wrapped using Fortran's type-bound procedures. This makes Fortran usage very similar to C++.

Now we'll add a simple class to the library:

```
class Class1
{
public:
    void Method1() {};
};
```

To wrap the class add the lines to the YAML file:

```
declarations:
- decl: class Class1
  declarations:
  - decl: Class1()  +name(new)
    format:
      function_suffix: _default
  - decl: ~Class1() +name(delete)
  - decl: int Method1()
```

The constructor and destructor have no method name associated with them. They default to **ctor** and **dtor**. The names can be overridden by supplying the **+name** annotation. These declarations will create wrappers over the `new` and `delete` C++ keywords.

The C++ code to call the function:

```
#include <tutorial.hpp>
tutorial::Class1 *cptr = new tutorial::Class1();

cptr->Method1();
```

And the Fortran version:

```
use tutorial_mod
type(class1) cptr

cptr = class1_new()
call cptr%method1
```

Python usage:

```
import tutorial
obj = tutorial.Class1()
obj.method1()
```

3.11.1 Class static methods

Class static methods are supported using the `NOPASS` keyword in Fortran. To wrap the method:

```
class Singleton {
    static Singleton& getReference();
};
```

Use the YAML input:

```
- decl: class Singleton
  declarations:
  - decl: static Singleton& getReference()
```

Called from Fortran as:

```
type(singleton) obj0
obj0 = obj0%get_reference()
```

Note that obj0 is not assigned a value before the function `get_reference` is called.

CHAPTER 4

Input

The input to Shroud is a YAML formatted file. YAML is a human friendly data serialization standard. [yaml] Structure is shown through indentation (one or more spaces). Sequence items are denoted by a dash, and key value pairs within a map are separated by a colon:

```
library: Tutorial

declarations:
- decl: typedef int TypeID

- decl: void Function1()

- decl: class Class1
  declarations:
  - decl: void Method1()
```

Each `decl` entry corresponds to a line of C or C++ code. The top level `declarations` field represents the source file while nested `declarations` fields corresponds to curly brace blocks. The above YAML file represent the source file:

```
typedef int TypeID;

void Function1();

class Class1
{
    void Method1();
}
```

A `block` can be used to group a collection of `decl` entires. Any `option` or `format` fields will apply to all declarations in the group:

```
declarations:
- block: True
  options:
```

(continues on next page)

(continued from previous page)

```
    F_name_impl_template: {library}_{undescore_name}
  format:
    F_impl_filename: localfile.f
  declarations:
  - decl: void func1()
  - decl: void func2()
```

Shroud use curly braces for format strings. If a string starts with a curly brace YAML will interpret it as a map/dictionary instead of as part of the string. To avoid this behavior, strings which start with a curly brace should be quoted:

```
name : "{fmt}"
```

Strings may be split across several lines by indenting the continued line:

```
- decl: void Sum(int len, const int *values+rank(1),
                 int *result+intent(out))
```

Some values consist of blocks of code. The pipe, `|`, is used to indicate that the string will span several lines and that newlines should be preserved:

```
C_invalid_name: |
    if (! isNameValid({cxx_var})) {{
        return NULL;
    }}
```

Note that to insert a literal `{`, a double brace, `{{`, is required since single braces are used for variable expansion. `{cxx_var}` in this example. However, using the pipe, it is not necessary to quote lines that contain other YAML meta characters such as colon and curly braces.

Literal newlines, `/n`, are respected. Format strings can use a tab, `/t`, to hint where it would be convenient to add a continuation if necessary. A formfeed, `/f`, will force a continuation. Lines which start with `0` are not indented. This can be used with labels. A trailing + will indent then next line a level and a leading − will deindent. Line lengths are controlled by the options *C_line_length* and *F_line_length* and default to 72.:

```
C_invalid_name: |
    if (! isNameValid({cxx_var})) {{+
    return NULL;
    -}}
```

The only formatting option is to control output line lengths. This is required for Fortran which has a maximum line length of 132 in free form which is generated by shroud. If you care where curly braces go in the C source then it is best to set *C_line_length* to a large number then use an external formatting tool such as `indent` or `uncrustify`.

4.1 Customizing Behavior in the YAML file

4.1.1 Fields

A field only applies to the type, enumeration, function, structure or class to which it belongs. It is not inherited. For example, *cxx_header* is a field which is used to define the header file for class *Names*. Likewise, setting *library* within a class does not change the library name.

```
library: testnames

declarations:
  - decl: class Names
    cxx_header: names.hpp
    declarations:
    -  decl: void method1
```

4.1.2 Options

Options are used to customize the behavior of Shroud. They are defined in the YAML file as a dictionary. Options can be defined at the global, class, or function level. Each level creates a new scope which can access all upper level options. This allows the user to modify behavior for all functions or just a single one:

```
options:
  option_a = false
  option_b = false
  option_c = false

declarations:
- class: class1
  options:
#    option_a = false     # inherited
     option_b = true
#    option_c = false     # inherited
  declarations:
  - decl: void function1
    options:
#     option_a = false    # inherited
#     option_b = true     # inherited
      option_c = true
```

4.2 Format

A format dictionary contains strings which can be inserted into generated code. Generated filenames are also entries in the format dictionary. Format dictionaries are also scoped like options. For example, setting a format in a class also effects all of the functions within the class.

4.2.1 How code is formatted

Format strings contain "replacement fields" surrounded by curly braces `{}`. Anything that is not contained in braces is considered literal text, which is copied unchanged to the output. If you need to include a brace character in the literal text, it can be escaped by doubling: `{{` and `}}`. [Python_Format]

There are some metacharacters that are used for formatting the line:

\f

Add an explicit formfeed

\t

A tab is used to suggest a place to break the line for a continuation before it exceeds option *C_line_length* or *F_line_length*. Any whitespace after a tab will be trimmed if the line is actually split at the tab. If a continuation was not needed (there was enough space on the current line) then the tab has no effect:

```
arg1,\t arg2
```

\+ -

Increase or decrease indention indention level. Used at the beginning or end of a line:

```
if (condition) {{+
do_one();
-}} else {{+
do_two();
-}}
```

The double curly braces are replace by a single curly. This will be indented as:

```
if (condition) {
    do_one();
} else {
    do_two();
}
```

\#

If the first character is a #, ignore indention and write in column 0. Useful for preprocessing directives.

^

If the first character is ^, ignore indention and write in column 0. Useful for comments or labels.

@

If the first character is @, treat the following character literally. Used to ignore a metacharacter:

```
struct aa = {{++
0// set field to 0
@0,
-}};
```

Formatted as:

```
struct aa = {
// set field to 0
    0,
};
```

4.3 Attributes

Annotations or attributes apply to specific arguments or results. They describe semantic behavior for an argument. An attribute may be set to true by listing its name or it may have a value in parens:

```
- decl: Class1()  +name(new)
- decl: void Sum(int len, const int *values+rank(1)+intent(in))
- decl: const std::string getName() +len(30)
```

Attributes may also be added external to *decl*:

```
- decl: void Sum(int len, const int *values)
  attrs:
      values:
          intent: in
          rank: 1
- decl: const std::string getName()
  fattrs:
      len: 30
```

Attributes must be added before default arguments since a default argument may include a plus symbol:

```
- decl: void Sum(int len, const int *values+rank(1)+intent(in) =nullptr)
```

4.3.1 assumedtype

When this attribute is applied to a `void *` argument, the Fortran assumed-type declaration, `type(*)`, will be used. Since Fortran defaults to pass-by-reference, the argument will be passed to C as a `void *` argument. The C function will need some other mechanism to determine the type of the argument before dereferencing the pointer. Note that *assumed-type* is part of Fortran 2018.

4.3.2 capsule

Name of capsule argument. Defaults to C_var_capsule_template.

4.3.3 cdesc

Pass argument from Fortran to C wrapper as a pointer to a context type. This struct contains the address, type, rank and size of the argument.

4.3.4 charlen

charlen is used to define the size of a `char *arg+intent(out)` argument in the Python wrapper. This deals with the case where `arg` is provided by the user and the function writes into the provided space. This technique has the inherent risk of overwritting memory if the supplied buffer is not long enough. For example, when used in C the user would write:

```
#define API_CHARLEN
char buffer[API_CHARLEN];
fill_buffer(buffer);
```

The Python wrapper must know the assumed length before calling the function. It will then be converted into a *str* object by `PyString_FromString`.

Fortran does not use this attribute since the *buffer* argument is supplied by the user. However, it is useful to provide the parameter by adding a splicer block in the YAML file:

```
splicer_code:
  f:
    module_top:
    -  "integer, parameter :: MAXNAME = 20"
```

Warning: Using *charlen* and *dimension* together is not currently supported.

4.3.5 default

Default value for C++ function argument. This value is implied by C++ default argument syntax.

4.3.6 deref

List how to dereference pointer arguments or function results. This may be used in conjunction with *dimension* to create arrays.

allocatable

For Fortran, add `ALLOCATABLE` attribute to argument. An `ALLOCATE` statement is added and the contents of the C++ argument is copied. If *owner(caller)* is also defined, the C++ argument is released. The caller is responsible to `DEALLOCATE` the array.

For Python, create a NumPy array (same as *pointer* attribute)

pointer

For *intent(in)* arguments, a `POINTER` Fortran attribute will be added. This allows a dynamic memory address to be passs to the library.

```
void giveMemory(arg *data +intent(in)+deref(pointer))
```

For *intent(out)* arguments this indicates that memory from the library is being passed back to the user and will be assigned using `c_f_pointer`.

If *owner(caller)* is also defined, an additional argument is added which is used to release the memory.

For Python, create a list or NumPy array.

```
- decl: double *ReturnPtrFun() +dimension(10)
- decl: void ReturnPtrArg(double **arg +intent(out)+dimension(10))

- decl: double *ReturnScalar() +deref(pointer)
```

A *pointer* to scalar will also return a NumPy array in Python. Use *+deref(scalar)* to get a scalar.

raw

For Fortran, return a `type(C_PTR)`.

For Python, return a `PyCapsule`.

scalar

Treat the pointee as a scalar. For Fortran, return a scalar and not a pointer to the scalar. For Python, this will not create a NumPy object.

4.3.7 dimension

A list of array extents for pointer or reference variables. All arrays use the language's default lower-bound (1 for Fortran and 0 for Python). Used to define the dimension of pointer arguments with *intent(out)* and function results. A dimension without any value is an error – `+dimension`.

The expression is evaluated in a C/C++ context.

```
struct {
  int len;
  double *array +dimension(len);
};
```

An expression can also contain a *intent(out)* argument of the function being wrapped.

```
int * get_array(int **count +intent(out)+hidden) +dimension(count)
```

Argument `count` will be used to define the shape of the function result but will not be part of the wrapped API since it is *hidden*.

rank and *dimension* can not be specified together.

4.3.8 external

This attribute is only valid with function pointers. It will ensure that a Fortran wrapper is created which uses the `external` statement for the argument. This will allow any function to be used as the dummy argument for the function pointer.

4.3.9 free_pattern

A name in the **patterns** section which lists code to be used to release memory. Used with function results. It is used in the *C_memory_dtor_function* and will have the variable `void *ptr` available as the pointer to the memory to be released. See *Memory Management* for details.

4.3.10 hidden

The argument will not appear in the Fortran API. But it will be passed to the C wrapper. This allows the value to be used in the C wrapper. For example, setting the shape of a pointer function:

```
int * ReturnIntPtr(int *len+intent(out)+hidden +dimension(len))
```

4.3.11 implied

The value of an arguments to the C++ function may be implied by other arguments. If so the *implied* attribute can be used to assign the value to the argument and it will not be included in the wrapped API.

Used to compute value of argument to C++ based on argument to Fortran or Python wrapper. Useful with array sizes:

```
int Sum(const int * array, int len +implied(size(array))
```

Several functions will be converted to the corresponding code for Python wrappers: `size`, `len` and `len_trim`.

4.3.12 intent

The Fortran intent of the argument. Valid values are `in`, `out`, `inout`.

in The argument will only be read from.

inout The argument will be read from and written to.

out The argument will be written to.

Nonpointer arguments can only be *intent(in)*. If the argument is `const`, the default is `in`.

In Python, *intent(out)* arguments are not used as input arguments to the function but are returned as values.

4.3.13 len

For a string argument, pass an additional argument to the C wrapper with the result of the Fortran intrinsic `len`. If a value for the attribute is provided it will be the name of the extra argument. If no value is provided then the argument name defaults to option *C_var_len_template*.

When used with a function, it will be the length of the return value of the function using the declaration:

```
character(kind=C_CHAR, len={c_var_len}) :: {F_result}
```

4.3.14 len_trim

For a string argument, pass an additional argument to the C wrapper with the result of the Fortran intrinsic `len_trim`. If a value for the attribute is provided it will be the name of the extra argument. If no value is provided then the argument name defaults to option *C_var_trim_template*.

4.3.15 name

Name of the method. Useful for constructor and destructor methods which have default names `ctor` and `dtor`. Also useful when class member variables use a convention such as `m_variable`. The *name* can be set to *variable* to avoid polluting the Fortran interface with the `m_` prefix. Fortran and Python both have an explicit scope of `self%variable` and `self.variable` instead of an implied `this`.

4.3.16 owner

Specifies who is responsible to release the memory associated with the argument/result.

The terms follow Python's reference counting . [Python_Refcount] The default is set by option *default_owner* which is initialized to *borrow*.

caller

The memory belongs to the user who is responsible to delete it. A shadow class must have a destructor wrapped in order to delete the memory.

library

The memory belongs to the library and should not be deleted by the user. This is the default value.

4.3.17 pass

Used to define the argument which is the passed-object dummy argument for type-bound procedures when treating a struct as a class. In C, which does not support the `class` keyword, a `struct` can be used as a class by defining option `wrap_struct_as=class`. Other functions can be associated with the class by setting option `class_method` to the name of the struct.

4.3.18 rank

Add an assumed-shape dimension with the given rank. *rank* must be 0-7. A rank of 0 implies a scalar argument.

```
double *array +rank(2)
```

Creates the declaration:

```
real(C_DOUBLE) :: array(:,:)
```

Use with `+intent(in)` arguments when the wrapper should accept any extent instead of using Fortran's assumed-shape with `dimension(:)`.

This can be simpler than the *dimension* attribute for multidimension arrays. *rank* and *dimension* can not be specified together.

4.3.19 readonly

May be added to struct or class member to avoid creating a setter function. If the member is *const*, this attribute is added by Shroud.

4.3.20 value

If true, pass-by-value; else, pass-by-reference. This attribute is implied when the argument is not a pointer or reference. This will also default to `intent(IN)` since there is no way to return a value.

Note: The Fortran wrapper may use an intrinsic function for some attributes. For example, *len*, *len_trim*, and *size*. If there is an argument with the same name, the generated code may not compile.

Shroud preserves the names of the arguments since Fortran allows them to be used in function calls - `call worker(len=10)`

4.4 Statements

The code generated for each argument and return value can be controlled by statement dictionaries. Shroud has many entries built in which are used for most arguments. But it is possible to add custom code to the wrapper by providing additional fields. Most wrappers will not need to provide this information.

An example from strings.yaml:

```
- decl: const string * getConstStringPtrLen() +len=30
  doxygen:
    brief: return a 'const string *' as character(30)
    description: |
      It is the caller's responsibility to release the string
      created by the C++ library.
      This is accomplished with C_finalize_buf which is possible
      because +len(30) so the contents are copied before returning.
  fstatements:
    c_buf:
      final:
      - delete {cxx_var};
```

An example from vectors.yaml:

```
- decl: void vector_iota_out_with_num(std::vector<int> &arg+intent(out))
  fstatements:
    c_buf:
      return_type: long
      ret:
      - return Darg->size;
    f:
      result: num
      f_module:
        iso_c_binding: ["C_LONG"]
      declare:
      -  "integer(C_LONG) :: {F_result}"
      call:
      -  "{F_result} = {F_C_call}({F_arg_c_call})"
```

4.5 Patterns

To address the issue of semantic differences between Fortran and C++, *patterns* may be used to insert additional code. A *pattern* is a code template which is inserted at a specific point in the wrapper. They are defined in the input YAML file:

```
declarations:
- decl: const string& getString2+len=30()
  C_error_pattern: C_invalid_name

patterns:
  C_invalid_name: |
      if ({cxx_var}.empty()) {{
          return NULL;
      }}
```

The **C_error_pattern** will insert code after the call to the C++ function in the C wrapper and before any post_call sections from the types. The bufferified version of a function will append `_buf` to the **C_error_pattern** value. The *pattern* is formatted using the context of the return argument if present, otherwise the context of the function is used. This means that *c_var* and *c_var_len* refer to the argument which is added to contain the function result for the `_buf` pattern.

The function `getString2` is returning a `std::string` reference. Since C and Fortran cannot deal with this directly, the empty string is converted into a `NULL` pointer:: will blank fill the result:

```
const char * STR_get_string2()
{
    const std::string & SHCXX_rv = getString2();
    // C_error_pattern
    if (SHCXX_rv.empty()) {
        return NULL;
    }
    const char * SHC_rv = SHCXX_rv.c_str();
    return SHC_rv;
}
```

4.6 Splicers

No matter how many features are added to Shroud there will always exist cases that it does not handle. One of the weaknesses of generated code is that if the generated code is edited it becomes difficult to regenerate the code and preserve the edits. To deal with this situation each block of generated code is surrounded by 'splicer' comments:

```
const char * STR_get_char3()
{
    // splicer begin function.get_char3
    const char * SH_rv = getChar3();
    return SH_rv;
    // splicer end function.get_char3
}
```

These comments delineate a section of code which can be replaced by the user. The splicer's name, `function.get_char3` in the example, is used to determine where to insert the code.

There are two ways to define splicers in the YAML file. First add a list of files which contain the splicer text:

```
splicer:
  f:
  -  fsplicer.f
  c:
  -  csplicer.c
```

In the listed file, add the begin and end splicer comments, then add the code which should be inserted into the wrapper inbetween the comments. Multiple splicer can be added to an input file. Any text that is not within a splicer block is ignored. Splicers must be sorted by language. If the input file ends with `.f` or `.f90` it is processed as splicers for the generated Fortran code. Code for the C wrappers must end with any of `.c`, `.h`, `.cpp`, `.hpp`, `.cxx`, `.hxx`, `.cc`, `.C`:

```
-- Lines outside blocks are ignore
// splicer begin function.get_char3
const char * SH_rv = getChar3();
SH_rv[0] = 'F';    // replace first character for Fortran
return SH_rv + 1;
// splicer end function.get_char3
```

This technique is useful when the splicers are very large or are generated by some other process.

The second method is to add the splicer code directly into the YAML file. A splicer can be added after the `decl` line. This splicer takes priority over other ways of defining splicers.

```
- decl: bool isNameValid(const std::string& name)
  splicer:
     c:
     - "return name != NULL;"
     f:
     - 'rv = name .ne. " "'
```

A splicer can be added in the `splicer_code` section. This can be used to add code to spliers which do not correspond directly to a declaration. Each level of splicer is a mapping and each line of text is an array entry:

```
splicer_code:
  c:
    function:
      get_char3:
      - const char * SH_rv = getChar3();
```

(continues on next page)

(continued from previous page)

```
      - SH_rv[0] = 'F';    // replace first character for Fortran
      - return SH_rv + 1;
```

In addition to replacing code for a function wrapper, there are splicers that are generated which allow a user to insert additional code for helper functions or declarations:

```
! file_top
module {F_module_name}
   ! module_use
   implicit none
   ! module_top

   type class1
     ! class.{cxx_class}.component_part
   contains
     ! class.{cxx_class}.generic.{F_name_generic}
     ! class.{cxx_class}.type_bound_procedure_part
   end type class1

   interface
      ! additional_interfaces
   end interface

   contains

   ! function.{F_name_function}

   ! {cxx_class}.method.{F_name_function}

   ! additional_functions

end module {F_module_name}
```

C header:

```
// class.{class_name}.CXX_declarations

extern "C" {
// class.{class_name}.C_declarations
}
```

C implementation:

```
// class.{class_name}.CXX_definitions

extern "C" {
  // class.{class_name}.C_definitions

  // function.{underscore_name}{function_suffix}

  // class.{cxx_class}.method.{underscore_name}{function_suffix}

}
```

The splicer comments can be eliminated by setting the option **show_splicer_comments** to false. This may be useful to eliminate the clutter of the splicer comments.

CHAPTER 5

Pointers and Arrays

Shroud will create code to map between C and Fortran pointers. The *interoperability with C* features of Fortran 2003 and the call-by-reference feature of Fortran provides most of the features necessary to pass arrays to C++ libraries. Shroud can also provide additional semantic information. Adding the `+rank(n)` attribute will declare the argument as an assumed-shape array with the given rank: `+rank(2)` creates `arg(:,:)`. The `+dimension(n)` attribute will instead give an explicit dimension: `+dimension(10,20)` creates `arg(10,20)`.

Using *dimension* on *intent(in)* arguments will use the dimension shape in the Fortran wrapper instead of assumed-shape. This adds some additional safety since many compiler will warn if the actual argument is too small. This is useful when the C++ function has an assumed shape. For example, it expects a pointer to 16 elements. The Fortran wrapper will pass a pointer to contiguous memory with no explicit shape information.

When a function returns a pointer, the default behavior of Shroud is to convert it into a Fortran variable with the `POINTER` attribute using `c_f_pointer`. This can be made explicit by adding `+deref(pointer)` to the function declaration in the YAML file. For example, `int *getData(void) +deref(pointer)` creates the Fortran function interface

```
function get_data() result(rv)
    integer(C_INT), pointer :: rv
end function get_data
```

The result of the the Fortran function directly accesses the memory returned from the C++ library.

An array can be returned by adding the attribute `+dimension(n)` to the function. The dimension expression will be used to provide the `shape` argument to `c_f_pointer`. The arguments to *dimension* are C++ expressions which are evaluated after the C++ function is called and can be the name of another argument to the function or call another C++ function. As a simple example, this declaration returns a pointer to a constant sized array.

```
- decl: int *returnIntPtrToFixedArray(void) +dimension(10)
```

If the dimension is unknown when the function returns, a `type(C_PTR)` can be returned with `+deref(raw)`. This will allow the user to call `c_f_pointer` once the shape is known. Instead of a Fortran pointer to a scalar, a scalar can be returned by adding `+deref(scalar)`.

A common idiom for C++ is to return pointers to memory via arguments. This would be declared as `int **arg +intent(out)`. By default, Shroud treats the argument similar to a function which returns a pointer: it adds the

deref(pointer) attribute to treats it as a `POINTER` to a scalar. The *dimension* attribute can be used to create an array similar to a function result.

Function which return multiple layers of indirection will return a `type(C_PTR)`. This is also true for function arguments beyond `int **arg +intent(out)`. This pointer can represent non-contiguous memory and Shroud has no way to know the extend of each pointer in the array.

A special case is provided for arrays of *NULL* terminated strings, `char **`. While this also represents non-contiguous memory, it is a common idiom and can be processed since the length of each string can be found with `strlen`. See example *acceptCharArrayIn*.

Shroud can be made to allocate an array before the C++ library is called using `deref(allocatable)`. For example, `int **arg +intent(out)+deref(allocatable)+dimension(n)`. The value of the *dimension* attribute is used to define the shape of the array and must be know before the library function is called. The *dimension* attribute can include the Fortran intrinsic `size` to define the shape in terms of another array. This is more useful in Python since *intent(out)* arguments are not used in the function call and instead they are returned by the function. In Fortran, it is easier to pass in the array and allow the C++ library function to fill it directly.

Python wrappers add some additional requirements on attributes. Python will create NumPy arrays for *intent(out)* arguments but require an explicit shape using *dimension* attribute. Fortran passes in an argument for *intent(out)* arguments which will be filled by the C++ library. However, Python will need to create the NumPy array before calling the C++ function. For example, using `+intent(out)+rank(1)` will have problems.

`char *` functions are treated differently. By default *deref* attribute will be set to *allocatable*. After the C++ function returns, a `CHARACTER` variable will be allocated and the contents copied. This will convert a `NULL` terminated string into the proper length of Fortran variable. For very long strings or strings with embedded `NULL`, `deref(raw)` will return a `type(C_PTR)`.

`void *` functions return a `type(C_PTR)` argument and cannot have *deref*, *dimension*, or *rank* attributes. A `type(C_PTR)` argument will be passed by value. For a `void **` argument, the `type(C_PTR)` will be passed by reference (the default). This will allow the C wrapper to assign a value to the argument. See example *passVoidStarStar*.

If the C++ library function can also provide the length of the pointer, then its possible to return a Fortran `POINTER` or `ALLOCATABLE` variable. This allows the caller to directly use the returned value of the C++ function. However, there is a price; the user will have to release the memory if *owner(caller)* is set. To accomplish this with `POINTER` arguments, an additional argument is added to the function which contains information about how to delete the array. If the argument is declared Fortran `ALLOCATABLE`, then the value of the C++ pointer are copied into a newly allocated Fortran array. The C++ memory is deleted by the wrapper and it is the callers responsibility to `deallocate` the Fortran array. However, Fortran will release the array automatically under some conditions when the caller function returns. If *owner(library)* is set, the Fortran caller never needs to release the memory.

See *Memory Management* for details of the implementation.

A void pointer may also be used in a C function when any type may be passed in. The attribute *assumedtype* can be used to declare a Fortran argument as assumed-type: `type(*)`.

```
- decl: int passAssumedType(void *arg+assumedtype)
```

```
function pass_assumed_type(arg) &
        result(SHT_rv) &
        bind(C, name="passAssumedType")
    use iso_c_binding, only : C_INT, C_PTR
    implicit none
    type(*) :: arg
    integer(C_INT) :: SHT_rv
end function pass_assumed_type
```

5.1 Memory Management

Shroud will maintain ownership of memory via the **owner** attribute. It uses the value of the attribute to decided when to release memory.

Use **owner(library)** when the library owns the memory and the user should not release it. For example, this is used when a function returns `const std::string &` for a reference to a string which is maintained by the library. Fortran and Python will both get the reference, copy the contents into their own variable (Fortran `CHARACTER` or Python `str`), then return without releasing any memory. This is the default behavior.

Use **owner(caller)** when the library allocates new memory which is returned to the caller. The caller is then responsible to release the memory. Fortran and Python can both hold on to the memory and then provide ways to release it using a C++ callback when it is no longer needed.

For shadow classes with a destructor defined, the destructor will be used to release the memory.

The *c_statements* may also define a way to destroy memory. For example, `std::vector` provides the lines:

```
destructor_name: std_vector_{cxx_T}
destructor:
-  std::vector<{cxx_T}> *cxx_ptr = reinterpret_cast<std::vector<{cxx_T}> *>(ptr);
-  delete cxx_ptr;
```

Patterns can be used to provide code to free memory for a wrapped function. The address of the memory to free will be in the variable `void *ptr`, which should be referenced in the pattern:

```
declarations:
- decl: char * getName() +free_pattern(free_getName)

patterns:
   free_getName: |
      decref(ptr);
```

Without any explicit *destructor_name* or pattern, `free` will be used to release POD pointers; otherwise, `delete` will be used.

5.2 C and Fortran

Fortran keeps track of C++ objects with the struct **C_capsule_data_type** and the `bind(C)` equivalent **F_capsule_data_type**. Their names in the format dictionary default to `{C_prefix}SHROUD_capsule_data` and `{C_prefix}SHROUD_capsule_data`. In the Tutorial these types are defined in `typesTutorial.h` as:

```
// helper capsule_CLA_Class1
struct s_CLA_Class1 {
    void *addr;     /* address of C++ memory */
    int idtor;      /* index of destructor */
};
typedef struct s_CLA_Class1 CLA_Class1;
```

And `wrapftutorial.f`:

```
! helper capsule_data_helper
type, bind(C) :: CLA_SHROUD_capsule_data
    type(C_PTR) :: addr = C_NULL_PTR  ! address of C++ memory
    integer(C_INT) :: idtor = 0       ! index of destructor
end type CLA_SHROUD_capsule_data
```

addr is the address of the C or C++ variable, such as a `char *` or `std::string *`. *idtor* is a Shroud generated index of the destructor code defined by *destructor_name* or the *free_pattern* attribute. These code segments are collected and written to function *C_memory_dtor_function*. A value of 0 indicated the memory will not be released and is used with the **owner(library)** attribute.

Each class creates its own capsule struct for the C wrapper. This is to provide a measure of type safety in the C API. All Fortran classes use the same derived type since the user does not directly access the derived type.

A typical destructor function would look like:

```
// Release library allocated memory.
void TUT_SHROUD_memory_destructor(TUT_SHROUD_capsule_data *cap)
{
    void *ptr = cap->addr;
    switch (cap->idtor) {
    case 0:   // --none--
    {
        // Nothing to delete
        break;
    }
    case 1:   // new_string
    {
        std::string *cxx_ptr = reinterpret_cast<std::string *>(ptr);
        delete cxx_ptr;
        break;
    }
    default:
    {
        // Unexpected case in destructor
        break;
    }
    }
    cap->addr = nullptr;
    cap->idtor = 0;  // avoid deleting again
}
```

5.2.1 Character and Arrays

In order to create an allocatable copy of a C++ pointer, an additional structure is involved. For example, `getConstStringPtrAlloc` returns a pointer to a new string. From `strings.yaml`:

```
declarations:
- decl: const std::string * getConstStringPtrAlloc() +owner(library)
```

The C wrapper calls the function and saves the result along with metadata consisting of the address of the data within the `std::string` and its length. The Fortran wrappers allocates its return value to the proper length, then copies the data from the C++ variable and deletes it.

The metadata for variables are saved in the C struct **C_array_type** and the `bind(C)` equivalent **F_array_type**.:

```
// helper array_context
struct s_STR_SHROUD_array {
    STR_SHROUD_capsule_data cxx;      /* address of C++ memory */
    union {
        const void * base;
        const char * ccharp;
    } addr;
```

(continues on next page)

(continued from previous page)

```
    int type;         /* type of element */
    size_t elem_len; /* bytes-per-item or character len in c++ */
    size_t size;      /* size of data in c++ */
    int rank;         /* number of dimensions, 0=scalar */
    long shape[7];
};
typedef struct s_STR_SHROUD_array STR_SHROUD_array;
```

The union for `addr` makes some assignments easier by removing the need for casts and also aids debugging. The union is replaced with a single `type(C_PTR)` for Fortran:

```
! helper array_context
type, bind(C) :: STR_SHROUD_array
    ! address of C++ memory
    type(STR_SHROUD_capsule_data) :: cxx
    ! address of data in cxx
    type(C_PTR) :: base_addr = C_NULL_PTR
    ! type of element
    integer(C_INT) :: type
    ! bytes-per-item or character len of data in cxx
    integer(C_SIZE_T) :: elem_len = 0_C_SIZE_T
    ! size of data in cxx
    integer(C_SIZE_T) :: size = 0_C_SIZE_T
    ! number of dimensions
    integer(C_INT) :: rank = -1
    integer(C_LONG) :: shape(7) = 0
end type STR_SHROUD_array
```

The C wrapper does not return a `std::string` pointer. Instead it passes in a **C_array_type** pointer as an argument. It calls `getConstStringPtrAlloc`, saves the results and metadata into the argument. This allows it to be easily accessed from Fortran. Since the attribute is **owner(library)**, `cxx.idtor` is set to `0` to avoid deallocating the memory.

```
void STR_get_const_string_ptr_alloc_bufferify(STR_SHROUD_array *DSHF_rv)
{
    // splicer begin function.get_const_string_ptr_alloc_bufferify
    const std::string * SHCXX_rv = getConstStringPtrAlloc();
    ShroudStrToArray(DSHF_rv, SHCXX_rv, 0);
    // splicer end function.get_const_string_ptr_alloc_bufferify
}
```

The Fortran wrapper uses the metadata to allocate the return argument to the correct length:

```
function get_const_string_ptr_alloc() &
        result(SHT_rv)
    type(STR_SHROUD_array) :: DSHF_rv
    character(len=:), allocatable :: SHT_rv
    ! splicer begin function.get_const_string_ptr_alloc
    call c_get_const_string_ptr_alloc_bufferify(DSHF_rv)
    allocate(character(len=DSHF_rv%elem_len):: SHT_rv)
    call STR_SHROUD_copy_string_and_free(DSHF_rv, SHT_rv, DSHF_rv%elem_len)
    ! splicer end function.get_const_string_ptr_alloc
end function get_const_string_ptr_alloc
```

Finally, the helper function `SHROUD_copy_string_and_free` is called to set the value of the result and possible free memory for **owner(caller)** or intermediate values:

```
// helper copy_string
// Copy the char* or std::string in context into c_var.
// Called by Fortran to deal with allocatable character.
void STR_ShroudCopyStringAndFree(STR_SHROUD_array *data, char *c_var, size_t c_var_
↪len) {
    const char *cxx_var = data->addr.ccharp;
    size_t n = c_var_len;
    if (data->elem_len < n) n = data->elem_len;
    std::strncpy(c_var, cxx_var, n);
    STR_SHROUD_memory_destructor(&data->cxx); // delete data->cxx.addr
}
```

Note: The three steps of call, allocate, copy could be replaced with a single call by using the *futher interoperability with C* features of Fortran 2018 (a.k.a TS 29113). This feature allows Fortran `ALLOCATABLE` variables to be allocated by C. However, not all compilers currently support that feature. The current Shroud implementation works with Fortran 2003.

5.3 Python

NumPy arrays control garbage collection of C++ memory by creating a `PyCapsule` as the base object of NumPy objects. Once the final reference to the NumPy array is removed, the reference count on the `PyCapsule` is decremented. When 0, the *destructor* for the capsule is called and releases the C++ memory. This technique is discussed at [blog1] and [blog2]

5.4 Old

Note: C_finalize is replaced by statement.final

Shroud generated C wrappers do not explicitly delete any memory. However a destructor may be automatically called for some C++ stl classes. For example, a function which returns a `std::string` will have its value copied into Fortran memory since the function's returned object will be destroyed when the C++ wrapper returns. If a function returns a `char *` value, it will also be copied into Fortran memory. But if the caller of the C++ function wants to transfer ownership of the pointer to its caller, the C++ wrapper will leak the memory.

The **C_finalize** variable may be used to insert code before returning from the wrapper. Use **C_finalize_buf** for the buffer version of wrapped functions.

For example, a function which returns a new string will have to `delete` it before the C wrapper returns:

```
std::string * getConstStringPtrLen()
{
    std::string * rv = new std::string("getConstStringPtrLen");
    return rv;
}
```

Wrapped as:

```
- decl: const string * getConstStringPtrLen+len=30()
  format:
    C_finalize_buf: delete {cxx_var};
```

The C buffer version of the wrapper is:

```
void STR_get_const_string_ptr_len_bufferify(char * SHF_rv, int NSHF_rv)
{
    const std::string * SHCXX_rv = getConstStringPtrLen();
    if (SHCXX_rv->empty()) {
        std::memset(SHF_rv, ' ', NSHF_rv);
    } else {
        ShroudStrCopy(SHF_rv, NSHF_rv, SHCXX_rv->c_str());
    }
    {
        // C_finalize
        delete SHCXX_rv;
    }
    return;
}
```

The unbuffer version of the function cannot `destroy` the string since only a pointer to the contents of the string is returned. It would leak memory when called:

```
const char * STR_get_const_string_ptr_len()
{
    const std::string * SHCXX_rv = getConstStringPtrLen();
    const char * SHC_rv = SHCXX_rv->c_str();
    return SHC_rv;
}
```

CHAPTER 6

Types

6.1 Numeric Types

The numeric types usually require no conversion. In this case the type map is mainly used to generate declaration code for wrappers:

```
type: int
fields:
    c_type: int
    cxx_type: int
    f_type: integer(C_INT)
    f_kind: C_INT
    f_module:
        iso_c_binding:
        - C_INT
    f_cast: int({f_var}, C_INT)
```

One case where a conversion is required is when the Fortran argument is one type and the C++ argument is another. This may happen when an overloaded function is generated so that a `C_INT` or `C_LONG` argument may be passed to a C++ function function expecting a `long`. The **f_cast** field is used to convert the argument to the type expected by the C++ function.

6.2 Bool

The first thing to notice is that **f_c_type** is defined. This is the type used in the Fortran interface for the C wrapper. The type is `logical(C_BOOL)` while **f_type**, the type of the Fortran wrapper argument, is `logical`.

The **f_statements** section describes code to add into the Fortran wrapper to perform the conversion. *c_var* and *f_var* default to the same value as the argument name. By setting **c_local_var**, a local variable is generated for the call to the C wrapper. It will be named `SH_{f_var}`.

There is no Fortran intrinsic function to convert between default `logical` and `logical(C_BOOL)`. The **pre_call** and **post_call** sections will insert an assignment statement to allow the compiler to do the conversion.

If a function returns a `bool` result then a wrapper is always needed to convert the result. The **result** section sets **need_wrapper** to force the wrapper to be created. By default a function with no argument would not need a wrapper since there will be no **pre_call** or **post_call** code blocks. Only the C interface would be required since Fortran could call the C function directly.

See example *checkBool*.

6.3 Char

Any C++ function which has `char` or `std::string` arguments or result will create an additional C function which include additional arguments for the length of the strings. Most Fortran compiler use this convention when passing `CHARACTER` arguments. Shroud makes this convention explicit for three reasons:

- It allows an interface to be used. Functions with an interface will not pass the hidden, non-standard length argument, depending on compiler.
- It may pass the result of `len` and/or `len_trim`. The convention just passes the length.
- Returning character argument from C to Fortran is non-portable.

Arguments with the *intent(in)* annotation are given the *len_trim* annotation. The assumption is that the trailing blanks are not part of the data but only padding. Return values and *intent(out)* arguments add a *len* annotation with the assumption that the wrapper will copy the result and blank fill the argument so it need to know the declared length.

The additional function will be named the same as the original function with the option **C_bufferify_suffix** appended to the end. The Fortran wrapper will use the original function name, but call the C function which accepts the length arguments.

The character type maps use the **c_statements** section to define code which will be inserted into the C wrapper. *intent_in*, *intent_out*, and *result* subsections add actions for the C wrapper. *intent_in_buf*, *intent_out_buf*, and *result_buf* are used for arguments with the *len* and *len_trim* annotations in the additional C wrapper.

There are occasions when the *bufferify* wrapper is not needed. For example, when using `char *` to pass a large buffer. It is better to just pass the address of the argument instead of creating a copy and appending a `NULL`. The **F_create_bufferify_function** options can set to *false* to turn off this feature.

6.3.1 Char

`Ndest` is the declared length of argument `dest` and `Lsrc` is the trimmed length of argument `src`. These generated names must not conflict with any other arguments. There are two ways to set the names. First by using the options **C_var_len_template** and **C_var_trim_template**. This can be used to control how the names are generated for all functions if set globally or just a single function if set in the function's options. The other is by explicitly setting the *len* and *len_trim* annotations which only effect a single declaration.

The pre_call code creates space for the C strings by allocating buffers with space for an additional character (the `NULL`). The *intent(in)* string copies the data and adds an explicit terminating `NULL`. The function is called then the post_call section copies the result back into the `dest` argument and deletes the scratch space. `ShroudStrCopy` is a function provided by Shroud which copies character into the destination up to `Ndest` characters, then blank fills any remaining space.

6.4 MPI_Comm

MPI_Comm is provided by Shroud and serves as an example of how to wrap a non-native type. MPI provides a Fortran interface and the ability to convert MPI_comm between Fortran and C. The type map tells Shroud how to use these

routines:

```
type: MPI_Comm
fields:
    cxx_type: MPI_Comm
    c_header: mpi.h
    c_type: MPI_Fint
    f_type: integer
    f_kind: C_INT
    f_c_type: integer(C_INT)
    f_c_module:
        iso_c_binding:
          - C_INT
    cxx_to_c: MPI_Comm_c2f({cxx_var})
    c_to_cxx: MPI_Comm_f2c({c_var})
```

This mapping makes the assumption that `integer` and `integer(C_INT)` are the same type.

CHAPTER 7

Namespaces

Namespaces in C++ are used to ensure the symbols in a library will not conflict with any symbols in another library. Fortran and Python both use a module to accomplish the same thing.

The global variable *namespace* is a blank delimited list of namespaces used as the initial namespace. This namespace will be used when accessing symbols in the library, but it will not be used when generating names for wrapper functions.

For example, the library `wrapped` is associated with the namespace `outer`. There are three functions all with the same name, `worker`. In C++ these functions are accessed by using a fully qualified name: `outer::worker`, `outer::innter1::worker` and `outer::inner2::worker`.

```
namespace outer {
  namespace inner1 {
    void worker();
  } // namespace inner1

  namespace inner2 {
    void worker();
  }  // namespace inner2

  void worker();
} // namespace outer
```

The YAML file would look like:

```
library: wrapped
namespace: outer
format:
  C_prefix: WWW_

declarations:
- decl: namespace inner1
  declarations:
  - decl: void worker();
```

(continues on next page)

(continued from previous page)

```
- decl: namespace inner2
  declarations:
  - decl: void worker();
- decl: void worker();
```

For each namespace, Shroud will generate a C++ header file, a C++ implementation file, a Fortran file and a Python file. The nested namespaces are added to the format field *C_name_scope*.

For the C wrapper, all symbols are globally visible and must be unique. The format fields *C_prefix* and *C_name_scope* are used to generate the names. This will essentiall "flatten* the namespaces into legal C identifiers.

```
void WWW_worker();
void WWW_inner1_worker();
void WWW_inner2_worker();
```

In Fortran each namespace creates a module. Each module will have a function named *worker*. This makes the user responsible for distinguising which implementation of *worker* is to be called.

```
subroutine work1
  ! Use a single module, unambiguous
  use wrapped_mod
  call worker
end subroutine work1

subroutine work2
  ! Rename symbol from namespace inner1
  use wrapped_mod
  use wrapped_inner1_mod, inner_worker => worker
  call worker
  call inner_worker
end subroutine work2
```

Each namespace creates a Python module.

```
import wrapped
wrapped.worker()
wrapped.inner1.worker()
```

Several fields in the format dictionary are updated for each namespace: *namespace_scope*, *C_name_scope*, *F_name_scope*.

7.1 std namespace

Shroud has builtin support for `std::string` and `std::vector`.

CHAPTER 8

Structs and Classes

All problems in computer science can be solved by another level of indirection. — David Wheeler

Classes are wrapped by a shadow derived-type with methods implemented as type-bound procedures in Fortran and an extension type in Python.

8.1 Class

Each class in the input file will create a struct which acts as a shadow class for the C++ class. A pointer to an instance is saved in the shadow class. This pointer is then passed down to the C++ routines to be used as the *this* instance.

Using the tutorial as an example, a simple class is defined in the C++ header as:

```
class Class1
{
public:
    void Method1() {};
};
```

And is wrapped in the YAML as:

```
declarations:
- decl: class Class1
  declarations:
  - decl: int Method1()
```

8.1.1 Fortran

The Fortran interface will create two derived types. The first is used to interact with the C wrapper and uses `bind(C)`. The C wrapper creates a corresponding struct. It contains a pointer to an instance of the class and index used to release the instance. The `idtor` argument is described in *Memory Management*.

`wrapfclasses.f`

```
! helper capsule_data_helper
type, bind(C) :: CLA_SHROUD_capsule_data
    type(C_PTR) :: addr = C_NULL_PTR  ! address of C++ memory
    integer(C_INT) :: idtor = 0       ! index of destructor
end type CLA_SHROUD_capsule_data
```

typeclasses.h

```
// helper capsule_CLA_Class1
struct s_CLA_Class1 {
    void *addr;     /* address of C++ memory */
    int idtor;      /* index of destructor */
};
typedef struct s_CLA_Class1 CLA_Class1;
```

The capsule is added to the Fortran shadow class. This derived type can contain type-bound procedures and may not use the `bind(C)` attribute.

```
type class1
    type(SHROUD_CLA_capsule_data) :: cxxmem
contains
    procedure :: method1 => class1_method1
end type class1
```

A function which returns a class, including constructors, is passed a pointer to a *F_capsule_data_type*. The argument's members are filled in by the function. The function will return a `type(C_PTR)` which contains the address of the *F_capsule_data_type* argument. The interface/prototype for the C wrapper function allows it to be used in expressions similar to the way that `strcpy` returns its destination argument.

A generic interface with the same name as the class is created to call the constructors for the class. The constructor will initialize the Fortran derived type.

```
type(class1) var      ! Create Fortran variable.
var = class1()        ! Allocate C++ class instance.
```

When the constructor is wrapped the destructor should also be wrapper or some other method is provided to release the memory.

Some other type-bound precedures are created to allow the user to get and set the address of the C++ memory directly. This can be used when the address of the instance is created in some other manner (perhaps a C++ module in the application) and it needs to be used in Fortran without being created in Fortran. There is no way to free this memory and must be released outside of Fortran.

```
type(class1) var
type(C_PTR) addr

addr = var%get_instance()
! addr will not be c_associated
call var%set_instance(caddr)    ! caddr contains address of an instance
```

Two instances of the class can be compared using the `associated` method.

```
type(class1) var1, var2
var1 = get_class(1)    ! A library function to fetch an instance
var2 = get_class(2)
if (var1%associated(var2) then
    print *, "Identical instances"
endif
```

A full example is at *Constructor and Destructor*.

Inheritance is implemented using the `EXTENDS` Fortran keyword. Only single inheritance is supported.

```
type shape
    type(CLA_SHROUD_capsule_data) :: cxxmem
contains
    procedure :: get_ivar => shape_get_ivar
end type shape

type, extends(shape) :: circle
end type circle
```

8.1.2 Python

An struct is created for each C++ class.

```
typedef struct {
PyObject_HEAD
    classes::Class1 * obj;
    int idtor;
    // splicer begin class.Class1.C_object
    // splicer end class.Class1.C_object
} PY_Class1;
```

The `idtor` argument is used to release memory and described at *Memory Management*. The splicer allows additional fields to be added by the developer which may be used in function wrappers.

8.1.3 Forward Declaration

A class may be forward declared by omitting `declarations`. All other fields, such as `format` and `options` must be provided on the initial `decl` of a Class. This will define the type and allow it to be used in following declarations. The class's declarations can be added later:

```
declarations:
- decl: class Class1
  options:
     foo: True

- decl: class Class2
  declarations:
  - decl: void accept1(Class1 & arg1)

- decl: class Class1
  declarations:
  - decl: void accept2(Class2 & arg2)
```

8.1.4 Constructor and Destructor

The constructor and destuctor methods may also be exposed to Fortran.

The class example from the tutorial is:

```
declarations:
- decl: class Class1
  declarations:
  - decl: Class1()          +name(new)
    format:
      function_suffix: _default
  - decl: Class1(int flag) +name(new)
    format:
    function_suffix: _flag
  - decl: ~Class1() +name(delete)
```

The default name of the constructor is `ctor`. The name can be specified with the **name** attribute. If the constructor is overloaded, each constructor must be given the same **name** attribute. The *function_suffix* must not be explicitly set to blank since the name is used by the `generic` interface.

The constructor and destructor will only be wrapped if explicitly added to the YAML file to avoid wrapping `private` constructors and destructors.

The Fortran wrapped class can be used very similar to its C++ counterpart.

```
use tutorial_mod
type(class1) obj
integer(C_INT) i

obj = class1_new()
i = obj%method1()
call obj%delete
```

For wrapping details see *Constructor and Destructor*.

8.1.5 Member Variables

For each member variable of a C++ class a C and Fortran wrapper function will be created to get or set the value. The Python wrapper will create a descriptor:

```
class Class1
{
public:
   int m_flag;
   int m_test;
};
```

It is added to the YAML file as:

```
- decl: class Class1
  declarations:
  - decl: int m_flag +readonly;
  - decl: int m_test +name(test);
```

The *readonly* attribute will not write the setter function or descriptor. Python will report:

```
>>> obj = tutorial.Class1()
>>> obj.m_flag =1
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
AttributeError: attribute 'm_flag' of 'tutorial.Class1' objects is not writable
```

The *name* attribute will change the name of generated functions and descriptors. This is helpful when using a naming convention like `m_test` and you do not want `m_` to be used in the wrappers.

For wrapping details see *Getter and Setter*.

8.2 Struct

Shroud supports both structs and classes. But it treats them much differently. Whereas in C++ a struct and class are essentially the same thing, Shroud treats structs as a C style struct. They do not have associated methods. This allows them to be mapped to a Fortran derived type with the `bind(C)` attribute and a Python NumPy array.

A struct is defined the same as a class with a *declarations* field for struct members. In addition, a struct can be defined in a single `decl` in the YAML file.

```
- decl: struct Cstruct1 {
          int ifield;
          double dfield;
        };
```

8.2.1 Fortran

This is translated directly into a Fortran derived type with the `bind(C)` attribute.

```
type, bind(C) :: cstruct1
    integer(C_INT) :: ifield
    real(C_DOUBLE) :: dfield
end type cstruct1
```

All creation and access of members can be done using Fortran.

```
type(cstruct1) st(2)

st(1)%ifield = 1_C_INT
st(1)%dfield = 1.5_C_DOUBLE
st(2)%ifield = 2_C_INT
st(2)%dfield = 2.6_C_DOUBLE
```

The option *wrap_struct_as* can be set to *class* to create a shadow type identical to how classes are wrapped. This is useful when wrapping C code which does not support `class` directly. *wrap_struct_as* defaults to *struct* which will create a derived type. *wrap_class_as* also exists and defaults to *class*.

8.2.2 Python

Python can treat a struct in several different ways by setting option *PY_struct_arg*. First, treat it the same as a class. An extension type is created with descriptors for the field methods. Second, as a numpy descriptor. This allows an array of structs to be used easily. Finally, as a tuple of Python types.

When treated as a class, a constructor is created which will create an instance of the class. This is similar to the default constructor for structs in C++ but will also work with a C struct.

```
import cstruct
a = cstruct.Cstruct1(1, 2.5)
a = cstruct.Cstruct1()
```

When treated as a NumPy array no memory will be copied since the NumPy array contains a pointer to the C++ memory.

```
import cstruct
dt = cstruct.Cstruct1_dtype
a = np.array([(1, 1.5), (2, 2.6)], dtype=dt)
```

The descriptor is created in the wrapper *NumPy Struct Descriptor*.

CHAPTER 9

Templates

Shroud will wrap templated classes and functions for explicit instantiations. The template is given as part of the `decl` and the instantations are listed in the `cxx_template` section:

```
- decl: |
      template<typename ArgType>
      void Function7(ArgType arg)
  cxx_template:
  - instantiation: <int>
  - instantiation: <double>
```

`options` and `format` may be provide to control the generated code:

```
- decl: template<typename T> class vector
  cxx_header: <vector>
  cxx_template:
  - instantiation: <int>
    format:
      C_impl_filename: wrapvectorforint.cpp
    options:
      optblah: two
  - instantiation: <double>
```

For a class template, the *class_name* is modified to included the instantion type. If only a single template parameter is provided, then the template argument is used. For the above example, *C_impl_filename* will default to `wrapvector_int.cpp` but has been explicitly changed to `wrapvectorforint.cpp`.

CHAPTER 10

Declarations

In order for Shroud to create an idiomatic wrapper, it needs to know how arguments are intended to be used. This information is supplied via attributes. This section describes how to describe the arguments to Shroud in order to implement the desired semantic.

10.1 No Arguments

A function with no arguments and which does not return a value, can be "wrapped" by creating a Fortran interface which allows the function to be called directly.

An example is detailed at *NoReturnNoArguments*.

10.2 Numeric Arguments

Integer and floating point numbers are supported by the *interoperabilty with C* feature of Fortran 2003. This includes the integer types `short`, `int`, `long` and `long long`. Size specific types `int8_t`, `int16_t`, `int32_t`, and `int64_t` are also supported. Floating point types are `float` and `double`.

Note: Fortran has no support for unsigned types. `size_t` will be the correct number of bytes, but will be signed.

In the following examples, `int` can be replaced by any numeric type.

`int arg` Pass a numeric value to C. The attribute `intent(in)` is defaulted. The Fortran 2003 attribute `VALUE` is used to change from Fortran's default call-by-reference to C's call-by-value. This argument can be called directly by Fortran and no C wrapper is necessary. See example *PassByValue*.

`const int *arg` Scalar call-by-reference. `const` pointers are defaulted to `+intent(in)`.

`int *arg +intent(out)` If the intent is to return a scalar value from a function, add the `intent(out)` attribute. See example *PassByReference*.

const int *arg +rank(1) The `rank(1)` attribute will create an assumed-shape Fortran dimension for the argument as `arg(:)`. The C library function needs to have some way to determine the length of the array. The length could be assumed by the library function. A better option is to add another argument which will explicitly pass the length of the array from Fortran - `int larg+implied(size(arg))`. An *implied* argument will not be part of the wrapped API but will still be passed to the C++ function. See example *Sum*.

int *arg +intent(out)+deref(allocatable)+dimension(n) Adds the Fortran attribute `ALLOCATABLE` to the argument, then use the `ALLOCATE` statment to allocate memory using *dimension* attribute as the shape. See example *truncate_to_int*.

intent **arg +intent(out) Return a pointer in an argument. This is converted into a Fortran `POINTER` to a scalar. See example *getPtrToScalar*.

intent **arg +intent(out)+dimension(ncount) Return a pointer in an argument. This is converted into a Fortran `POINTER` to an array by the *dimension* attribute. See example *getPtrToDynamicArray*.

intent **arg +intent(out)+deref(raw) Return a pointer in an argument. The Fortran argument will be a `type(C_PTR)`. This gives the caller the flexibility to dereference the pointer themselves using `c_f_pointer`. This is useful when the shape is not know when the function is called. See example *getRawPtrToFixedArray*.

int ***arg +intent(out) Pointers nested to a deeper level are treated as a Fortran `type(C_PTR)` argument. This gives the user the most flexibility. The `type(C_PTR)` can be passed back to to library which should know how to cast it. There is no checks on the pointer before passing it to the library so it's very easy to pass bad values. The user can also explicitly dereferences the pointers using `c_f_pointer`. See example *getRawPtrToInt2d*.

int **arg +intent(in) Multiple levels of indirection are converted into a `type(C_PTR)` argument. See below for an exception for `char **`. See example *checkInt2d*.

int &min +intent(out) A declaration to a scalar gets converted into pointers in the C wrapper. See example *getMinMax*.

int *&arg Return a pointer in an argument. From Fortran, this is the same as `int **arg`. See above examples.

10.3 Numeric Functions

int *func() Return a Fortran `POINTER` to a scalar. See example *returnIntPtrToScalar*.

int *func() +dimension(10) Return a Fortran `POINTER` to a array. See example *returnIntPtrToFixedArray*.

int *func() +deref(scalar) Return a scalar. See example *returnIntScalar*.

10.4 Bool

C and C++ functions with a `bool` argument generate a Fortran wrapper with a `logical` argument. One of the goals of Shroud is to produce an idiomatic interface. Converting the types in the wrapper avoids the awkwardness of requiring the Fortran user to passing in `.true._c_bool` instead of just `.true.`. Using an integer for a `bool` argument is not portable since some compilers use 1 for `.true.` and others use -1.

bool arg Non-pointer arguments default to `intent(IN)`. See example *checkBool*.

10.5 Char

Fortran, C, and C++ each have their own semantics for character variables.

- Fortran `character` variables know their length and are blank filled
- C `char *` variables are assumed to be `NULL` terminated.
- C++ `std::string` know their own length and can provide a `NULL` terminated pointer.

It is not sufficient to pass an address between Fortran and C++ like it is with other native types. In order to get idiomatic behavior in the Fortran wrappers it is often necessary to copy the values. This is to account for blank filled vs `NULL` terminated.

`const char *arg` Create a `NULL` terminated string in Fortran using `trim(arg)//C_NULL_CHAR` and pass to C. Since the argument is `const`, it is treated as `intent(in)`. A bufferify function is not required to convert the argument. This is the same as `char *arg+intent(in)`. See example *acceptName*.

`char *arg` Pass a `char` pointer to a function which assign to the memory. `arg` must be `NULL` terminated by the function. Add the *intent(out)* attribute. The bufferify function will then blank-fill the string to the length of the Fortran `CHARACTER(*)` argument. It is the users responsibility to avoid overwriting the argument. See example *returnOneName*.

Fortran must provide a CHARACTER argument which is at least as long as the amount that the C function will write into. This includes space for the terminating NULL which will be converted into a blank for Fortran.

`char *arg, int larg` Similar to above, but pass in the length of `arg`. The argument `larg` does not need to be passed to Fortran explicitly since its value is implied. The *implied* attribute is defined to use the `len` Fortran intrinsic to pass the length of `arg` as the value of `larg`: `char *arg+intent(out), int larg+implied(len(arg))`. See example *ImpliedTextLen*.

`char **names +intent(in)` This is a standard C idiom for an array of `NULL` terminated strings. Shroud takes an array of `CHARACTER(len=*) arg(:)` and creates the C data structure by copying the data and adding the terminating `NULL`. See example *acceptCharArrayIn*.

10.6 std::string

`std::string & arg` `arg` will default to `intent(inout)`. See example *acceptStringReference*.

10.7 char functions

Functions which return a `char *` provide an additional challenge. Taken literally they should return a `type(C_PTR)`. And if you call the C library function via the interface, that's what you get. However, Shroud provides several options to provide a more idiomatic usage.

Each of these declaration call identical C++ functions but they are wrapped differently.

`char *getCharPtr1` Return a pointer and convert into an `ALLOCATABLE CHARACTER` variable. Fortran 2003 is required. The Fortran application is responsible to release the memory. However, this may be done automatically by the Fortran runtime. See example *getCharPtr1*.

`char *getCharPtr2` Create a Fortran function which returns a predefined `CHARACTER` value. The size is determined by the *len* argument on the function. This is useful when the maximum size is already known. Works with Fortran 90. See example *getCharPtr2*.

`char *getCharPtr3` Create a Fortran subroutine in an additional `CHARACTER` argument for the C function result. Any size character string can be returned limited by the size of the Fortran argument. The argument is defined by the *F_string_result_as_arg* format string. Works with Fortran 90. See example *getCharPtr3*.

10.8 string functions

Functions which return `std::string` values are similar but must provide the extra step of converting the result into a `char *`.

`const string &` See example *getConstStringRefPure*.

10.9 std::vector

A `std::vector` argument for a C++ function can be created from a Fortran array. The address and size of the array is extracted and passed to the C wrapper to create the `std::vector`

`const std::vector<int> &arg` `arg` defaults to `intent(in)` since it is const. See example *vector_sum*.

`std::vector<int> &arg` See example *vector_iota_out*.

See example *vector_iota_out_alloc*.

See example *vector_iota_inout_alloc*.

On `intent(in)`, the `std::vector` constructor copies the values from the input pointer. With `intent(out)`, the values are copied after calling the function.

Note: With `intent(out)`, if *vector_iota* changes the size of `arg` to be longer than the original size of the Fortran argument, the additional values will not be copied.

10.10 Void Pointers

The Fortran 2003 stardard added the `type(C_PTR)` derived type which is used to hold a C `void *`. Fortran is not able to directly dereference `type(C_PTR)` variables. The function `c_f_pointer` must be used.

`void *arg` If the intent is to be able to pass any variable to the function, add the `+assumedtype` attribute. `type(*)` is only available with TS 29113. The Fortran wrapper will only accept scalar arguments. To pass an array, add the `dimension` attribute See examples *passAssumedType* and *passAssumedTypeDim*.

`void *arg` Passes the value of a `type(C_PTR)` argument. See example *passVoidStarStar*.

`void **arg` Used to return a `void *` from a function in an argument. Passes the address of a `type(C_PTR)` argument. See example *passVoidStarStar*.

10.11 Function Pointers

C or C++ arguments which are pointers to functions are supported. The function pointer type is wrapped using a Fortran `abstract interface`. Only C compatible arguments in the function pointer are supported since no wrapper for the function pointer is created. It must be callable directly from Fortran.

`int (*incr)(int)` Create a Fortran abstract interface for the function pointer. Only functions which match the interface can be used as a dummy argument. See example *callback1*.

`void (*incr)()` Adding the `external` attribute will allow any function to be passed. In C this is accomplished by using a cast. See example *callback1c*.

The `abstract interface` is named from option **F_abstract_interface_subprogram_template** which defaults to `{underscore_name}_{argname}` where *argname* is the name of the function argument.

If the function pointer uses an abstract declarator (no argument name), the argument name is created from option **F_abstract_interface_argument_template** which defaults to `arg{index}` where *index* is the 0-based argument index. When a name is given to a function pointer argument, it is always used in the `abstract interface`.

To change the name of the subprogram or argument, change the option. There are no format fields **F_abstract_interface_subprogram** or **F_abstract_interface_argument** since they vary by argument (or argument to an argument):

```
options:
  F_abstract_interface_subprogram_template: custom_funptr
  F_abstract_interface_argument_template: XX{index}arg
```

It is also possible to pass a function which will accept any function interface as the dummy argument. This is done by adding the *external* attribute. A Fortran wrapper function is created with an `external` declaration for the argument. The C function is called via an interace with the `bind(C)` attribute. In the interface, an `abstract interface` for the function pointer argument is used. The user's library is responsible for calling the argument correctly since the interface is not preserved by the `external` declaration.

10.12 Struct

See example *passStruct1*.

See example *passStructByValue*.

CHAPTER 11

Output

11.1 What files are created

Shroud will create multiple output file which must be compiled with C++ or Fortran compilers.

One C++ file will be created for the library and one file for each C++ class.

Fortran creates a file for the library and one per additional namespace. Since Fortran does not support forward referencing of derived types, it is necessary to add all classes from a namespace into a single module.

Each Fortran file will only contain one module to make it easier to create makefile dependencies using pattern rules:

```
%.o %.mod : %.f
```

File names for the header and implementation files can be set explicitly by setting variables in the format of the global or class scope:

```
format:
  C_header_filename: top.h
  C_impl_filename: top.cpp
  F_impl_filename: top.f

declarations:
- decl: class Names
  format:
    C_header_filename: foo.h
    C_impl_filename: foo.cpp
    F_impl_filename: foo.f
```

The default file names are controlled by global options. The option values can be changed to avoid setting the name for each class file explicitly. It's also possible to change just the suffix of files:

```
options:
    YAML_type_filename_template: {library_lower}_types.yaml
```

(continues on next page)

(continued from previous page)

```
    C_header_filename_suffix: h
    C_impl_filename_suffix: cpp
    C_header_filename_library_template: wrap{library}.{C_header_filename_suffix}
    C_impl_filename_library_template: wrap{library}.{C_impl_filename_suffix}

    C_header_filename_namespace_template: wrap{file_scope}.{C_header_file_suffix}
    C_impl_filename_namespace_template: wrap{file_scope}.{C_impl_filename_suffix}

    C_header_filename_class_template: wrap{cxx_class}.{C_header_file_suffix}
    C_impl_filename_class_template: wrap{cxx_class}.{C_impl_filename_suffix}

    F_filename_suffix: f
    F_impl_filename_library_template: wrapf{library_lower}.{F_filename_suffix}
    F_impl_filename_namespace_template: wrapf{file_scope}.{F_filename_suffix}
```

A file with helper functions may also be created. For C the file is named by the format field *C_impl_utility*. It contains files which are implemented in C but are called from Fortran via `BIND(C)`.

11.2 How names are created

Shroud attempts to provide user control of names while providing reasonable defaults. Each name is based on the library, class, function or argument name in the current scope. Most names have a template which may be used to control how the names are generated on a global scale. Many names may also be explicitly specified by a field.

For example, a library has an `initialize` function which is in a namespace. In C++ it is called as:

```
#include "library.hpp"

library::initialize()
```

By default this will be a function in a Fortran module and can be called as:

```
use library

call initialize
```

Since `initialize` is a rather common name for a function, it may be desirable to rename the Fortran wrapper to something more specific. The name of the Fortran implementation wrapper can be changed by setting *F_name_impl*:

```
library: library

declarations:
- decl: namespace library
  declarations:
  - decl: void initialize
    format:
      F_name_impl: library_initialize
```

To rename all functions, set the template in the toplevel *options*:

```
library: library

options:
  F_name_impl_template: "{library}_{underscore_name}{function_suffix}"
```

(continues on next page)

(continued from previous page)

```
declarations:
- decl: namespace library
  declarations:
  - decl: void initialize
```

C++ allows allows overloaded functions and will mangle the names behind the scenes. With Fortran, the mangling must be explicit. To accomplish this Shroud uses the *function_suffix* format string. By default, Shroud will use a sequence number. By explicitly setting *function_suffix*, a more meaningful name can be provided:

```
- decl: void Function6(const std::string& name)
  format:
    function_suffix: _from_name
- decl: void Function6(int indx)
  format:
    function_suffix: _from_index
```

This will create the Fortran functions `function6_from_name` and `function6_from_index`. A generic interface named `function6` will also be created which will include the two generated functions.

Likewise, default arguments will produce several Fortran wrappers and a generic interface for a single C++ function. The format dictionary only allows for a single *function_default* per function. Instead the field *default_arg_suffix* can be set. It contains a list of *function_suffix* values which will be applied from the minimum to the maximum number of arguments:

```
- decl: int overload1(int num,
          int offset = 0, int stride = 1)
  default_arg_suffix:
  - _num
  - _num_offset
  - _num_offset_stride
```

Finally, multiple Fortran wrappers can be generated from a single templated function. Each instantiation will generate an additional Fortran Wrapper and can be distinguished by the *template_suffix* entry of the format dictionary.

If there is a single template argument, then *template_suffix* will be set to the *flat_name* field of the instantiated argument. For example, `<int>` defaults to `_int`. This works well for POD types. The entire qualified name is used. For `<std::string>` this would be `std_string`. Classes which are deeply nested can produce very long values for *template_suffix*. To deal with this, the *function_template* field can be set on Class declarations:

```
- decl: namespace internal
  declarations:
  - decl: class ImplWorker1
    format:
      template_suffix: instantiation3
```

By default `internal_implworker1` would be used for the *template_suffix*. But in this case `instantiation3` will be used.

For multiple template arguments, *template_suffix* defaults to a sequence number to avoid long function names. In this case, specifying an explicit *template_suffix* can produce a more user friendly name:

```
- decl: template<T,U> void FunctionTU(T arg1, U arg2)
  cxx_template:
  - instantiation: <int, long>
    format:
```

(continues on next page)

(continued from previous page)

```
      template_suffix: instantiation1
  - instantiation: <float, double>
    format:
      template_suffix: instantiation2
```

The Fortran functions will be named `function_tu_instantiation1` and `function_tu_instantiation2`.

11.3 Additional Wrapper Functions

Functions can be created in the Fortran wrapper which have no corresponding function in the C++ library. This may be necessary to add functionality which may unnecessary in C++. For example, a library provides a function which returns a string reference to a name. If only the length is desired no extra function is required in C++ since the length is extracted used a `std::string` method:

```
ExClass1 obj("name")
int len = obj.getName().length();
```

Calling the Fortran `getName` wrapper will copy the string into a Fortran array but you need the length first to make sure there is enough room. You can create a Fortran wrapper to get the length without adding to the C++ library:

```
declarations:
- decl: class ExClass1
  declarations:
  - decl: int GetNameLength() const
    format:
      C_code: |
        {C_pre_call}
        return {CXX_this}->getName().length();
```

The generated C wrapper will use the *C_code* provided for the body:

```
int AA_exclass1_get_name_length(const AA_exclass1 * self)
{
    const ExClass1 *SH_this = static_cast<const ExClass1 *>(
        static_cast<const void *>(self));
    return SH_this->getName().length();
}
```

The *C_pre_call* format string is generated by Shroud to convert the `self` argument into *CXX_this* and must be included in *C_code* to get the definition.

11.4 Helper functions

Shroud provides some additional file static function which are inserted at the beginning of the wrapped code. Some helper functions are used to communicate between C and Fortran. They are global and written into the *fmt.C_impl_utility* file. The names of these files will have *C_prefix* prefixed to create unique names.

C helper functions

`ShroudStrCopy(char *dest, int ndest, const char *src, int nsrc)` Copy *src* into *dest*, blank fill to *ndest* characters Truncate if *dest* is too short to hold all of *src*. *dest* will not be NULL terminated.

int ShroudLenTrim(const char *src, int nsrc) Returns the length of character string *src* with length *nsrc*, ignoring any trailing blanks.

Each Python helper is prefixed by format variable *PY_helper_prefix* which defaults to `SHROUD_`. This is used to avoid conflict with other wrapped functions.

The option *PY_write_helper_in_util* will write all of the helper fuctions into the file defined by *PY_utility_filename*. This can be useful to avoid clutter when there are a lot of classes which may create lots of duplicate helpers. The helpers will no longer be file static and instead will also be prefixed with *C_prefix* to avoid conflicting with helpers created by another Shroud wrapped library.

11.4.1 Header Files

The header files for the library are included by the generated C++ source files.

The library source file will include the global *cxx_header* field. Each class source file will include the class *cxx_header* field unless it is blank. In that case the global *cxx_header* field will be used.

To include a file in the implementation list it in the global or class options:

```
cxx_header: global_header.hpp

declarations:
- decl: class Class1
  cxx_header: class_header.hpp

- decl: typedef int CustomType
    c_header:  type_header.h
    cxx_header : type_header.hpp
```

The *c_header* field will be added to the header file of contains functions which reference the type. This is used for files which are not part of the library but which contain code which helps map C++ constants to C constants

11.4.2 Local Variable

*SH_* prefix on local variables which are created for a corresponding argument. For example the argument *char *name*, may need to create a local variable named *std::string SH_name*.

Shroud also generates some code which requires local variables such as loop indexes. These are prefixed with *SHT_*. This name is controlled by the format variable *c_temp*.

Results are named from *fmt.C_result* or *fmt.F_result*.

Format variable which control names are

- c_temp
- C_local
- C_this
- CXX_local
- CXX_this
- C_result
- F_pointer - `SHT_pointer`
- F_result - `SHT_rv` (return value)

- F_this - `obj`
- LUA_result
- PY_result

11.5 C Preprocessor

It is possible to add C preprocessor conditional compilation directives to the generated source. For example, if a function should only be wrapped if `USE_MPI` is defined the `cpp_if` field can be used:

```
- decl: void testmpi(MPI_Comm comm)
  format:
    function_suffix: _mpi
  cpp_if: ifdef HAVE_MPI
- decl: void testmpi()
  format:
    function_suffix: _serial
  cpp_if: ifndef HAVE_MPI
```

The function wrappers will be created within `#ifdef`/`#endif` directives. This includes the C wrapper, the Fortran interface and the Fortran wrapper. The generated Fortran interface will be:

```
    interface testmpi
#ifdef HAVE_MPI
        module procedure testmpi_mpi
#endif
#ifndef HAVE_MPI
        module procedure testmpi_serial
#endif
    end interface testmpi
```

Class generic type-bound function will also insert conditional compilation directives:

```
- decl: class ExClass3
  cpp_if: ifdef USE_CLASS3
  declarations:
  - decl: void exfunc()
    cpp_if: ifdef USE_CLASS3_A
  - decl: void exfunc(int flag)
    cpp_if: ifndef USE_CLASS3_A
```

The generated type will be:

```
    type exclass3
        type(SHROUD_capsule_data), private :: cxxmem
    contains
        procedure :: exfunc_0 => exclass3_exfunc_0
        procedure :: exfunc_1 => exclass3_exfunc_1
#ifdef USE_CLASS3_A
        generic :: exfunc => exfunc_0
#endif
#ifndef USE_CLASS3_A
        generic :: exfunc => exfunc_1
#endif
    end type exclass3
```

A `cpp_if` field in a class will add a conditional directive around the entire class.

Finally, `cpp_if` can be used with types. This would be required in the first example since `mpi.h` should only be included when `USE_MPI` is defined:

```
typemaps:
- type: MPI_Comm
  fields:
    cpp_if: ifdef USE_MPI
```

When using `cpp_if`, it is useful to set the option `F_filename_suffix` to `F`. This will cause most compilers to process the Fortran souce with `cpp` before compilation.

The `typemaps` field can only appear at the outermost layer and is used to augment existing typemaps.

11.6 Debugging

Shroud generates a JSON file with all of the input from the YAML and all of the format dictionaries and type maps. This file can be useful to see which format keys are available and how code is generated.

CHAPTER 12

C and C++

A C API is created for a C++ library. Wrapper functions are within an `extern "C"` block so they may be called by C or Fortran. But the file must be compiled with the C++ compiler since it is wrapping a C++ library.

When wrapping a C library, additional functions may be created which pass meta-data arguments. When called from Fortran, its wrappers will provide the meta-data. When called directly by a C application, the meta-data must be provided by the user.

To help control the scope of C names, all externals add a prefix. It defaults to the first three letters of the **library** but may be changed by setting the format **C_prefix**:

```
format:
  C_prefix: NEW_
```

12.1 Wrapper

As each function declaration is parsed a format dictionary is created with fields to describe the function and its arguments. The fields are then expanded into the function wrapper.

C wrapper:

```
extern "C" {

{C_return_type} {C_name}({C_prototype})
{
    {C_code}
}

}
```

The wrapper is within an `extern "C"` block so that **C_name** will not be mangled by the C++ compiler.

C_return_code can be set from the YAML file to override the return value:

```
-  decl: void vector_string_fill(std::vector< std::string > &arg+intent(out))
   format:
     C_return_type: int
     C_return_code: return SH_arg.size();
```

The C wrapper (and the Fortran wrapper) will return `int` instead of `void` using **C_return_code** to compute the value. In this case, the wrapper will return the size of the vector. This is useful since C and Fortran convert the vector into an array.

12.2 Struct Type

While C++ considers a struct and a class to be similar, Shroud assumes a struct is intended to be a C compatible data structure. It has no methods which will cause a v-table to be created. This will cause an array of structs to be identical in C and C++.

The main use of wrapping a struct for C is to provide access to the name. If the struct is defined within a `namespace`, then a C application will be unable to access the struct. Shroud creates an identical struct as the one defined in the YAML file but at the global level.

12.3 Class Types

A C++ class is represented by the *C_capsule_data_type*. This struct contains a pointer to the C++ instance allocated and an index passed to generated *C_memory_dtor_function* used to destroy the memory:

```
struct s_{C_capsule_data_type} {
    void *addr;     /* address of C++ memory */
    int idtor;      /* index of destructor */
};
typedef struct s_{C_capsule_data_type} {C_capsule_data_type};
```

In addition, an identical struct is created for each class. Having a unique struct and typedef for each class add a measure of type safety to the C wrapper:

```
struct s_{C_type_name} {
    void *addr;   /* address of C++ memory */
    int idtor;    /* index of destructor */
};
typedef struct s_{C_type_name} {C_type_name};
```

`idtor` is the index of the destructor code. It is used with memory managerment and discussed in *Memory Management*.

The C wrapper for a function which returns a class instance will return a *C_capsule_data_type* by value. Functions which take a class instance will receive a pointer to a *C_capsule_data_type*.

CHAPTER 13

Fortran

This section discusses Fortran specific wrapper details. This will also include some C wrapper details since some C wrappers are created specificially to be called by Fortran.

13.1 Wrapper

As each function declaration is parsed a format dictionary is created with fields to describe the function and its arguments. The fields are then expanded into the function wrapper.

The template for Fortran code showing names which may be controlled directly by the input YAML file:

```
module {F_module_name}

  ! use_stmts
  implicit none

  abstract interface
     subprogram {F_abstract_interface_subprogram_template}
        type :: {F_abstract_interface_argument_template}
     end subprogram
  end interface

  interface
    {F_C_pure_clause} {F_C_subprogram} {F_C_name}
         {F_C_result_clause} bind(C, name="{C_name}")
      ! arg_f_use
      implicit none
      ! arg_c_decl
    end {F_C_subprogram} {F_C_name}
  end interface

  interface {F_name_generic}
    module procedure {F_name_impl}
```

(continues on next page)

(continued from previous page)

```
  end interface {F_name_generic}

contains

  {F_subprogram} {F_name_impl}
    decl_args
    declare      ! local variables
    pre_call
    call  {arg_c_call}
    post_call
  end {F_subprogram} {F_name_impl}

end module {F_module_name}
```

13.2 Class

Use of format fields for creating class wrappers.

```
type, bind(C) :: {F_capsule_data_type}
    type(C_PTR) :: addr = C_NULL_PTR  ! address of C++ memory
    integer(C_INT) :: idtor = 0       ! index of destructor
end type {F_capsule_data_type}

type {F_derived_name}
    type({F_capsule_data_type}) :: {F_derived_member}
contains
    procedure :: {F_name_function} => {F_name_impl}
    generic :: {F_name_generic} => {F_name_function}, ...

    ! F_name_getter, F_name_setter, F_name_instance_get as underscore_name
    procedure :: [F_name_function_template] => [F_name_impl_template]

end type {F_derived_name}
```

13.2.1 Standard type-bound procedures

Several type bound procedures can be created to make it easier to use class from Fortran.

Usually the *F_derived_name* is constructed from wrapped C++ constructor. It may also be useful to take a pointer to a C++ struct and explicitly put it into a the derived type. The functions *F_name_instance_get* and *F_name_instance_set* can be used to access the pointer directly.

Two predicate function are generated to compare derived types:

```
    interface operator (.eq.)
        module procedure class1_eq
        module procedure singleton_eq
    end interface

    interface operator (.ne.)
        module procedure class1_ne
        module procedure singleton_ne
    end interface
```

(continues on next page)

(continued from previous page)

```
contains

    function {F_name_scope}eq(a,b) result (rv)
        use iso_c_binding, only: c_associated
        type({F_derived_name}), intent(IN) ::a,b
        logical :: rv
        if (c_associated(a%{F_derived_member}%addr, b%{F_derived_member}%addr)) then
            rv = .true.
        else
            rv = .false.
        endif
    end function {F_name_scope}eq

    function {F_name_scope}ne(a,b) result (rv)
        use iso_c_binding, only: c_associated
        type({F_derived_name}), intent(IN) ::a,b
        logical :: rv
        if (.not. c_associated(a%{F_derived_member}%addr, b%{F_derived_member}%addr))␣
↪then
            rv = .true.
        else
            rv = .false.
        endif
    end function {F_name_scope}ne
```

CHAPTER 14

Python

Note: Work in progress

This section discusses Python specific wrapper details.

14.1 Wrapper

14.2 Types

14.3 type fields

14.3.1 PY_build_arg

Argument for Py_BuildValue. Defaults to *{cxx_var}*. This field can be used to turn the argument into an expression such as *(int) {cxx_var}* or *{cxx_var}{cxx_member}c_str() PY_build_format* is used as the format:

```
Py_BuildValue("{PY_build_format}", {PY_build_arg});
```

14.3.2 PY_build_format

'format unit' for Py_BuildValue. If *None*, use value of *PY_format*. Defaults to *None*

14.3.3 PY_format

'format unit' for PyArg_Parse and Py_BuildValue. Defaults to *O*

14.3.4 PY_PyTypeObject

Variable name of PyTypeObject instance. Defaults to *None*.

14.3.5 PY_PyObject

Typedef name of PyObject instance. Defaults to *None*.

14.3.6 PY_ctor

Expression to create object. ex. `PyInt_FromLong({rv})` Defaults to *None*.

14.3.7 PY_get

Expression to get value from an object. ex. `PyInt_AsLong({py_var})` Defaults to *None*.

14.3.8 PY_to_object_idtor

Create an Python object for the type. Includes the index of the destructor function. Used with structs/classes that are created by functions and must be wrapped. `object = converter(address, idtor)`. Defaults to *None*.

14.3.9 PY_to_object

PyBuild - `object = converter(address)`. Defaults to *None*.

14.3.10 PY_from_object

PyArg_Parse - `status = converter(object, address)`. Defaults to *None*.

14.3.11 py_ctype

The type returned by *PY_get* function. Defaults to `None` which implies it is the same as the typemap. i.e. `PyInt_AsLong` returns a `long`.

Defined for complex types because `PyComplex_AsCComplex` returns type `Py_complex`. See also *pytype_to_pyctor* and *pytype_to_cxx*.

14.3.12 pytype_to_pyctor

Expression to use with *PY_ctor*. Defaults to `None` which indicates no additional processing of the argument is required. Only needs to be defined when *py_ctype* is defined.

With complex types, it is used to extract the real and imaginary parts from `Py_complex` (defined with *py_ctype*) with `creal({ctor_expr}), cimag({ctor_expr})`. *ctor_expr* is the expression used with *Py_ctor*.

14.3.13 pytype_to_cxx

Expression to convert *py_ctype* into a C++ value. Only needs to be defined when *py_ctype* is defined.

Used with complex to convert `Py_complex` (defined with *py_ctype*) to C using `{work_var}.real + {work_var}.imag * I` or C++ with `std::complex(\tcvalue.real, cvalue.imag)`.

14.3.14 cxx_to_pytype

Statements to convert *cxx_var* to *py_ctype*/ Only needs to be defined when *py_ctype* is defined.

```
cxx_to_pytype: |
    {ctype_var}.real = creal({cxx_var});
    {ctype_var}.imag = cimag({cxx_var});
```

14.3.15 PYN_descr

Name of `PyArray_Descr` variable which describe type. Used with structs. Defaults to *None*.

14.3.16 PYN_typenum

NumPy type number. ex. `NPY_INT` Defaults to *None*.

14.4 Statements

The template for a function is:

```
static char {PY_name_impl}__doc__[] = "{PY_doc_string}";

static PyObject *'
{PY_name_impl}(
    {PY_PyObject} *{PY_param_self},
    PyObject *{PY_param_args},
    PyObject *{PY_param_kwds})
{
    {declare}

    // {parse_format}  {parse_args}
    if (!PyArg_ParseTupleAndKeywords(
        {PY_param_args}, {PY_param_kwds}, "{PyArg_format}",
        SH_kw_list, {PyArg_vargs})) {
        return NULL;
    }

    // result pre_call

    // Create C from Python objects
    // Create C++ from C
    {post_parse}
    {               create scope before fail
      {pre_call}    pre_call declares variables for arguments
```

(continues on next page)

(continued from previous page)

```
      call  {arg_call}
      {post_call}

      per argument
        // Create Python object from C++
        {ctor}    {post_call}

        {PyObject} *  {py_var} Py_BuildValue("{Py_format}", {vargs});
        {cleanup}
     }
     return;

   fail:
      {fail}
      Py_XDECREF(arr_x);
}
```

The template for a setter is:

```
static PyObject *{PY_getter}(
    {PY_PyObject} *{PY_param_self},
    void *SHROUD_UNUSED(closure)) {
    {setter}
}
```

The template for a getter is:

```
static int {PY_setter}("
    {PY_PyObject} *{PY_param_self},
    PyObject *{py_var},
    void *SHROUD_UNUSED(closure)) {
    {getter}
    return 0;
}
```

Fields listed in the order they generate code. C variables are created before the call to `Py_ParseArgs`. C++ variables are then created in *post_parse* and *pre_call*. For example, creating a `std::string` from a `char *`.

14.4.1 allocate_local_var

Functions which return a struct/class instance (such as std::vector) need to allocate a local variable which will be used to store the result. The Python object will maintain a pointer to the instance until it is deleted.

14.4.2 c_header

14.4.3 cxx_header

14.4.4 c_helper

Blank delimited list of helper functions required for the wrapper. The name may contain format strings and will be expand before it is used. ex. `to_PyList_{cxx_type}`. The function associated with the helper will be named *hnamefunc0*, *hnamefunc1*, ... for each helper listed.

14.4.5 need_numpy

If *True*, add NumPy headers and initialize in the module.

14.4.6 fmtdict

Update format dictionary to override generated values. Each field will be evaluated before assigment.

ctor_expr - Expression passed to Typemap.PY_ctor `PyInt_FromLong({ctor_expr})`. Useful to add dereferencing if necessary. `PyInt_FromLong` is from typemap.PY_ctor.

```
fmtdict=dict(
    ctor_expr="{c_var}",
),
```

14.4.7 arg_declare

By default a local variable will be declared the same type as the argument to the function.

For some cases, this will not be correct. This field will be used to replace the default declaration.

references

In some cases the declaration is correct but need to be initialized. For example, setting a pointer.

Assign a blank list will not add any declarations. This is used when only an output `std::string` or `std::vector` is created after parsing arguments.

This variables is used with `PyArg_ParseTupleAndKeywords`.

The argument will be non-const to allow it to be assigned later.

```
name="py_char_*_out_charlen",
arg_declare=[
    "{c_const}char {c_var}[{charlen}];  // intent(out)",
],
```

14.4.8 declare

Code needed to declare local variable. Often used to define variables of type `PyObject *`.

14.4.9 cxx_local_var

Set when a C++ variable is created by post_parse. *scalar*

Used to set format fields *cxx_member*

14.4.10 parse_format

Works together with *parse_args* to describe how to parse `PyObject` in `PyArg_ParseTupleAndKeywords`. *parse_format* is used in the *format* arguments and *parse_args* is append to the call as a vararg.

```
int PyArg_ParseTupleAndKeywords(PyObject *args, PyObject *kw,
    const char *format, char *keywords[], ...)
```

The simplest use is to pass the object directly through so that it can be operated on by *post_parse* or *pre_call* to convert the object into a C/C++ variable. For example, convert a `PyObject` into an `int *`.

```
parse_format="O",
parse_args=["&{pytmp_var}"],
declare=[
    "PyObject * {pytmp_var};",
],
```

The format field *pytmp_var* is created by Shroud, but must be declared if it is used.

It can also be used to provide a *converter* function which converts the object:

```
parse_format="O&",
parse_args=["{hnamefunc0}", "&{py_var}"],
```

From the Python manual: Note that any Python object references which are provided to the caller (of *PyArg_Parse*) are borrowed references; do not decrement their reference count!

14.4.11 parse_args

A list of wrapper variables that are passed to `PyArg_ParseTupleAndKeywords`. Used with *parse_format*.

14.4.12 cxx_local_var

Set to *scalar* or *pointer* depending on the declaration in *post_declare post_parse* or *pre_call*.

14.4.13 post_declare

Declaration of C++ variables after calling `PyArg_ParseTupleAndKeywords`. Usually involves object constructors such as `std::string` or `std::vector`. Or for extracting struct and class pointers out of a *PyObject*.

These declarations should not include `goto fail`. This allows them to be created without a "jump to label 'fail' crosses initialization of" error.

"It is possible to transfer into a block, but not in a way that bypasses declarations with initialization. A program that jumps from a point where a local variable with automatic storage duration is not in scope to a point where it is in scope is ill-formed unless the variable has POD type (3.9) and is declared without an initializer."

14.4.14 post_parse

Statements to execute after the call to `PyArg_ParseTupleAndKeywords`. Used to convert C values into C++ values:

```
{var} = PyObject_IsTrue({var_obj});
```

Will not be added for class constructor objects. since there is no need to build return values.

Allow *intent(in)* arguments to be processed. For example, process `PyObject` into `PyArrayObject`.

14.4.15 pre_call

Location to allocate memory for output variables. All *intent(in)* variables have been processed by *post_parse* so their lengths are known.

14.4.16 arg_call

List of arguments to pass to function.

14.4.17 post_call

Convert result and *intent(out)* into `PyObject`. Set *object_created* to True if a `PyObject` is created.

14.4.18 cleanup

Code to remove any intermediate variables.

14.4.19 fail

Code to remove allocated memory and created objects.

14.4.20 goto_fail

If *True*, one of the other blocks such as *post_parse*, *pre_call*, and *post_call* contain a call to `fail`. If any statements block sets *goto_fail*, then the *fail* block will be inserted into the code/

14.4.21 object_created

Set to `True` when a `PyObject` is created by *post_call*. This prevents `Py_BuildValue` from converting it into an Object. For example, when a pointer is converted into a `PyCapsule` or when NumPy is used to create an object.

14.5 Predefined Types

14.5.1 Int

An `int` argument is converted to Python with the typemap:

```
type: int
fields:
    PY_format: i
    PY_ctor: PyInt_FromLong({c_deref}{c_var})
    PY_get: PyInt_AsLong({py_var})
    PYN_typenum: NPY_INT
```

14.6 Pointers

When a function returns a pointer to a POD type several Python interfaces are possible. When a function returns an `int *` the simplest result is to return a `PyCapsule`. This is just the raw pointer returned by C++. It's also the least useful to the caller since it cannot be used directly. The more useful option is to assume that the result is a pointer to a scalar. In this case a NumPy scalar can be returned or a Python object such as `int` or `float`.

If the C++ library function can also provide the length of the pointer, then its possible to return a NumPy array. If *owner(library)* is set, the memory will never be released. If *owner(caller)* is set, the the memory will be released when the object is deleted.

The argument `int *result+intent(OUT)+dimension(3)` will create a NumPy array, then pass the pointer to the data to the C function which will presumably fill the contents. The NumPy array will be returned as part of the function result. The dimension attribute must specify a length.

14.7 Class Types

An extension type is created for each C++ class:

```
typedef struct {
PyObject_HEAD
    {namespace_scope}{cxx_class} * {PY_obj};
} {PY_PyObject};
```

14.7.1 Extension types

Additional type information can be provided in the YAML file to generate place holders for extension type methods:

```
- name: ExClass2
  cxx_header: ExClass2.hpp
  python:
    type: [dealloc, print, compare, getattr, setattr,
           getattro, setattro,
           repr, hash, call, str,
           init, alloc, new, free, del]
```

CHAPTER 15

Cookbook

15.1 Function is really a macro or function pointer

When wrapping a C library, a function which is really a macro may not create a C wrapper. It is necessary to use the option `C_force_wrapper: true` to create a wrapper which will expand the macro and create a function which the Fortran wrapper may call. This same issue occurs when the function is really a function pointer.

When wrapping C++, a C wrapper is always created to create a extern C symbol that Fortran can call. So this problem does not occur.

15.2 F_name_impl with fortran_generic

Using the *F_name_impl* format string to explicitly name a Fortran wrapper combined with the *fortran_generic* field may present some surprising behavior. The routine `BA_change` takes a `long` argument. However, this is inconvenient in Fortran since the default integer is typically an `int`. When passing a constant you need to explicitly state the kind as `0_C_LONG`. Shroud lets you create a generic routine which will also accept `0`. But if you explicitly name the function using *F_name_impl*, both Fortran generated functions will have the same name. The solution is to set format field *F_name_generic* and the option for *F_name_impl_template*.

```
- decl: int BA_change(const char *name, long n)
  format:
    F_name_generic: change
  options:
    F_name_impl_template: "{F_name_generic}{function_suffix}"
  fortran_generic:
  - decl: (int n)
    function_suffix: int
  - decl: (long n)
    function_suffix: long
```

Will generate the Fortran code

```
interface change
    module procedure change_int
    module procedure change_long
end interface change
```

CHAPTER 16

Typemaps

A typemap is created for each type to describe to Shroud how it should convert a type between languages for each wrapper. Native types are predefined and a Shroud typemap is created for each `struct` and `class` declaration.

The general form is:

```
declarations:
- type: type-name
  fields:
     field1:
     field2:
```

type-name is the name used by C++. There are some fields which are used by all wrappers and other fields which are used by language specific wrappers.

16.1 type fields

These fields are common to all wrapper languages.

16.1.1 base

The base type of *type-name*. This is used to generalize operations for several types. The base types that Shroud uses are **string**, **vector**, or **shadow**.

16.1.2 cpp_if

A c preprocessor test which is used to conditionally use other fields of the type such as *c_header* and *cxx_header*:

```
- type: MPI_Comm
  fields:
    cpp_if: ifdef USE_MPI
```

16.1.3 flat_name

A flattened version of **cxx_type** which allows the name to be used as a legal identifier in C, Fortran and Python. By default any scope separators are converted to underscores i.e. `internal::Worker` becomes `internal_Worker`. Imbedded blanks are converted to underscores i.e. `unsigned int` becomes `unsigned_int`. And template arguments are converted to underscores with the trailing `>` being replaced i.e. `std::vector<int>` becomes `std_vector_int`.

Complex types set this explicitly since C and C++ have much different type names. The *flat_name* is always `double_complex` while *c_type* is `double complex` and *cxx_type* is `complex<double>`.

One use of this name is as the **function_suffix** for templated functions.

16.1.4 idtor

Index of `capsule_data` destructor in the function *C_memory_dtor_function*. This value is computed by Shroud and should not be set. It can be used when formatting statements as `{idtor}`. Defaults to *0* indicating no destructor.

16.2 C and C++

16.2.1 c_type

Name of type in C. Default to *None*.

16.2.2 c_header

Name of C header file required for type. This file is included in the interface header. Only used with *language=c*. Defaults to *None*.

See also *cxx_header*.

16.2.3 c_to_cxx

Expression to convert from C to C++. Defaults to *None* which implies *{c_var}*. i.e. no conversion required.

16.2.4 c_templates

c_statements for cxx_T

A dictionary indexed by type of specialized *c_statements* When an argument has a *template* field, such as type `vector<string>`, some additional specialization of c_statements may be required:

```
c_templates:
    string:
       intent_in_buf:
       - code to copy CHARACTER to vector<string>
```

16.2.5 c_return_code

None

16.2.6 c_union

None # Union of C++ and C type (used with structs and complex)

16.2.7 cxx_type

Name of type in C++. Defaults to *None*.

16.2.8 cxx_to_c

Expression to convert from C++ to C. Defaults to *None* which implies *{cxx_var}*. i.e. no conversion required.

16.2.9 cxx_header

Name of C++ header file required for implementation. For example, if cxx_to_c was a function. Only used with *language=c++*. Defaults to *None*. Note the use of *stdlib* which adds `std::` with *language=c++*:

```
c_header='<stdlib.h>',
cxx_header='<cstdlib>',
pre_call=[
    'char * {cxx_var} = (char *) {stdlib}malloc({c_var_len} + 1);',
],
```

See also *c_header*.

A C `int` is represented as:

```
type: int
fields:
    c_type: int
    cxx_type: int
```

16.3 Fortran

16.3.1 f_c_module

Fortran modules needed for type in the interface. A dictionary keyed on the module name with the value being a list of symbols. Similar to **f_module**. Defaults to *None*.

16.3.2 f_c_type

Type declaration for `bind(C)` interface. Defaults to *None* which will then use *f_type*.

16.3.3 f_cast

Expression to convert Fortran type to C type. This is used when creating a Fortran generic functions which accept several type but call a single C function which expects a specific type. For example, type `int` is defined as `int({f_var}, C_INT)`. This expression converts *f_var* to a `integer(C_INT)`. Defaults to *{f_var}* i.e. no conversion.

16.3.4 f_derived_type

Fortran derived type name. Defaults to *None* which will use the C++ class name for the Fortran derived type name.

16.3.5 f_kind

Fortran kind of type. For example, `C_INT` or `C_LONG`. Defaults to *None*.

16.3.6 f_module

Fortran modules needed for type in the implementation wrapper. A dictionary keyed on the module name with the value being a list of symbols. Defaults to *None*.:

```
f_module:
   iso_c_binding:
   - C_INT
```

16.3.7 f_type

Name of type in Fortran. (`integer(C_INT)`) Defaults to *None*.

16.3.8 f_to_c

None Expression to convert from Fortran to C.

example

An `int` argument is converted to Fortran with the typemap:

```
type: int
fields:
    f_type: integer(C_INT)
    f_kind: C_INT
    f_module:
        iso_c_binding:
        - C_INT
    f_cast: int({f_var}, C_INT)
```

16.4 Statements

Each language also provides a section that is used to insert language specific statements into the wrapper. These are named **c_statements**, **f_statements**, and **py_statements**.

The are broken down into several resolutions. The first is the intent of the argument. *result* is used as the intent for function results.

in Code to add for argument with `intent(IN)`. Can be used to convert types or copy-in semantics. For example, `char *` to `std::string`.

out Code to add after call when `intent(OUT)`. Used to implement copy-out semantics.

inout Code to add after call when `intent(INOUT)`. Used to implement copy-out semantics.

result Result of function. Including when it is passed as an argument, *F_string_result_as_arg*.

Each intent is then broken down into code to be added into specific sections of the wrapper. For example, **declaration**, **pre_call** and **post_call**.

Each statement is formatted using the format dictionary for the argument. This will define several variables.

c_var The C name of the argument.

cxx_var Name of the C++ variable.

f_var Fortran variable name for argument.

For example:

```
f_statements:
  intent_in:
  - '{c_var} = {f_var}  ! coerce to C_BOOL'
  intent_out:
  - '{f_var} = {c_var}  ! coerce to logical'
```

Note that the code lines are quoted since they begin with a curly brace. Otherwise YAML would interpret them as a dictionary.

See the language specific sections for details.

CHAPTER 17

C Statements

Note: Work in progress

```
extern "C" {

{C_return_type} {C_name}({C_prototype})    buf_args
{
    {pre_call}
    {call_code}    arg_call
    {post_call_pattern}
    {post_call}
    {final}
    {ret}
}
```

17.1 c_statements

17.1.1 buf_args

buf_args lists the arguments which are used by the C wrapper. The default is to provide a one-for-one correspondance with the arguments of the function which is being wrapped. However, often an additional function is created which will pass additional or different arguments to provide meta-data about the argument.

The Fortran wrapper will call the generated 'bufferified' function and provide the meta-data to the C wrapper.

arg

Use the library argument as the wrapper argument. This is the default when *buf_args* is not explicit.

arg_decl The explicit declarations will be provided in the fields *c_arg_decl* and *f_arg_decl*.

capsule

An argument of type *C_capsule_data_type*/*F_capsule_data_type*. It provides a pointer to the C++ memory as well as information to release the memory.

context

An argument of *C_array_type*/*F_array_type*. For example, used with `std::vector` to hold address and size of data contained in the argument in a form which may be used directly by Fortran.

c_var_context options.C_var_context_template

len

Result of Fortran intrinsic `LEN` for string arguments. Type `int`.

len_trim

Result of Fortran intrinsic `LEN_TRIM` for string arguments. Type `int`.

size

Result of Fortran intrinsic `SIZE` for array arguments. Type `long`.

shadow

Argument will be of type *C_capsule_data_type*.

arg

default.

shadow size capsule context len_trim len

17.1.2 buf_extra

Used to add argument for return values. For example, function which return class instance.

17.1.3 c_header

List of blank delimited header files which will be included by the generated header for the C wrapper. These headers must be C only. For example, `size_t` requires stddef.h:

```
type: size_t
fields:
    c_type: size_t
    cxx_type: size_t
    c_header: <stddef.h>
```

17.1.4 c_helper

A blank delimited list of helper functions which will be added to the wrapper file. The list will be formatted to allow for additional flexibility:

```
c_helper: capsule_data_helper vector_context vector_copy_{cxx_T}
```

These functions are defined in whelper.py. There is no current way to add additional functions.

17.1.5 c_local_var

If a local C variable is created for the return value by post_call, *c_local_var* indicates if the local variable is a **pointer** or **scalar**. For example, when a structure is returned by a C++ function, the C wrapper creates a local variable which contains a pointer to the C type of the struct.

The local variable can be passed in when buf_args is *shadow*.

If true, generate a local variable using the C declaration for the argument. This variable can be used by the pre_call and post_call statements. A single declaration will be added even if with `intent(inout)`.

17.1.6 cxx_header

A blank delimited list of header files which will be added to the C wrapper implementation. These headers may include C++ code.

17.1.7 cxx_local_var

If a local C++ variable is created for an argument by pre_call, *cxx_local_var* indicates if the local variable is a **pointer** or **scalar**. .. This sets *cxx_var* is set to `SH_{c_var}`. This in turns will set the format fields *cxx_member*. For example, a `std::string` argument is created for the C++ function from the `char *` argument passed into the C API wrapper.

17.1.8 c_arg_decl

A list of declarations in the C wrapper when buf_arg includes "arg_decl".

17.1.9 f_arg_decl

A list of declarations in the Fortran interface when buf_arg includes "arg_decl". The variable to be declared is *c_var*. *f_module* can be used to add `USE` statements.

17.1.10 f_result_decl

A list of declarations in the Fortran interface for a function result value.

17.1.11 f_module

Fortran modules used in the Fortran interface:

```
f_module=dict(iso_c_binding=["C_PTR"]),
```

17.1.12 arg_call

17.1.13 pre_call

Code used with *intent(in)* arguments to convert from C to C++.

17.1.14 call

Code to call function. This is usually generated. An exception which require explicit call code are constructors and destructors for shadow types.

17.1.15 post_call

Code used with *intent(out)* arguments and function results. Can be used to convert results from C++ to C.

17.1.16 final

Inserted after *post_call* and before *ret*. Can be used to release intermediate memory in the C wrapper.

17.1.17 ret

Code for return statement. Usually generated but can be replaced. For example, with constructors.

Useful to convert a subroutine into a function. For example, convert a `void` function which fills a `std::vector` to return the number of items.

17.1.18 return_type

Explicit return type when it is different than the functions return type. For example, with shadow types.

```
return_type: long
ret:
- return Darg->size;
```

17.1.19 return_cptr

If *true*, the function will return a C pointer. This will be used by the Fortran interface to declare the function as `type(C_PTR)`.

17.1.20 destructor_name

A name for the destructor code in *destructor*. Must be unique. May include format strings:

```
destructor_name: std_vector_{cxx_T}
```

17.1.21 destructor

A list of lines of code used to delete memory. Usually allocated by a *pre_call* statement. The code is inserted into *C_memory_dtor_function* which will provide the address of the memory to destroy in the variable `void *ptr`. For example:

```
destructor:
-  std::vector<{cxx_T}> *cxx_ptr = reinterpret_cast<std::vector<{cxx_T}> *>(ptr);
-  delete cxx_ptr;
```

17.1.22 owner

Set *owner* of the memory. Similar to attribute *owner*.

Used where the `new` operator is part of the generated code. For example where a class is returned by value or a constructor. The C wrapper must explicitly allocate a class instance which will hold the value from the C++ library function. The Fortran shadow class must keep this copy until the shadow class is deleted.

Defaults to *library*.

CHAPTER 18

Fortran Statements

Note: Work in progress.

Typemaps are used to add code to the generated wrappers to replace the default code.

The statements work together to pass variables and metadata between Fortran and C.

18.1 fc_statements

A Fortran wrapper is created out of several segments.

```
{F_subprogram} {F_name_impl}({F_arguments}){F_result_clause}
  arg_f_use
  arg_f_decl
  ! splicer begin
  declare
  pre_call
  call
  post_call
  ! splicer end
end {F_subprogram} {F_name_impl}
```

18.1.1 f_helper

Blank delimited list of Fortran helper function names to add to generated Fortran code. These functions are defined in whelper.py. There is no current way to add user defined helper functions.

18.1.2 f_module

`USE` statements to add to Fortran wrapper. A dictionary of list of `ONLY` names:

```
f_module:
  iso_c_binding:
  - C_SIZE_T
```

18.1.3 need_wrapper

If true, the Fortran wrapper will always be created. This is used when an assignment is needed to do a type coercion; for example, with logical types.

18.1.4 arg_name

List of name of arguments for Fortran subprogram. Will be formated before use to allow `{f_var}`.

Any function result arguments will be added at the end. Only added if *arg_decl* is also defined.

18.1.5 arg_decl

List of argument or result declarations. Usually constructed from YAML *decl* but sometimes needs to be explicit to add Fortran attributes such as `TARGET` or `POINTER`. Added before splicer.

```
arg_decl=[
    "character, value, intent(IN) :: {f_var}",
],
```

18.1.6 arg_c_call

List of arguments to pass to C wrapper. This can include an expression or additional arguments if required.

```
arg_c_call=["C_LOC({f_var})"],
```

18.1.7 declare

A list of declarations needed by *pre_call* or *post_call*. Usually a *c_local_var* is sufficient. Implies *need_wrapper*.

18.1.8 pre_call

Statement to execute before call, often to coerce types when *f_cast* cannot be used. Implies *need_wrapper*.

18.1.9 call

Code used to call the function. Defaults to `{F_result} = {F_C_call}({F_arg_c_call})`

For example, to assign to an intermediate variable:

```
declare=[
    "type(C_PTR) :: {F_pointer}",
],
call=[
    "{F_pointer} = {F_C_call}({F_arg_c_call})",
],
```

18.1.10 post_call

Statement to execute after call. Can be use to cleanup after *pre_call* or to coerce the return value. Implies *need_wrapper*.

18.1.11 result

Name of result variable. Added as the `RESULT` clause of the subprogram statement. Can be used to change a subroutine into a function.

In this example, the subroutine is converted into a function which will return the number of items copied into the result argument.

```
- decl: void vector_iota_out_with_num2(std::vector<int> &arg+intent(out))
  fstatements:
    f:
      result: num
      f_module:
        iso_c_binding: ["C_LONG"]
      declare:
      -  "integer(C_LONG) :: num"
      post_call:
      -  "num = Darg%size"
```

18.2 How typemaps are found

18.2.1 alias

Names another node which will be used for its contents.

CHAPTER 19

Reference

19.1 Command Line Options

help Show this help message and exit.

version Show program's version number and exit.

outdir OUTDIR Directory for output files. Defaults to current directory.

outdir-c-fortran OUTDIR_C_FORTRAN Directory for C/Fortran wrapper output files, overrides *–outdir*.

outdir-python OUTDIR_PYTHON Directory for Python wrapper output files, overrides *–outdir*.

outdir-lua OUTDIR_LUA Directory for Lua wrapper output files, overrides *–outdir*.

outdir-yaml OUTDIR_YAML Directory for YAML output files, overrides *–outdir*.

logdir LOGDIR Directory for log files. Defaults to current directory.

cfiles CFILES Output file with list of C and C++ files created.

ffiles FFILES Output file with list of Fortran created.

path PATH Colon delimited paths to search for splicer files, may be supplied multiple times to append to path.

sitedir Return the installation directory of shroud and exit. This path can be used to find cmake/SetupShroud.cmake.

write-helpers BASE Write files which contain the available helper functions into the files BASE.c and BASE.f.

write-version Write Shroud version into generated files. `--nowrite-version` will not write the version and is used by the testsuite to avoid changing every reference file when the version changes.

yaml-types FILE Write a YAML file with the default types.

19.2 Global Fields

copyright A list of lines to add to the top of each generate file. Do not include any language specific comment characters since Shroud will add the appropriate comment delimiters for each language.

classes A list of classes. Each class may have fields as detailed in *Class Fields*.

cxx_header Blank delimited list of header files which will be included in the implementation file. The order will be preserved when generating wrapper files.

format Dictionary of Format fields for the library. Described in *Format Fields*.

language The language of the library to wrap. Valid values are `c` and `c++`. The default is `c++`.

library The name of the library. Used to name output files and modules. The first three letters are used as the default for **C_prefix** option. Defaults to *library*. Each YAML file is intended to wrap a single library.

options Dictionary of option fields for the library. Described in *Options*

patterns Code blocks to insert into generated code. Described in *Patterns*.

splicer A dictionary mapping file suffix to a list of splicer files to read:

```
splicer:
  c:
  -  filename1.c
  -  filename2.c
```

types A dictionary of user define types. Each type is a dictionary of members describing how to map a type between languages. Described in *Typemaps* and *Types Map*.

19.3 Class Fields

cxx_header C++ header file name which will be included in the implementation file. If unset then the global *cxx_header* will be used.

format Format fields for the class. Creates scope within library. Described in *Format Fields*.

declarations A list of declarations in the class. Each function is defined by *Function Fields*

fields: A dictionary of fields used to update the typemap.

options Options fields for the class. Creates scope within library. Described in *Options*

19.4 Function Fields

Each function can define fields to define the function and how it should be wrapped. These fields apply only to a single function i.e. they are not inherited.

C_prototype XXX override prototype of generated C function

cxx_template A list that define how each templated argument should be instantiated:

```
decl: void Function7(ArgType arg)
cxx_template:
- instantiation: <int>
- instantiation: <double>
```

decl Function declaration. Parsed to extract function name, type and arguments descriptions.

default_arg_suffix A list of suffixes to apply to C and Fortran functions generated when wrapping a C++ function with default arguments. The first entry is for the function with the fewest arguments and the final entry should be for all of the arguments.

format Format fields for the function. Creates scope within container (library or class). Described in *Format Fields*.

fortran_generic A dictionary of lists that define generic functions which will be created. This allows different types to be passed to the function. This feature is provided by C which will promote arguments. Each generic function will have a suffix which defaults to an underscore plus a sequence number. This change be changed by adding *function_suffix* for a declaration.

```
  decl: void GenericReal(double arg)
  fortran_generic:
  - decl: (float arg)
    function_suffix: suffix1
  - decl: (double arg)

A full example is at :ref:`GenericReal <example_GenericReal>`.
```

options Options fields for the function. Creates scope within container (library or class). Described in *Options*

return_this If true, the method returns a reference to `this`. This idiom can be used to chain calls in C++. This idiom does not translate to C and Fortran. Instead the *C_return_type* format is set to `void`.

19.5 Options

C_API_case Control case of *C_name_scope*. Possible values are 'lower' or 'upper'. Any other value will have no effect.

C_extern_C Set to *true* when the C++ routine is `extern "C"`. Defaults to *false*.

C_force_wrapper If *true*, always create an explicit C wrapper. When *language* is c++ a C wrapper is always created. When wrapping C, the wrapper is automatically created if there is work for it to do. For example, pre_call or post_call is defined. The user should set this option when wrapping C and the function is really a macro or a function pointer variable. This forces a function to be created allowing Fortran to use the macro or function pointer.

C_line_length Control length of output line for generated C. This is not an exact line width, but is instead a hint of where to break lines. A value of 0 will give the shortest possible lines. Defaults to 72.

class_baseclass Used to define a baseclass for a struct for *wrap_struct_as=class*". The baseclase must already be defined earlier in the YAML file. It must be in the same namespace as the struct.

```
   - decl: struct Cstruct_as_class
     options:
       wrap_struct_as: class
   - decl: struct Cstruct_as_subclass
     options:
       wrap_struct_as: class
       class_baseclass: Cstruct_as_class

This is equivelent to the C++ code

.. code-block:: c++

   class Cstruct_as_class;
   class Cstruct_as_subclass : public Cstruct_as_class;
```

The corresponding Fortran wrapper will have

```
type cstruct_as_class
  type(STR_SHROUD_capsule_data) :: cxxmem
end type cstruct_as_class
type, extends(cstruct_as_class) ::  cstruct_as_class
end type cstruct_as_subclass
```

class_ctor Indicates that this function is a constructor for a struct. The value is the name of the struct. Useful for *wrap_struct_as=class* when used with C.

```
- decl: struct Cstruct_as_class {
          int x1;
          int y1;
        };
  options:
    wrap_struct_as: class

- decl: Cstruct_as_class *Create_Cstruct_as_class(void)
  options:
    class_ctor: Cstruct_as_class
```

class_method Indicates that this function is a method for a struct.

CXX_standard C++ standard. Defaults to *2011*. See *nullptr*.

debug Print additional comments in generated files that may be useful for debugging. Defaults to *false*.

debug_index Print index number of function and relationships between C and Fortran wrappers in the wrappers and json file. The number changes whenever a new function is inserted and introduces lots of meaningless differenences in the test answers. This option is used to avoid the clutter. If needed for debugging, then set to *true*. **debug** must also be *true*. Defaults to *false*.

doxygen If True, create doxygen comments.

F_create_bufferify_function Controls creation of a *bufferify* function. If *true*, an additional C function is created which receives *bufferified* arguments - i.e. the len, len_trim, and size may be added as additional arguments. Set to *false* when when you want to avoid passing this information. This will avoid a copy of `CHARACTER` arguments required to append a trailing null. Defaults to *true*.

F_create_generic Controls creation of a generic interface. It defaults to *true* for most cases but will be set to *False* if a function is templated on the return type since Fortran does not distiuguish generics based on return type (similar to overloaded functions based on return type in C++).

F_line_length Control length of output line for generated Fortran. This is not an exact line width, but is instead a hint of where to break lines. A value of 0 will give the shortest possible lines. Defaults to 72.

F_force_wrapper If *true*, always create an explicit Fortran wrapper. If *false*, only create the wrapper when there is work for it to do; otherwise, call the C function directly. For example, a function which only deals with native numeric types does not need a wrapper since it can be called directly by defining the correct interface. The default is *false*.

F_standard The fortran standard. Defaults to *2003*. This effects the `mold` argument of the `allocate` statement.

F_string_len_trim For each function with a `std::string` argument, create another C function which accepts a buffer and length. The C wrapper will call the `std::string` constructor, instead of the Fortran wrapper creating a `NULL` terminated string using `trim`. This avoids copying the string in the Fortran wrapper. Defaults to *true*.

F_return_fortran_pointer Use `c_f_pointer` in the Fortran wrapper to return a Fortran pointer instead of a `type(C_PTR)` in routines which return a pointer It does not apply to `char *`, `void *`, and routines which return a pointer to a class instance. Defaults to *true*.

literalinclude

Write some text lines which can be used with Sphinx's literalinclude directive. This is used to insert the generated code into the documentation. Can be applied at the top level or any declaration. Setting *literalinclude* at the top level implies *literalinclude2*.

literalinclude2

Write some text lines which can be used with Sphinx's literalinclude directive. Only effects some entities which do not map to a declarations such as some helper functions or types. Only effective at the top level.

Each Fortran interface will be encluded in its own `interface` block. This is to provide the interface context when code is added to the documentation.

PY_create_generic Controls creation of a multi-dispatch function with overloaded/templated functions. It defaults to *true* for most cases but will be set to *False* if a function is templated on the return type since Fortran does not distiuguish generics based on return type (similar to overloaded functions based on return type in C++).

PY_write_helper_in_util When *True* helper functions will be written into the utility file *PY_utility_filename*. Useful when there are lots of classes since helper functions may be duplicated in several files. The value of format *PY_helper_prefix* will have *C_prefix* append to create names that are unique to the library. Defaults to *False*.

return_scalar_pointer Determines how to treat a function which returns a pointer to a scalar (it does not have the *dimension* or *rank* attribute). **scalar** return as a scalar or **pointer** to return as a pointer. This option does not effect the C or Fortran wrapper. For Python, **pointer** will return a NumPy scalar. Defaults to *pointer*.

SH_shadow Prefix for shadow variables to avoid conflicting with other variables. Defaults to `SHadow_`.

show_splicer_comments If `true` show comments which delineate the splicer blocks; else, do not show the comments. Only the global level option is used.

wrap_class_as Defines how a `class` should be wrapped. If *class*, wrap using a shadow type. If *struct*, wrap the same as a `struct`. Default is *class*.

wrap_struct_as Defines how a `struct` should be wrapped. If *struct*, wrap a struct as a Fortran derived-type. If *class*, wrap a struct the same as a class using a shadow type. Default is *struct*.

wrap_c If *true*, create C wrappers. Defaults to *true*.

wrap_fortran If *true*, create Fortran wrappers. Defaults to *true*.

wrap_python If *true*, create Python wrappers. Defaults to *false*.

wrap_lua If *true*, create Lua wrappers. Defaults to *false*.

19.5.1 Option Templates

Templates are set in options then expanded to assign to the format dictionary.

C_enum_template Name of enumeration in C wrapper. `{C_prefix}{C_name_scope}{enum_name}`

C_enum_member_template Name of enumeration member in C wrapper. `{C_prefix}{C_name_scope}{enum_member_name}`

C_header_filename_class_template `wrap{file_scope}.{C_header_filename_suffix}`

C_header_filename_library_template `wrap{library}.{C_header_filename_suffix}`

C_header_filename_namespace_template `wrap{scope_file}.{C_header_filename_suffix}`

C_impl_filename_class_template `wrap{file_scope}.{C_impl_filename_suffix}`

C_impl_filename_library_template `wrap{library}.{C_impl_filename_suffix}`

C_impl_filename_namespace_template `wrap{scope_file}.{C_impl_filename_suffix}`

C_memory_dtor_function_template Name of function used to delete memory allocated by C or C++. defaults to `{C_prefix}SHROUD_memory_destructor`.

C_name_template `{C_prefix}{C_name_scope}{underscore_name}{function_suffix}{template_suffix}`

C_var_len_template Format for variable created with *len* annotation. Default `N{c_var}`

C_var_size_template Format for variable created with *size* annotation. Default `S{c_var}`

C_var_trim_template Format for variable created with *len_trim* annotation. Default `L{c_var}`

F_C_name_template `{F_C_prefix}{F_name_scope}{underscore_name}{function_suffix}{template_suffi`

F_abstract_interface_argument_template The name of arguments for an abstract interface used with function pointers. Defaults to `{underscore_name}_{argname}` where *argname* is the name of the function argument. see *Function Pointers*.

F_abstract_interface_subprogram_template The name of the abstract interface subprogram which represents a function pointer. Defaults to `arg{index}` where *index* is the 0-based argument index. see *Function Pointers*.

F_array_type_template `{C_prefix}SHROUD_array`

F_capsule_data_type_template Name of the derived type which is the `BIND(C)` equivalent of the struct used to implement a shadow class (**C_capsule_data_type**). All classes use the same derived type. Defaults to `{C_prefix}SHROUD_capsule_data`.

F_capsule_type_template `{C_prefix}SHROUD_capsule`

F_enum_member_template Name of enumeration member in Fortran wrapper. `{F_name_scope}{enum_member_lower}` Note that *F_enum_template* does not exist since only the members are in the Fortran code, not the enum name itself.

F_name_generic_template `{underscore_name}`

F_impl_filename_library_template `wrapf{library_lower}.{F_filename_suffix}`

F_name_impl_template `{F_name_scope}{underscore_name}{function_suffix}{template_suffix}`

F_module_name_library_template `{library_lower}_mod`

F_module_name_namespace_template `{file_scope}_mod`

F_name_function_template `{underscore_name}{function_suffix}{template_suffix}`

LUA_class_reg_template Name of *luaL_Reg* array of function names for a class. `{LUA_prefix}{cxx_class}_Reg`

LUA_ctor_name_template Name of constructor for a class. Added to the library's table. `{cxx_class}`

LUA_header_filename_template `lua{library}module.{LUA_header_filename_suffix}`

LUA_metadata_template Name of metatable for a class. `{cxx_class}.metatable`

LUA_module_filename_template `lua{library}module.{LUA_impl_filename_suffix}`

LUA_module_reg_template Name of *luaL_Reg* array of function names for a library. `{LUA_prefix}{library}_Reg`

LUA_name_impl_template Name of implementation function. All overloaded function use the same Lua wrapper so *function_suffix* is not needed. `{LUA_prefix}{C_name_scope}{underscore_name}`

LUA_name_template Name of function as know by Lua. All overloaded function use the same Lua wrapper so *function_suffix* is not needed. `{function_name}`

LUA_userdata_type_template `{LUA_prefix}{cxx_class}_Type`

LUA_userdata_member_template Name of pointer to class instance in userdata. `self`

PY_array_arg How to wrap arrays - numpy or list. Applies to function arguments and to structs when **PY_struct_arg** is *class* (struct-as-class). Defaults to *numpy*. Added to fmt for functions. Useful for *c_helpers* in statements.

```
c_helper="get_from_object_{c_type}_{PY_array_arg}",
```

PY_module_filename_template `py{library}module.{PY_impl_filename_suffix}`

PY_header_filename_template `py{library}module.{PY_header_filename_suffix}`

PY_utility_filename_template `py{library}util.{PY_impl_filename_suffix}`

PY_PyTypeObject_template `{PY_prefix}{cxx_class}_Type`

PY_PyObject_template `{PY_prefix}{cxx_class}`

PY_member_getter_template Name of descriptor getter method for a class variable. `{PY_prefix}{cxx_class}_{variable_name}_getter`

PY_member_setter_template Name of descriptor setter method for a class variable. `{PY_prefix}{cxx_class}_{variable_name}_setter`

PY_member_object_template Name of struct member of type *PyObject* * which contains the data for member pointer fields. `{variable_name}_obj`.

PY_name_impl_template `{PY_prefix}{function_name}{function_suffix}{template_suffix}`

PY_numpy_array_capsule_name_template Name of `PyCapsule object` used as base object of NumPy arrays. Used to make sure a valid capsule is passed to *PY_numpy_array_dtor_function*. `{PY_prefix}array_dtor`

PY_numpy_array_dtor_context_template Name of `const char * []` array used as the *context* field for *PY_numpy_array_dtor_function*. `{PY_prefix}array_destructor_context`

PY_numpy_array_dtor_function_template Name of *destructor* in `PyCapsule` base object of NumPy arrays. `{PY_prefix}array_destructor_function`

PY_struct_array_descr_create_template Name of C/C++ function to create a `PyArray_Descr` pointer for a structure. `{PY_prefix}{cxx_class}_create_array_descr`

PY_struct_arg How to wrap structs - numpy, list or class. Defaults to *numpy*.

PY_struct_array_descr_variable_template Name of C/C++ variable which is a pointer to a `PyArray_Descr` variable for a structure. `{PY_prefix}{cxx_class}_array_descr`

PY_struct_array_descr_name_template Name of Python variable which is a `numpy.dtype` for a struct. Can be used to create instances of a C/C++ struct from Python. `np.array((1,3.14), dtype=tutorial.struct1_dtype) {cxx_class}_dtype`

PY_type_filename_template `py{file_scope}type.{PY_impl_filename_suffix}`

PY_type_impl_template Names of functions for type methods such as `tp_init`. `{PY_prefix}{cxx_class}_{PY_type_method}{function_suffix}{template_suffix}`

PY_use_numpy Allow NumPy arrays to be used in the module. For example, when assigning to a struct-as-class member.

YAML_type_filename_template Default value for global field YAML_type_filename `{library_lower}_types.yaml`

19.6 Format Fields

Each scope (library, class, function) has its own format dictionary. If a value is not found in the dictionary, then the parent scopes will be recursively searched.

19.6.1 Library

C_array_type Name of structure used to store information about an array such as its address and size. Defaults to *{C_prefix}SHROUD_array*.

C_bufferify_suffix Suffix appended to generated routine which pass strings as buffers with explicit lengths. Defaults to *_bufferify*

C_capsule_data_type Name of struct used to share memory information with Fortran. Defaults to *SHROUD_capsule_data*.

C_header_filename Name of generated header file for the library. Defaulted from expansion of option *C_header_filename_library_template*.

C_header_filename_suffix Suffix added to C header files. Defaults to `h`. Other useful values might be `hh` or `hxx`.

C_header_utility A header file with shared Shroud internal typedefs for the library. Default is `types{library}.{C_header_filename_suffix}`.

C_impl_filename Name of generated C++ implementation file for the library. Defaulted from expansion of option *C_impl_filename_library_template*.

C_impl_filename_suffix: Suffix added to C implementation files. Defaults to `cpp`. Other useful values might be `cc` or `cxx`.

C_impl_utility A implementation file with shared Shroud helper functions. Typically routines which are implemented in C but called from Fortran via `BIND(C)`. The must have global scope. Default is `util{library}.{C_header_filename_suffix}`.

C_local Prefix for C compatible local variable. Defaults to *SHC_*.

C_memory_dtor_function Name of function used to delete memory allocated by C or C++.

C_name_scope Underscore delimited name of namespace, class, enumeration. Used with creating names in C. Does not include toplevel *namespace*.

C_result The name of the C wrapper's result variable. It must not be the same as any of the routines arguments. It defaults to *rv*.

C_string_result_as_arg The name of the output argument for string results. Function which return `char` or `std::string` values return the result in an additional argument in the C wrapper. See also *F_string_result_as_arg*.

c_temp Prefix for wrapper temporary working variables. Defaults to *SHT_*.

C_this Name of the C object argument. Defaults to `self`. It may be necessary to set this if it conflicts with an argument name.

CXX_local Prefix for C++ compatible local variable. Defaults to *SHCXX_*.

CXX_this Name of the C++ object pointer set from the *C_this* argument. Defaults to `SH_this`.

F_array_type Name of derived type used to store information about an array such as its address and size. Default value from option *F_array_type_template* which defaults to *{C_prefix}SHROUD_array*.

F_C_prefix Prefix added to name of generated Fortran interface for C routines. Defaults to **c_**.

F_capsule_data_type Name of derived type used to share memory information with C or C++. Member of *F_array_type*. Default value from option *F_capsule_data_type_template* which defaults to *{C_prefix}SHROUD_capsule_data*.

Each class has a similar derived type, but with a different name to enforce type safety.

F_capsule_delete_function Name of type-bound function of *F_capsule_type* which will delete the memory in the capsule. Defaults to *SHROUD_capsule_delete*.

F_capsule_final_function Name of function used was `FINAL` of *F_capsule_type*. The function is used to release memory allocated by C or C++. Defaults to *SHROUD_capsule_final*.

F_capsule_type Name of derived type used to release memory allocated by C or C++. Default value from option *F_capsule_type_template* which defaults to *{C_prefix}SHROUD_capsule*. Contains a *F_capsule_data_type*.

F_derived_member A *F_capsule_data_type* use to reference C++ memory. Defaults to *cxxmem*.

F_derived_member_base The *F_derived_member* for the base class of a class. Only single inheritance is support via the `EXTENDS` keyword in Fortran.

F_filename_suffix Suffix added to Fortran files. Defaults to `f`. Other useful values might be `F` or `f90`.

F_module_name Name of module for Fortran interface for the library. Defaulted from expansion of option *F_module_name_library_template* which is **{library_lower}_mod**. Then converted to lower case.

F_name_scope Underscore delimited name of namespace, class, enumeration. Used with creating names in Fortran. Does not include toplevel *namespace*.

F_impl_filename Name of generated Fortran implementation file for the library. Defaulted from expansion of option *F_impl_filename_library_template*.

F_pointer The name of Fortran wrapper local variable to save result of a function which returns a pointer. The pointer is then set in `F_result` using `c_f_pointer`. It must not be the same as any of the routines arguments. It defaults to *SHT_ptr* It is defined for each argument in case it is used by the fc_statements. Set to *SHPTR_arg_name*, where *arg_name* is the argument name.

F_result The name of the Fortran wrapper's result variable. It must not be the same as any of the routines arguments. It defaults to *SHT_rv* (Shroud temporary return value).

F_result_ptr The name of a variable in the Fortran wrapper which holds the result of the C wrapper for functions which return a class instance. It will be type `type(C_PTR)`.

F_result_capsule The name of the additional argument in the interface for functions which return a class instance. It will be type *F_capsule_data_type*.

F_string_result_as_arg The name of the output argument. Function which return a `char *` will instead be converted to a subroutine which require an additional argument for the result. See also *C_string_result_as_arg*.

F_this Name of the Fortran argument which is the derived type which represents a C++ class. It must not be the same as any of the routines arguments. Defaults to `obj`.

file_scope Used in filename creation to identify library, namespace, class.

library The value of global **field** *library*.

library_lower Lowercase version of *library*.

library_upper Uppercase version of *library*.

LUA_header_filename_suffix Suffix added to Lua header files. Defaults to `h`. Other useful values might be `hh` or `hxx`.

LUA_impl_filename_suffix Suffix added to Lua implementation files. Defaults to `cpp`. Other useful values might be `cc` or `cxx`.

LUA_module_name Name of Lua module for library. `{library_lower}`

LUA_prefix Prefix added to Lua wrapper functions.

LUA_result The name of the Lua wrapper's result variable. It defaults to *rv* (return value).

LUA_state_var Name of argument in Lua wrapper functions for lua_State pointer.

namespace_scope The current C++ namespace delimited with `::` and a trailing `::`. Used when referencing identifiers: `{namespace_scope}id`.

nullptr Set to *NULL* or *nullptr* based on option *CXX_standard*. Always *NULL* when *language* is C.

PY_ARRAY_UNIQUE_SYMBOL C preprocessor define used by NumPy to allow NumPy to be imported by several source files.

PY_header_filename_suffix Suffix added to Python header files. Defaults to `h`. Other useful values might be `hh` or `hxx`.

PY_impl_filename_suffix Suffix added to Python implementation files. Defaults to `cpp`. Other useful values might be `cc` or `cxx`.

PY_module_init Name of module and submodule initialization routine. library and namespaces delimited by _. Setting *PY_module_name* will update *PY_module_init*.

PY_module_name Name of generated Python module. Defaults to library name or namespace name.

PY_module_scope Name of module and submodule initialization routine. library and namespaces delimited by `.`. Setting *PY_module_name* will update *PY_module_scope*.

PY_name_impl Name of Python wrapper implemenation function. Each class and namespace is implemented in its own function with file static functions. There is no need to include the class or namespace in this name. Defaults to *{PY_prefix}{function_name}{function_suffix}*.

PY_prefix Prefix added to Python wrapper functions.

PY_result The name of the Python wrapper's result variable. It defaults to *SHTPy_rv* (return value). If the function returns multiple values (due to *intent(out)*) and the function result is already an object (for example, a NumPy array) then **PY_result** will be **SHResult**.

file_scope library plus any namespaces. The namespaces listed in the top level variable *namespace* is not included in the value. It is assumed that *library* will be used to generate unique names. Used in creating a filename.

stdlib Name of C++ standard library prefix. blank when *language=c*. `std::` when *language=c++*.

YAML_type_filename Output filename for type maps for classes.

19.6.2 Enumeration

cxx_value Value of enum from YAML file.

enum_lower

enum_name

enum_upper

enum_member_lower

enum_member_name

enum_member_upper

flat_name Scoped name of enumeration mapped to a legal C identifier. Scope operator *::* replaced with _. Used with *C_enum_template*.

C_enum_member C name for enum member. Computed from *C_enum_member_template*.

C_value Evalued value of enumeration. If the enum does not have an explict value, it will not be present.

C_scope_name Set to *flat_name* with a trailing undersore. Except for non-scoped enumerations in which case it is blank. Used with *C_enum_member_template*. Does not include the enum name in member names for non-scoped enumerations.

F_scope_name Value of *C_scope_name* converted to lower case. Used with *F_enum_member_template*.

F_enum_member Fortran name for enum member. Computed from *F_enum_member_template*.

F_value Evalued value of enumeration. If the enum does not have an explict value, it is the previous value plus one.

19.6.3 Class

C_header_filename Name of generated header file for the class. Defaulted from expansion of option *C_header_filename_class_template*.

C_impl_file Name of generated C++ implementation file for the library. Defaulted from expansion of option *C_impl_filename_class_template*.

F_derived_name Name of Fortran derived type for this class. Defaults to the value *cxx_class* (usually the C++ class name) converted to lowercase.

F_name_assign Name of method that controls assignment of shadow types. Used to help with reference counting.

F_name_associated Name of method to report if shadow type is associated. If the name is blank, no function is generated.

F_name_final Name of function used in `FINAL` for a class.

F_name_instance_get Name of method to get `type(C_PTR)` instance pointer from wrapped class. Defaults to *get_instance*. If the name is blank, no function is generated.

F_name_instance_set Name of method to set `type(C_PTR)` instance pointer in wrapped class. Defaults to *set_instance*. If the name is blank, no function is generated.

cxx_class The name of the C++ class from the YAML input file. Used in generating names for C and Fortran and filenames. When the class is templated, it willl be converted to a legal identifier by adding the *template_suffix* or a sequence number.

When *cxx_class* is set in the YAML file for a class, its value will be used in *class_scope*, *C_name_scope*, *F_name_scope* and *F_derived_name*.

cxx_type The namespace qualified name of the C++ class, including information from *template_arguments*, ex. `std::vector<int>`. Same as *cxx_class* if *template_arguments* is not defined. Used in generating C++ code.

class_scope Used to to access class static functions. Blank when not in a class. `{cxx_class}::`

C_prefix Prefix for C wrapper functions. The prefix helps to ensure unique global names. Defaults to the first three letters of *library_upper*.

PY_helper_prefix Prefix added to helper functions for the Python wrapper. This allows the helper functions to have names which will not conflict with any wrapped routines. When option *PY_write_helper_in_util* is *True*, *C_prefix* will be prefixed to the value to ensure the helper functions will not conflict with any routines in other wrapped libraries.

PY_type_obj Name variable which points to C or C++ memory. Defaults to *obj*.

PY_type_dtor Pointer to information used to release memory.

PY_PyTypeObject Name of *PyTypeObject* variable for a C++ class. Computed from option *PY_PyTypeObject*.

PY_PyTypeObject_base The name of *PyTypeObject* variable for base class of C++ class. Only single inheritance is support via the tp_base field of *PyTypeObject* struct.

19.6.4 Function

C_call_list Comma delimited list of function arguments.

C_name Name of the C wrapper function. Defaults to evaluation of option *C_name_template*.

C_prototype C prototype for the function. This will include any arguments required by annotations or options, such as length or **F_string_result_as_arg**.

C_return_type Return type of the C wrapper function. If the **return_this** field is true, then set to `void`.

Set to function's return type.

CXX_template The template component of the function declaration. `<{type}>`

CXX_this_call How to call the function. `{CXX_this}->` for instance methods and blank for library functions.

F_arg_c_call Comma delimited arguments to call C function from Fortran.

F_arguments Set from option *F_arguments* or generated from YAML decl.

F_C_arguments Argument names to the `bind(C)` interface for the subprogram.

F_C_call The name of the C function to call. Usually *F_C_name*, but it may be different if calling a generated routine. This can be done for functions with string arguments.

F_C_name Name of the Fortran `BIND(C)` interface for a C function. Defaults to the lower case version of *F_C_name_template*.

F_C_pure_clause TODO

F_C_result_clause Result clause for the `bind(C)` interface.

F_C_subprogram `subroutine` or `function`.

F_pure_clause For non-void function, `pure` if the *pure* annotation is added or the function is `const` and all arguments are `intent(in)`.

F_name_function The name of the *F_name_impl* subprogram when used as a type procedure. Defaults to evaluation of option *F_name_function_template*.

F_name_generic Defaults to evaluation of option *F_name_generic_template*.

F_name_impl Name of the Fortran implementation function. Defaults to evaluation of option *F_name_impl_template* .

F_result_clause `` result({F_result}) `` for functions. Blank for subroutines.

function_name Name of function in the YAML file.

function_suffix String append to a generated function name. Useful to distinguish overloaded function and functions with default arguments. Defaults to a sequence number with a leading underscore (e.g. *_0*, *_1*, ...) but can be set by using the function field *function_suffix*. Multiple suffixes may be applied – overloaded with default arguments.

LUA_name Name of function as known by LUA. Defaults to evaluation of option *LUA_name_template*.

shadow_var Name of variables which are shadow variables that represent a class. Used with C++ classes for C structs with *wrap_struct_as=class*.

template_suffix String which is append to the end of a generated function names to distinguish template instatiations. Default values generated by Shroud will include a leading underscore. i.e `_int` or `_0`.

underscore_name *function_name* converted from CamelCase to snake_case.

19.6.5 Argument

c_const `const` if argument has the *const* attribute.

c_deref Used to dereference *c_var*. `*` if it is a pointer, else blank.

c_var The C name of the argument.

c_var_len Function argument generated from the *len* annotation. Used with char/string arguments. Set from option **C_var_len_template**.

c_var_size Function argument generated from the *size* annotation. Used with array/std::vector arguments. Set from option **C_var_size_template**.

c_var_trim Function argument generated from the *len_trim* annotation. Used with char/string arguments. Set from option **C_var_trim_template**.

cxx_addr Syntax to take address of argument. `&` or blank.

cxx_nonconst_ptr A non-const pointer to *cxx_addr* using *const_cast* in C++ or a cast for C.

cxx_member Syntax to access members of *cxx_var*. If *cxx_local_var* is *object*, then set to `.`; if *pointer*, then set to `->`.

cxx_T The template parameter for std::vector arguments. `std::vector<cxx_T>`

cxx_type The C++ type of the argument.

cxx_var Name of the C++ variable.

f_var Fortran variable name for argument.

size_var Name of variable which holds the size of an array in the Python wrapper.

19.6.6 Result

cxx_rv_decl Declaration of variable to hold return value for function.

19.6.7 Variable

PY_struct_context Prefix used to to access struct/class variables. Includes trailing syntax to access member in a struct i.e. `.` or `->`. `self->obj->`.

19.7 Types Map

Types describe how to handle arguments from Fortran to C to C++. Then how to convert return values from C++ to C to Fortran.

Since Fortran 2003 (ISO/IEC 1539-1:2004(E)) there is a standardized way to generate procedure and derived-type declarations and global variables which are interoperable with C (ISO/IEC 9899:1999). The bind(C) attribute has been added to inform the compiler that a symbol shall be interoperable with C; also, some constraints are added. Note, however, that not all C features have a Fortran equivalent or vice versa. For instance, neither C's unsigned integers nor C's functions with variable number of arguments have an equivalent in Fortran.[1]

[1] https://gcc.gnu.org/onlinedocs/gfortran/Interoperability-with-C.html

forward Forward declaration. Defaults to *None*.

typedef Initialize from existing type Defaults to *None*.

f_return_code Fortran code used to call function and assign the return value. Defaults to *None*.

f_to_c Expression to convert Fortran type to C type. If this field is set, it will be used before f_cast. Defaults to *None*.

19.8 Doxygen

Used to insert directives for doxygen for a function.

brief Brief description.

description Full description.

return Description of return value.

19.9 Patterns

C_error_pattern Inserted after the call to the C++ function in the C wrapper. Format is evaluated in the context of the result argument. *c_var*, *c_var_len* refer to the result argument.

C_error_pattern_buf Inserted after the call to the C++ function in the buffer C wrapper for functions with string arguments. Format is evaluated in the context of the result argument.

PY_error_pattern Inserted into Python wrapper.

CHAPTER 20

Fortran Previous Work

Communicating between languages has a long history.

20.1 Babel

https://computation.llnl.gov/projects/babel-high-performance-language-interoperability Babel parses a SIDL (Scientific Interface Definition Language) file to generate source. It is a hub-and-spokes approach where each language it supports is mapped to a Babel runtime object. The last release was 2012-01-06. http://en.wikipedia.org/wiki/Babel_Middleware

20.2 Chasm

http://chasm-interop.sourceforge.net/ - This page is dated July 13, 2005

Chasm is a tool to improve C++ and Fortran 90 interoperability. Chasm parses Fortran 90 source code and automatically generates C++ bridging code that can be used in C++ programs to make calls to Fortran routines. It also automatically generates C structs that provide a bridge to Fortran derived types. Chasm supplies a C++ array descriptor class which provides an interface between C and F90 arrays. This allows arrays to be created in one language and then passed to and used by the other language. http://www.cs.uoregon.edu/research/pdt/users.php

- **CHASM: Static Analysis and Automatic Code Generation for Improved Fortran 90 and C++ Interoperability** C.E. Rasmussen, K.A. Lindlan, B. Mohr, J. Striegnitz
- Bridging the language gap in scientific computing: the Chasm approach C. E. Rasmussen, M. J. Sottile, S. S. Shende, A. D. Malony (2005)

20.3 wrap

https://github.com/scalability-llnl/wrap

a PMPI wrapper generator

20.4 Trilinos

http://trilinos.org/

Trilonos wraps C++ with C, then the Fortran over the C. Described in the book Scientific Software Design. http://www.amazon.com/Scientific-Software-Design-The-Object-Oriented/dp/0521888131

- On the object-oriented design of reference-counted shadow objects Karla Morris, Damian W.I. Rouson, Jim Xia (2011)
- This Isn't Your Parents' Fortran: Managing C++ Objects with Modern Fortran Damian Rouson, Karla Morris, Jim Xia (2012)

Directory packages/ForTrilinos/src/skeleton has a basic template which must be edited to create a wrapper for a class.

Exascale Programming: Adapting What We Have Can (and Must) Work

> In 2009 and 2010, the C++ based Trilinos project developed Fortran interface capabilities, called ForTrilinos. As an object-oriented (OO) collection of libraries, we assumed that the OO features of Fortran 2003 would provide us with natural mappings of Trilinos classes into Fortran equivalents. Over the two-year span of the ForTrilinos effort, we discovered that compiler support for 2003 features was very immature. ForTrilinos developers quickly came to know the handful of compiler developers who worked on these features and, despite close collaboration with them to complete and stabilize the implementation of Fortran 2003 features (in 2010), ForTrilinos stalled and is no longer developed.

http://www.hpcwire.com/2016/01/14/24151/

https://github.com/Trilinos/ForTrilinos https://www.researchgate.net/project/ForTrilinos

This is the new effort to provide Fortran interfaces to Trilinos through automatic code generation using SWIG. The previous effort (ca. 2008-2012) can be obtained by downloading Trilinos releases prior to 12.12.

https://trilinos.github.io/ForTrilinos/files/ForTrilinos_Design_Document.pdf

The custom version of swig available at https://github.com/swig-fortran/swig

20.5 MPICH

MPICH uses a custom perl scripts which has routine names and types in the source.

http://git.mpich.org/mpich.git/blob/HEAD:/src/binding/fortran/use_mpi/buildiface

20.6 GTK

gtk-fortran uses a python script which grep the C source to generate the Fortran.

https://github.com/jerryd/gtk-fortran/blob/master/src/cfwrapper.py https://github.com/vmagnin/gtk-fortran/wiki

20.7 CDI

CDI is a C and Fortran Interface to access Climate and NWP model Data. https://code.zmaw.de/projects/cdi

"One part of CDI[1] is a such generator. It still has some rough edges and we haven't yet decided what to do about functions returning char * (it seems like that will need some wrapping unless we simply return TYPE(c_ptr) and let the caller deal with that) but if you'd like to have a starting point in Ruby try interfaces/f2003/bindGen.rb from the tarball you can download" https://groups.google.com/d/msg/comp.lang.fortran/oadwd3HHtGA/J8DD8kGeVw8J

20.8 Forpy

This is a Fortran interface over the Python API written using the metaprogramming tool Fypp.

- Forpy: A library for Fortran-Python interoperability
- Fypp — Python powered Fortran metaprogramming

20.9 CNF

http://www.starlink.ac.uk/docs/sun209.htx/sun209.html

The CNF package comprises two sets of software which ease the task of writing portable programs in a mixture of FORTRAN and C. F77 is a set of C macros for handling the FORTRAN/C subroutine linkage in a portable way, and CNF is a set of functions to handle the difference between FORTRAN and C character strings, logical values and pointers to dynamically allocated memory.

20.10 Links

- Technical Specification ISO/IEC TS 29113:2012
- Generating C Interfaces
- Shadow-object interface between Fortran95 and C++ Mark G. Gray, Randy M. Roberts, and Tom M. Evans (1999)
- Generate C interface from C++ source code using Clang libtooling
- Memory leaks in derived types revisited G. W. Stewart (2003)
- A General Approach to Creating Fortran Interface for C++ Application Libraries

CHAPTER 21

Python Previous Work

There a several available tools to creating a Python interface to a C or C++ library.

21.1 Ctypes

- http://docs.python.org/lib/module-ctypes.html

21.1.1 Pros

- No need for compiler.

21.1.2 Cons

- Difficult wrapping C++ due to mangling and object ABI.

21.2 SWIG

- http://www.swig.org/

21.3 PyBindgen

- https://github.com/gjcarneiro/pybindgen
- http://pybindgen.readthedocs.io/en/latest/

21.4 Cython

- http://cython.org
- https://cython.readthedocs.io/en/latest/

http://blog.kevmod.com/2020/05/python-performance-its-not-just-the-interpreter/

I ran Cython (a Python->C converter) on the previous benchmark, and it runs in exactly the same amount of time: 2.11s. I wrote a simplified C extension in 36 lines compared to Cython's 3600, and it too runs in 2.11s.

21.5 SIP

Sip was developed to create PyQt.

- https://www.riverbankcomputing.com/software/sip/intro

21.6 Shiboken

Shiboken was developed to create PySide.

- https://wiki.qt.io/Qt_for_Python
- http://doc.qt.io/qtforpython/shiboken2/contents.html

21.7 Boost Python

- https://www.boost.org/doc/libs/1_66_0/libs/python/doc/html/index.html

21.8 Pybind11

- https://github.com/pybind/pybind11
- https://pybind11.readthedocs.io/en/stable/

21.9 Links

- Interfacing with C - Scipy lecture notes
- SciPy Cookbook

CHAPTER 22

Future Work

- complex
- pointers to pointers and in particular `char **` are not supported. An argument like `Class **ptr+intent(out)` does not work. Instead use a function which return a pointer to `Class *`
- reference counting and garbage collection
- Support for *Further Interoperability of Fortran with C*. This includes the ISO_Fortran_binding.h header file.

The copying of strings solves the blank-filled vs null-terminated differences between Fortran and C and works well for many strings. However, if a large buffer is passed, it may be desirable to avoid the copy.

There is some initial work to support Python and Lua wrappers.

22.1 Possible Future Work

Use a tool to parse C++ and extract info.

- https://github.com/CastXML/CastXML
- https://pypi.python.org/pypi/pygccxml
- Wrapping C and C++ Libraries with CastXML | SciPy 2015 | Brad King, Bill Hoffman, Matthew McCormick https://www.youtube.com/watch?v=O2lBgtaDdyk&index=20&list=PLYx7XA2nY5Gcpabmu61kKcToLz0FapmHu

CHAPTER 23

Sample Fortran Wrappers

This chapter gives details of the generated code. It's intended for users who want to understand the details of how the wrappers are created.

All of these examples are derived from tests in the `regression` directory.

23.1 No Arguments

C library function in `clibrary.c`:

```
void NoReturnNoArguments(void)
{
    strncpy(last_function_called, "Function1", MAXLAST);
    return;
}
```

`clibrary.yaml`:

```
- decl: void NoReturnNoArguments()
```

Fortran calls C via the following interface:

```
interface
    subroutine no_return_no_arguments() &
            bind(C, name="NoReturnNoArguments")
        implicit none
    end subroutine no_return_no_arguments
end interface
```

If wrapping a C++ library, a function with a C API will be created that Fortran can call.

```
void TUT_no_return_no_arguments(void)
{
```

(continues on next page)

(continued from previous page)

```
    // splicer begin function.no_return_no_arguments
    tutorial::NoReturnNoArguments();
    // splicer end function.no_return_no_arguments
}
```

Fortran usage:

```
use tutorial_mod
call no_return_no_arguments
```

The C++ usage is similar:

```
#include "tutorial.hpp"

tutorial::NoReturnNoArguments();
```

23.2 Numeric Types

23.2.1 PassByValue

C library function in `clibrary.c`:

```
double PassByValue(double arg1, int arg2)
{
    strncpy(last_function_called, "PassByValue", MAXLAST);
    return arg1 + arg2;
}
```

`clibrary.yaml`:

```
- decl: double PassByValue(double arg1, int arg2)
```

Both types are supported directly by the `iso_c_binding` module so there is no need for a Fortran function. The C function can be called directly by the Fortran interface using the `bind(C)` keyword.

Fortran calls C via the following interface:

```
interface
    function pass_by_value(arg1, arg2) &
            result(SHT_rv) &
            bind(C, name="PassByValue")
        use iso_c_binding, only : C_DOUBLE, C_INT
        implicit none
        real(C_DOUBLE), value, intent(IN) :: arg1
        integer(C_INT), value, intent(IN) :: arg2
        real(C_DOUBLE) :: SHT_rv
    end function pass_by_value
end interface
```

Fortran usage:

```
real(C_DOUBLE) :: rv_double
rv_double = pass_by_value(1.d0, 4)
call assert_true(rv_double == 5.d0)
```

23.2.2 PassByReference

C library function in `clibrary.c`:

```
void PassByReference(double *arg1, int *arg2)
{
    strncpy(last_function_called, "PassByReference", MAXLAST);
    *arg2 = *arg1;
}
```

`clibrary.yaml`:

```
- decl: void PassByReference(double *arg1+intent(in), int *arg2+intent(out))
```

Fortran calls C via the following interface:

```
interface
    subroutine pass_by_reference(arg1, arg2) &
            bind(C, name="PassByReference")
        use iso_c_binding, only : C_DOUBLE, C_INT
        implicit none
        real(C_DOUBLE), intent(IN) :: arg1
        integer(C_INT), intent(OUT) :: arg2
    end subroutine pass_by_reference
end interface
```

Example usage:

```
integer(C_INT) var
call pass_by_reference(3.14d0, var)
call assert_equals(3, var)
```

23.2.3 Sum

C++ library function from `pointers.cpp`:

```
void Sum(int len, const int *values, int *result)
{
    int sum = 0;
    for (int i=0; i < len; i++) {
        sum += values[i];
    }
    *result = sum;
    return;
}
```

`pointers.yaml`:

```
- decl: void Sum(int len +implied(size(values)),
                 int *values +rank(1)+intent(in),
                 int *result +intent(out))
```

The `POI` prefix to the function names is derived from the format field *C_prefix* which defaults to the first three letters of the *library* field, in this case *pointers*. This is a C++ file which provides a C API via `extern "C"`.

`wrappointers.cpp`:

```
void POI_sum(int len, const int * values, int * result)
{
    // splicer begin function.sum
    Sum(len, values, result);
    // splicer end function.sum
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_sum(len, values, result) &
            bind(C, name="POI_sum")
        use iso_c_binding, only : C_INT
        implicit none
        integer(C_INT), value, intent(IN) :: len
        integer(C_INT), intent(IN) :: values(*)
        integer(C_INT), intent(OUT) :: result
    end subroutine c_sum
end interface
```

The Fortran wrapper:

```
interface
    function sum_fixed_array() &
            result(SHT_rv) &
            bind(C, name="POI_sum_fixed_array")
        use iso_c_binding, only : C_INT
        implicit none
        integer(C_INT) :: SHT_rv
    end function sum_fixed_array
end interface
```

Example usage:

```
integer(C_INT) rv_int
call sum([1,2,3,4,5], rv_int)
call assert_true(rv_int .eq. 15, "sum")
```

23.2.4 truncate_to_int

Sometimes it is more convenient to have the wrapper allocate an `intent(out)` array before passing it to the C++ function. This can be accomplished by adding the *deref(allocatable)* attribute.

C++ library function from `pointers.c`:

```
void truncate_to_int(double *in, int *out, int size)
{
    int i;
    for(i = 0; i < size; i++) {
        out[i] = in[i];
    }
}
```

`pointers.yaml`:

```
- decl: void truncate_to_int(double * in      +intent(in)  +rank(1),
                             int *    out     +intent(out)
                                              +deref(allocatable)+dimension(size(in)),
                             int      sizein  +implied(size(in)))
```

Fortran calls C via the following interface:

```
interface
    subroutine c_truncate_to_int(in, out, sizein) &
            bind(C, name="truncate_to_int")
        use iso_c_binding, only : C_DOUBLE, C_INT
        implicit none
        real(C_DOUBLE), intent(IN) :: in(*)
        integer(C_INT), intent(OUT) :: out(*)
        integer(C_INT), value, intent(IN) :: sizein
    end subroutine c_truncate_to_int
end interface
```

The Fortran wrapper:

```
subroutine truncate_to_int(in, out)
    use iso_c_binding, only : C_DOUBLE, C_INT
    real(C_DOUBLE), intent(IN) :: in(:)
    integer(C_INT), intent(OUT), allocatable :: out(:)
    integer(C_INT) :: SH_sizein
    ! splicer begin function.truncate_to_int
    allocate(out(size(in)))
    SH_sizein = size(in,kind=C_INT)
    call c_truncate_to_int(in, out, SH_sizein)
    ! splicer end function.truncate_to_int
end subroutine truncate_to_int
```

Example usage:

```
integer(c_int), allocatable :: out_int(:)
call truncate_to_int([1.2d0, 2.3d0, 3.4d0, 4.5d0], out_int)
```

23.2.5 getRawPtrToFixedArray

C++ library function from `pointers.c`:

```
void getRawPtrToFixedArray(int **count)
{
    *count = (int *) &global_fixed_array;
}
```

`pointers.yaml`:

```
- decl: void getRawPtrToFixedArray(int **count+intent(out)+deref(raw))
```

Fortran calls C via the following interface:

```
subroutine get_raw_ptr_to_fixed_array(count)
    use iso_c_binding, only : C_INT, C_PTR
    type(C_PTR), intent(OUT) :: count
```

(continues on next page)

(continued from previous page)

```
    ! splicer begin function.get_raw_ptr_to_fixed_array
    type(POI_SHROUD_array) Dcount
    call c_get_raw_ptr_to_fixed_array_bufferify(Dcount)
    count = Dcount%base_addr
    ! splicer end function.get_raw_ptr_to_fixed_array
end subroutine get_raw_ptr_to_fixed_array
```

Example usage:

```
type(C_PTR) :: cptr_array
call get_raw_ptr_to_fixed_array(cptr_array)
```

23.2.6 getPtrToScalar

C++ library function from `pointers.c`:

```
void getPtrToScalar(int **nitems)
{
    *nitems = &global_int;
}
```

`pointers.yaml`:

```
- decl: void getPtrToScalar(int **nitems+intent(out))
```

This is a C file which provides the bufferify function.

`wrappointers.c`:

```
void POI_get_ptr_to_scalar_bufferify(POI_SHROUD_array *Dnitems)
{
    // splicer begin function.get_ptr_to_scalar_bufferify
    int *nitems;
    getPtrToScalar(&nitems);
    Dnitems->cxx.addr  = nitems;
    Dnitems->cxx.idtor = 0;
    Dnitems->addr.base = nitems;
    Dnitems->type = SH_TYPE_INT;
    Dnitems->elem_len = sizeof(int);
    Dnitems->rank = 0;
    Dnitems->size = 1;
    // splicer end function.get_ptr_to_scalar_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_ptr_to_scalar(nitems) &
            bind(C, name="getPtrToScalar")
        use iso_c_binding, only : C_PTR
        implicit none
        type(C_PTR), intent(OUT) :: nitems
    end subroutine c_get_ptr_to_scalar
end interface
```

The Fortran wrapper:

```
subroutine get_ptr_to_scalar(nitems)
    use iso_c_binding, only : C_INT, c_f_pointer
    integer(C_INT), intent(OUT), pointer :: nitems
    type(POI_SHROUD_array) :: Dnitems
    ! splicer begin function.get_ptr_to_scalar
    call c_get_ptr_to_scalar_bufferify(Dnitems)
    call c_f_pointer(Dnitems%base_addr, nitems)
    ! splicer end function.get_ptr_to_scalar
end subroutine get_ptr_to_scalar
```

Assigning to `iscalar` will modify the C++ variable. Example usage:

```
integer(C_INT), pointer :: iscalar
call get_ptr_to_scalar(iscalar)
iscalar = 0
```

23.2.7 getPtrToDynamicArray

C++ library function from `pointers.c`:

```
void getPtrToDynamicArray(int **count, int *len)
{
    *count = (int *) &global_fixed_array;
    *len = sizeof(global_fixed_array)/sizeof(int);
}
```

`pointers.yaml`:

```
- decl: void getPtrToDynamicArray(int **count+intent(out)+dimension(ncount),
                                  int *ncount+intent(out)+hidden)
```

This is a C file which provides the bufferify function.

`wrappointers.c`:

```
void POI_get_ptr_to_dynamic_array_bufferify(POI_SHROUD_array *Dcount,
    int * ncount)
{
    // splicer begin function.get_ptr_to_dynamic_array_bufferify
    int *count;
    getPtrToDynamicArray(&count, ncount);
    Dcount->cxx.addr  = count;
    Dcount->cxx.idtor = 0;
    Dcount->addr.base = count;
    Dcount->type = SH_TYPE_INT;
    Dcount->elem_len = sizeof(int);
    Dcount->rank = 1;
    Dcount->shape[0] = *ncount;
    Dcount->size = Dcount->shape[0];
    // splicer end function.get_ptr_to_dynamic_array_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_ptr_to_dynamic_array(count, ncount) &
```

(continues on next page)

(continued from previous page)

```
            bind(C, name="getPtrToDynamicArray")
        use iso_c_binding, only : C_INT, C_PTR
        implicit none
        type(C_PTR), intent(OUT) :: count
        integer(C_INT), intent(OUT) :: ncount
    end subroutine c_get_ptr_to_dynamic_array
end interface
```

The Fortran wrapper:

```
subroutine get_ptr_to_dynamic_array(count)
    use iso_c_binding, only : C_INT, c_f_pointer
    integer(C_INT), intent(OUT), pointer :: count(:)
    type(POI_SHROUD_array) :: Dcount
    integer(C_INT) :: ncount
    ! splicer begin function.get_ptr_to_dynamic_array
    call c_get_ptr_to_dynamic_array_bufferify(Dcount, ncount)
    call c_f_pointer(Dcount%base_addr, count, Dcount%shape(1:1))
    ! splicer end function.get_ptr_to_dynamic_array
end subroutine get_ptr_to_dynamic_array
```

Assigning to `iarray` will modify the C++ variable. Example usage:

```
integer(C_INT), pointer :: iarray(:)
call get_ptr_to_dynamic_array(iarray)
iarray = 0
```

23.2.8 getRawPtrToInt2d

global_int2d is a two dimensional array of non-contiguous rows. C stores the address of each row. Shroud can only deal with this as a `type(C_PTR)` and expects the user to dereference the address.

C++ library function from `pointers.c`:

```
static int global_int2d_1[] = {1,2,3};
static int global_int2d_2[] = {4,5};
static int *global_int2d[] = {global_int2d_1, global_int2d_2};

void getRawPtrToInt2d(int ***arg)
{
    *arg = (int **) global_int2d;
}
```

`pointers.yaml`:

```
- decl: void getRawPtrToInt2d(int ***arg +intent(out))
```

Fortran calls C via the following interface:

```
interface
    subroutine get_raw_ptr_to_int2d(arg) &
            bind(C, name="getRawPtrToInt2d")
        use iso_c_binding, only : C_PTR
        implicit none
        type(C_PTR), intent(OUT) :: arg
```

(continues on next page)

(continued from previous page)

```
    end subroutine get_raw_ptr_to_int2d
end interface
```

Example usage:

```
type(C_PTR) :: addr
type(C_PTR), pointer :: array2d(:)
integer(C_INT), pointer :: row1(:), row2(:)
integer total

call get_raw_ptr_to_int2d(addr)

! Dereference the pointers into two 1d arrays.
call c_f_pointer(addr, array2d, [2])
call c_f_pointer(array2d(1), row1, [3])
call c_f_pointer(array2d(2), row2, [2])

total = row1(1) + row1(2) + row1(3) + row2(1) + row2(2)
call assert_equals(15, total)
```

23.2.9 checkInt2d

Example of using the `type(C_PTR)` returned *getRawPtrToInt2d*.

`pointers.yaml`:

```
- decl: int checkInt2d(int **arg +intent(in))
```

Fortran calls C via the following interface. Note the use of `VALUE` attribute.

```
interface
    function check_int2d(arg) &
            result(SHT_rv) &
            bind(C, name="checkInt2d")
        use iso_c_binding, only : C_INT, C_PTR
        implicit none
        type(C_PTR), intent(IN), value :: arg
        integer(C_INT) :: SHT_rv
    end function check_int2d
end interface
```

Example usage:

```
type(C_PTR) :: addr
integer total

call get_raw_ptr_to_int2d(addr)
total = check_int2d(addr)
call assert_equals(15, total)
```

23.2.10 getMinMax

No Fortran function is created. Only an interface to a C wrapper which dereference the pointers so they can be treated as references.

C++ library function in `tutorial.cpp`:

```
void getMinMax(int &min, int &max)
{
  min = -1;
  max = 100;
}
```

`tutorial.yaml`:

```
- decl: void getMinMax(int &min +intent(out), int &max +intent(out))
```

The C wrapper:

```
void TUT_get_min_max(int * min, int * max)
{
    // splicer begin function.get_min_max
    tutorial::getMinMax(*min, *max);
    // splicer end function.get_min_max
}
```

Fortran calls C via the following interface:

```
interface
    subroutine get_min_max(min, max) &
            bind(C, name="TUT_get_min_max")
        use iso_c_binding, only : C_INT
        implicit none
        integer(C_INT), intent(OUT) :: min
        integer(C_INT), intent(OUT) :: max
    end subroutine get_min_max
end interface
```

Fortran usage:

```
call get_min_max(minout, maxout)
call assert_equals(-1, minout, "get_min_max minout")
call assert_equals(100, maxout, "get_min_max maxout")
```

23.2.11 returnIntPtrToScalar

`pointers.yaml`:

```
- decl: int *returnIntPtrToScalar(void)
```

Fortran calls C via the following interface:

```
interface
    function c_return_int_ptr_to_scalar() &
            result(SHT_rv) &
            bind(C, name="returnIntPtrToScalar")
        use iso_c_binding, only : C_PTR
        implicit none
        type(C_PTR) SHT_rv
    end function c_return_int_ptr_to_scalar
end interface
```

The Fortran wrapper:

```
function return_int_ptr_to_scalar() &
        result(SHT_rv)
    use iso_c_binding, only : C_INT, C_PTR, c_f_pointer
    integer(C_INT), pointer :: SHT_rv
    ! splicer begin function.return_int_ptr_to_scalar
    type(C_PTR) :: SHT_ptr
    SHT_ptr = c_return_int_ptr_to_scalar()
    call c_f_pointer(SHT_ptr, SHT_rv)
    ! splicer end function.return_int_ptr_to_scalar
end function return_int_ptr_to_scalar
```

Example usage:

```
integer(C_INT), pointer :: irvscalar
irvscalar => return_int_ptr_to_scalar()
```

23.2.12 returnIntPtrToFixedArray

`pointers.yaml`:

```
- decl: int *returnIntPtrToFixedArray(void) +dimension(10)
```

This is a C file which provides the bufferify function.

`wrappointers.c`:

```
int * POI_return_int_ptr_to_fixed_array_bufferify(
    POI_SHROUD_array *DSHC_rv)
{
    // splicer begin function.return_int_ptr_to_fixed_array_bufferify
    int * SHC_rv = returnIntPtrToFixedArray();
    DSHC_rv->cxx.addr  = SHC_rv;
    DSHC_rv->cxx.idtor = 0;
    DSHC_rv->addr.base = SHC_rv;
    DSHC_rv->type = SH_TYPE_INT;
    DSHC_rv->elem_len = sizeof(int);
    DSHC_rv->rank = 1;
    DSHC_rv->shape[0] = 10;
    DSHC_rv->size = DSHC_rv->shape[0];
    return SHC_rv;
    // splicer end function.return_int_ptr_to_fixed_array_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    function c_return_int_ptr_to_fixed_array_bufferify(DSHC_rv) &
            result(SHT_rv) &
            bind(C, name="POI_return_int_ptr_to_fixed_array_bufferify")
        use iso_c_binding, only : C_PTR
        import :: POI_SHROUD_array
        implicit none
        type(POI_SHROUD_array), intent(INOUT) :: DSHC_rv
        type(C_PTR) SHT_rv
```

(continues on next page)

(continued from previous page)

```
    end function c_return_int_ptr_to_fixed_array_bufferify
end interface
```

The Fortran wrapper:

```
function return_int_ptr_to_fixed_array() &
        result(SHT_rv)
    use iso_c_binding, only : C_INT, C_PTR, c_f_pointer
    type(POI_SHROUD_array) :: DSHC_rv
    integer(C_INT), pointer :: SHT_rv(:)
    ! splicer begin function.return_int_ptr_to_fixed_array
    type(C_PTR) :: SHT_ptr
    SHT_ptr = c_return_int_ptr_to_fixed_array_bufferify(DSHC_rv)
    call c_f_pointer(SHT_ptr, SHT_rv, DSHC_rv%shape(1:1))
    ! splicer end function.return_int_ptr_to_fixed_array
end function return_int_ptr_to_fixed_array
```

Example usage:

```
integer(C_INT), pointer :: irvarray(:)
irvarray => return_int_ptr_to_fixed_array()
```

23.2.13 returnIntScalar

`pointers.yaml`:

```
- decl: int *returnIntScalar(void) +deref(scalar)
```

This is a C file which provides the bufferify function.

`wrappointers.c`:

```
int POI_return_int_scalar(void)
{
    // splicer begin function.return_int_scalar
    int * SHC_rv = returnIntScalar();
    return *SHC_rv;
    // splicer end function.return_int_scalar
}
```

Fortran calls C via the following interface:

```
interface
    function return_int_scalar() &
            result(SHT_rv) &
            bind(C, name="POI_return_int_scalar")
        use iso_c_binding, only : C_INT
        implicit none
        integer(C_INT) :: SHT_rv
    end function return_int_scalar
end interface
```

Example usage:

```
ivalue = return_int_scalar()
```

23.3 Bool

23.3.1 checkBool

Assignments are done in the Fortran wrapper to convert between `logical` and `logical(C_BOOL)`.

C library function in `clibrary`:

```
void checkBool(const bool arg1, bool *arg2, bool *arg3)
{
    strncpy(last_function_called, "checkBool", MAXLAST);
    *arg2 = ! arg1;
    *arg3 = ! *arg3;
    return;
}
```

`clibrary.yaml`:

```
- decl: void checkBool(const bool arg1,
                       bool *arg2+intent(out),
                       bool *arg3+intent(inout))
```

Fortran calls C via the following interface:

```
interface
    subroutine c_check_bool(arg1, arg2, arg3) &
            bind(C, name="checkBool")
        use iso_c_binding, only : C_BOOL
        implicit none
        logical(C_BOOL), value, intent(IN) :: arg1
        logical(C_BOOL), intent(OUT) :: arg2
        logical(C_BOOL), intent(INOUT) :: arg3
    end subroutine c_check_bool
end interface
```

The Fortran wrapper:

```
subroutine check_bool(arg1, arg2, arg3)
    use iso_c_binding, only : C_BOOL
    logical, value, intent(IN) :: arg1
    logical, intent(OUT) :: arg2
    logical, intent(INOUT) :: arg3
    ! splicer begin function.check_bool
    logical(C_BOOL) SH_arg1
    logical(C_BOOL) SH_arg2
    logical(C_BOOL) SH_arg3
    SH_arg1 = arg1  ! coerce to C_BOOL
    SH_arg3 = arg3  ! coerce to C_BOOL
    call c_check_bool(SH_arg1, SH_arg2, SH_arg3)
    arg2 = SH_arg2  ! coerce to logical
    arg3 = SH_arg3  ! coerce to logical
    ! splicer end function.check_bool
end subroutine check_bool
```

Fortran usage:

```
logical rv_logical, wrk_logical
rv_logical = .true.
wrk_logical = .true.
call check_bool(.true., rv_logical, wrk_logical)
call assert_false(rv_logical)
call assert_false(wrk_logical)
```

23.4 Character

23.4.1 acceptName

Pass a NULL terminated string to a C function. The string will be unchanged.

C library function in clibrary.c:

```
void acceptName(const char *name)
{
    strncpy(last_function_called, "acceptName", MAXLAST);
}
```

clibrary.yaml:

```
- decl: void acceptName(const char *name)
```

Fortran calls C via the following interface:

```
interface
    subroutine c_accept_name(name) &
            bind(C, name="acceptName")
        use iso_c_binding, only : C_CHAR
        implicit none
        character(kind=C_CHAR), intent(IN) :: name(*)
    end subroutine c_accept_name
end interface
```

The Fortran wrapper:

```
subroutine accept_name(name)
    use iso_c_binding, only : C_NULL_CHAR
    character(len=*), intent(IN) :: name
    ! splicer begin function.accept_name
    call c_accept_name(trim(name)//C_NULL_CHAR)
    ! splicer end function.accept_name
end subroutine accept_name
```

No C wrapper is required since the Fortran wrapper creates a NULL terminated string by calling the Fortran intrinsic function trim and concatenating C_NULL_CHAR (from iso_c_binding). This can be done since the argument name is const which sets the attribute *intent(in)*.

Fortran usage:

```
call accept_name("spot")
```

23.4.2 returnOneName

Pass the pointer to a buffer which the C library will fill. The length of the string is implicitly known by the library to not exceed the library variable `MAXNAME`.

C library function in `clibrary.c`:

```
void returnOneName(char *name1)
{
  strcpy(name1, "bill");
}
```

`clibrary.yaml`:

```
- decl: void returnOneName(char *name1+intent(out)+charlen(MAXNAME))
```

The C wrapper:

```
void CLI_return_one_name_bufferify(char * name1, int Nname1)
{
    // splicer begin function.return_one_name_bufferify
    returnOneName(name1);
    ShroudStrBlankFill(name1, Nname1);
    // splicer end function.return_one_name_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_return_one_name_bufferify(name1, Nname1) &
            bind(C, name="CLI_return_one_name_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(OUT) :: name1(*)
        integer(C_INT), value, intent(IN) :: Nname1
    end subroutine c_return_one_name_bufferify
end interface
```

The Fortran wrapper:

```
subroutine return_one_name(name1)
    use iso_c_binding, only : C_INT
    character(len=*), intent(OUT) :: name1
    ! splicer begin function.return_one_name
    call c_return_one_name_bufferify(name1, len(name1, kind=C_INT))
    ! splicer end function.return_one_name
end subroutine return_one_name
```

Fortran usage:

```
name1 = " "
call return_one_name(name1)
call assert_equals("bill", name1)
```

23.4.3 passCharPtr

The function `passCharPtr(dest, src)` is equivalent to the Fortran statement `dest = src`:

C++ library function in `strings.cpp`:

```
void passCharPtr(char *dest, const char *src)
{
    std::strcpy(dest, src);
}
```

`strings.yaml`:

```
- decl: void passCharPtr(char * dest+intent(out)+charlen(40),
                         const char *src)
```

The intent of `dest` must be explicit. It defaults to *intent(inout)* since it is a pointer. `src` is implied to be *intent(in)* since it is `const`. This single line will create five different wrappers.

The native C version. The only feature this provides to Fortran is the ability to call a C++ function by wrapping it in an `extern "C"` function. The user is responsible for providing the `NULL` termination. The result in `str` will also be `NULL` terminated instead of blank filled.:

```
void STR_pass_char_ptr(char * dest, const char * src)
{
    // splicer begin function.pass_char_ptr
    passCharPtr(dest, src);
    // splicer end function.pass_char_ptr
}
```

The C wrapper:

```
void STR_pass_char_ptr_bufferify(char * dest, int Ndest,
    const char * src)
{
    // splicer begin function.pass_char_ptr_bufferify
    passCharPtr(dest, src);
    ShroudStrBlankFill(dest, Ndest);
    // splicer end function.pass_char_ptr_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_pass_char_ptr(dest, src) &
            bind(C, name="STR_pass_char_ptr")
        use iso_c_binding, only : C_CHAR
        implicit none
        character(kind=C_CHAR), intent(OUT) :: dest(*)
        character(kind=C_CHAR), intent(IN) :: src(*)
    end subroutine c_pass_char_ptr
end interface
```

```
interface
    subroutine c_pass_char_ptr_bufferify(dest, Ndest, src) &
            bind(C, name="STR_pass_char_ptr_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(OUT) :: dest(*)
        integer(C_INT), value, intent(IN) :: Ndest
        character(kind=C_CHAR), intent(IN) :: src(*)
```

(continues on next page)

(continued from previous page)

```
    end subroutine c_pass_char_ptr_bufferify
end interface
```

The Fortran wrapper:

```
subroutine pass_char_ptr(dest, src)
    use iso_c_binding, only : C_INT, C_NULL_CHAR
    character(len=*), intent(OUT) :: dest
    character(len=*), intent(IN) :: src
    ! splicer begin function.pass_char_ptr
    call c_pass_char_ptr_bufferify(dest, len(dest, kind=C_INT), &
        trim(src)//C_NULL_CHAR)
    ! splicer end function.pass_char_ptr
end subroutine pass_char_ptr
```

The function can be called without the user aware that it is written in C++:

```
character(30) str
call pass_char_ptr(dest=str, src="mouse")
```

23.4.4 ImpliedTextLen

Pass the pointer to a buffer which the C library will fill. The length of the buffer is passed in `ltext`. Since Fortran knows the length of `CHARACTER` variable, the Fortran wrapper does not need to be explicitly told the length of the variable. Instead its value can be defined with the *implied* attribute.

This can be used to emulate the behavior of most Fortran compilers which will pass an additional, hidden argument which contains the length of a `CHARACTER` argument.

C library function in `clibrary.c`:

```
void ImpliedTextLen(char *text, int ltext)
{
    strncpy(text, "ImpliedTextLen", ltext);
    strncpy(last_function_called, "ImpliedTextLen", MAXLAST);
}
```

`clibrary.yaml`:

```
- decl: void ImpliedTextLen(char *text+intent(out)+charlen(MAXNAME),
                            int ltext+implied(len(text)))
```

The C wrapper:

```
void CLI_implied_text_len_bufferify(char * text, int Ntext, int ltext)
{
    // splicer begin function.implied_text_len_bufferify
    ImpliedTextLen(text, ltext);
    ShroudStrBlankFill(text, Ntext);
    // splicer end function.implied_text_len_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_implied_text_len_bufferify(text, Ntext, ltext) &
            bind(C, name="CLI_implied_text_len_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(OUT) :: text(*)
        integer(C_INT), value, intent(IN) :: Ntext
        integer(C_INT), value, intent(IN) :: ltext
    end subroutine c_implied_text_len_bufferify
end interface
```

The Fortran wrapper:

```
subroutine implied_text_len(text)
    use iso_c_binding, only : C_INT
    character(len=*), intent(OUT) :: text
    integer(C_INT) :: SH_ltext
    ! splicer begin function.implied_text_len
    SH_ltext = len(text,kind=C_INT)
    call c_implied_text_len_bufferify(text, len(text, kind=C_INT), &
        SH_ltext)
    ! splicer end function.implied_text_len
end subroutine implied_text_len
```

Fortran usage:

```
character(MAXNAME) name1
call implied_text_len(name1)
call assert_equals("ImpliedTextLen", name1)
```

23.4.5 acceptCharArrayIn

Arguments of type `char **` are assumed to be a list of `NULL` terminated strings. In Fortran this pattern would be an array of `CHARACTER` where all strings are the same length. The Fortran variable is converted into the the C version by copying the data then releasing it at the end of the wrapper.

`pointers.yaml`:

```
- decl: void acceptCharArrayIn(char **names +intent(in))
```

This is a C file which provides the bufferify function.

`wrappointers.c`:

```
int POI_accept_char_array_in_bufferify(char *names, long Snames,
    int Nnames)
{
    // splicer begin function.accept_char_array_in_bufferify
    char **SHCXX_names = ShroudStrArrayAlloc(names, Snames, Nnames);
    int SHC_rv = acceptCharArrayIn(SHCXX_names);
    ShroudStrArrayFree(SHCXX_names, Snames);
    return SHC_rv;
    // splicer end function.accept_char_array_in_bufferify
}
```

Most of the work is done by the helper function:

```
// helper ShroudStrArrayAlloc
// Copy src into new memory and null terminate.
static char **ShroudStrArrayAlloc(const char *src, int nsrc, int len)
{
   char **rv = malloc(sizeof(char *) * nsrc);
   const char *src0 = src;
   for(int i=0; i < nsrc; ++i) {
      int ntrim = ShroudLenTrim(src0, len);
      char *tgt = malloc(ntrim+1);
      memcpy(tgt, src0, ntrim);
      tgt[ntrim] = '\0';
      rv[i] = tgt;
      src0 += len;
   }
   return rv;
}
```

Fortran calls C via the following interface:

```
interface
    function c_accept_char_array_in(names) &
            result(SHT_rv) &
            bind(C, name="acceptCharArrayIn")
        use iso_c_binding, only : C_INT, C_PTR
        implicit none
        type(C_PTR), intent(IN) :: names(*)
        integer(C_INT) :: SHT_rv
    end function c_accept_char_array_in
end interface
```

The Fortran wrapper:

```
function accept_char_array_in(names) &
        result(SHT_rv)
    use iso_c_binding, only : C_INT, C_LONG
    character(len=*), intent(IN) :: names(:)
    integer(C_INT) :: SHT_rv
    ! splicer begin function.accept_char_array_in
    SHT_rv = c_accept_char_array_in_bufferify(names, &
        size(names, kind=C_LONG), len(names, kind=C_INT))
    ! splicer end function.accept_char_array_in
end function accept_char_array_in
```

Example usage:

```
character(10) :: in(3) = [ &
     "dog       ", &
     "cat       ", &
     "monkey    "  &
     ]
call accept_char_array_in(in)
```

23.5 std::string

23.5.1 acceptStringReference

C++ library function in `strings.c`:

```
void acceptStringReference(std::string & arg1)
{
    arg1.append("dog");
}
```

`strings.yaml`:

```
- decl: void acceptStringReference(std::string & arg1)
```

A reference defaults to *intent(inout)* and will add both the *len* and *len_trim* annotations.

Both generated functions will convert `arg` into a `std::string`, call the function, then copy the results back into the argument.

Which will call the C wrapper:

```
void STR_accept_string_reference(char * arg1)
{
    // splicer begin function.accept_string_reference
    std::string SHCXX_arg1(arg1);
    acceptStringReference(SHCXX_arg1);
    strcpy(arg1, SHCXX_arg1.c_str());
    // splicer end function.accept_string_reference
}
```

The C wrapper:

```
void STR_accept_string_reference_bufferify(char * arg1, int Larg1,
    int Narg1)
{
    // splicer begin function.accept_string_reference_bufferify
    std::string SHCXX_arg1(arg1, Larg1);
    acceptStringReference(SHCXX_arg1);
    ShroudStrCopy(arg1, Narg1, SHCXX_arg1.data(), SHCXX_arg1.size());
    // splicer end function.accept_string_reference_bufferify
}
```

An interface for the native C function is also created:

```
interface
    subroutine c_accept_string_reference(arg1) &
            bind(C, name="STR_accept_string_reference")
        use iso_c_binding, only : C_CHAR
        implicit none
        character(kind=C_CHAR), intent(INOUT) :: arg1(*)
    end subroutine c_accept_string_reference
end interface
```

Fortran calls C via the following interface:

```
interface
    subroutine c_accept_string_reference_bufferify(arg1, Larg1, &
            Narg1) &
            bind(C, name="STR_accept_string_reference_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(INOUT) :: arg1(*)
        integer(C_INT), value, intent(IN) :: Larg1
        integer(C_INT), value, intent(IN) :: Narg1
    end subroutine c_accept_string_reference_bufferify
end interface
```

The Fortran wrapper:

```
subroutine accept_string_reference(arg1)
    use iso_c_binding, only : C_INT
    character(len=*), intent(INOUT) :: arg1
    ! splicer begin function.accept_string_reference
    call c_accept_string_reference_bufferify(arg1, &
        len_trim(arg1, kind=C_INT), len(arg1, kind=C_INT))
    ! splicer end function.accept_string_reference
end subroutine accept_string_reference
```

The important thing to notice is that the pure C version could do very bad things since it does not know how much space it has to copy into. The bufferify version knows the allocated length of the argument. However, since the input argument is a fixed length it may be too short for the new string value:

Fortran usage:

```
character(30) str
str = "cat"
call accept_string_reference(str)
call assert_true( str == "catdog")
```

23.6 char functions

23.6.1 getCharPtr1

Return a pointer and convert into an `ALLOCATABLE CHARACTER` variable. The Fortran application is responsible to release the memory. However, this may be done automatically by the Fortran runtime.

C++ library function in `strings.cpp`:

```
const char * getCharPtr1()
{
    return static_char;
}
```

`strings.yaml`:

```
- decl: const char * getCharPtr1()
```

The C wrapper copies all of the metadata into a `SHROUD_array` struct which is used by the Fortran wrapper:

```
void STR_get_char_ptr1_bufferify(STR_SHROUD_array *DSHF_rv)
{
    // splicer begin function.get_char_ptr1_bufferify
    const char * SHC_rv = getCharPtr1();
    DSHF_rv->cxx.addr = const_cast<char *>(SHC_rv);
    DSHF_rv->cxx.idtor = 0;
    DSHF_rv->addr.ccharp = SHC_rv;
    DSHF_rv->type = SH_TYPE_OTHER;
    DSHF_rv->elem_len = SHC_rv == nullptr ? 0 : std::strlen(SHC_rv);
    DSHF_rv->size = 1;
    DSHF_rv->rank = 0;
    // splicer end function.get_char_ptr1_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_char_ptr1_bufferify(DSHF_rv) &
            bind(C, name="STR_get_char_ptr1_bufferify")
        import :: STR_SHROUD_array
        implicit none
        type(STR_SHROUD_array), intent(OUT) :: DSHF_rv
    end subroutine c_get_char_ptr1_bufferify
end interface
```

The Fortran wrapper uses the metadata in `DSHF_rv` to allocate a `CHARACTER` variable of the correct length. The helper function `SHROUD_copy_string_and_free` will copy the results of the C++ function into the return variable:

```
function get_char_ptr1() &
        result(SHT_rv)
    type(STR_SHROUD_array) :: DSHF_rv
    character(len=:), allocatable :: SHT_rv
    ! splicer begin function.get_char_ptr1
    call c_get_char_ptr1_bufferify(DSHF_rv)
    allocate(character(len=DSHF_rv%elem_len):: SHT_rv)
    call STR_SHROUD_copy_string_and_free(DSHF_rv, SHT_rv, DSHF_rv%elem_len)
    ! splicer end function.get_char_ptr1
end function get_char_ptr1
```

Fortran usage:

```
character(len=:), allocatable :: str
str = get_char_ptr1()
```

23.6.2 getCharPtr2

If you know the maximum size of string that you expect the function to return, then the *len* attribute is used to declare the length. The explicit `ALLOCATE` is avoided but any result which is longer than the length will be silently truncated.

C++ library function in `strings.cpp`:

```
const char * getCharPtr2()
{
    return static_char;
}
```

strings.yaml:

```
- decl: const char * getCharPtr2() +len(30)
```

The C wrapper:

```
void STR_get_char_ptr2_bufferify(char * SHF_rv, int NSHF_rv)
{
    // splicer begin function.get_char_ptr2_bufferify
    const char * SHC_rv = getCharPtr2();
    ShroudStrCopy(SHF_rv, NSHF_rv, SHC_rv, -1);
    // splicer end function.get_char_ptr2_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_char_ptr2_bufferify(SHF_rv, NSHF_rv) &
            bind(C, name="STR_get_char_ptr2_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(OUT) :: SHF_rv(*)
        integer(C_INT), value, intent(IN) :: NSHF_rv
    end subroutine c_get_char_ptr2_bufferify
end interface
```

The Fortran wrapper:

```
function get_char_ptr2() &
        result(SHT_rv)
    use iso_c_binding, only : C_INT
    character(len=30) :: SHT_rv
    ! splicer begin function.get_char_ptr2
    call c_get_char_ptr2_bufferify(SHT_rv, len(SHT_rv, kind=C_INT))
    ! splicer end function.get_char_ptr2
end function get_char_ptr2
```

Fortran usage:

```
character(30) str
str = get_char_ptr2()
```

23.6.3 getCharPtr3

Create a Fortran subroutine with an additional CHARACTER argument for the C function result. Any size character string can be returned limited by the size of the Fortran argument. The argument is defined by the *F_string_result_as_arg* format string.

C++ library function in strings.cpp:

```
const char * getCharPtr3()
{
    return static_char;
}
```

strings.yaml:

```
- decl: const char * getCharPtr3()
  format:
    F_string_result_as_arg: output
```

The C wrapper:

```
void STR_get_char_ptr3_bufferify(char * output, int Noutput)
{
    // splicer begin function.get_char_ptr3_bufferify
    const char * SHC_rv = getCharPtr3();
    ShroudStrCopy(output, Noutput, SHC_rv, -1);
    // splicer end function.get_char_ptr3_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_char_ptr3_bufferify(output, Noutput) &
            bind(C, name="STR_get_char_ptr3_bufferify")
        use iso_c_binding, only : C_CHAR, C_INT
        implicit none
        character(kind=C_CHAR), intent(OUT) :: output(*)
        integer(C_INT), value, intent(IN) :: Noutput
    end subroutine c_get_char_ptr3_bufferify
end interface
```

The Fortran wrapper:

```
subroutine get_char_ptr3(output)
    use iso_c_binding, only : C_INT
    character(len=*), intent(OUT) :: output
    ! splicer begin function.get_char_ptr3
    call c_get_char_ptr3_bufferify(output, len(output, kind=C_INT))
    ! splicer end function.get_char_ptr3
end subroutine get_char_ptr3
```

Fortran usage:

```
character(30) str
call get_char_ptrs(str)
```

23.7 string functions

23.7.1 getConstStringRefPure

C++ library function in `strings.cpp`:

```
const std::string& getConstStringRefPure()
{
    return static_str;
}
```

`strings.yaml`:

```
- decl: const string& getConstStringRefPure()
```

The C wrapper:

```
void STR_get_const_string_ref_pure_bufferify(STR_SHROUD_array *DSHF_rv)
{
    // splicer begin function.get_const_string_ref_pure_bufferify
    const std::string & SHCXX_rv = getConstStringRefPure();
    ShroudStrToArray(DSHF_rv, &SHCXX_rv, 0);
    // splicer end function.get_const_string_ref_pure_bufferify
}
```

The native C wrapper:

```
const char * STR_get_const_string_ref_pure(void)
{
    // splicer begin function.get_const_string_ref_pure
    const std::string & SHCXX_rv = getConstStringRefPure();
    const char * SHC_rv = SHCXX_rv.c_str();
    return SHC_rv;
    // splicer end function.get_const_string_ref_pure
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_get_const_string_ref_pure_bufferify(DSHF_rv) &
            bind(C, name="STR_get_const_string_ref_pure_bufferify")
        import :: STR_SHROUD_array
        implicit none
        type(STR_SHROUD_array), intent(OUT) :: DSHF_rv
    end subroutine c_get_const_string_ref_pure_bufferify
end interface
```

The Fortran wrapper:

```
function get_const_string_ref_pure() &
        result(SHT_rv)
    type(STR_SHROUD_array) :: DSHF_rv
    character(len=:), allocatable :: SHT_rv
    ! splicer begin function.get_const_string_ref_pure
    call c_get_const_string_ref_pure_bufferify(DSHF_rv)
    allocate(character(len=DSHF_rv%elem_len):: SHT_rv)
    call STR_SHROUD_copy_string_and_free(DSHF_rv, SHT_rv, DSHF_rv%elem_len)
    ! splicer end function.get_const_string_ref_pure
end function get_const_string_ref_pure
```

Fortran usage:

```
str = 'XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX'
str = get_const_string_ref_pure()
call assert_true( str == static_str, "getConstStringRefPure")
```

23.8 std::vector

23.8.1 vector_sum

C++ library function in `vectors.cpp`:

```
int vector_sum(const std::vector<int> &arg)
{
  int sum = 0;
  for(std::vector<int>::const_iterator it = arg.begin(); it != arg.end(); ++it) {
    sum += *it;
  }
  return sum;
}
```

`vectors.yaml`:

```
- decl: int vector_sum(const std::vector<int> &arg)
```

`intent(in)` is implied for the *vector_sum* argument since it is `const`. The Fortran wrapper passes the array and the size to C.

The C wrapper:

```
int VEC_vector_sum_bufferify(const int * arg, long Sarg)
{
    // splicer begin function.vector_sum_bufferify
    const std::vector<int> SHCXX_arg(arg, arg + Sarg);
    int SHC_rv = vector_sum(SHCXX_arg);
    return SHC_rv;
    // splicer end function.vector_sum_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    function c_vector_sum_bufferify(arg, Sarg) &
            result(SHT_rv) &
            bind(C, name="VEC_vector_sum_bufferify")
        use iso_c_binding, only : C_INT, C_LONG
        implicit none
        integer(C_INT), intent(IN) :: arg(*)
        integer(C_LONG), value, intent(IN) :: Sarg
        integer(C_INT) :: SHT_rv
    end function c_vector_sum_bufferify
end interface
```

The Fortran wrapper:

```
function vector_sum(arg) &
        result(SHT_rv)
    use iso_c_binding, only : C_INT, C_LONG
    integer(C_INT), intent(IN) :: arg(:)
    integer(C_INT) :: SHT_rv
    ! splicer begin function.vector_sum
    SHT_rv = c_vector_sum_bufferify(arg, size(arg, kind=C_LONG))
```

(continues on next page)

(continued from previous page)

```
    ! splicer end function.vector_sum
end function vector_sum
```

Fortran usage:

```
integer(C_INT) intv(5)
intv = [1,2,3,4,5]
irv = vector_sum(intv)
call assert_true(irv .eq. 15)
```

23.8.2 vector_iota_out

C++ library function in `vectors.cpp` accepts an empty vector then fills in some values. In this example, a Fortran array is passed in and will be filled.

```
void vector_iota_out(std::vector<int> &arg)
{
  for(unsigned int i=0; i < 5; i++) {
    arg.push_back(i + 1);
  }
  return;
}
```

`vectors.yaml`:

```
- decl: void vector_iota_out(std::vector<int> &arg+intent(out))
```

The C wrapper allocates a new `std::vector` instance which will be returned to the Fortran wrapper. Variable `Darg` will be filled with the meta data for the `std::vector` in a form that allows Fortran to access it. The value of `Darg->cxx.idtor` is computed by Shroud and used to release the memory (index of destructor).

```
void VEC_vector_iota_out_bufferify(VEC_SHROUD_array *Darg)
{
    // splicer begin function.vector_iota_out_bufferify
    std::vector<int> *SHCXX_arg = new std::vector<int>;
    vector_iota_out(*SHCXX_arg);
    Darg->cxx.addr  = SHCXX_arg;
    Darg->cxx.idtor = 1;
    Darg->addr.base = SHCXX_arg->empty() ? nullptr : &SHCXX_arg->front();
    Darg->type = SH_TYPE_INT;
    Darg->elem_len = sizeof(int);
    Darg->size = SHCXX_arg->size();
    Darg->rank = 1;
    Darg->shape[0] = Darg->size;
    // splicer end function.vector_iota_out_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_vector_iota_out_bufferify(Darg) &
            bind(C, name="VEC_vector_iota_out_bufferify")
        import :: VEC_SHROUD_array
        implicit none
```

(continues on next page)

(continued from previous page)

```
        type(VEC_SHROUD_array), intent(INOUT) :: Darg
    end subroutine c_vector_iota_out_bufferify
end interface
```

The Fortran wrapper passes a `SHROUD_array` instance which will be filled by the C wrapper.

```
subroutine vector_iota_out(arg)
    use iso_c_binding, only : C_INT, C_SIZE_T
    integer(C_INT), intent(OUT) :: arg(:)
    type(VEC_SHROUD_array) :: Darg
    ! splicer begin function.vector_iota_out
    call c_vector_iota_out_bufferify(Darg)
    call VEC_SHROUD_copy_array_int(Darg, arg, &
        size(arg,kind=C_SIZE_T))
    ! splicer end function.vector_iota_out
end subroutine vector_iota_out
```

Function `SHROUD_copy_array_int` copies the values into the user's argument. If the argument is too short, not all values returned by the library function will be copied.

```
// helper copy_array
// Copy std::vector into array c_var(c_var_size).
// Then release std::vector.
// Called from Fortran.
void VEC_ShroudCopyArray(VEC_SHROUD_array *data, void *c_var,
    size_t c_var_size)
{
    const void *cxx_var = data->addr.base;
    int n = c_var_size < data->size ? c_var_size : data->size;
    n *= data->elem_len;
    std::memcpy(c_var, cxx_var, n);
    VEC_SHROUD_memory_destructor(&data->cxx); // delete data->cxx.addr
}
```

Finally, the `std::vector` is released based on the value of `idtor`:

```
// Release library allocated memory.
void VEC_SHROUD_memory_destructor(VEC_SHROUD_capsule_data *cap)
{
    void *ptr = cap->addr;
    switch (cap->idtor) {
    case 0:   // --none--
    {
        // Nothing to delete
        break;
    }
    case 1:   // std_vector_int
    {
        std::vector<int> *cxx_ptr =
            reinterpret_cast<std::vector<int> *>(ptr);
        delete cxx_ptr;
        break;
    }
    case 2:   // std_vector_double
    {
        std::vector<double> *cxx_ptr =
```

(continues on next page)

(continued from previous page)

```
            reinterpret_cast<std::vector<double> *>(ptr);
        delete cxx_ptr;
        break;
    }
    default:
    {
        // Unexpected case in destructor
        break;
    }
    }
    cap->addr = nullptr;
    cap->idtor = 0;  // avoid deleting again
}
```

Fortran usage:

```
integer(C_INT) intv(5)
intv(:) = 0
call vector_iota_out(intv)
call assert_true(all(intv(:) .eq. [1,2,3,4,5]))
```

23.8.3 vector_iota_out_alloc

C++ library function in `vectors.cpp` accepts an empty vector then fills in some values. In this example, the Fortran argument is `ALLOCATABLE` and will be sized based on the output of the library function.

```
void vector_iota_out_alloc(std::vector<int> &arg)
{
  for(unsigned int i=0; i < 5; i++) {
    arg.push_back(i + 1);
  }
  return;
}
```

The attribute *+deref(allocatable)* will cause the argument to be an `ALLOCATABLE` array.

`vectors.yaml`:

```
- decl: void vector_iota_out_alloc(std::vector<int> &
↪arg+intent(out)+deref(allocatable))
```

The C wrapper:

```
void VEC_vector_iota_out_alloc_bufferify(VEC_SHROUD_array *Darg)
{
    // splicer begin function.vector_iota_out_alloc_bufferify
    std::vector<int> *SHCXX_arg = new std::vector<int>;
    vector_iota_out_alloc(*SHCXX_arg);
    Darg->cxx.addr  = SHCXX_arg;
    Darg->cxx.idtor = 1;
    Darg->addr.base = SHCXX_arg->empty() ? nullptr : &SHCXX_arg->front();
    Darg->type = SH_TYPE_INT;
    Darg->elem_len = sizeof(int);
    Darg->size = SHCXX_arg->size();
    Darg->rank = 1;
```

(continues on next page)

(continued from previous page)

```
    Darg->shape[0] = Darg->size;
    // splicer end function.vector_iota_out_alloc_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_vector_iota_out_alloc_bufferify(Darg) &
            bind(C, name="VEC_vector_iota_out_alloc_bufferify")
        import :: VEC_SHROUD_array
        implicit none
        type(VEC_SHROUD_array), intent(INOUT) :: Darg
    end subroutine c_vector_iota_out_alloc_bufferify
end interface
```

The Fortran wrapper passes a `SHROUD_array` instance which will be filled by the C wrapper. After the function returns, the `allocate` statement allocates an array of the proper length.

```
subroutine vector_iota_out_alloc(arg)
    use iso_c_binding, only : C_INT, C_SIZE_T
    integer(C_INT), intent(OUT), allocatable :: arg(:)
    type(VEC_SHROUD_array) :: Darg
    ! splicer begin function.vector_iota_out_alloc
    call c_vector_iota_out_alloc_bufferify(Darg)
    allocate(arg(Darg%size))
    call VEC_SHROUD_copy_array_int(Darg, arg, &
        size(arg,kind=C_SIZE_T))
    ! splicer end function.vector_iota_out_alloc
end subroutine vector_iota_out_alloc
```

`inta` is `intent(out)`, so it will be deallocated upon entry to `vector_iota_out_alloc`.

Fortran usage:

```
integer(C_INT), allocatable :: inta(:)
call vector_iota_out_alloc(inta)
call assert_true(allocated(inta))
call assert_equals(5 , size(inta))
call assert_true( all(inta == [1,2,3,4,5]), &
     "vector_iota_out_alloc value")
```

23.8.4 vector_iota_inout_alloc

C++ library function in `vectors.cpp`:

```
void vector_iota_inout_alloc(std::vector<int> &arg)
{
  for(unsigned int i=0; i < 5; i++) {
    arg.push_back(i + 11);
  }
  return;
}
```

`vectors.yaml`:

```
- decl: void vector_iota_out_alloc(std::vector<int> &
↪arg+intent(inout)+deref(allocatable))
```

The C wrapper creates a new `std::vector` and initializes it to the Fortran argument.

```
void VEC_vector_iota_inout_alloc_bufferify(int * arg, long Sarg,
    VEC_SHROUD_array *Darg)
{
    // splicer begin function.vector_iota_inout_alloc_bufferify
    std::vector<int> *SHCXX_arg = new std::vector<int>(arg, arg + Sarg);
    vector_iota_inout_alloc(*SHCXX_arg);
    Darg->cxx.addr  = SHCXX_arg;
    Darg->cxx.idtor = 1;
    Darg->addr.base = SHCXX_arg->empty() ? nullptr : &SHCXX_arg->front();
    Darg->type = SH_TYPE_INT;
    Darg->elem_len = sizeof(int);
    Darg->size = SHCXX_arg->size();
    Darg->rank = 1;
    Darg->shape[0] = Darg->size;
    // splicer end function.vector_iota_inout_alloc_bufferify
}
```

Fortran calls C via the following interface:

```
interface
    subroutine c_vector_iota_inout_alloc_bufferify(arg, Sarg, Darg) &
            bind(C, name="VEC_vector_iota_inout_alloc_bufferify")
        use iso_c_binding, only : C_INT, C_LONG
        import :: VEC_SHROUD_array
        implicit none
        integer(C_INT), intent(INOUT) :: arg(*)
        integer(C_LONG), value, intent(IN) :: Sarg
        type(VEC_SHROUD_array), intent(INOUT) :: Darg
    end subroutine c_vector_iota_inout_alloc_bufferify
end interface
```

The Fortran wrapper will deallocate the argument after returning since it is *intent(inout)*. The *in* values are now stored in the `std::vector`. A new array is allocated to the current size of the `std::vector`. Fortran has no reallocate statement. Finally, the new values are copied into the Fortran array and the `std::vector` is released.

```
subroutine vector_iota_inout_alloc(arg)
    use iso_c_binding, only : C_INT, C_LONG, C_SIZE_T
    integer(C_INT), intent(INOUT), allocatable :: arg(:)
    type(VEC_SHROUD_array) :: Darg
    ! splicer begin function.vector_iota_inout_alloc
    call c_vector_iota_inout_alloc_bufferify(arg, &
        size(arg, kind=C_LONG), Darg)
    if (allocated(arg)) deallocate(arg)
    allocate(arg(Darg%size))
    call VEC_SHROUD_copy_array_int(Darg, arg, &
        size(arg,kind=C_SIZE_T))
    ! splicer end function.vector_iota_inout_alloc
end subroutine vector_iota_inout_alloc
```

`inta` is `intent(inout)`, so it will NOT be deallocated upon entry to `vector_iota_inout_alloc`. Fortran usage:

```
call vector_iota_inout_alloc(inta)
call assert_true(allocated(inta))
call assert_equals(10 , size(inta))
call assert_true( all(inta == [1,2,3,4,5,11,12,13,14,15]), &
     "vector_iota_inout_alloc value")
deallocate(inta)
```

23.9 Void Pointers

23.9.1 passAssumedType

C library function in `clibrary.c`:

```
int passAssumedType(void *arg)
{
    strncpy(last_function_called, "passAssumedType", MAXLAST);
    return *(int *) arg;
}
```

`clibrary.yaml`:

```
- decl: int passAssumedType(void *arg+assumedtype)
```

Fortran calls C via the following interface:

```
interface
    function pass_assumed_type(arg) &
             result(SHT_rv) &
             bind(C, name="passAssumedType")
        use iso_c_binding, only : C_INT
        implicit none
        type(*) :: arg
        integer(C_INT) :: SHT_rv
    end function pass_assumed_type
end interface
```

Fortran usage:

```
use iso_c_binding, only : C_INT
integer(C_INT) rv_int
rv_int = pass_assumed_type(23_C_INT)
```

As a reminder, `23_C_INT` creates an `integer(C_INT)` constant.

Note: Assumed-type was introduced in Fortran 2018.

23.9.2 passAssumedTypeDim

C library function in `clibrary.c`:

```
void passAssumedTypeDim(void *arg)
{
    strncpy(last_function_called, "passAssumedTypeDim", MAXLAST);
}
```

clibrary.yaml:

```
- decl: int passAssumedTypeDim(void *arg+assumedtype+rank(1))
```

Fortran calls C via the following interface:

```
interface
    subroutine pass_assumed_type_dim(arg) &
            bind(C, name="passAssumedTypeDim")
        implicit none
        type(*) :: arg(*)
    end subroutine pass_assumed_type_dim
end interface
```

Example usage:

```
use iso_c_binding, only : C_INT, C_DOUBLE
integer(C_INT) int_array(10)
real(C_DOUBLE) double_array(2,5)
call pass_assumed_type_dim(int_array)
call pass_assumed_type_dim(double_array)
```

Note: Assumed-type was introduced in Fortran 2018.

23.9.3 passVoidStarStar

C library function in clibrary.c:

```
void passVoidStarStar(void *in, void **out)
{
    strncpy(last_function_called, "passVoidStarStar", MAXLAST);
    *out = in;
}
```

clibrary.yaml:

```
- decl: void passVoidStarStar(void *in+intent(in), void **out+intent(out))
```

Fortran calls C via the following interface:

```
interface
    subroutine pass_void_star_star(in, out) &
            bind(C, name="passVoidStarStar")
        use iso_c_binding, only : C_PTR
        implicit none
        type(C_PTR), value, intent(IN) :: in
        type(C_PTR), intent(OUT) :: out
    end subroutine pass_void_star_star
end interface
```

Example usage:

```
use iso_c_binding, only : C_INT, C_NULL_PTR, c_associated
integer(C_INT) int_var
cptr1 = c_loc(int_var)
cptr2 = C_NULL_PTR
call pass_void_star_star(cptr1, cptr2)
call assert_true(c_associated(cptr1, cptr2))
```

23.10 Function Pointers

23.10.1 callback1

C++ library function in `tutorial.cpp`:

```
int callback1(int in, int (*incr)(int))
{
  return incr(in);
}
```

`tutorial.yaml`:

```
- decl: int callback1(int in, int (*incr)(int));
```

The C wrapper:

```
int TUT_callback1(int in, int ( * incr)(int))
{
    // splicer begin function.callback1
    int SHC_rv = tutorial::callback1(in, incr);
    return SHC_rv;
    // splicer end function.callback1
}
```

Creates the abstract interface:

```
abstract interface
    function callback1_incr(arg0) bind(C)
        use iso_c_binding, only : C_INT
        implicit none
        integer(C_INT), value :: arg0
        integer(C_INT) :: callback1_incr
    end function callback1_incr
end interface
```

Fortran calls C via the following interface:

```
interface
    function callback1(in, incr) &
            result(SHT_rv) &
            bind(C, name="TUT_callback1")
        use iso_c_binding, only : C_INT
        import :: callback1_incr
        implicit none
        integer(C_INT), value, intent(IN) :: in
```

(continues on next page)

(continued from previous page)

```
        procedure(callback1_incr) :: incr
        integer(C_INT) :: SHT_rv
    end function callback1
end interface
```

Fortran usage:

```
module worker
  use iso_c_binding
contains
  subroutine userincr(i) bind(C)
    integer(C_INT), value :: i
    ! do work of callback
  end subroutine user

  subroutine work
    call callback1(1, userincr)
  end subroutine work
end module worker
```

23.10.2 callback1c

C library function in `clibrary.c`:

```
void callback1(int type, void (*incr)(void))
{
  // Use type to decide how to call incr
}
```

`clibrary.yaml`:

```
- decl: int callback1(int type, void (*incr)()+external)
```

Creates the abstract interface:

```
abstract interface
    subroutine callback1_incr() bind(C)
        implicit none
    end subroutine callback1_incr
end interface
```

Fortran calls C via the following interface:

```
interface
    subroutine c_callback1(type, incr) &
            bind(C, name="callback1")
        use iso_c_binding, only : C_INT
        import :: callback1_incr
        implicit none
        integer(C_INT), value, intent(IN) :: type
        procedure(callback1_incr) :: incr
    end subroutine c_callback1
end interface
```

The Fortran wrapper. By using `external` no abstract interface is used:

```
subroutine callback1(type, incr)
    use iso_c_binding, only : C_INT
    integer(C_INT), value, intent(IN) :: type
    external :: incr
    ! splicer begin function.callback1
    call c_callback1(type, incr)
    ! splicer end function.callback1
end subroutine callback1
```

Fortran usage:

```
module worker
  use iso_c_binding
contains
  subroutine userincr_int(i) bind(C)
    integer(C_INT), value :: i
    ! do work of callback
  end subroutine user_int

  subroutine userincr_double(i) bind(C)
    real(C_DOUBLE), value :: i
    ! do work of callback
  end subroutine user_int

  subroutine work
    call callback1c(1, userincr_int)
    call callback1c(1, userincr_double)
  end subrouine work
end module worker
```

23.11 Struct

Struct creating is described in *Fortran Structs*.

23.11.1 passStruct1

C library function in `struct.c`:

```
int passStruct1(const Cstruct1 *s1)
{
    strncpy(last_function_called, "passStruct1", MAXLAST);
    return s1->ifield;
}
```

`struct.yaml`:

```
- decl: int passStruct1(Cstruct1 *s1)
```

Fortran calls C via the following interface:

```
interface
    function pass_struct1(arg) &
            result(SHT_rv) &
```

(continues on next page)

(continued from previous page)

```
            bind(C, name="passStruct1")
        use iso_c_binding, only : C_INT
        import :: cstruct1
        implicit none
        type(cstruct1), intent(IN) :: arg
        integer(C_INT) :: SHT_rv
    end function pass_struct1
end interface
```

Fortran usage:

```
type(cstruct1) str1
str1%ifield = 12
str1%dfield = 12.6
call assert_equals(12, pass_struct1(str1), "passStruct1")
```

23.11.2 passStructByValue

C library function in `struct.c`:

```
int passStructByValue(Cstruct1 arg)
{
  int rv = arg.ifield * 2;
  // Caller will not see changes.
  arg.ifield += 1;
  return rv;
}
```

`struct.yaml`:

```
- decl: double passStructByValue(struct1 arg)
```

Fortran calls C via the following interface:

```
interface
    function pass_struct_by_value(arg) &
            result(SHT_rv) &
            bind(C, name="passStructByValue")
        use iso_c_binding, only : C_INT
        import :: cstruct1
        implicit none
        type(cstruct1), value, intent(IN) :: arg
        integer(C_INT) :: SHT_rv
    end function pass_struct_by_value
end interface
```

Fortran usage:

```
type(cstruct1) str1
str1%ifield = 2_C_INT
str1%dfield = 2.0_C_DOUBLE
rvi = pass_struct_by_value(str1)
call assert_equals(4, rvi, "pass_struct_by_value")
! Make sure str1 was passed by value.
```

(continues on next page)

(continued from previous page)

```
call assert_equals(2_C_INT, str1%ifield, "pass_struct_by_value ifield")
call assert_equals(2.0_C_DOUBLE, str1%dfield, "pass_struct_by_value dfield")
```

23.12 Class Type

23.12.1 constructor and destructor

The C++ header file from `classes.hpp`.

```
class Class1
{
public:
    int m_flag;
    int m_test;
    Class1()          : m_flag(0), m_test(0)    {};
    Class1(int flag) : m_flag(flag), m_test(0) {};
};
```

`classes.yaml`:

```
declarations:
- decl: class Class1
  declarations:
  - decl: Class1()
    format:
      function_suffix: _default
  - decl: Class1(int flag)
    format:
    function_suffix: _flag
  - decl: ~Class1() +name(delete)
```

A C wrapper function is created for each constructor and the destructor.

The C wrappers:

```
CLA_Class1 * CLA_Class1_ctor_default(CLA_Class1 * SHadow_rv)
{
    // splicer begin class.Class1.method.ctor_default
    classes::Class1 *SHCXX_rv = new classes::Class1();
    SHadow_rv->addr = static_cast<void *>(SHCXX_rv);
    SHadow_rv->idtor = 1;
    return SHadow_rv;
    // splicer end class.Class1.method.ctor_default
}
```

```
CLA_Class1 * CLA_Class1_ctor_flag(int flag, CLA_Class1 * SHadow_rv)
{
    // splicer begin class.Class1.method.ctor_flag
    classes::Class1 *SHCXX_rv = new classes::Class1(flag);
    SHadow_rv->addr = static_cast<void *>(SHCXX_rv);
    SHadow_rv->idtor = 1;
    return SHadow_rv;
    // splicer end class.Class1.method.ctor_flag
}
```

```
void CLA_Class1_delete(CLA_Class1 * self)
{
    classes::Class1 *SH_this = static_cast<classes::Class1 *>
        (self->addr);
    // splicer begin class.Class1.method.delete
    delete SH_this;
    self->addr = nullptr;
    // splicer end class.Class1.method.delete
}
```

The corresponding Fortran interfaces:

```
interface
    function c_class1_ctor_default(SHT_crv) &
            result(SHT_rv) &
            bind(C, name="CLA_Class1_ctor_default")
        use iso_c_binding, only : C_PTR
        import :: CLA_SHROUD_capsule_data
        implicit none
        type(CLA_SHROUD_capsule_data), intent(OUT) :: SHT_crv
        type(C_PTR) SHT_rv
    end function c_class1_ctor_default
end interface
```

```
interface
    function c_class1_ctor_flag(flag, SHT_crv) &
            result(SHT_rv) &
            bind(C, name="CLA_Class1_ctor_flag")
        use iso_c_binding, only : C_INT, C_PTR
        import :: CLA_SHROUD_capsule_data
        implicit none
        integer(C_INT), value, intent(IN) :: flag
        type(CLA_SHROUD_capsule_data), intent(OUT) :: SHT_crv
        type(C_PTR) SHT_rv
    end function c_class1_ctor_flag
end interface
```

```
interface
    subroutine c_class1_delete(self) &
            bind(C, name="CLA_Class1_delete")
        import :: CLA_SHROUD_capsule_data
        implicit none
        type(CLA_SHROUD_capsule_data), intent(IN) :: self
    end subroutine c_class1_delete
end interface
```

And the Fortran wrappers:

```
function class1_ctor_default() &
        result(SHT_rv)
    use iso_c_binding, only : C_PTR
    type(class1) :: SHT_rv
    ! splicer begin class.Class1.method.ctor_default
    type(C_PTR) :: SHT_prv
    SHT_prv = c_class1_ctor_default(SHT_rv%cxxmem)
    ! splicer end class.Class1.method.ctor_default
end function class1_ctor_default
```

```
function class1_ctor_flag(flag) &
        result(SHT_rv)
    use iso_c_binding, only : C_INT, C_PTR
    integer(C_INT), value, intent(IN) :: flag
    type(class1) :: SHT_rv
    ! splicer begin class.Class1.method.ctor_flag
    type(C_PTR) :: SHT_prv
    SHT_prv = c_class1_ctor_flag(flag, SHT_rv%cxxmem)
    ! splicer end class.Class1.method.ctor_flag
end function class1_ctor_flag
```

```
subroutine class1_delete(obj)
    class(class1) :: obj
    ! splicer begin class.Class1.method.delete
    call c_class1_delete(obj%cxxmem)
    ! splicer end class.Class1.method.delete
end subroutine class1_delete
```

The Fortran shadow class adds the type-bound method for the destructor:

```
type, bind(C) :: SHROUD_class1_capsule
    type(C_PTR) :: addr = C_NULL_PTR  ! address of C++ memory
    integer(C_INT) :: idtor = 0       ! index of destructor
end type SHROUD_class1_capsule

type class1
    type(SHROUD_class1_capsule) :: cxxmem
contains
    procedure :: delete => class1_delete
end type class1
```

The constructors are not type-bound procedures. But they are combined into a generic interface.

```
interface class1
    module procedure class1_ctor_default
    module procedure class1_ctor_flag
end interface class1
```

A class instance is created and destroy from Fortran as:

```
use classes_mod
type(class1) obj

obj = class1()
call obj%delete
```

Corresponding C++ code:

```
include <classes.hpp>

classes::Class1 * obj = new classes::Class1;

delete obj;
```

23.12.2 Getter and Setter

The C++ header file from `classes.hpp`.

```
class Class1
{
public:
    int m_flag;
    int m_test;
};
```

`classes.yaml`:

```
declarations:
- decl: class Class1
  declarations:
  - decl: int m_flag +readonly;
  - decl: int m_test +name(test);
```

A C wrapper function is created for each getter and setter. If the *readonly* attribute is added, then only a getter is created. In this case `m_` is a convention used to designate member variables. The Fortran attribute is renamed as **test** to avoid cluttering the Fortran API with this convention.

The C wrappers:

```
int CLA_Class1_get_m_flag(CLA_Class1 * self)
{
    classes::Class1 *SH_this = static_cast<classes::Class1 *>
        (self->addr);
    // splicer begin class.Class1.method.get_m_flag
    return SH_this->m_flag;
    // splicer end class.Class1.method.get_m_flag
}
```

```
int CLA_Class1_get_test(CLA_Class1 * self)
{
    classes::Class1 *SH_this = static_cast<classes::Class1 *>
        (self->addr);
    // splicer begin class.Class1.method.get_test
    return SH_this->m_test;
    // splicer end class.Class1.method.get_test
}
```

```
void CLA_Class1_set_test(CLA_Class1 * self, int val)
{
    classes::Class1 *SH_this = static_cast<classes::Class1 *>
        (self->addr);
    // splicer begin class.Class1.method.set_test
    SH_this->m_test = val;
    return;
    // splicer end class.Class1.method.set_test
}
```

The corresponding Fortran interfaces:

```
interface
    function c_class1_get_m_flag(self) &
```

(continues on next page)

(continued from previous page)

```
            result(SHT_rv) &
            bind(C, name="CLA_Class1_get_m_flag")
        use iso_c_binding, only : C_INT
        import :: CLA_SHROUD_capsule_data
        implicit none
        type(CLA_SHROUD_capsule_data), intent(IN) :: self
        integer(C_INT) :: SHT_rv
    end function c_class1_get_m_flag
end interface
```

```
interface
    function c_class1_get_test(self) &
            result(SHT_rv) &
            bind(C, name="CLA_Class1_get_test")
        use iso_c_binding, only : C_INT
        import :: CLA_SHROUD_capsule_data
        implicit none
        type(CLA_SHROUD_capsule_data), intent(IN) :: self
        integer(C_INT) :: SHT_rv
    end function c_class1_get_test
end interface
```

```
interface
    subroutine c_class1_set_test(self, val) &
            bind(C, name="CLA_Class1_set_test")
        use iso_c_binding, only : C_INT
        import :: CLA_SHROUD_capsule_data
        implicit none
        type(CLA_SHROUD_capsule_data), intent(IN) :: self
        integer(C_INT), value, intent(IN) :: val
    end subroutine c_class1_set_test
end interface
```

And the Fortran wrappers:

```
function class1_get_m_flag(obj) &
        result(SHT_rv)
    use iso_c_binding, only : C_INT
    class(class1) :: obj
    integer(C_INT) :: SHT_rv
    ! splicer begin class.Class1.method.get_m_flag
    SHT_rv = c_class1_get_m_flag(obj%cxxmem)
    ! splicer end class.Class1.method.get_m_flag
end function class1_get_m_flag
```

```
function class1_get_test(obj) &
        result(SHT_rv)
    use iso_c_binding, only : C_INT
    class(class1) :: obj
    integer(C_INT) :: SHT_rv
    ! splicer begin class.Class1.method.get_test
    SHT_rv = c_class1_get_test(obj%cxxmem)
    ! splicer end class.Class1.method.get_test
end function class1_get_test
```

```
subroutine class1_set_test(obj, val)
    use iso_c_binding, only : C_INT
    class(class1) :: obj
    integer(C_INT), value, intent(IN) :: val
    ! splicer begin class.Class1.method.set_test
    call c_class1_set_test(obj%cxxmem, val)
    ! splicer end class.Class1.method.set_test
end subroutine class1_set_test
```

The Fortran shadow class adds the type-bound methods:

```
type class1
    type(SHROUD_class1_capsule) :: cxxmem
contains
    procedure :: get_m_flag => class1_get_m_flag
    procedure :: get_test => class1_get_test
    procedure :: set_test => class1_set_test
end type class1
```

The class variables can be used as:

```
use classes_mod
type(class1) obj
integer iflag

obj = class1()
call obj%set_test(4)
iflag = obj%get_test()
```

Corresponding C++ code:

```
include <classes.hpp>
classes::Class1 obj = new * classes::Class1;
obj->m_test = 4;
int iflag = obj->m_test;
```

23.12.3 Struct as a Class

While C does not support object-oriented programming directly, it can be emulated by using structs. The 'base class' struct is `Cstruct_as_clss`. It is subclassed by `Cstruct_as_subclass` which explicitly duplicates the members of `C_struct_as_class`. The C header file from `struct.h`.

```
struct Cstruct_as_class {
    int x1;
    int y1;
};
typedef struct Cstruct_as_class Cstruct_as_class;

/* The first members match Cstruct_as_class */
struct Cstruct_as_subclass {
    int x1;
    int y1;
    int z1;
};
typedef struct Cstruct_as_subclass Cstruct_as_subclass;
```

The C 'constructor' returns a pointer to an instance of the object.

```
Cstruct_as_class *Create_Cstruct_as_class(void);
Cstruct_as_class *Create_Cstruct_as_class_args(int x, int y);
```

The 'methods' pass an instance of the class as an explicit *this* object.

```
int Cstruct_as_class_sum(const Cstruct_as_class *point);
```

The methods are wrapped in `classes.yaml`:

```
declarations:
- decl: struct Cstruct_as_class {
         int x1;
         int y1;
       };
  options:
    wrap_struct_as: class

- decl: Cstruct_as_class *Create_Cstruct_as_class(void)
  options:
    class_ctor: Cstruct_as_class
- decl: Cstruct_as_class *Create_Cstruct_as_class_args(int x, int y)
  options:
    class_ctor: Cstruct_as_class

- decl: int Cstruct_as_class_sum(const Cstruct_as_class *point +pass)
  options:
    class_method: Cstruct_as_class
  format:
    F_name_function: sum

- decl: struct Cstruct_as_subclass {
         int x1;
         int y1;
         int z1;
       };
  options:
    wrap_struct_as: class
    class_baseclass: Cstruct_as_class
- decl: Cstruct_as_subclass *Create_Cstruct_as_subclass_args(int x, int y, int z)
  options:
    wrap_python: False
    class_ctor: Cstruct_as_subclass
```

This uses several options to creates the class features for the struct: *wrap_struct_as*, *class_ctor*, *class_method*.

```
    type cstruct_as_class
        type(STR_SHROUD_capsule_data) :: cxxmem
        ! splicer begin class.Cstruct_as_class.component_part
        ! splicer end class.Cstruct_as_class.component_part
    contains
        procedure :: get_x1 => cstruct_as_class_get_x1
        procedure :: set_x1 => cstruct_as_class_set_x1
        procedure :: get_y1 => cstruct_as_class_get_y1
        procedure :: set_y1 => cstruct_as_class_set_y1
        procedure :: sum => cstruct_as_class_sum
        ! splicer begin class.Cstruct_as_class.type_bound_procedure_part
```

(continues on next page)

(continued from previous page)

```
        ! splicer end class.Cstruct_as_class.type_bound_procedure_part
    end type cstruct_as_class
```

The subclass is created using the Fortran `EXTENDS` keyword. No additional members are added. The `cxxmem` field from `cstruct_as_class` will now point to an instance of the C struct `Cstruct_as_subclass`.

```
    type, extends(cstruct_as_class) :: cstruct_as_subclass
        ! splicer begin class.Cstruct_as_subclass.component_part
        ! splicer end class.Cstruct_as_subclass.component_part
    contains
        procedure :: get_x1 => cstruct_as_subclass_get_x1
        procedure :: set_x1 => cstruct_as_subclass_set_x1
        procedure :: get_y1 => cstruct_as_subclass_get_y1
        procedure :: set_y1 => cstruct_as_subclass_set_y1
        procedure :: get_z1 => cstruct_as_subclass_get_z1
        procedure :: set_z1 => cstruct_as_subclass_set_z1
        ! splicer begin class.Cstruct_as_subclass.type_bound_procedure_part
        ! splicer end class.Cstruct_as_subclass.type_bound_procedure_part
    end type cstruct_as_subclass
```

The C wrapper to construct the struct-as-class. It calls the C function and fills in the fields for the shadow struct.

```
STR_Cstruct_as_class * STR_create__cstruct_as_class(
    STR_Cstruct_as_class * SHadow_rv)
{
    // splicer begin function.create__cstruct_as_class
    Cstruct_as_class * SHC_rv = Create_Cstruct_as_class();
    SHadow_rv->addr = SHC_rv;
    SHadow_rv->idtor = 0;
    return SHadow_rv;
    // splicer end function.create__cstruct_as_class
}
```

A Fortran generic interface is created for the class:

```
interface Cstruct_as_class
    module procedure create__cstruct_as_class
    module procedure create__cstruct_as_class_args
end interface Cstruct_as_class
```

And the Fortran constructor call the C wrapper function.

```
function create__cstruct_as_class() &
        result(SHT_rv)
    use iso_c_binding, only : C_PTR
    type(cstruct_as_class) :: SHT_rv
    ! splicer begin function.create__cstruct_as_class
    type(C_PTR) :: SHT_prv
    SHT_prv = c_create__cstruct_as_class(SHT_rv%cxxmem)
    ! splicer end function.create__cstruct_as_class
end function create__cstruct_as_class
```

The class can be used as:

```
type(cstruct_as_class) point1, point2
type(cstruct_as_subclass) subpoint1
```

(continues on next page)

(continued from previous page)

```
call assert_false(point1%associated())

point1 = Cstruct_as_class()
call assert_equals(0, point1%get_x1())
call assert_equals(0, point1%get_y1())

point2 = Cstruct_as_class(1, 2)
call assert_equals(1, point2%get_x1())
call assert_equals(2, point2%get_y1())

call assert_equals(3, cstruct_as_class_sum(point2))
call assert_equals(3, point2%sum())

subpoint1 = Cstruct_as_subclass(1, 2, 3)
call assert_equals(1, subpoint1%get_x1())
call assert_equals(2, subpoint1%get_y1())
call assert_equals(3, subpoint1%get_z1())
call assert_equals(3, subpoint1%sum())
```

23.13 Default Value Arguments

The default values are provided in the function declaration.

C++ library function in `tutorial.cpp`:

```
double UseDefaultArguments(double arg1 = 3.1415, bool arg2 = true);
```

`tutorial.yaml`:

```
- decl: double UseDefaultArguments(double arg1 = 3.1415, bool arg2 = true)
  default_arg_suffix:
  -
  -  _arg1
  -  _arg1_arg2
```

A C++ wrapper is created which calls the C++ function with no arguments with default values and then adds a wrapper with an explicit argument for each default value argument. In this case, three wrappers are created. Since the C++ compiler provides the default value, it is necessary to create each wrapper.

`wrapTutorial.cpp`:

```
double TUT_use_default_arguments(void)
{
    // splicer begin function.use_default_arguments
    double SHC_rv = tutorial::UseDefaultArguments();
    return SHC_rv;
    // splicer end function.use_default_arguments
}
```

```
double TUT_use_default_arguments_arg1(double arg1)
{
    // splicer begin function.use_default_arguments_arg1
    double SHC_rv = tutorial::UseDefaultArguments(arg1);
```

(continues on next page)

(continued from previous page)

```
    return SHC_rv;
    // splicer end function.use_default_arguments_arg1
}
```

```
double TUT_use_default_arguments_arg1_arg2(double arg1, bool arg2)
{
    // splicer begin function.use_default_arguments_arg1_arg2
    double SHC_rv = tutorial::UseDefaultArguments(arg1, arg2);
    return SHC_rv;
    // splicer end function.use_default_arguments_arg1_arg2
}
```

This creates three corresponding Fortran interfaces:

```
interface
    function c_use_default_arguments() &
            result(SHT_rv) &
            bind(C, name="TUT_use_default_arguments")
        use iso_c_binding, only : C_DOUBLE
        implicit none
        real(C_DOUBLE) :: SHT_rv
    end function c_use_default_arguments
end interface
```

```
interface
    function c_use_default_arguments_arg1(arg1) &
            result(SHT_rv) &
            bind(C, name="TUT_use_default_arguments_arg1")
        use iso_c_binding, only : C_DOUBLE
        implicit none
        real(C_DOUBLE), value, intent(IN) :: arg1
        real(C_DOUBLE) :: SHT_rv
    end function c_use_default_arguments_arg1
end interface
```

```
interface
    function c_use_default_arguments_arg1_arg2(arg1, arg2) &
            result(SHT_rv) &
            bind(C, name="TUT_use_default_arguments_arg1_arg2")
        use iso_c_binding, only : C_BOOL, C_DOUBLE
        implicit none
        real(C_DOUBLE), value, intent(IN) :: arg1
        logical(C_BOOL), value, intent(IN) :: arg2
        real(C_DOUBLE) :: SHT_rv
    end function c_use_default_arguments_arg1_arg2
end interface
```

In many case the interfaces would be enough to call the routines. However, in order to have a generic interface, there must be explicit Fortran wrappers:

```
function use_default_arguments() &
        result(SHT_rv)
    use iso_c_binding, only : C_DOUBLE
    real(C_DOUBLE) :: SHT_rv
    ! splicer begin function.use_default_arguments
```

(continues on next page)

(continued from previous page)

```
    SHT_rv = c_use_default_arguments()
    ! splicer end function.use_default_arguments
end function use_default_arguments
```

```
function use_default_arguments_arg1(arg1) &
        result(SHT_rv)
    use iso_c_binding, only : C_DOUBLE
    real(C_DOUBLE), value, intent(IN) :: arg1
    real(C_DOUBLE) :: SHT_rv
    ! splicer begin function.use_default_arguments_arg1
    SHT_rv = c_use_default_arguments_arg1(arg1)
    ! splicer end function.use_default_arguments_arg1
end function use_default_arguments_arg1
```

```
function use_default_arguments_arg1_arg2(arg1, arg2) &
        result(SHT_rv)
    use iso_c_binding, only : C_BOOL, C_DOUBLE
    real(C_DOUBLE), value, intent(IN) :: arg1
    logical, value, intent(IN) :: arg2
    real(C_DOUBLE) :: SHT_rv
    ! splicer begin function.use_default_arguments_arg1_arg2
    logical(C_BOOL) SH_arg2
    SH_arg2 = arg2  ! coerce to C_BOOL
    SHT_rv = c_use_default_arguments_arg1_arg2(arg1, SH_arg2)
    ! splicer end function.use_default_arguments_arg1_arg2
end function use_default_arguments_arg1_arg2
```

The Fortran generic interface adds the ability to call any of the functions by the C++ function name:

```
interface use_default_arguments
    module procedure use_default_arguments
    module procedure use_default_arguments_arg1
    module procedure use_default_arguments_arg1_arg2
end interface use_default_arguments
```

Usage:

```
real(C_DOUBLE) rv
rv = use_default_arguments()
rv = use_default_arguments(1.d0)
rv = use_default_arguments(1.d0, .false.)
```

23.14 Generic Real

C library function in `clibrary.c`:

```
void GenericReal(double arg)
{
    global_double = arg;
    return;
}
```

`generic.yaml`:

```
- decl: void GenericReal(double arg)
  fortran_generic:
  - decl: (float arg)
    function_suffix: float
  - decl: (double arg)
    function_suffix: double
```

Fortran calls C via the following interface:

```
interface
    subroutine c_generic_real(arg) &
            bind(C, name="GenericReal")
        use iso_c_binding, only : C_DOUBLE
        implicit none
        real(C_DOUBLE), value, intent(IN) :: arg
    end subroutine c_generic_real
end interface
```

There is a single interface since there is a single C function. A generic interface is created for each declaration in the *fortran_generic* block.

```
interface generic_real
    module procedure generic_real_float
    module procedure generic_real_double
end interface generic_real
```

A Fortran wrapper is created for each declaration in the *fortran_generic* block. The argument is explicitly converted to a `C_DOUBLE` before calling the C function in `generic_real_float`. There is no conversion necessary in `generic_real_double`.

```
subroutine generic_real_float(arg)
    use iso_c_binding, only : C_DOUBLE, C_FLOAT
    real(C_FLOAT), value, intent(IN) :: arg
    ! splicer begin function.generic_real_float
    call c_generic_real(real(arg, C_DOUBLE))
    ! splicer end function.generic_real_float
end subroutine generic_real_float
```

```
subroutine generic_real_double(arg)
    use iso_c_binding, only : C_DOUBLE
    real(C_DOUBLE), value, intent(IN) :: arg
    ! splicer begin function.generic_real_double
    call c_generic_real(arg)
    ! splicer end function.generic_real_double
end subroutine generic_real_double
```

The function can be called via the generic interface with either type. If the specific function is called, the correct type must be passed.

```
call generic_real(0.0)
call generic_real(0.0d0)

call generic_real_float(0.0)
call generic_real_double(0.0d0)
```

In C, the compiler will promote the argument.

```
GenericReal(0.0f);
GenericReal(0.0);
```

CHAPTER 24

Numpy Struct Descriptor

struct.yaml:

```
- decl: struct Cstruct1 {
          int ifield;
          double dfield;
        };
```

```
// Create PyArray_Descr for Cstruct1
static PyArray_Descr *PY_Cstruct1_create_array_descr(void)
{
    int ierr;
    PyObject *obj = NULL;
    PyObject * lnames = NULL;
    PyObject * ldescr = NULL;
    PyObject * dict = NULL;
    PyArray_Descr *dtype = NULL;

    lnames = PyList_New(2);
    if (lnames == NULL) goto fail;
    ldescr = PyList_New(2);
    if (ldescr == NULL) goto fail;

    // ifield
    obj = PyString_FromString("ifield");
    if (obj == NULL) goto fail;
    PyList_SET_ITEM(lnames, 0, obj);
    obj = (PyObject *) PyArray_DescrFromType(NPY_INT);
    if (obj == NULL) goto fail;
    PyList_SET_ITEM(ldescr, 0, obj);

    // dfield
    obj = PyString_FromString("dfield");
    if (obj == NULL) goto fail;
    PyList_SET_ITEM(lnames, 1, obj);
```

(continues on next page)

(continued from previous page)

```
    obj = (PyObject *) PyArray_DescrFromType(NPY_DOUBLE);
    if (obj == NULL) goto fail;
    PyList_SET_ITEM(ldescr, 1, obj);
    obj = NULL;

    dict = PyDict_New();
    if (dict == NULL) goto fail;
    ierr = PyDict_SetItemString(dict, "names", lnames);
    if (ierr == -1) goto fail;
    lnames = NULL;
    ierr = PyDict_SetItemString(dict, "formats", ldescr);
    if (ierr == -1) goto fail;
    ldescr = NULL;
    ierr = PyArray_DescrAlignConverter(dict, &dtype);
    if (ierr == 0) goto fail;
    return dtype;
fail:
    Py_XDECREF(obj);
    if (lnames != NULL) {
        for (int i=0; i < 2; i++) {
            Py_XDECREF(PyList_GET_ITEM(lnames, i));
        }
        Py_DECREF(lnames);
    }
    if (ldescr != NULL) {
        for (int i=0; i < 2; i++) {
            Py_XDECREF(PyList_GET_ITEM(ldescr, i));
        }
        Py_DECREF(ldescr);
    }
    Py_XDECREF(dict);
    Py_XDECREF(dtype);
    return NULL;
}
```

CHAPTER 25

Indices and tables

- genindex
- modindex
- search

Bibliography

[Python_Format] https://docs.python.org/2/library/string.html#format-string-syntax

[Python_Refcount] https://docs.python.org/3/c-api/intro.html#reference-count-details

[yaml] yaml.org

[blog1] http://blog.enthought.com/python/numpy-arrays-with-pre-allocated-memory

[blog2] http://blog.enthought.com/python/numpy/simplified-creation-of-numpy-arrays-from-pre-allocated-memory