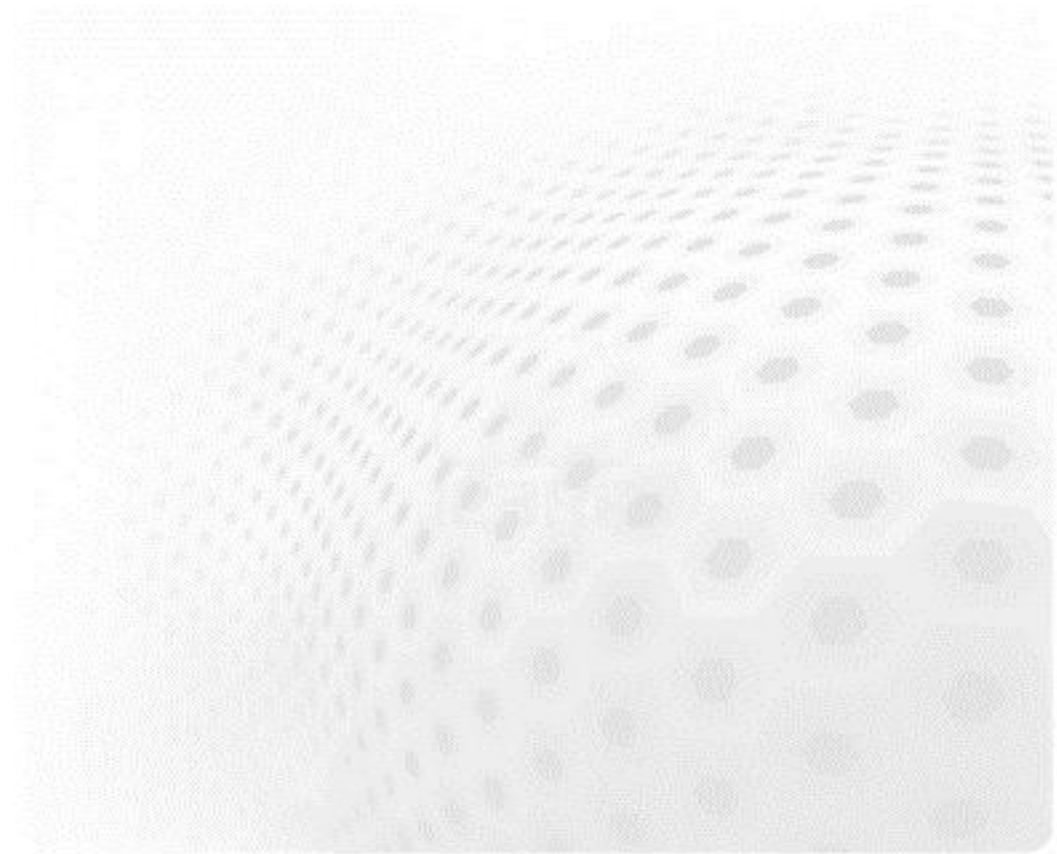


## C - EXTENSIONS



## 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

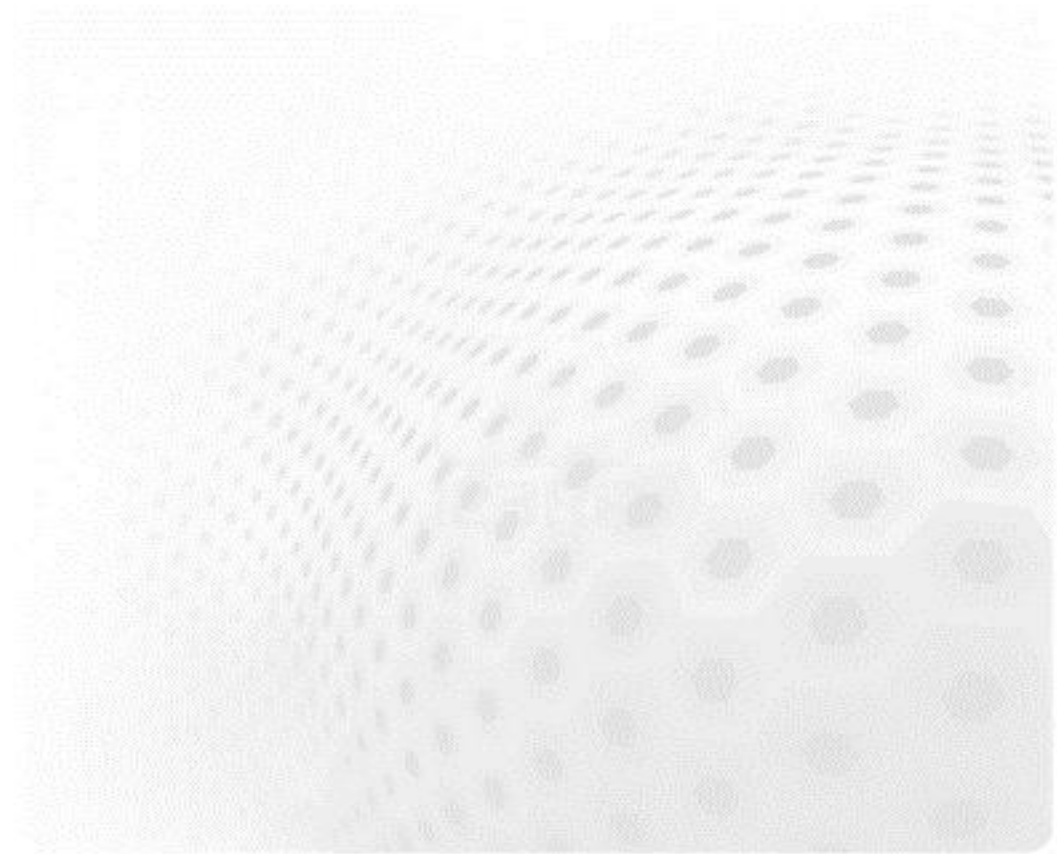
```
hello3.c
```

```
...
```

```
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>