NetworkX Tutorial

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Local Installation

- install manually from
  `http://pypi.python.org/pypi/networkx`
- or use built-in python package manager, easy install
  `$ easy_install networkx`
- or use macports
  `$ sudo port install py27-networkx`
- use pip (replacement for easy_install)
  `$ sudo pip install networkx`
- or use debian package manager
  `$ sudo apt-get install python-networkx`

Cluster Setup

- networkx is already installed on the corn cluster
- Only works for python version 2.6, 2.7
- However default mapping of command 'python' is to version 2.4
- Just type 'python2.6' instead or make an alias in your shell configuration

Basic Example

```
>>> import networkx as nx
>>> G = nx.Graph()
>>> G.add_node("spam")
>>> G.add_edge(1,2)
>>> print(G.nodes())
[1, 2, 'spam']
>>> print(G.edges())
[(1, 2)]
```

Graph Types

- Graph : Undirected simple (allows self loops)
- DiGraph : Directed simple (allows self loops)
- MultiGraph : Undirected with parallel edges
- MultiDiGraph : Directed with parallel edges
- can convert to undirected: `g.to_undirected()`
- can convert to directed: `g.to_directed()`

To construct, use standard python syntax:

```
>>> g = nx.Graph()
>>> d = nx.DiGraph()
>>> m = nx.MultiGraph()
>>> h = nx.MultiDiGraph()
```

Adding Nodes

- `add_nodes_from()` takes any iterable collection and any object

```
>>> g = nx.Graph()
>>> g.add_node('a')
>>> g.add_nodes_from( ['b','c','d'])
>>> g.add_nodes_from('xyz')
>>> h = nx.path_graph(5)
>>> g.add_nodes_from(h)
>>> g.nodes()
[0,1,'c','b',4,'d',2,3,5,'x','y','z']
```

Adding Edges

- Adding an edge between nodes that don't exist will automatically add those nodes
- `add_nodes_from()` takes any iterable collection and any type (anything that has a `__iter__()` method)

```
>>> g = nx.Graph( [('a','b'),('b','c'),('c'
    ,'a')] )
>>> g.add_edge('a', 'd')
>>> g.add_edges_from([('d', 'c'), ('d', 'b')
    ])
```

Adding Node and Edge attributes

- Every node and edge is associated with a dictionary from attribute keys to values
- Type indifferent, just needs to be hashable
  - i.e. can't use `list`, must use `tuple`

```
>>> G = nx.Graph()
>>> G.add_node([1,2])
Traceback (most recent call last):
File "<stdin>", line 1, in <module>
File "/usr/lib/pymodules/python2.7/
    networkx/classes/graph.py", line 377,
    in add_node
     if n not in self.adj:
TypeError: unhashable type: 'list'
```

- No consistency among attribute dicts enforced by NetworkX

Node attributes

- Can add node attributes as optional arguments along with most add methods

```
>>> g = nx.Graph()
>>> g.add_node(1,name='Obrian')
>>> g.add_nodes_from([2],name='Quintana'])
>>> g[1]['name']
'Obrian'
```

Edge attributes

- Can add edge attributes as optional arguments along with most add methods

```
>>> g.add_edge(1, 2, w=4.7 )
>>> g.add_edges_from([(3,4),(4,5)], w =3.0)
>>> g.add_edges_from([(1,2,{'val':2.0})])
# adds third value in tuple as 'weight' attr
>>> g.add_weighted_edges_from([(6,7,3.0)])
>>> g.get_edge_data(3,4)
{'w' : 3.0}
>>> g.add_edge(5,6)
>>> g[5][6]
{}
```

Simple Properties

- Number of nodes :

```
>>> len(g)
>>> g.number_of_nodes()
>>> g.order()
```

- Number of Edges

```
>>> g.number_of_edges()
```

- Check node membership

```
>>> g.has_node(1)
```

- Check edge presence

```
>>> g.has_edge(1)
```

Neighbors

- Iterating over edges
- can be useful for efficiency

```
>>> G = nx.Graph()
>>> G.add_path([0,1,2,3])
>>> [e for e in G.edges_iter()]
[(0, 1), (1, 2), (2, 3)]
>>> [(n,nbrs) for n,nbrs in G.adjacency_iter
    ()]
[(0, {1: {}}), (1, {0: {}, 2: {}}), (2, {1:
    {}, 3: {}}), (3, {2: {}})]
>>> G[1][2]['new_attr'] = 5
>>> G[1][2]['new_attr']
5
```

Degrees

```
 >>> G.degree(0)
1
>>> G.degree([0,1])
{0: 1, 1: 2}
>>> G.degree()
{1: 1, 2: 2, 3: 2, 4: 1}
>>> G.degree().values() # useful for degree
    dist
[1, 2, 2, 1]
```

Simple Graph Generators

- located in `networkx.generators.classic` module
- Complete Graph

```
nx.complete_graph(5)
```

- Chain

```
nx.path_graph(5)
```

- Bipartite

```
nx.complete_bipartite_graph(n1, n2)
```

- Arbitrary Dimensional Lattice (nodes are tuples of ints)

```
nx.grid_graph([10,10,10,10]) # 4D, 100^4
    nodes
```

Random Graph Generators

- located in module `networkx.generators.random_graphs`
- Preferential Attachment

```
nx.barabasi_albert_graph(n, m)
```

- $G_{n,p}$

```
nx.gnp_random_graph(n,p)
```

```
nx.gnm_random_graph(n, m)
```

-

```
nx.watts_strogatz_graph(n, k, p}
```

Stochastic Graph Generators

- located in module `networkx.generators.stochastic`
- Configuration Model / Rewired
  deg_sequence is a list of integers representing the degree for each node. Does not eliminate self loops

```
configuration_model(deg_sequence)
```

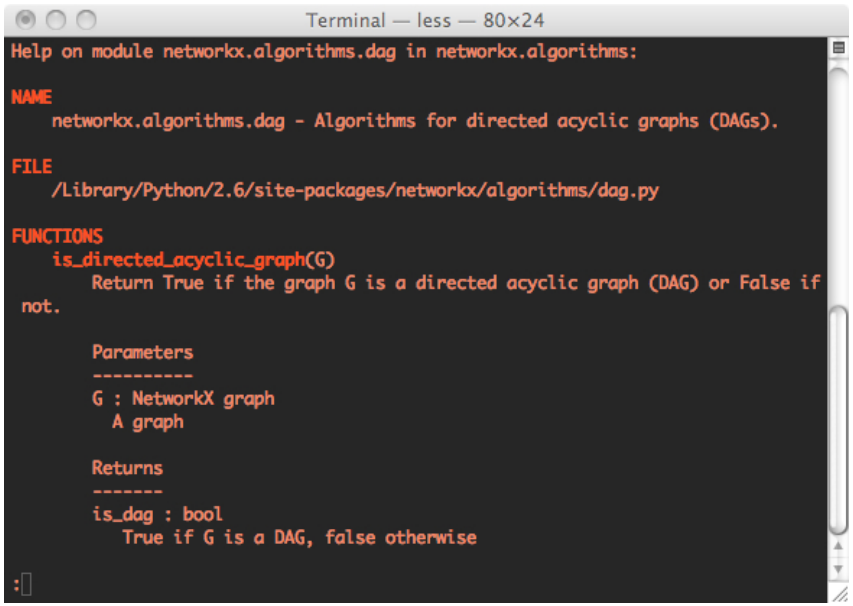
Algorithms Package (`networkx.algorithms`)

- bipartite
- block
- boundary
- centrality (package)
- clique
- cluster
- components (package)
- core
- cycles
- dag
- distance_measures
- flow (package)
- isolates
- isomorphism (package)
- link_analysis (package)
- matching
- mixing
- mst
- operators
- shortest_paths (package)
- smetric

Use the Python Help Viewer

```
>>> import networkx as nx
>>> help(nx.algorithms)
```

- pops up an instance of 'less' (the pager utility)



A Few Useful Functions

- As subgraphs

```
nx.connected_component_subgraphs(G)
```

- Operations on Graph

```
nx.union(G,H), intersection(G,H),
    complement(G)
```

- *k*-cores

```
nx.find_cores(G)
```

A Few More

- shortest path

```
nx.shortest_path(G,s,t)
nx.betweenness_centrality(G)
```

- clustering

```
nx.average_clustering(G)
```

```
>>> G=nx.complete_graph(5)
>>> nx.clustering(G)
{0: 1.0, 1: 1.0, 2: 1.0, 3: 1.0, 4: 1.0}
```

- diameter

```
nx.diameter(G)
```

Edge List Text File

```
nx.read_edgelist('elist',comment='#',
    delimiter='\t')
nx.write_edgelist(G, path)
>>> G.edges()
[(u'1', u'3'), (u'1', u'2'), (u'3', u'2')]
>>> G.add_edge(u'1',u'3')
>>> nx.save_edgelist(G,'elist_new',data=
    False)
```

```
# edge list file
1        2
3        2
```

```
# new edge list file
1        2
3        2
3        1
```

Importing Other Graph Formats

- GML
- Pickle
- GraphML
- YAML
- Pajek
- GEXF
- LEDA
- SparseGraph6
- GIS Shapefile

Matplotlib

- A python package which emulates matlab functionality
  - Well documented at `http://matplotlib.sourceforge.net/contents.html`
- Interfaces nicely with NetworkX
- Depends on Numpy which provides multidimensional array support:
  - `http://numpy.scipy.org/`
- We only really need it for plotting

```
>>> import matplotlib.pyplot as plt
>>> plt.plot(range(10),range(10))
```

Backend

- Need to specify a **backend**
- This is the program which is responsible for either displaying or writing the plots to file
- does not change matplotlib plotting tools
- options include
  - **'MacOSX'** interactive plot tool for mac OS X
  - **'GTKAgg'** cross-platform interactive plot tool
  - **'PDF'** A "renderer" in PDF format
  - **'PS'** A "renderer" in PostScript format
- For more info, see: `http://matplotlib.sourceforge.net/faq/installing_faq.html#what-is-a-backend`
- renderers are useful for working on clusters because they don't require a windowing system

Configuring Backend

- can be set within the script itself:

```
import matplotlib
matplotlib.use('PDF')
import matplotlib.pyplot as plt
# need to do these steps in this order
```

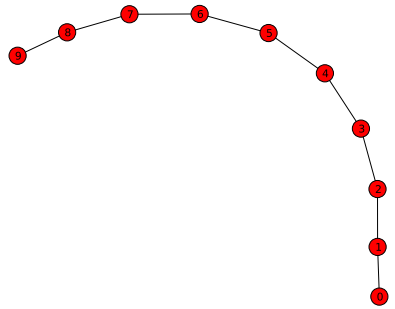
- can be set in the matplotlib config file:
  `/.matplotlib/matplotlibrc`

```
...
backend      : MacOSX
...
```

Basic Graph Drawing (with matplotlib)

```
import networkx as nx
import matplotlib.pyplot as plt
>>> G = nx.path_graph(10)
>>> nx.draw(G)
>>> plt.savefig("path_graph.pdf")
```

- consult package `nx.drawing` for more options

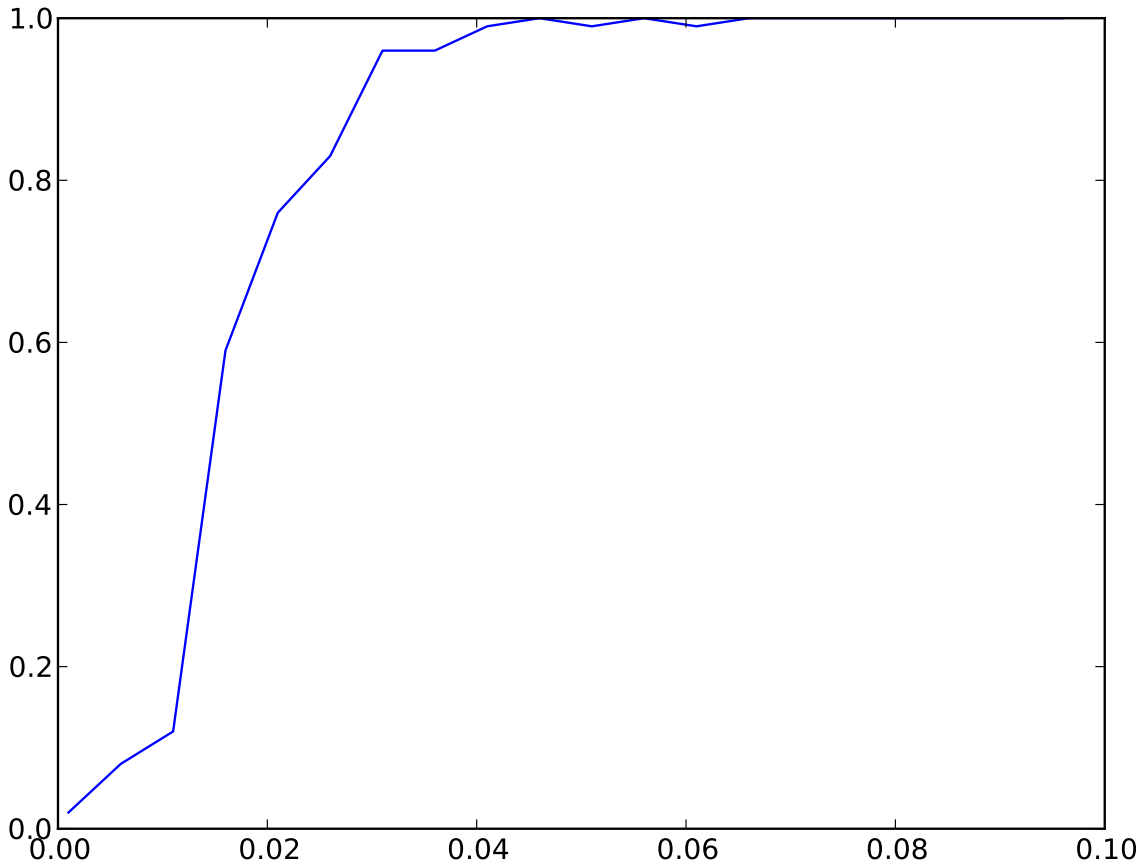


Basic Data Plotting

```
def get_phase_curve(n):
    ps = np.arange(0.001,0.1,0.005)
    cs = []
    for p in ps:
        G = nx.gnp_random_graph(n,p)
        c = nx.connected_component_subgraphs
            (G)[0].order()
        cs.append(float(c)/100)
    return cs

plt.plot(ps,get_phase_curve(100))
plt.savefig('phase.pdf')
```

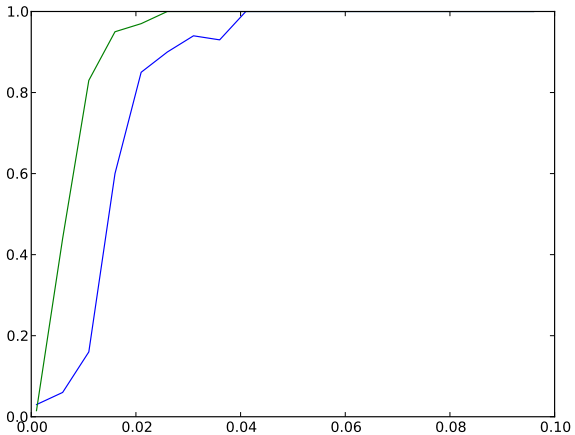
Phase Change Plot



Plotting Multiple Series on Same Axes

- Let's add another curve

```
plt.clf()
ps = np.arange(0.001,0.1,0.005)
plt.plot(ps,get_phase_curve(ps,100))
plt.plot(ps,get_phase_curve(ps,200))
plt.savefig('phase_100_200.pdf')
```



Plotting Basics

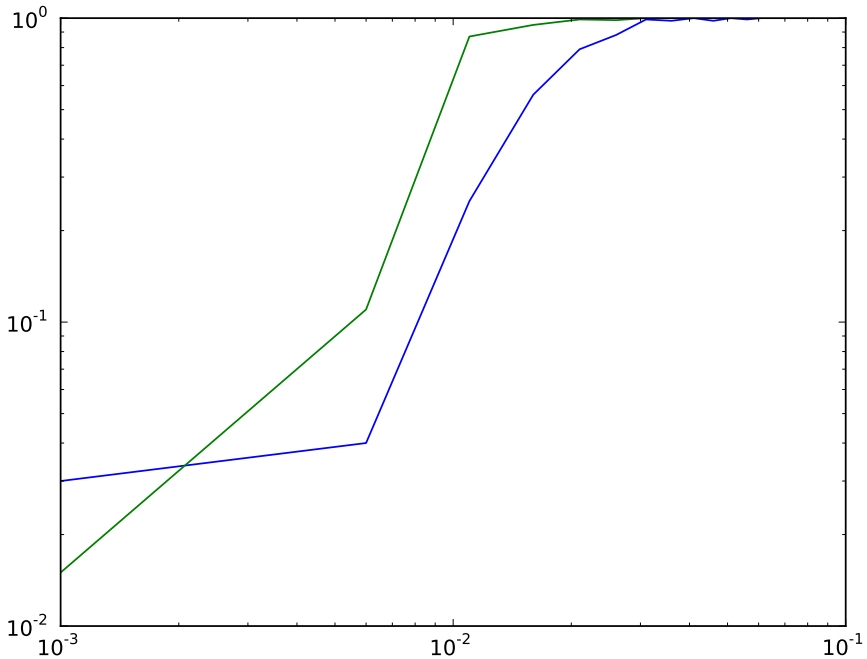
- matplotlib has an internal structure much like matlab
- good resource:
  - `matplotlib.sourceforge.net/users/artists.html`
- several objects involved in every plot

  `figure` top level container for all plot elements
  `axes` a specific set of axes (as in a subplot)
  `axis` a specific axis (x or y)

```
>>> fig = plt.figure()
>>> ax = fig.add_subplot(1,1,1)
>>> h = ax.plot(range(10),range(10))
>>> plt.show()
```

Log Plots

```
ps,cs = get_phase_curve(100)
plt.loglog(ps,cs) # also see semilog
plt.savefig('phase_log_log.pdf')
```

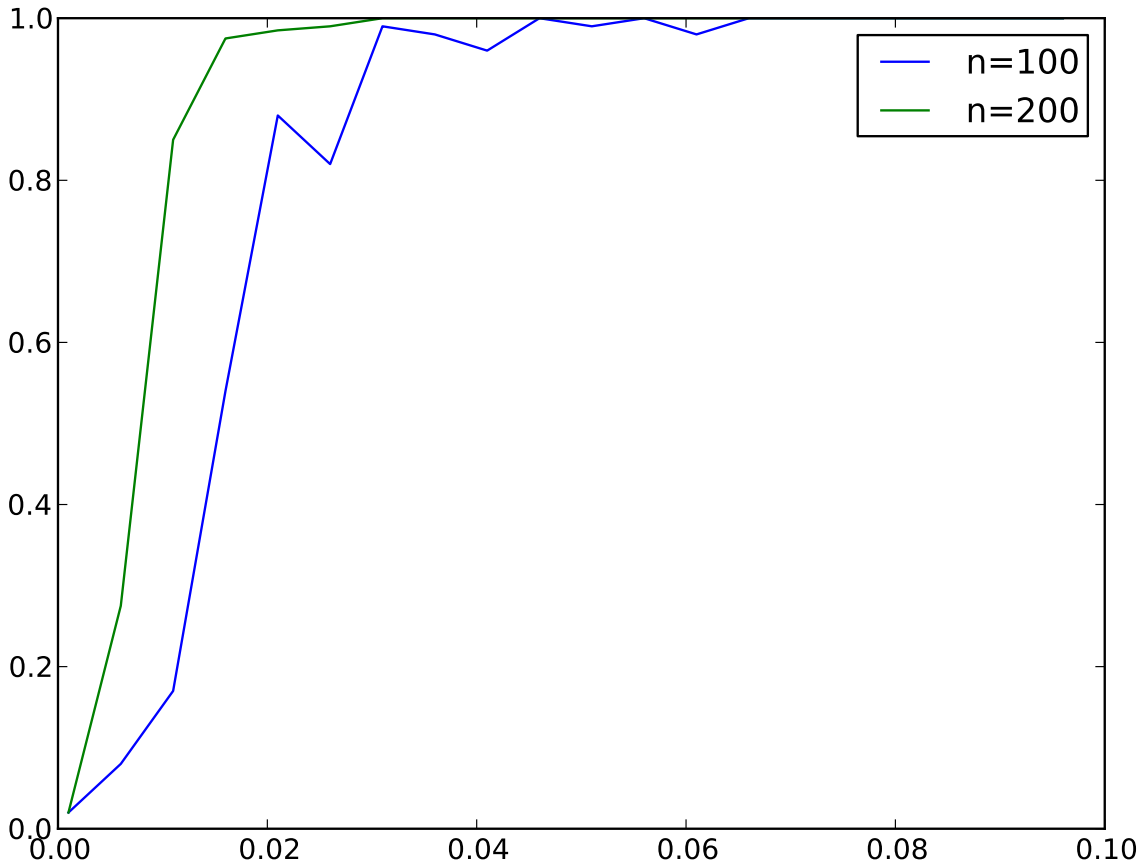


Legends

- each call to `plt.plot` returns a **handle** object for the series of type `matplotlib.lines.Line2D`
- to add a legend, call use method `plt.legend([handles],[labels])`
- can control placement with keyword argument `loc=[1,...,10]` (uppper left, lower left, ...)

```
h_100 = plt.plot(ps,get_phase_curve(100))
h_200 = plt.plot(ps,get_phase_curve(200))
plt.legend([h_100,h_200],['n=100','n=200'])
```

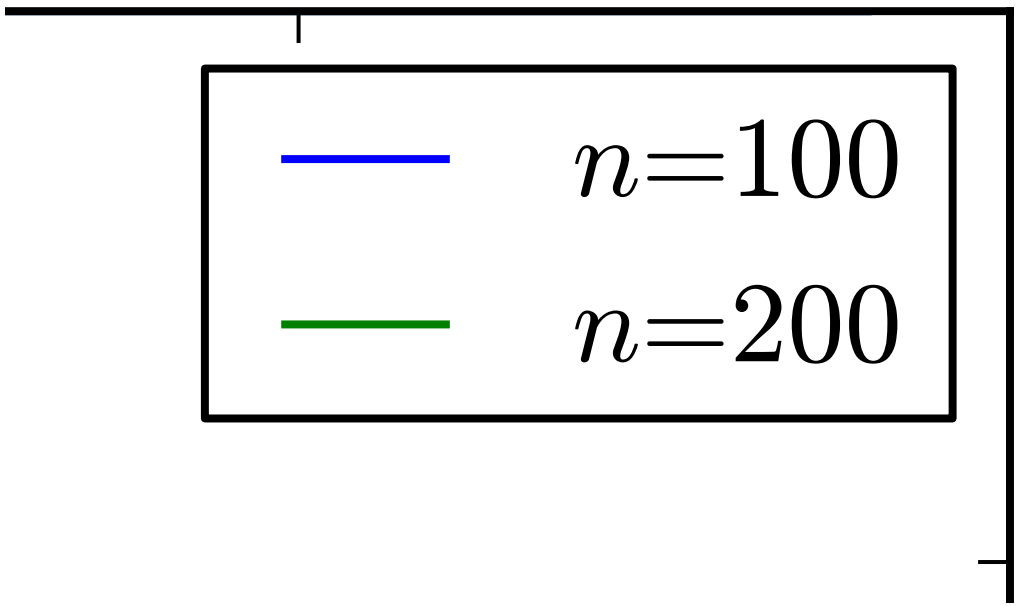
Legends



Legends

- Can use Latex:

```
plt.legend([h_100,h_200],['$$ n=100 $$','
    $$ n=200 $$'])
```



Resources

- NetworkX Docs
  `http://networkx.lanl.gov/tutorial/index.html`
- NetworkX Tutorial
  `http://networkx.lanl.gov/contents.html`
- Matplotlib Docs
  `http://matplotlib.sourceforge.net/contents.html`
- Matplotlib Tutorial
  `http://matplotlib.sourceforge.net/users/pyplot_tutorial.html`
- Numpy Docs
  `http://numpy.scipy.org/`
- MacPorts
  `http://macports.org`