C - EXTENSIONS

C - extensions

- Some times there are time critical parts of code which would benefit from compiled language
- 90/10 rule: 90 % of time is spent in 10 % of code
  - only a small part of application benefits from compiled code
- It is relatively straightforward to create a Python interface to C-functions
  - data is passed from Python, routine is executed without any Python overheads

C - extensions

- C routines are build into a shared library
- Routines are loaded dynamically with normal import statements

```
>>> import hello
>>> hello.world()
```

- A library **hello.so** is looked for
- A function **world** (defined in hello.so) is called

Creating C-extension

1) Include Python headers

hello.c

```
#include <Python.h>
```

2) Define the C-function

hello.c

```
...
PyObject* world_c(PyObject *self, PyObject *args)
{
  printf("Hello world!\n");
  Py_RETURN_NONE;
}
```

- Type of function is always PyObject
- Function arguments are always the same
  (args is used for passing data from Python to C)
- A macro Py_RETURN_NONE is used for returning "nothing"

Creating C-extension

3) Define the Python interfaces for functions

hello.c

```
...
static PyMethodDef functions[] = {
 {"world", world_c, METH_VARARGS, 0},
 {"honey", honey_c, METH_VARARGS, 0},
 {0, 0, 0, 0}  /* "Sentinel" notifies the end of definitions */
};
```

- **world** is the function name used in Python code, **world_c** is the actual C-function to be called
- Single extension module can contain several functions (world, honey, ...)

Creating C-extension

4) Define the module initialization function

hello.c

```
...
PyMODINIT_FUNC inithello(void)
{
    (void) Py_InitModule("hello", functions);
}
```

- Extension module should be build into **hello.so**
- Extension is module is imported as **import hello**
- Functions/interfaces defined in functions are called as hello.world(), hello.honey(), ...

Creating C-extension

5) Compile as shared library

```
$ gcc -shared -o hello.so -I/usr/include/python2.6 -fPIC hello.c
$
$ python
Python 2.4.3 (#1, Jul 16 2009, 06:20:46)
[GCC 4.1.2 20080704 (Red Hat 4.1.2-44)] on linux2
Type "help", "copyright", "credits" or "license" for more information.
>>> import hello
>>> hello.world()
Hello world!
```

- The location of Python headers (/usr/include/...) may vary in different systems
- Use *exercises/include_paths.py* to find out yours!

Full listing of hello.c

hello.c

```
#include <Python.h>

PyObject* world_c(PyObject *self, PyObject *args)
{
  printf("Hello world!\n");
  Py_RETURN_NONE;
}

static PyMethodDef functions[] = {
 {"world", world_c, METH_VARARGS, 0},
 {0, 0, 0, 0}
};

PyMODINIT_FUNC inithello(void)
{
    (void) Py_InitModule("hello", functions);
}
```

Passing arguments to C-functions

hello2.c

```
...
PyObject* pass_c(PyObject *self, PyObject *args)
{
  int a;
  double b;
  char* str;
  if (!PyArg_ParseTuple(args, "ids", &a, &b, &str))
    return NULL;
  printf("int %i, double %f, string %s\n", a, b, str);
  Py_RETURN_NONE;
}
```

- **PyArg_ParseTuple** checks that function is called with proper arguments
  “ids” : integer, double, string
  and does the conversion from Python to C types

Returning values

hello2.c

```
...
PyObject* square_c(PyObject *self, PyObject *args)
{
  int a;
  if (!PyArg_ParseTuple(args, "i", &a))
    return NULL;
  a = a*a;
  return Py_BuildValue("i", a);
}
```

- Create and return Python integer from C variable. A “d” would create Python double etc.
- Returning tuple:
  Py_BuildValue("(ids)", a, b, str);

Operating with NumPy array

hello3.c

```
#include <Python.h>
#include <numpy/arrayobject.h>

PyObject* array(PyObject *self, PyObject *args)
{
  PyArrayObject* a;
  if (!PyArg_ParseTuple(args, "O", &a))
    return NULL;

  int size = PyArray_SIZE(a);     /* Total size of array */
  double *data = PyArray_DATA(a); /* Pointer to data */
  for (int i=0; i < size; i++) {
     data[i] = data[i] * data[i];
  }
  Py_RETURN_NONE;
}
```

- NumPy provides API also for determining the dimensions of an array etc.

Operating with NumPy array

- Function **import_array()** should be called in the module initialization function when using NumPy C-API

hello3.c

```
...

PyMODINIT_FUNC inithello(void)
{
    import_array();
    (void) Py_InitModule("hello", functions);
}
```

Tools for easier interfacing

- Cython
- SWIG
- pyrex
- f2py (for Fortran code)

Summary

- Python can be extended with C-functions relatively easily
- C-extension build as shared library
- It is possible to pass data between Python and C code
- Extending Python:
  http://docs.python.org/extending/
- NumPy C-API
  http://docs.scipy.org/doc/numpy/reference/c-api.html