

Module IV - Basic Analysis

Drew Conway — Department of Politics



NEW YORK UNIVERSITY

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Agenda for Module IV

Loading data from multiple sources

- ▶ Local network data files
- ▶ Connecting to a database
- ▶ Building directly from the Internet

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Brief review of Python dictionaries

- ▶ Why is the dict so useful?
- ▶ How NetworkX utilizes it?

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Running basic centralities

- ▶ Degree, Closeness, Betweenness Eigenvector
- ▶ Calculating degree distribution
- ▶ Plotting statistics using matplotlib
- ▶ Calculating cliques, clustering and transitivity

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- ▶ Writing network data
- ▶ Saving network analysis statistics

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Basic visualization

- ▶ Review of NetworkX's plotting algorithms
- ▶ Adding analysis to visualization

Loading a network file

As we have seen, one of the main advantages of working with NetworkX is that it can read many different network formats

- For those that are unfamiliar with working at the **command-line**, however, the process can be confusing

NX syntax for loading a file

```
>>> G = read_format("path/to/file.txt", ...options...)
      ↑           ↑           ↑
Net variable  NX function, file directory path  Graph type, nodes type, etc.
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Let's try!

- ▶ We will load the edge list of Hartford drug users network
- ▶ Specify that the network be a directed graph, and the nodes be integers
- ▶ Use `info()` to check that data has been loaded correctly

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It's time to fire up your console and load Python!

Loading the Hartford drug users network

Starting NetworkX and loading data

```
>>> from networkx import *
>>> hartford=read_edgelist("../data/hartford_drug.txt",create_using=DiGraph(),nodetype=int)
>>> info(hartford)
Name:
Type:          DiGraph
Number of nodes: 212
Number of edges: 337
Average in degree: 1.5896
Average out degree: 1.5896
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- ▶ Specified path to Hartford drug users file

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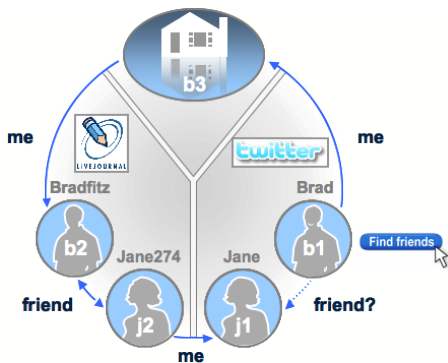
Some formats may have more or less options, **always check the documentations!**

Building a network from a database

As data sets become larger and persistently changing, it may make more sense to store them in a database rather than a single file

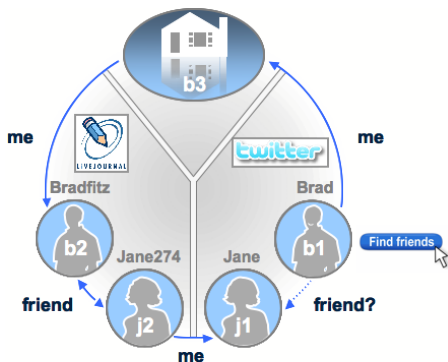
- ▶ As we have seen, Python provides binding to many modern database frameworks

Building the social network among LiveJournal users



Perhaps the most powerful aspect of NetworkX is its ability to work in Python to generate networks from live-streaming data

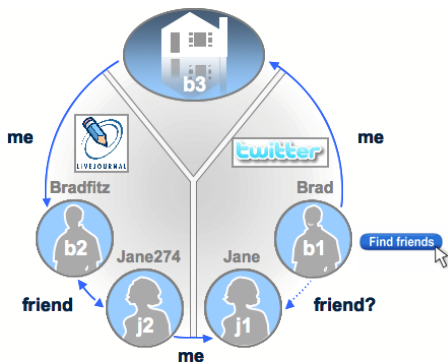
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- In Python, use NetworkX, cjson and a other standard scientific libraries to parse Google's SocialGraph data

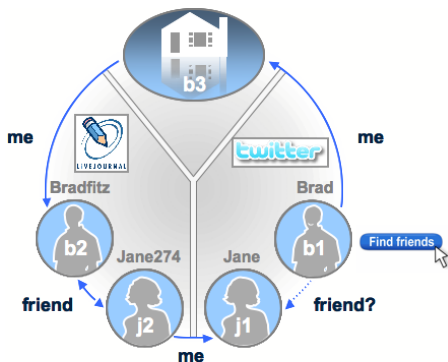
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- ▶ Using a "seed" user, we will build out a network

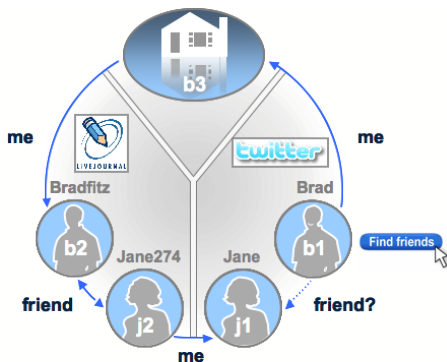
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- ▶ In Python, use NetworkX, cjson and a other standard scientific libraries to parse Google's SocialGraph data
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- ▶ Through a process called "k-snowball searching"
 $seed \rightarrow friend \rightarrow \dots \rightarrow friend_k$

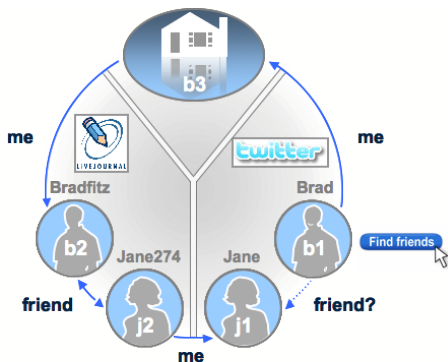
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 - ▶ Seed: imichaeldotorg.livejournal.com
 - ▶ $k = 3$

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 $seed \rightarrow friend \rightarrow \dots \rightarrow friend_k$
 - ▶ Seed: imichaeldotorg.livejournal.com
 - ▶ $k = 3$
- ▶ Note the low value of k

The code, part 1

Loading the libraries and setting things up

```
from cjson import *
from urllib import *
from networkx import *
from time import *
from scipy import array,unique
...
if __name__ == "__main__":
    seed_url='http://imichaeldotorg.livejournal.com'
    sg=get_sg(seed_url)
    net,newnodes=create_egonet(sg)
    info(net)
```

Get the JSON from SocialGraph

```
def get_sg(seed_url):
    sgapi_url="http://socialgraph.apis.google.com/lookup?q="+seed_url+"&edo=1&edi=1&fme=1&pretty=0"
    try:
        furl=urlopen(sgapi_url)
        fr=furl.read()
        furl.close()
        return fr
    except IOError:
        print "Could not connect to website"
        print sgapi_url
        return
```

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```

Name:	['http://imichaeldotorg.livejournal.com/']
Type:	DiGraph
Number of nodes:	5
Number of edges:	5
Average in degree:	1.0
Average out degree:	1.0

Get the JSON from SocialGraph

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def get_sg(seed_url):
    sgapi_url="http://socialgraph.apis.google.com/lookup?q="+seed_url+"&edo=1&edi=1&fme=1&pretty=0"
    try:
        furl=urlopen(sgapi_url)
        fr=furl.read()
        furl.close()
        return fr
    except IOError:
        print "Could not connect to website"
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        return
```

Build egonet and snowball

Creating the egonet

```
def create_egonet(s):
    try:
        raw=decode(s)
        G=DiGraph()
        pendants=[]
        n=raw['nodes']
        nk=n.keys()
        G.name=str(nk)
        pendants=[]
        for a in range(0,len(nk)):
            for b in range(0,len(nk)):
                if a!=b:
                    G.add_edge(nk[a],nk[b])
        for k in nk:
            ego=n[k]
            ego_out=ego['nodes_referenced']
            for o in ego_out:
                G.add_edge(k,o)
                pendants.append(o)
            ego_in=ego['nodes_referenced_by']
            for i in ego_in:
                G.add_edge(i,k)
                pendants.append(i)
        pendants=array(pendants, dtype=str)
        pendants.flatten()
        pendants=unique(pendants)
        return G, pendants
    except DecodeError:
        ...
    except KeyError:
```

Rolling the snowball

```
def snowball_round(G, seeds, myspace=False):
    t0=time()
    if myspace:
        seeds=get_myspace_url(seeds)
    sb_data=[]
    for s in range(0,len(seeds)):
        s_sg=get_sg(seeds[s])
        new_ego, pen=create_egonet(s_sg)
        for p in pen:
            sb_data.append(p)
    if s<1:
        sb_net=compose(G, new_ego)
    else:
        sb_net=compose(new_ego, sb_data)
    del new_ego
    if s==round(len(seeds)*0.2):
        sb_net.name='20% complete'
        sb_net.info()
        print 'AT: ' + strftime('%m/%d/%Y, %H:%M:%S', gmtime())
        print ''
    ...
    # More time keeping, probably a MUCH better way to do this
    sb_data=array(sb_data)
    sb_data.flatten()
    sb_data=unique(sb_data)
    sb_net.info()
    return sb_net, sb_data
```

Build the whole network

Step	Nodes	Edges	Mean Degree	Density
Seed	5	5	2.0	0.25
$k = 2$	75	115	3.0	0.02
$k = 3$	4,938	8,659	3.5	$3.6(10^{-4})$

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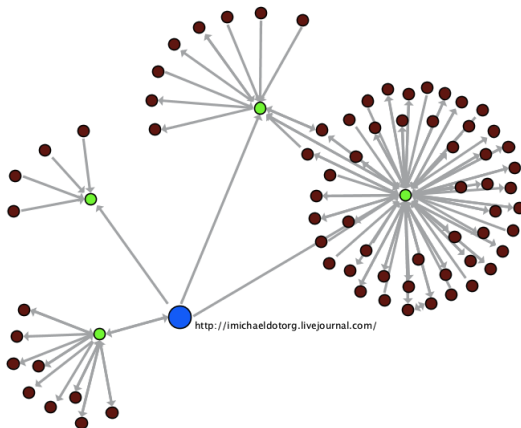
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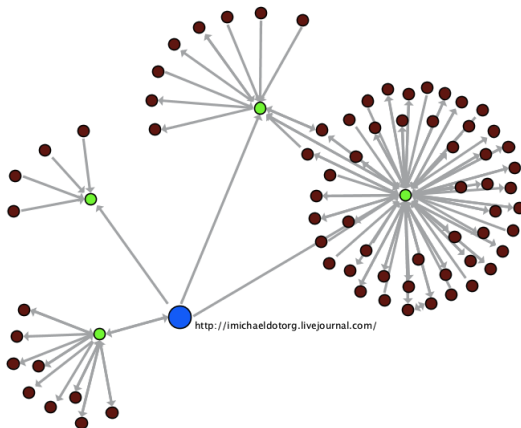
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- ▶ Our seed is abnormally isolated, with only four neighbors
- ▶ Large jump after first snowball
- ▶ Massive structural leap at $k = 3$

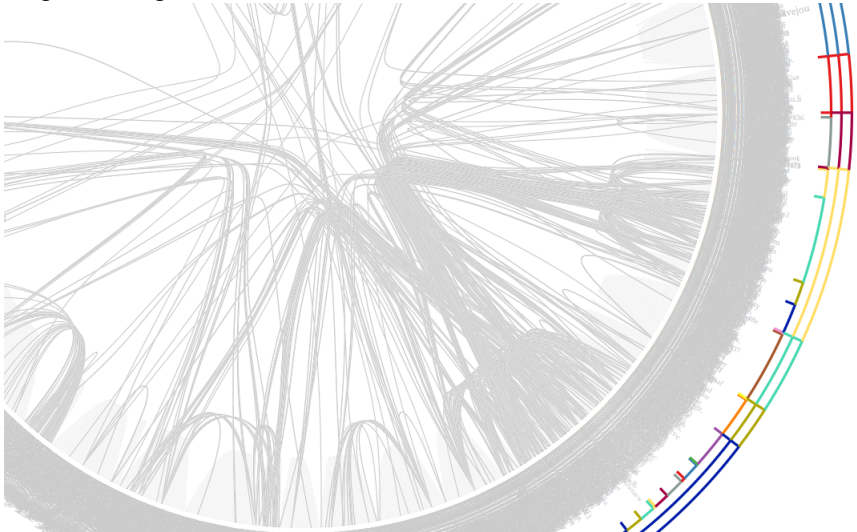


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The Python dict
Running basic centralities
Getting things out of NetworkX

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The full network

To get a feeling for the size of the full network...



Python Dictionaries

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# Can retrieve the keys and values as Python lists (vector)
>>> fruit_dict.keys()
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Now, try creating a dict of your own

Using dictionaries for network analysis

From the documentation...

networkx.closeness centrality

```
closeness centrality(G, v=None, weighted_edges=False)
```

Compute closeness centrality for nodes.

Closeness centrality at a node is 1/average distance to all other nodes.

Parameters: G : graph

A networkx graph

v : node, optional

Return only the value for node v.

weighted_edges : bool, optional

Consider the edge weights in determining the shortest paths. If False, all edge weights are considered equal.

Returns: nodes : dictionary

Dictionary of nodes with closeness centrality as the value.

NetworkX's metric's make extensive use of the dict type

- In this case the key→value mapping is of the form: {node_label: metric}

Let's look at an example:

In-degree centrality of Hartford data

```
>>> in_cen=in_degree_centrality(hartford)
>>> in_cen
{1: 0.014218009478672987, 2: 0.018957345971563982,...
...
90: 0.0047393364928909956, 293: 0.0}
```

We can see that node #90 has in-degree centrality 0.0047

- But we can do so much more!

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We can see that node #90 has in-degree centrality 0.0047

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Running multiple measures

For our first analysis in NetworkX, we will do some basic network manipulation, then run multiple measures to find highest centrality nodes

- ▶ First, we will need to convert to an undirected network, and extract the main component

Find main component & symmetrize

```
# Many of the centrality metrics require undirected graphs, so we will symmetrize
>>> hartford_ud=hartford.to_undirected()
# The network also has many small components, but for
# this analysis we are interested in the largest
>>> hartford_mc=hartford_main=connected_component_subgraphs(hartford_ud)[0]
```

Next, we will calculate multiple measures

Computing multiple centralities

```
# Betweenness centrality
>>> bet_cen=betweenness centrality(hartford_mc)
# Closeness centrality
>>> clo_cen=closeness centrality(hartford_mc)
# Eigenvector centrality
>>> eig_cen=eigenvector centrality(hartford_mc)
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>>> hartford_mc=hartford_main=connected_component_subgraphs(hartford_ud)[0]
```

Next, we will calculate multiple measures

Computing multiple centralities

```
# Betweenness centrality
>>> bet_cen=betweenness centrality(hartford_mc)
# Closeness centrality
>>> clo_cen=closeness centrality(hartford_mc)
# Eigenvector centrality
>>> eig_cen=eigenvector centrality(hartford_mc)
```

Running multiple measures

For our first analysis in NetworkX, we will do some basic network manipulation, then run multiple measures to find highest centrality nodes

- ▶ First, we will need to convert to an undirected network, and extract the main component

Find main component & symmetrize

```
# Many of the centrality metrics require undirected graphs, so we will symmetrize
>>> hartford_ud=hartford.to_undirected()
# The network also has many small components, but for
# this analysis we are interested in the largest
>>> hartford_mc=hartford_main=connected_component_subgraphs(hartford_ud)[0]
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```


Finding most central actors

To find the most central actors we will use Python's list comprehension technique to do basic data manipulation on our centrality dictionaries

Function for finding most central actor

```
def highest centrality(cent_dict):  
    """Returns node key with largest value from  
    NX centrality dict"""  
    # Create ordered tuple of centrality data  
    cent_items=cent_dict.items()  
    # List comprehension!  
    cent_items=[(b,a) for (a,b) in cent_items]  
    # Sort in descending order  
    cent_items.sort()  
    cent_items.reverse()  
    return cent_items[0][1]
```

Now, just ask for the answer

Finding Most central actors

```
>>> print("Actor "+str(highest centrality(bet_cen))+" has the highest Betweenness centrality")  
Actor 82 has the highest Betweenness centrality
```

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```

List comprehension

- ▶ Given a dict: d={1: 0.15, 2: 0.67}
- ▶ d.items() → [(1,0.15),(2,0.67)]
- ▶ d=[(b,a) for (a,b) in d] → [(0.15,1),(0.67,2)]

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Introduction to matplotlib

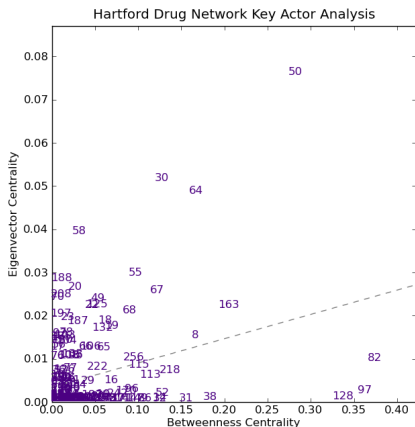
Recall Python's scientific computing trinity: NumPy, SciPy and matplotlib

- ▶ While NumPy and SciPy do most of the behind the scenes work, you will interact with matplotlib frequently for when doing network analysis

Introduction to matplotlib

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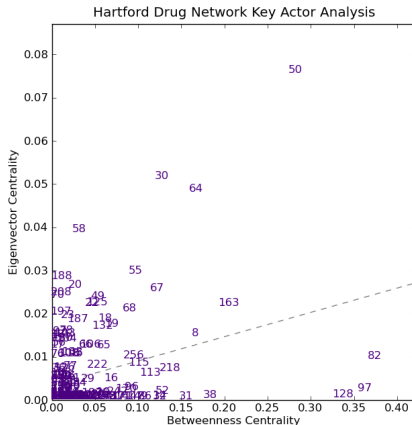
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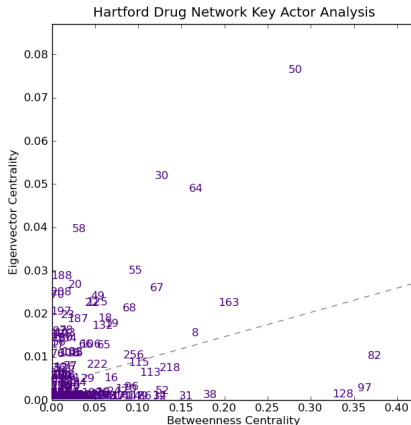


We will need to create a function that takes two centrality dict and generates this plot

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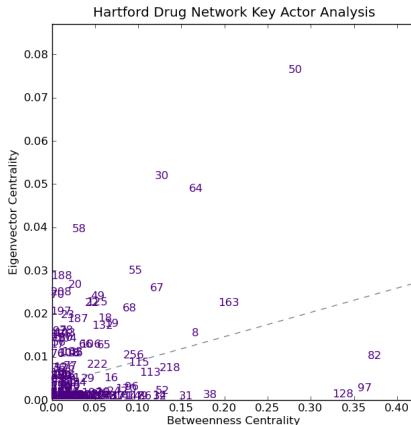
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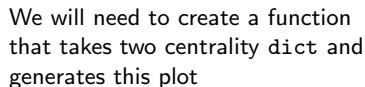


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1. Create a matplotlib figure
2. Plot each node label as a point

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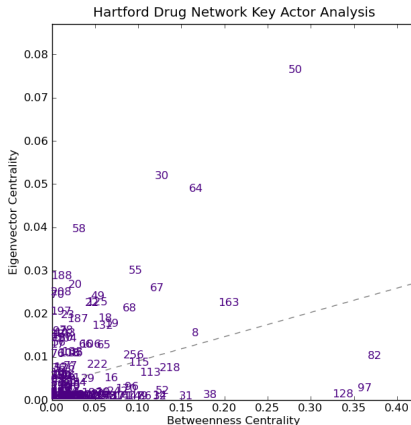


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3. Add a “best fit” line

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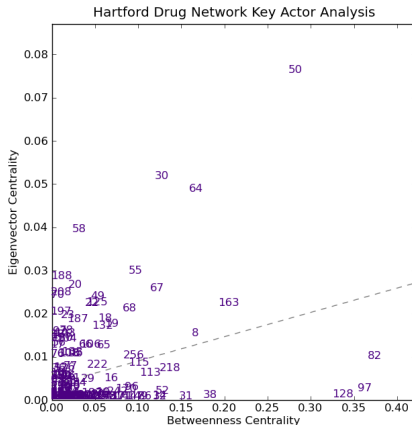
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We will need to create a function that takes two centrality dict and generates this plot

1. Create a matplotlib figure
2. Plot each node label as a point
3. Add a “best fit” line
4. Add axis and title labels
5. Save figure as a PNG file

Creating a key actor plot in matplotlib

The centrality_scatter function, part one

```
def centrality_scatter(met_dict1,met_dict2,path="",ylab="",xlab="",title="",reg=False):
    # Create figure and drawing axis
    fig=P.figure(figsize=(7,7))
    ax1=fig.add_subplot(111)
    # Create items so actors can be sorted properly
    met_items1=met_dict1.items()
    met_items2=met_dict2.items()
    met_items1.sort()
    met_items2.sort()
    # Grab data
    xdata=[(b) for (a,b) in met_items1]
    ydata=[(b) for (a,b) in met_items2]
    # Add each actor to the plot by ID
    for p in xrange(len(met_items1)):
        ax1.text(x=xdata[p],y=ydata[p],s=str(met_items1[p][0]),color="indigo")
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- Create a canvas to draw on

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- ▶ Create a canvas to draw on
- ▶ manipulate and store centrality data

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- ▶ Create a canvas to draw on
- ▶ manipulate and store centrality data
- ▶ Add points to plot as node labels

Creating a key actor plot in matplotlib

The centrality_scatter function, part one

```
def centrality_scatter(met_dict1,met_dict2,path="",ylab="",xlab="",title="",reg=False):
    ...
    # If adding a best fit line, we will use NumPy to calculate the points.
    if reg:
        # Function returns y-intercept and slope. So, we create a function to
        # draw LOBF from this data
        slope,yint=polyfit(xdata,ydata,1)
        xline=P.xticks()[0]
        yline=map(lambda x: slope*x+yint,xline)
        # Add line
        ax1.plot(xline,yline,ls='--',color='grey')
    # Set new x- and y-axis limits to data
    P.xlim((0.0,max(xdata)+(.15*max(xdata)))) # Give a little buffer
    P.ylim((0.0,max(ydata)+(.15*max(ydata))))
    # Add labels
    ax1.set_title(title)
    ax1.set_xlabel(xlab)
    ax1.set_ylabel(ylab)
    # Save figure
    P.savefig(path,dpi=100)
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- Add a best fit line

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- ▶ Add a best fit line
- ▶ Resize figure to fit data

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    P.savefig(path,dpi=100)
```

- ▶ Add a best fit line
- ▶ Resize figure to fit data
- ▶ Add labels, and save the figure as a PNG file

Exporting network data and analytics

As powerful as NetworkX and the complementing scientific computing packages in Python are, it may often be useful or necessary to output your data for additional analysis

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In most cases this will entail either exporting the raw network data, or metrics from some network analysis

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1. NetworkX can write out network data in as many formats as it can read them, and the process is equally straightforward

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2. When you want to export metrics we can use Python's built-in XML and CSV libraries

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Next, we will review how to save data in different formats and export metrics to a CSV file using the Hartford drug net data

Saving network data in different formats

The syntax for exporting network data follows exactly the syntax for loading it

NX syntax for loading a file

```
>>> write_format(G, "path/to/file.txt", ...options...)
```

↑
NX function, net variable

↑
File to be written

↑
Nodes/edge data, etc.

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Let's try!

- ▶ Output the Hartford drug net data as an adjacency list
- ▶ Add metric data to each node of the network
- ▶ Output new network in Pajek format with node attributes

Saving network data and adding node attributes

As shown, this is a simple one line operation

Output Hartford drug net data as an adjacency list

```
write_adjlist(hartford_mc,"../data/hartford_mc_adj.txt")
```

Next, we will add the Eigenvector centrality of each node to the graph object

Adding node attributes

```
def add_metric(G,met_dict):  
    """Adds metric data to G from a dictionary keyed by node labels"""  
    if(G.nodes().sort()==met_dict.keys().sort()):  
        for i in met_dict.keys():  
            G.add_node(i,metric=met_dict[i])  
        return G  
    else:  
        raise ValueError("Node labels do not match")
```

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- Quick error checking

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- ▶ Quick error checking
- ▶ Add node attribute as “metric”

Using the Python CSV library

Python has powerful built-in tools for reading and writing standard data formats

- ▶ One of the most useful, and frequently used, is the CSV library and the DictWriter

Exporting centrality data to CSV

```
import csv
...
def csv_exporter(data_dict,path):
    """Takes a dict of centralities keyed by column headers and exports
    data as a CSV file"""
    # Create column header list
    col_headers=["Actor"]
    col_headers.extend(data_dict.keys())
    # Create CSV writer and write column headers
    writer=csv.DictWriter(open(path,"w"),fieldnames=col_headers)
    writer.writerow(dict((h,h) for h in col_headers))
    # Write each row of data
    for j in data_dict[col_headers[1]].keys():
        # Create a new dict for each row
        row=dict.fromkeys(col_headers)
        row["Actor"]=j
        for k in data_dict.keys():
            row[k]=data_dict[k][j]
        writer.writerow(row)
```

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    writer.writerow(dict((h,h) for h in col_headers))
    # Write each row of data
    for j in data_dict[col_headers[1]].keys():
        # Create a new dict for each row
        row=dict.fromkeys(col_headers)
        row["Actor"]=j
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            row[k]=data_dict[k][j]
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Using the Python CSV library

Python has powerful built-in tools for reading and writing standard data formats

- ▶ One of the most useful, and frequently used, is the CSV library and the DictWriter

Exporting centrality data to CSV

```
import csv
...
def csv_exporter(data_dict, path):
    """Takes a dict of centralities keyed by column headers and exports
    data as a CSV file"""
    # Create column header list
    col_headers=["Actor"]
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The results of CSV export

We can now open the CSV file in our favorite spreadsheet program

- ▶ Perform traditional data exploration
- ▶ Load into other analytics platforms for additional analysis (e.g., R)
- ▶ Store for latter use

◇	A	B	C	D
1	Actor	Closeness	Betweenness	Eigenvector
2	1	0.12467532	0.0072576	0.00025176
3	2	0.12475634	0.01767427	0.00025964
4	3	0.12565445	0.05687441	0.00023185
5	4	0.10223642	0.03108639	1.44E-05
6	5	0.1443609	0	0.00313152
7	6	0.09943035	0.01041667	1.49E-07
8	7	0.11340815	0.04362093	6.78E-05
9	8	0.20512821	0.16354003	0.01471888
10	9	0.11267606	0.00741624	0.0001101
11	10	0.13983977	0.05258239	0.00095456
12	11	0.1703638	0.01250999	0.0032333
13	13	0.13892909	0	1.79E-05
14	14	0.17219731	0.11848775	0.00029737
15	15	0.13521127	0.00079897	2.11E-05
16	16	0.15907208	0.06203647	0.00432838