Cython C-Extensions for Python

Example with GCoptimization

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Cython overview

- Syntax between Python and C (keyword `cdef`)
- C/C++ code automatically generated,
  then compiled into a Python module
- For a speed gain, variables must be declared
- C++ templates must be instantiated (compiled code)
- Choose between accessing low-level C++ or a blackbox

Documentation: `docs.cython.org`

Learn from examples:
scikit-learn, scikit-image, `github.com/amueller`

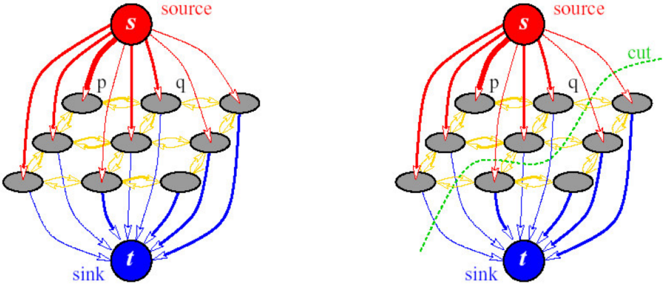
How to?

1. Organize your C/C++ code
2. Write `module.pyx`
3. Write `setup.py`
4. Build

Example 1

Interface the whole API

Graphcut (Boykov & Kolmogorov)



$$V(p,q) = \begin{cases} \frac{1}{\|p-q\|_2} e^{-(I_p - I_q)^2/2\sigma^2} & \text{if } I_p \geq I_q \\ \frac{1}{\|p-q\|_2} & \text{if } I_p < I_q \end{cases}$$

σ : noise estimate

GCoptimisation (Boykov & Kolmogorov)

```
template <typename captype,
         typename tcaptype,
         typename flowtype> class Graph {
public:
  ...
Graph( int node_num_max, int edge_num_max,
          void (*err_function)(const char *) = NULL);
void add_edge( node_id i, node_id j,
                captype cap, captype rev_cap);
void add_tweights( node_id i,
                    tcaptype cap_source, tcaptype cap_sink);
flowtype maxflow( bool reuse_trees = false,
                   Block<node_id>* changed_list = NULL);
termtype what_segment( node_id i,
                       termtype default_segm = SOURCE);
  ...
}
```

Begin your `module.pyx`

```
import numpy as np
cimport numpy as np

np.import_array()

ctypedef double captype
ctypedef double tcaptype
ctypedef double flowtype
```

Declare what you need from C++

```
cdef extern from "graph.h":
    cdef cppclass Graph[captype,tcaptype,flowtype]:
        Graph( size_t, size_t )
        size_t add_node(size_t)
        void add_edge(size_t,size_t,captype,captype)
        void add_tweights(size_t,tcaptype,tcaptype)
        flowtype maxflow()
        int what_segment(size_t)
```

Create your Python class

```
cdef class PyGraph:
    # hold a C++ instance which we're wrapping
    cdef Graph[captype,tcaptype,flowtype] *thisptr
    def __cinit__(self, size_t nb_nodes, size_t nb_edges):
        self.thisptr = new Graph[captype,
                      tcaptype, flowtype](nb_nodes,nb_edges)
    def __dealloc__(self):
        del self.thisptr
```

Create your Python class

```
def add_node(self, size_t nb_nodes=1):
    self.thisptr.add_node(nb_nodes)
def add_edge(self, size_t i, size_t j,
                      captype cap, captype rev_cap):
    self.thisptr.add_edge(i,j,cap,rev_cap)
def add_tweights(self, size_t i,
                    tcaptype cap_source, tcaptype cap_sink):
    self.thisptr.add_tweights(i,cap_source,cap_sink)
def maxflow(self):
    return self.thisptr.maxflow()
def what_segment(self, size_t i):
    return self.thisptr.what_segment(i)
```

Write setup.py

```
from distutils.core import setup
from distutils.extension import Extension
from Cython.Distutils import build_ext
from numpy.distutils.misc_util import get_numpy_include_dirs

setup(
    cmdclass = {’build_ext’: build_ext},
    ext_modules = [
        Extension( "graphcut",
                   [ "graphcut.pyx",
                     "../maxflow-v3.02.src/graph.cpp",
                     "../maxflow-v3.02.src/maxflow.cpp" ],
                   language="c++",
                   include_dirs=get_numpy_include_dirs()+["../maxflow-v3.02.src"],
                  )
        ]
    )
```

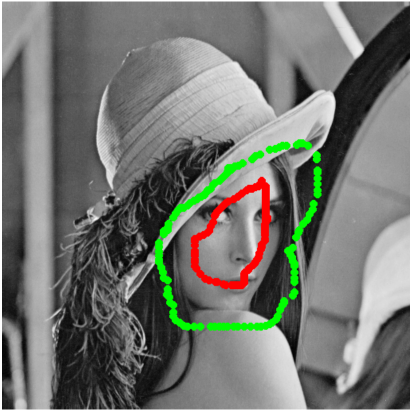
And build:

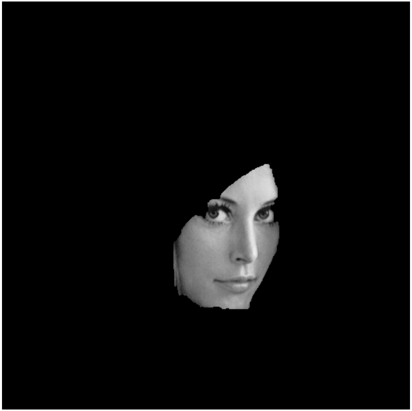
```
python setup.py build_ext --build-temp tmp \\
                          --build-lib lib \\
                          --pyrex-c-in-temp
```

And use it!

```
from lib import graphcut
G = graphcut.PyGraph(nb_pixels,nb_pixels*(8+2))
G.add_node(nb_pixels)
...
print "building graph..."
for i in range(img.shape[0]):
    for j in range(img.shape[1]):
        for a,b in neighbourhood:
            if ( 0 <= i+a < img.shape[0]
                 and 0 <= j+b < img.shape[1] ):
                    dist = np.sqrt( a**2 + b**2 )
                    if img[i,j] < img[i+a,j+b]:
                        w = 1.0/dist
                    else:
                        w = np.exp(-(img[i,j] - img[i+a,j+b])**2
                        w /= 2.0 * std**2 * dist
                    G.add_edge( index(i,j,img),
                                index(i+a,j+b,img),
                                w, 0 )
```

Result





Example 2

Use C++ as a blackbox

Declare C++ function

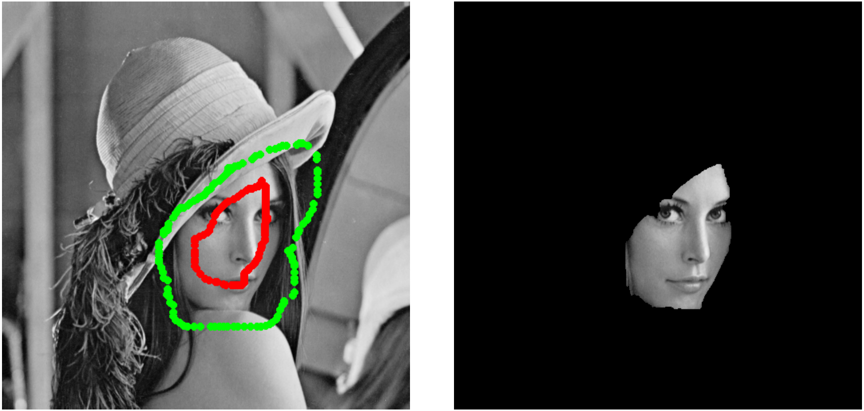
```
cdef extern from "_graphcut.h":
    void _graphcut( voxel_t*,
                    int, int,
                    double,
                    unsigned char*,
                    unsigned char* )
```

And use it!

```
def graphcut( np.ndarray[voxel_t, ndim=2, mode="c"] img,
              np.ndarray[unsigned char, ndim=2, mode="c"] mask,
              double std ):

    cdef np.ndarray[unsigned char,
                    ndim=2,
                    mode="c"] seg = np.zeros( (img.shape[0],
                                               img.shape[1]),
                                              dtype='uint8')
    print "starting graphcut..."
    _graphcut( <voxel_t*> img.data,
               img.shape[0], img.shape[1],
               std,
               <unsigned char*> mask.data,
               <unsigned char*> seg.data )
    return seg
```

Result

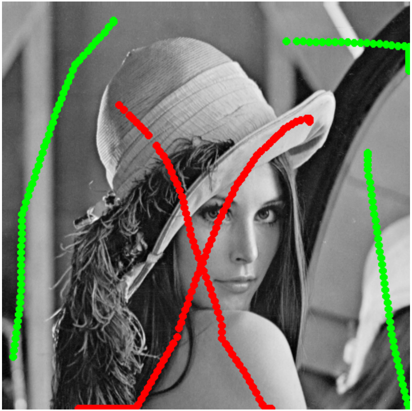


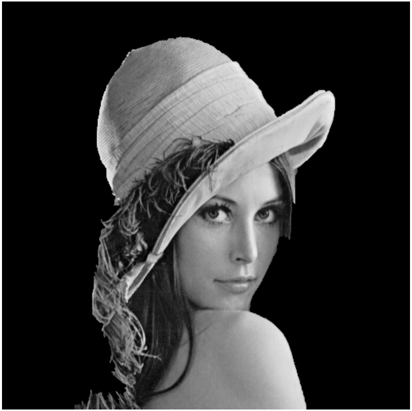
Timing

Example 1: 18.01s
Example 2: 0.37s

Nearly 50 times faster...

Another result...





Conclusion

- Huge speedup for a low amount of code
- Perfect if C++ code already exists
- Make sure your Python code is optimised (good use of `numpy`) before using `cython`

Slides and code are on github

`github.com/kevin-keraudren/talk-cython`

Thanks!