pyBCN BARCELONA PYTHON MEETUP

cffi: C Foreign Function Interface for Python

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Outline

Introduction

C $\leftrightarrow$ Python

`cffi`: a better approach

Real example: `ingenialink`

Conclusions

Introduction

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  - #7/23 (PYPL)
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- Lots of **existing and proven** libraries
- Usually **good choice** for code that requires **high-performance**
- Can be **wrapped to almost any language**
  - See for example libgit2 (Python, Perl, NodeJS, Go, PHP...)

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- A way to **test a C library** using Python facilities

C $\leftrightarrow$ Python

Native extensions

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- `libpython` **API is cumbersome**, hard to learn and use
- Need to support **API differences** between Python versions

Native extensions: example

Objective: Implement a module that allows to execute system commands by wrapping the C `system` command.

```
import spam
status = spam.system("ls -l")
```

Example taken from the Python official documentation

Native extensions: example (II)

```c
#include <Python.h>

static PyObject *
spam_system(PyObject *self, PyObject *args)
{
    const char *command;
    int sts;

    if (!PyArg_ParseTuple(args, "s", &command))
        return NULL;
    sts = system(command);
    return PyLong_FromLong(sts);
}
```

Native extensions: example (III)

```c
static PyMethodDef SpamMethods[] = {
    {"system",  spam_system, METH_VARARGS,
     "Execute a shell command."},
    {NULL, NULL, 0, NULL}        /* Sentinel */
};

static struct PyModuleDef spammodule = {
    PyModuleDef_HEAD_INIT,
    "spam",   /* name of module */
    NULL,     /* module documentation, may be NULL */
    -1,       /* size of per-interpreter state of the module,
                 or -1 if the module keeps state in global variables. */
    SpamMethods
};

PyMODINIT_FUNC
PyInit_spam(void)
{
    return PyModule_Create(&spammodule);
}
```

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- `libffi` introduces **overhead**
- Need to **manually declare the functions, data types**, etc.

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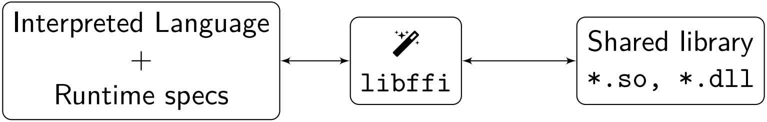


ctypes: example

Objective: Traverse a directory content using `readdir`, found in glibc.

```
struct dirent *readdir(DIR *dirp);
```

The `readdir()` function returns a pointer to a dirent structure representing the next directory entry in the directory stream pointed to by dirp. It returns NULL on reaching the end of the directory stream or if an error occurred. On Linux, the dirent structure is defined as follows:

```
struct dirent {
    ino_t          d_ino;       /* inode number */
    off_t          d_off;       /* offset to the next dirent */
    unsigned short d_reclen;    /* length of this record */
    unsigned char  d_type;      /* type of file; not supported
                                   by all file system types */
    char           d_name[256]; /* filename */
};
```

Example taken from the Eli Bendersky's website

ctypes: example (II)

```python
import ctypes as ct

# load library
# None as libc is already loaded, could be explicitely loaded
lib = ct.CDLL(None)

# declare the types needed for readdir.
class DIRENT(ct.Structure):
    _fields_ = [('d_ino', ct.c_long),
                ('d_off', ct.c_long),
                ('d_reclen', ct.c_ushort),
                ('d_type', ct.c_ubyte),
                ('d_name', ct.c_char * 256)]

DIR_p = ct.c_void_p
DIRENT_p = ct.POINTER(DIRENT)
```

ctypes: example (III)

```
# declare needed functions
readdir = lib.readdir
readdir.argtypes = [DIR_p]
readdir.restype = DIRENT_p

opendir = lib.opendir
opendir.argtypes = [ct.c_char_p]
opendir.restype = DIR_p

closedir = lib.closedir
closedir.argtypes = [DIR_p]
closedir.restype = ct.c_int
```

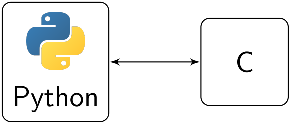
ctypes: example (IV)

```
# open directory
dir = opendir(b'/tmp')
if not dir:
    raise RuntimeError('opendir failed')

# traverse directory
dirent = readdir(dir)
while dirent:
    print(dirent.contents.d_name)
    dirent = readdir(dir)

# close directory
closedir(dir)
```

`cffi`: a better approach

What is `cffi`?

`cffi` is a C Foreign Function Interface for Python. It allows to interact with **almost any C code from Python**, based on C-like **declarations** that you can often **copy-paste from header files** or documentation.



Better with an example

```
>>> from cffi import FFI
>>> ffi = FFI()
>>> ffi.cdef("""
...     /* copy pasted from the man page */
...     int printf(const char *format, ...);
... """)
>>> # loads the entire C namespace
>>> C = ffi.dlopen(None)
>>> # equivalent to C code: char arg[] = "world";
>>> arg = ffi.new("char[]", b"world")
>>> C.printf(b"hi there, %s.\n", arg)
hi there, world.
17                  # <- this is the return value
```

ABI vs. API levels

What really makes `cffi` different from `ctypes`, apart from easier declarations, is that it **offers two access levels**: **ABI** and **API**.

But what does it mean?

ABI level

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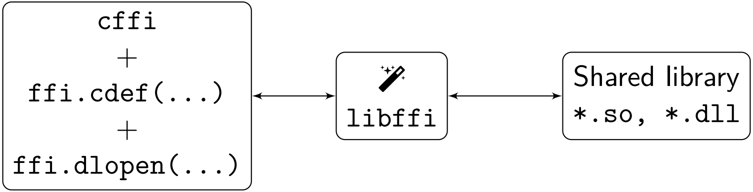

cffi ABI, previous example

```python
from cffi import FFI

ffi = FFI()
ffi.cdef("""
    typedef void DIR;
    typedef long ino_t;
    typedef long off_t;

    struct dirent {
        ino_t          d_ino;       /* inode number */
        off_t          d_off;       /* offset to the next dirent */
        unsigned short d_reclen;    /* length of this record */
        unsigned char  d_type;      /* type of file; not supported
                                       by all file system types */
        char           d_name[256]; /* filename */
    };

    DIR *opendir(const char *name);
    struct dirent *readdir(DIR *dirp);
    int closedir(DIR *dirp);
""")
```

`cffi` ABI, previous example (II)

```
# load library
# None as libc is already loaded, could be explicitely loaded
lib = ffi.dlopen(None)

# open directory
dir = lib.opendir(b'/tmp')
if not dir:
    raise RuntimeError('opendir failed')

# traverse directory
dirent = lib.readdir(dir)
while dirent:
    print(ffi.string(dirent.d_name))
    dirent = lib.readdir(dir)

# close directory
lib.closedir(dir)
```

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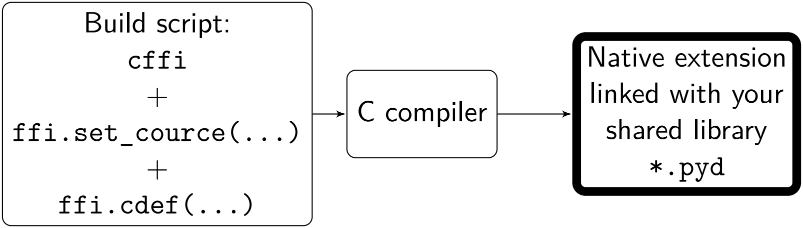


cffi API, previous example

We first create the extension build script:

```
from cffi import FFI

ffibuilder = FFI()
ffibuilder.set_source("_example",
        """ /* passed to the compiler */
            #include <dirent.h>
        """,
        libraries=[] # can link to any library)

ffibuilder.cdef("""
    typedef void DIR;
    typedef long ino_t;
    typedef long off_t;

    struct dirent {
        ino_t          d_ino;       /* inode number */
    ... // truncated
""")

if __name__ == "__main__":
    ffibuilder.compile(verbose=True)
```

cffi API, previous example (II)

Which, when built, can then be used like this:

```
from _example import lib, ffi

# open directory
dir = lib.opendir(b'/tmp')
if not dir:
    raise RuntimeError('opendir failed')

# traverse directory
dirent = lib.readdir(dir)
while dirent:
    print(ffi.string(dirent.d_name))
    dirent = lib.readdir(dir)

# close directory
lib.closedir(dir)
```

But not only that...

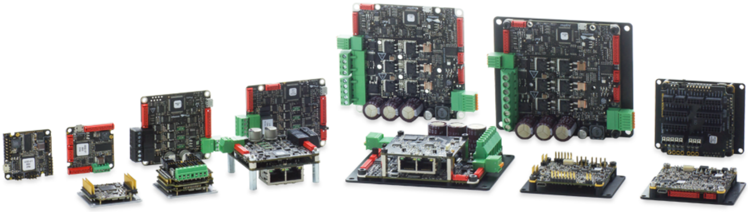
You can even **create extensions where no existing library is called**, e.g. to **implement** some algorithms **directly in C**. Or even **a mix**!

```python
# file "example_build.py"

from cffi import FFI
ffibuilder = FFI()

ffibuilder.cdef("int foo(int *, int *, int);")

ffibuilder.set_source("_example",
r"""
    static int foo(int *buffer_in, int *buffer_out, int x)
    {
        /* some algorithm that is seriously faster in C than in Python */
    }
""")

if __name__ == "__main__":
    ffibuilder.compile(verbose=True)
```

Real example: `ingenialink`

Background

Ingenia: producer of advanced **motion controllers**, with customers in the fields of **automation**, **robotics**, etc.



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- A **single code base**, cannot maintain too many libraries
- An **easy to learn language**, with a **strong community** and lots of resources

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- We love Python, but **not everybody in the world does**
- **Automation industry** is really **conservative**, non-friendly to changes
- Most of our **customers are not up to date** with today's development practices
- Customers **still with PLC (sigh), VB, VB.NET, Win32-like APIs** and similar crap

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https://github.com/ingenialink
https://github.com/ingenialink-python

How the extension is built

`setup.py` → `cffi_modules`

Build script: `ingenialink_build.py`

`git clone` C library (and dependencies)
Build libraries as **static, but PIC**
Extract **declarations automatically from headers**
Invoke `cffi`, linking with the built libraries

Native extension with `ingenialink` **embedded**

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- Python GC (*Garbage Collector*) may **not necessarily destroy objects in order when exiting** and we have object dependencies (e.g. `Servo` depends on `Network` resources)
- Linux binary wheels **need to be built using an ancient CentOS image**, which does not come with one of our dependencies (part of `systemd`)

Example

```c
#include <ingenalink/ingenialink.h>

double position;

il_net_t *net = il_net_create("/dev/ttyACM0");
il_servo_t *servo = il_servo_create(net, ID, TIMEOUT);

il_servo_read(servo, &IL_REG_POS_ACT, &position);
printf("Position: %.2f\n", position);

il_servo_destroy(servo);
il_net_destroy(net);
```

becomes...

```python
import ingenalink as il
from ingenalink import regs

net = il.Network('/dev/ttyACM0')
servo = il.Servo(net, ID)

position = servo.read(regs.POS_ACT)
print('Position: {.2f}'.format(position))
```

Application Example

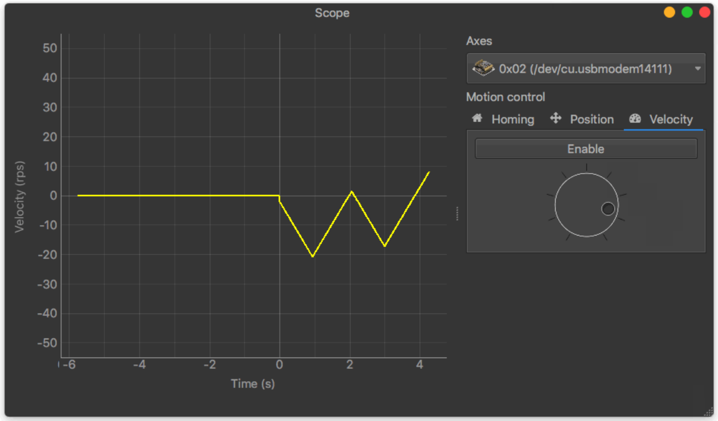

Figure: Application example (uses PyQt/PySide and pyqtgraph)

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- With `cffi` we can **directly define C functions** for critical parts with no need to create a shared library
- We can create a **single code base in C**, then wrap to *any language*

THANK YOU!

Questions?

https://github.com/gmarull/pybcn-cffi