Extending Python

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November 21, 2015

https://github.com/fcofdez/talks/blob/master/extending/presentation_1.pdf

Overview

1. Motivations
2. Guidelines
3. Native extensions
4. CTypes
5. CFFI
6. Conclusions

Caution

- Huge topic
- *Toy* examples
- Unix ĈPython centric

Motivation

Why write in C?

Motivation

- **Speed**
- Using legacy code
- Integration

Motivation

Why is Python *slow*?

- Interpretation overhead
- Boxed arithmetic and automatic overflow handling
- Dynamic dispatch of operations
- Dynamic lookup of methods and attributes
- Everything can change on runtime
- Extreme introspective and reflective capabilities

Motivation

- Speed
- **Using legacy code**
- Integration

Motivation

- Speed
- Using legacy code
- **Integration**

Shared libraries

- Single copy in memory
- Runtime load

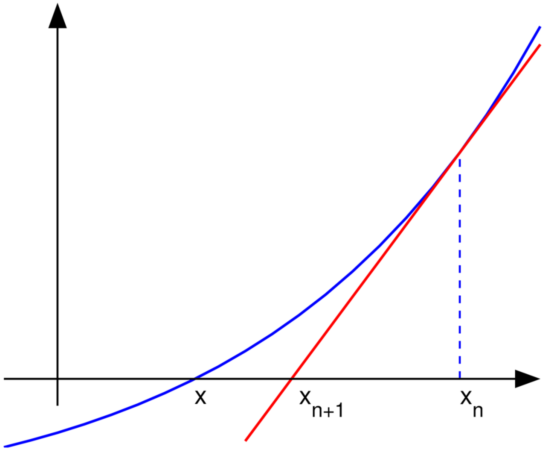
Native extensions

C API

Native extensions

Hello world, Newton method

Native extensions



Native extensions

```c
#include "Python.h"

static PyObject *
newton(PyObject *self, PyObject *args)
{
    float guess;
    float x;

    if (!PyArg_ParseTuple(args, "ff", &guess, &x))
        return NULL;

    while (fabs(powf(guess, 2) - x) > 0.01)
    {
        guess = ((x / guess) + guess) / 2;
    }

    return Py_BuildValue("f", guess);
}
```

Native extensions

```c
static PyMethodDef
module_functions[] = {
    {"newton", newton, METH_VARARGS, "Newton method."},
    {NULL}
};


PyMODINIT_FUNC
initnewton(void)
{
    Py_InitModule3("newton", module_functions, "Newton");
}
```

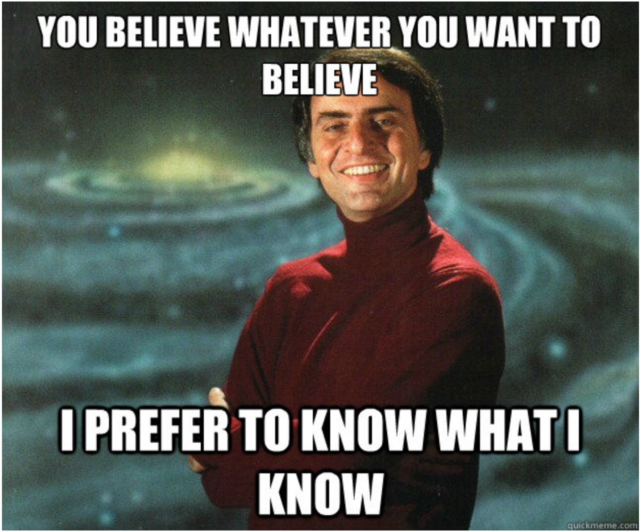
Native extensions

```python
from distutils.core import setup, Extension

setup(name='fosdem',
      version=1.0,
      ext_modules=[
        Extension('newton', ['newton.c'])])
```

Native extensions

```
Python 2.7.5 (default, Nov  3 2014, 14:26:24)
[GCC 4.8.3 20140911 (Red Hat 4.8.3-7)] on linux2
>>> import newton
>>> newton.newton(1, 2)
1.4166667461395264
>>>
```

How?


YOU BELIEVE WHATEVER YOU WANT TO BELIEVE
I PREFER TO KNOW WHAT I KNOW
quickmeme.com

Native extensions

```
NAME
dlopen--load and link a dynamic library or bundle

SYNOPSIS
#include <dlfcn.h>

void*
dlopen(const char* path, int mode);
```

Native extensions

```
$ nm -g newton.so
00000000002010a0 B __bss_start
                 w __cxa_finalize@@GLIBC_2.2.5
00000000002010a0 D _edata
00000000002010a8 B _end
0000000000000944 T _fini
                 w __gmon_start__
00000000000006d0 T _init
0000000000000920 T initnewton
                 w _ITM_deregisterTMCloneTable
                 w _ITM_registerTMCloneTable
                 w _Jv_RegisterClasses
                 U PyArg_ParseTuple
                 U Py_BuildValue
                 U Py_InitModule4_64
```

Native extensions

cpython/Python/dynload_shlib.c

```
handle = dlopen(pathname, dlopenflags);

if (handle == NULL) {
    const char *error = dlerror();
    if (error == NULL)
        error = "unknown dlopen() error";
    PyErr_SetString(PyExc_ImportError, error);
    return NULL;
}
if (fp != NULL && nhandles < 128)
    handles[nhandles++].handle = handle;
p = (dl_funcptr) dlsym(handle, funcname);

return p;
```

Native extensions

Memory management

- Manual memory management
- Python GC - RC
- Cycle detector
- Py_INCREF(x) Py_DECREF(x)

Native extensions

Error management

- Return NULL as a convention
- Register exceptions

Native extensions

Error management

```c
if (err < 0) {
  PyErr_SetString(PyExc_Exception, "Err");
  return NULL;
}
```

Native extensions

Python 3 differences

```c
static struct PyModuleDef examplemodule = {
  PyModuleDef_HEAD_INIT,
  "newton",
  "newton module doc string",
  -1,
  module_functions,
  NULL,
  NULL,
  NULL,
  NULL};
```

Native extensions

Python 3 differences

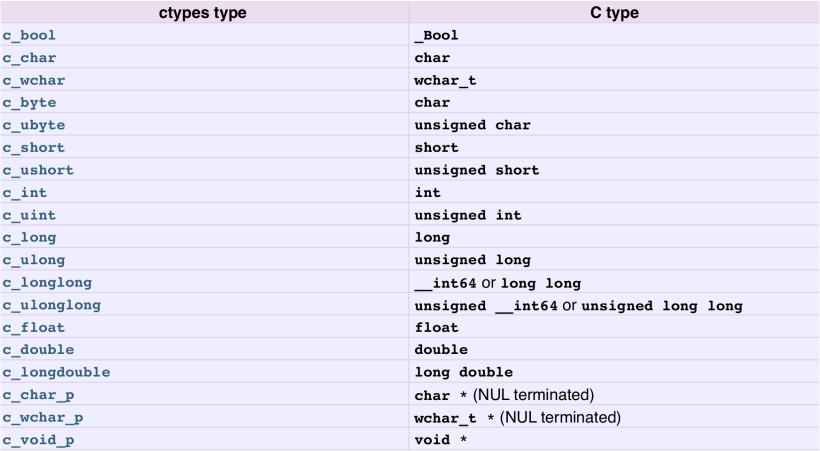
```
PyMODINIT_FUNC
PyInit_sum(void)
{
PyModule_Create(&examplemodule);
}
```

CTypes

- Advanced FFI for Python
- Allows call functions from Shared libs
- Create, access, manipulate C data types

CTypes

Types correspondence



ctypes type	C type
`c_bool`	`_Bool`
`c_char`	`char`
`c_wchar`	`wchar_t`
`c_byte`	`char`
`c_ubyte`	`unsigned char`
`c_short`	`short`
`c_ushort`	`unsigned short`
`c_int`	`int`
`c_uint`	`unsigned int`
`c_long`	`long`
`c_ulong`	`unsigned long`
`c_longlong`	`__int64` or `long long`
`c_ulonglong`	`unsigned __int64` or `unsigned long long`
`c_float`	`float`
`c_double`	`double`
`c_longdouble`	`long double`
`c_char_p`	`char *` (NUL terminated)
`c_wchar_p`	`wchar_t *` (NUL terminated)
`c_void_p`	`void *`

CTypes

Structs

```python
from ctypes import *

class POINT(Structure):
    _fields_ = [("x", c_int), ("y", c_int)]

class RECT(Structure):
    _fields_ = [("upperleft", POINT),
                ("lowerright", POINT)]
```

CTypes

Example

- Implemented fibonacci as c function
- Map as Python code
- Measure differences between Python and C

CTypes

```c
int fib(int n){
  if (n < 2)
      return n;
  else
      return fib(n - 1) + fib(n - 2);
}
```

CTypes

```python
import ctypes
lib_fib = ctypes.CDLL("libfib.so")

def ctypes_fib(n):
    return lib_fib.fib(ctypes.c_int(n))

def py_fib(n):
    if n < 2:
        return n
    else:
        return py_fib(n-1) + py_fib(n-2)
```

CTypes

```
In [3]: %timeit fib.ctypes_fib(20)
10000 loops, best of 3: 63.8 micro s per loop

In [4]: %timeit fib.py_fib(20)
100 loops, best of 3: 3.62 ms per loop
```

CTypes

Fortran example

- Use of existing fortran code
- Take random code at github
- https://github.com/astrofrog/fortranlib
- Wrap using ctypes

CTypes

Fortran example

```
real(dp) function mean_dp(x, mask)
    implicit none
    real(dp),intent(in) :: x(:)
    logical,intent(in),optional :: mask(:)
    if(present(mask)) then
       mean_dp = sum(x, mask=mask)/size(x)
    else
       mean_dp = sum(x)/size(x)
    end if
end function mean_dp
```

CTypes

Fortran example

```
gfortran -fPIC -shared statistic.f90 -o lib_statistics.so
```

CTypes

Fortran example

```
bin git:(master) -> nm -g lib_statistics.so
001eab T ___lib_statistics_MOD_clipped_mean_dp
000afc T ___lib_statistics_MOD_clipped_mean_sp
00306c T ___lib_statistics_MOD_mean_dp
001c55 T ___lib_statistics_MOD_mean_sp
002db0 T ___lib_statistics_MOD_median_dp
0019b0 T ___lib_statistics_MOD_median_sp
002544 T ___lib_statistics_MOD_quantile_dp
00115a T ___lib_statistics_MOD_quantile_sp
002299 T ___lib_statistics_MOD_variance_dp
000ec3 T ___lib_statistics_MOD_variance_sp
U __gfortran_arandom_r4
U __gfortran_arandom_r8
U __gfortran_os_error
U __gfortran_pack
U __gfortran_pow_i4_i4
U __gfortran_runtime_error
U __gfortran_runtime_error_at
U __gfortran_st_write
```

CTypes

Fortran example

```
from ctypes import *

# Statistics fortran lib
st_lib = CDLL(’lib_statistics.so’)

mean = st_lib.__lib_statistics_MOD_mean_dp
mean.argtypes = [POINTER(c_float*2)]
mean.restype = c_float

vals = (c_float*2)(2.0, 3.0)

print mean(vals)
```

CTypes

CTypes source

cpython/Modules/_ctypes/callproc.c

```c
static PyObject *py_dl_open(PyObject *self, PyObject *args)
{
  char *name;
  void * handle;
  #ifdef RTLD_LOCAL
    int mode = RTLD_NOW | RTLD_LOCAL;
  #else
    /* cygwin doesn't define RTLD_LOCAL */
    int mode = RTLD_NOW;
  #endif
  if (!PyArg_ParseTuple(args, "z|i:dlopen", &name, &mode))
     return NULL;
  mode |= RTLD_NOW;
  handle = ctypes_dlopen(name, mode);
  .
  return PyLong_FromVoidPtr(handle);
}
```

CFFI

- Advanced FFI for Python
- Allows call functions from Shared libs
- Create, access, manipulate C data types
- Both API and ABI access

CFFI

Mostly the same as CTypes

CFFI

Recommended way to extend PyPy

CFFI

ABI

```python
from cffi import FFI

ffi = FFI()
ffi.cdef("""int printf(const char *format, ...);""")
C = ffi.dlopen(None)
arg = ffi.new("char[]", "world")
C.printf("hi there, %s!\n", arg)
```

CFFI

ABI- Fibonacci

```python
from cffi import FFI

ffi = FFI()
ffi.cdef("""int fib(int n);""")
libfib = ffi.dlopen(’libfib.so’)
libfib.fib(10)
```

CFFI

API Level

```
import cffi
ffi = cffi.FFI()

ffi.cdef("""int fib(int n);""")

ffi.set_source("_fib", r’’’
int fib(int n){
if ( n < 2 )
return n;
else
return fib(n-1) + fib(n-2);
}’’’)

if __name__ == ’__main__’:
  ffi.compile()
```

CFFI

API Level

```python
from _fib import fib
print(fib(10))
```

CFFI

API Level

```python
from _fib import fib
print(fib("asdasd"))
```

CFFI

API Level

```
Traceback (most recent call last):
File "fib.py", line 16, in <module>
print lib.fib("asd")
TypeError: an integer is required
```

CFFI

API Level

```python
from cffi import FFI
ffi = FFI()
ffi.cdef("""typedef struct { float x, y; } point;""")
point = ffi.new("point *")
point.x = 2.0
point.y = 3.0
```

CFFI

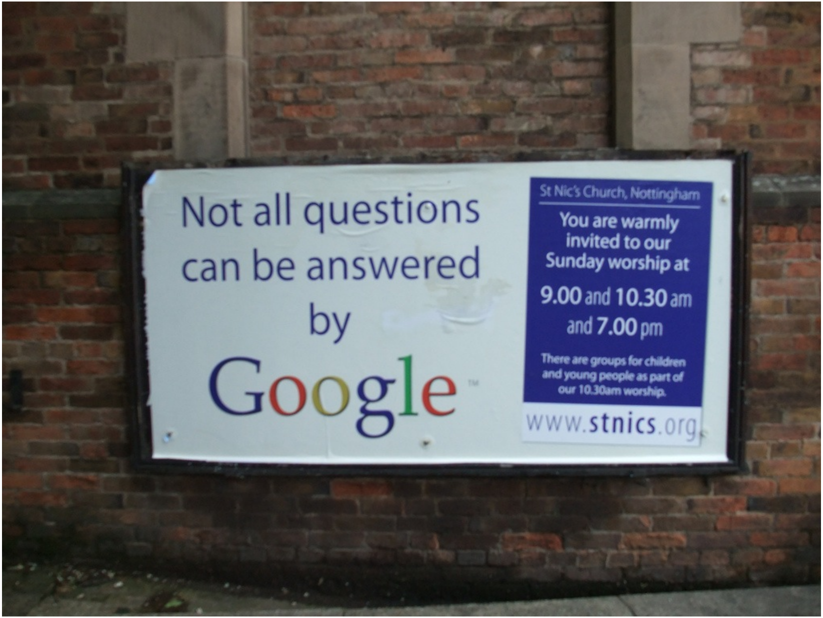
Internals

cffi/c/_cffi_backend.c

```c
static PyObject *
b_load_library(PyObject *self, PyObject *args)
{
    void *handle;
    DynLibObject *dlobj;

    if ((flags & (RTLD_NOW | RTLD_LAZY)) == 0)
        flags |= RTLD_NOW;

    printable_filename = filename_or_null ? filename_or_null :
    handle = dlopen(filename_or_null, flags);

    dlobj = PyObject_New(DynLibObject, &dl_type);
    dlobj->dl_handle = handle;
    dlobj->dl_name = strdup(printable_filename);
    return (PyObject *)dlobj;
}
```

Conclusions

- Three different ways
- Same principles
- Less portable - More portable
- Harder - Easier



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