Cython: Compiled Code meets Dynamic Python

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...so what's the **catch**?

Python

For **some usecases**, Python, *by itself*, is too **slow**.

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- Use a **low-level** language with **wrappers**.
  - Where to draw the **line**? (see above)
  - Span **multiple languages**, extra **wrapper code**.

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- Use **Cython**.
  - Spans **high** and **low-level** paradigms.
  - **Complements** existing libraries such as **NumPy**.

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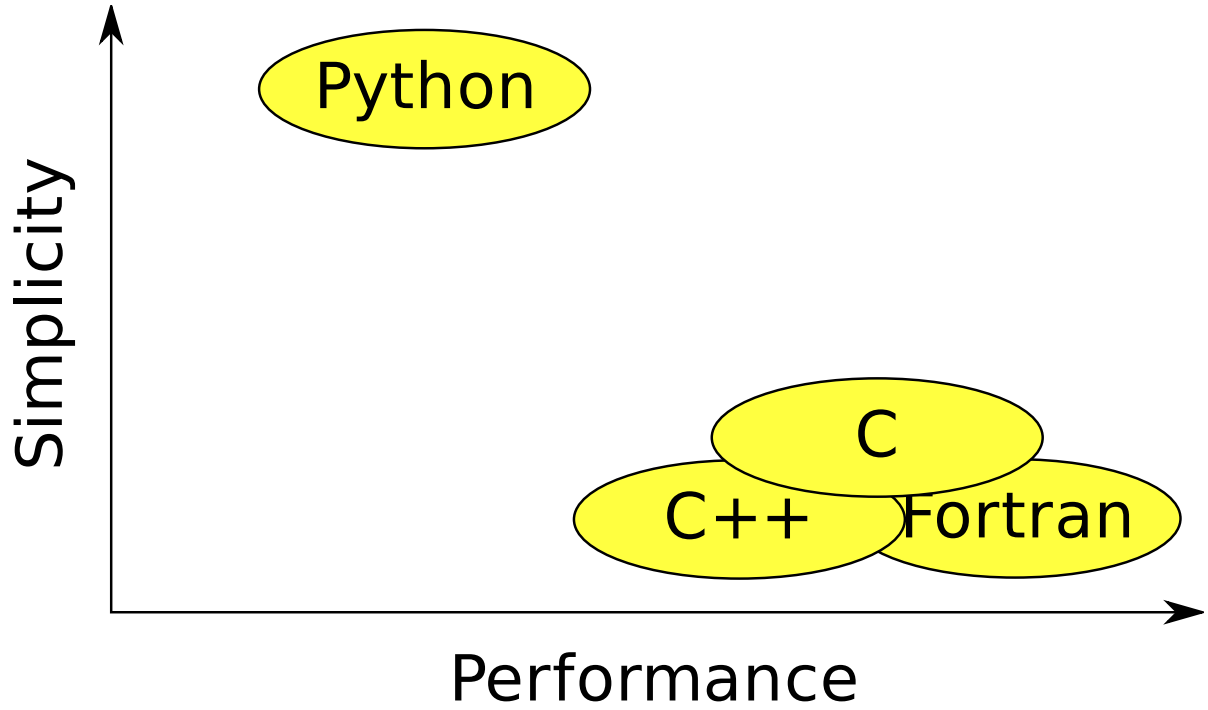
- Language extensions for **statically declaring types**
  - Potentially massive speedups
  - Integration with external libraries
- Python **memory management** and Python object $\leftrightarrow$ c data **type conversions** done automatically.
  - removes almost all the headaches of writing C extensions
  - malloc, realloc, free still used for C memory management (could be imporved)

What is Cython?

Cython is the missing link between the **simplicity of Python** and the **speed of C** / C++ / Fortran.



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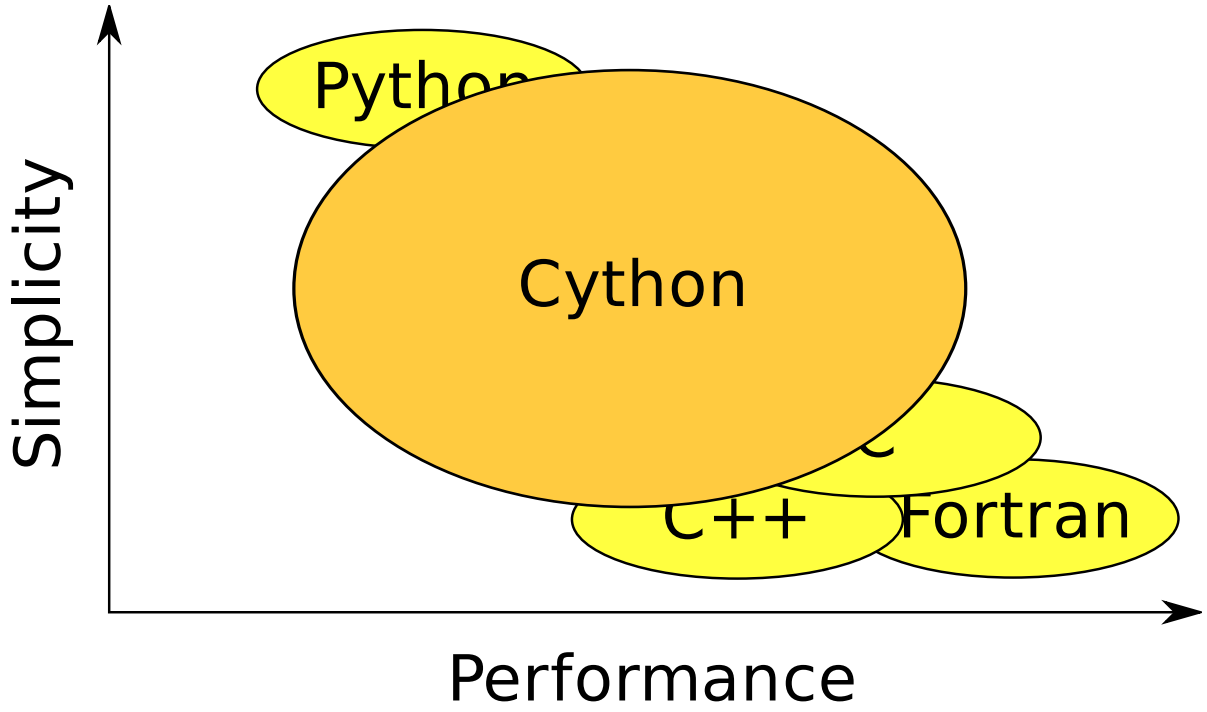

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- Leverage **existing libraries**
  - Directly call **C**, **C++**, and **Fortran** code
  - Use anything from the **Python ecosystem** as well

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- complicated calling conventions
  - *Cython has* `cdef` **functions**
- object-oriented primatives
  - *Cython has* `cdef` **values and types**

Example

integrate.py

```
def f(x):
    return x**2 - x


def integrate_f(a, b, N):
    s = 0.0
    dx = (b - a)/N
    for i in range(N):
        s += f(a + i*dx)
    return s * dx
```

```
%timeit integrate_f(0, 1.0, 1000)
625 loops, best of 3: 504 µs per loop
```

Example

integrate.pyx

```
def f(x):
    return x**2 - x


def integrate_f(a, b, N):
    s = 0.0
    dx = (b - a)/N
    for i in range(N):
        s += f(a + i*dx)
    return s * dx
```

```
%timeit integrate_f(0, 1.0, 1000)
625 loops, best of 3: 283 µs per loop
```

Example

integrate.pyx

```
cdef double f(double x):
    return x**2 - x

def integrate_f(double a, double b, int N):
    cdef int i
    s = 0.0
    dx = (b - a)/N
    for i in range(N):
        s += f(a + i*dx)
    return s * dx
```

```
%timeit integrate_f(0, 1.0, 1000)
625 loops, best of 3: 3.77 µs per loop
```

Example - NumPy

Cython has **native** support for **NumPy** arrays via the **buffer interface**.

module.pyx

```
cimport numpy as np

# Unpack pointer and stride information
cdef np.ndarray[int, ndim=2] arr = ...

for i in range(arr.shape[0]):
    for j in range(arr.shape[1]):
        ...
        # fast C-level indexing
        arr[i,j] = ...
```

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Working, **debugged**, **tested**, code has significant advantages over unwritten code.

- Cython's **static type declarations** make it easy to **call** and link to **existing libraries**.
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Working, **debugged**, **tested**, code has significant advantages over unwritten code.

- Cython's **static type declarations** make it easy to **call** and link to **existing libraries**.
- Not a wrapper-generator, but easy to write **efficient**, **Pythonic** wrappers.
- Ongoing work to to make this even easier (e.g. **Fwrap**).

Existing code - math.h

Declare the functions you need, then **use** them as if from C.

gamma.pyx

```
cdef extern from "math.h":
    double gamma(double)
    double lgamma(double)

def call_gamma(x):
    return gamma(x), lgamma(x)
```

```
>>> call_gamma(3)
(2.0, 0.6931471805599454)
```

Existing code - MPFR

gamma.pxd

```
cdef extern from "mpfr.h":
    cdef enum mpfr_rnd_t:
        GMP_RNDN
    ctypedef void* mpfr_t[1]
    cdef int mpfr_init2(mpfr_t, long prec)
    cdef int mpfr_init_set_d(
        mpfr_t rop, double op, mpfr_rnd_t rnd)
    cdef int mpfr_clear(mpfr_t)
    cdef int mpfr_lngamma(
        mpfr_t res, mpfr_t value, mpfr_rnd_t rnd)
    cdef int mpfr_sprintf(
        char *buf, char *template, ...)
```

Existing code - MPFR

gamma.pyx

```
def log_gamma(double x):
    cdef char[110] buf
    cdef mpfr_t input, res
    mpfr_init_set_d(input, x, GMP_RNDN)
    mpfr_init2(res, 500)
    mpfr_lngamma(res, input, GMP_RNDN)
    mpfr_sprintf(buf, "%.100RNF", res)
    mpfr_clear(input)
    mpfr_clear(res)
    return buf
```

```
>>> log_gamma(3)
0.693147180559945309417232121458176568075500134360255254
```

About

Who? When?

- **Pyrex** released in 2002 (Greg Ewing), enhanced for **Sage** in 2005-06 (William Stein, Bradshaw), **forked** as Cython in 2007 (Stefan Behnel, Bradshaw). Interest and development pace **grown** at an increasing rate from then. The first Cython **workshop** is in Munich at the end of this month.
- Support from Google (Summer of Code), Enthought, University of Washington, and NSF (via Sage).
- **Hundreds of thousands** of lines of code in a **wide variety** of projects.

Recent developments

There is a huge amount going on

- Type inferance
- C++ support `cdef cppclass vector[T]`
- gdb support `cydgb`
- Weave-like functionality `cython.inline("...")`
- IronPython and .NET backend (ongoing)
- Progress towards full Python compatibility (Cython 1.0 goal, Python regression test suite).

Lots of other exciting directions and optimizations we intend to pursue.

About

Where?

- Web site **http://cython.org**
- Documentation **http://docs.cython.org**
- Repository **https://github.com/cython/cython**
- Bug tracker **https://trac.cython.org**
- Mailing lists **cython-devel@python.org**, **cython-users@googlegroups.com**

Questions?