

Speeding up Python using Cython

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What is Cython?

- ▶ Compiler, compiles Python-like code to C-code
- ▶ Code is still executed in the Python runtime environment
- ▶ But is compiled to native machine code instead of Python bytecode
- ▶ Can result in more speed and easy wrapping of C libraries

Cython workflow

first approach

- ▶ Write a helloworld.pyx source file

```
1 print "Hello_World"
```

- ▶ Run the Cython compiler to generate a C file

```
1 $ cython helloworld.pyx
```

- ▶ Run a C compiler to generate a compiled library

```
1 $ gcc [...] -o helloworld.so helloworld.c
```

- ▶ Run the Python interpreter and import the module

```
1 >>> import helloworld
2 Hello World
```

Cython workflow

first approach

- ▶ Write a helloworld.pyx source file

```
1 print "Hello World"
```

- ▶ Run the Cython compiler to generate a C file

```
1 $ cython helloworld.pyx
```

- ▶ Run a C compiler to generate a compiled library

```
1 $ gcc [...] -o helloworld.so helloworld.c
```

- ▶ Run the Python interpreter and import the module

```
1 >>> import helloworld
2 Hello World
```

Cython workflow

second approach

- ▶ Write a helloworld.pyx source file
- ▶ Write a setup.py file with compile information

```
1 from distutils.core import setup
2 from Cython.Build import cythonize
3
4 setup(
5     ext_modules = cythonize("helloworld.pyx")
6 )
```

- ▶ Let Python compile the file

```
1 $ python setup.py build_ext --inplace
```

- ▶ Run the Python interpreter and import the module

Cython workflow

second approach

- ▶ Write a helloworld.pyx source file
- ▶ Write a setup.py file with compile information

```
1 from distutils.core import setup
2 from Cython.Build import cythonize
3
4 setup(
5     ext_modules = cythonize("helloworld.pyx")
6 )
```

- ▶ Let Python compile the file

```
1 $ python setup.py build_ext --inplace
```

- ▶ Run the Python interpreter and import the module

Cython workflow

third approach: pyximport

- ▶ Write a helloworld.pyx source file
- ▶ Use Pyximport

```
1 >>> import pyximport; pyximport.install()  
2 >>> import helloworld  
3 Hello World
```

KOGS



WINTER

of

CODE

FIRST

2014

YEAR

Pure Python

```
1 import numpy as np
2
3 def my_add(a, b):
4     (...) # validate parameter
5
6     dtype = a.dtype
7     height = a.shape[0]
8     width = a.shape[1]
9
10    result = np.zeros((height, width), dtype=dtype)
11
12    for y in range(height):
13        for x in range(width):
14            result[y,x] = a[y,x] + b[y,x]
15
16    return result
```

Listing 1: add1.py

Pure Python

```
1 import numpy as np
2
3 def my_add(a, b):
4     (...) # validate parameter
5
6     dtype = a.dtype
7     height = a.shape[0]
8     width = a.shape[1]
9
10    result = np.zeros((height, width), dtype=dtype)
11
12    for y in range(height):
13        for x in range(width):
14            result[y,x] = a[y,x] + b[y,x]
15
16    return result
```

Listing 1: add1.py

Time: ~19 minutes (2048x2048, 100x)

Python run through Cython

```
1 import numpy as np
2
3 def my_add(a, b):
4     (...) # validate parameter
5
6     dtype = a.dtype
7     height = a.shape[0]
8     width = a.shape[1]
9
10    result = np.zeros((height, width), dtype=dtype)
11
12    for y in range(height):
13        for x in range(width):
14            result[y,x] = a[y,x] + b[y,x]
15
16    return result
```

Listing 2: add2.pyx

Python run through Cython

```
1 import numpy as np
2
3 def my_add(a, b):
4     (...) # validate parameter
5
6     dtype = a.dtype
7     height = a.shape[0]
8     width = a.shape[1]
9
10    result = np.zeros((height, width), dtype=dtype)
11
12    for y in range(height):
13        for x in range(width):
14            result[y,x] = a[y,x] + b[y,x]
15
16    return result
```

Listing 2: add2.pyx

Time: ~16 minutes (2048x2048, 100x)

Cython: Adding types

```
1  import numpy as np; cimport numpy as np
2
3  DTYPE = np.uint8
4  ctypedef np.uint8_t DTYPE_t
5
6  def my_add(np.ndarray a, np.ndarray b):
7      (...) # validate parameter
8
9      cdef int height = a.shape[0]
10     cdef int width = a.shape[1]
11     cdef np.ndarray result = np.zeros((height, width), dtype=DTYPE)
12
13     cdef int x, y
14     for y in range(height):
15         for x in range(width):
16             result[y,x] = a[y,x] + b[y,x]
17
18     return result
```

Listing 3: add3.pyx

Cython: Adding types

```
1 import numpy as np; cimport numpy as np
2
3 DTYPE = np.uint8
4 ctypedef np.uint8_t DTYPE_t
5
6 def my_add(np.ndarray a, np.ndarray b):
7     (...) # validate parameter
8
9     cdef int height = a.shape[0]
10    cdef int width = a.shape[1]
11    cdef np.ndarray result = np.zeros((height, width), dtype=DTYPE)
12
13    cdef int x, y
14    for y in range(height):
15        for x in range(width):
16            result[y,x] = a[y,x] + b[y,x]
17
18    return result
```

Listing 3: add3.pyx

Time: ~16 minutes (2048x2048, 100x)

Cython: Efficient indexing

```
1 import numpy as np; cimport numpy as np
2
3 DTYPE = np.uint8
4 ctypedef np.uint8_t DTYPE_t
5
6 def my_add(np.ndarray[DTYPE_t, ndim=2] a, np.ndarray[DTYPE_t, ndim=2] b):
7     (...) # validate parameter
8
9     cdef int height = a.shape[0]
10    cdef int width = a.shape[1]
11    cdef np.ndarray[DTYPE_t, ndim=2] result = np.zeros((height, width),
12                                                       dtype=DTYPE)
13
14    cdef int x, y
15    for y in range(height):
16        for x in range(width):
17            result[y,x] = a[y,x] + b[y,x]
18
19    return result
```

Listing 4: add4.pyx

Cython: Efficient indexing

```
1 import numpy as np; cimport numpy as np
2
3 DTYPE = np.uint8
4 ctypedef np.uint8_t DTYPE_t
5
6 def my_add(np.ndarray[DTYPE_t,ndim=2] a, np.ndarray[DTYPE_t,ndim=2] b):
7     (...) # validate parameter
8
9     cdef int height = a.shape[0]
10    cdef int width = a.shape[1]
11    cdef np.ndarray[DTYPE_t, ndim=2] result = np.zeros((height, width),
12                                                       dtype=DTYPE)
13
14    cdef int x, y
15    for y in range(height):
16        for x in range(width):
17            result[y,x] = a[y,x] + b[y,x]
18
19    return result
```

Listing 4: add4.pyx

Time: 1.249 seconds (2048x2048, 100x)

Cython: Don't check boundaries

```
1 import numpy as np; cimport numpy as np; cimport cython
2
3 DTYPE = np.uint8
4 ctypedef np.uint8_t DTYPE_t
5
6 @cython.boundscheck(False)
7 def my_add(np.ndarray[DTYPE_t, ndim=2] a, np.ndarray[DTYPE_t, ndim=2] b):
8     (...) # validate parameter
9
10    cdef int height = a.shape[0]
11    cdef int width = a.shape[1]
12    cdef np.ndarray[DTYPE_t, ndim=2] result = np.zeros((height, width),
13                                                       dtype=DTYPE)
14
15    cdef int x, y
16    for y in range(height):
17        for x in range(width):
18            result[y,x] = a[y,x] + b[y,x]
19
19    return result
```

Listing 5: add5.pyx

Cython: Don't check boundaries

```
1 import numpy as np; cimport numpy as np; cimport cython
2
3 DTYPE = np.uint8
4 ctypedef np.uint8_t DTYPE_t
5
6 @cython.boundscheck(False)
7 def my_add(np.ndarray[DTYPE_t,ndim=2] a, np.ndarray[DTYPE_t,ndim=2] b):
8     (...) # validate parameter
9
10    cdef int height = a.shape[0]
11    cdef int width = a.shape[1]
12    cdef np.ndarray[DTYPE_t, ndim=2] result = np.zeros((height, width),
13                                                       dtype=DTYPE)
14
15    cdef int x, y
16    for y in range(height):
17        for x in range(width):
18            result[y,x] = a[y,x] + b[y,x]
19
19    return result
```

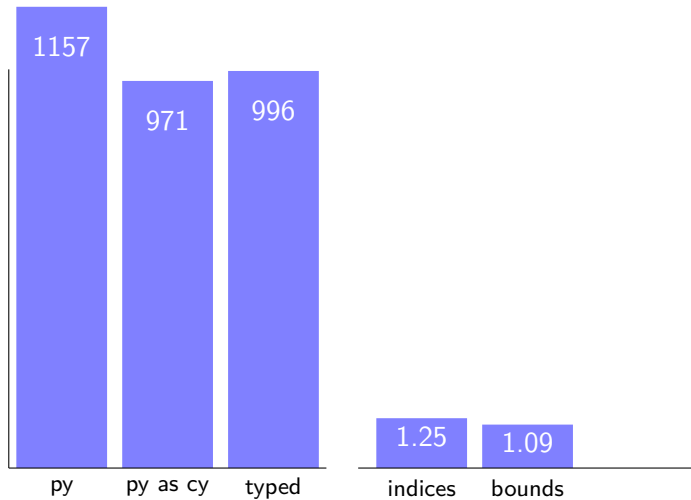
Listing 5: add5.pyx

Time: 1.086 seconds (2048x2048, 100x)

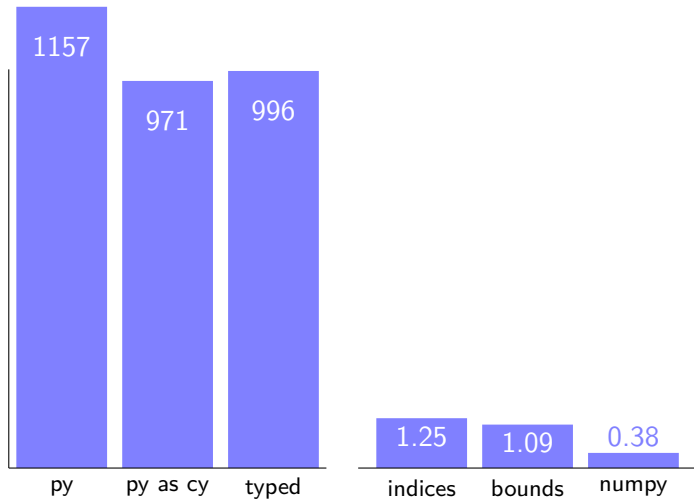
Obtaining speedup

- ▶ Static typing
- ▶ Access data buffer directly at C level
- ▶ Cython gimmicks

Conclusion



Conclusion



Now what?

1. <http://docs.cython.org> (tutorial style plus reference)
2. `with nogil:` release GIL
3. `cython.parallel`, parallelism with OpenMP support
4. PyPy support (considered mostly usable since Cython 0.17)
5. actual speedup compared to CPython; but compared to PyPy etc. ?

Now back to work

