An Introduction to Snap.py: SNAP for Python

http://snap.stanford.edu/snappy

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CS224W, Autumn 2015 **September, 2015**

Snap.py Tutorial: Content

- Introduction to SNAP
- Snap.py for Python
- Network analytics

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What is SNAP?

- **S**tanford **N**etwork **A**nalysis **P**latform (SNAP) is a general purpose, high-performance system for analysis and manipulation of large networks
  - http://snap.stanford.edu
  - Scales to massive networks with hundreds of millions of nodes and billions of edges
- **SNAP software**
  - Snap.py for Python, SNAP C++
- **SNAP datasets**
  - Over 70 network datasets

Snap.py Resources

- **Prebuilt packages** available for Mac OS X, Windows, Linux
  http://snap.stanford.edu/snappy/index.html
- **Snap.py documentation**:
  http://snap.stanford.edu/snappy/doc/index.html
  - Quick Introduction, Tutorial, Reference Manual
- **SNAP user mailing list**
  http://groups.google.com/group/snap-discuss
- **Developer resources**
  - Software available as open source under BSD license
  - GitHub repository
    https://github.com/snap-stanford/snap-python

SNAP C++ Resources

- **Source code** available for Mac OS X, Windows, Linux
  http://snap.stanford.edu/snap/download.html
- **SNAP documentation**
  http://snap.stanford.edu/snap/doc.html
  - Quick Introduction, User Reference Manual
  - Source code, see **tutorials**
- **SNAP user mailing list**
  http://groups.google.com/group/snap-discuss
- **Developer resources**
  - Software available as open source under BSD license
  - GitHub repository
    https://github.com/snap-stanford/snap
  - SNAP C++ Programming Guide

SNAP Network Datasets

Collection of over 70 social network datasets: http://snap.stanford.edu/data

Mailing list: http://groups.google.com/group/snap-datasets

- **Social networks:** online social networks, edges represent interactions between people
- **Twitter and Memetracker :** Memetracker phrases, links and 467 million Tweets
- **Citation networks:** nodes represent papers, edges represent citations
- **Collaboration networks:** nodes represent scientists, edges represent collaborations (co-authoring a paper)
- **Amazon networks :** nodes represent products and edges link commonly co-purchased products

Snap.py: SNAP for Python

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What is Snap.py ?

- **Snap.py** (pronounced “snappy”): **SNAP for Python**

  http://snap.stanford.edu/snappy

User interaction	Python
Snap.py	Python
SNAP	C++

Solution	Fast Execution	Easy to use, interactive
C++	✓	
Python		✓
Snap.py (C++, Python)	✓	✓

Installing Snap.py

- **Requires Python 2.x**
  - **Download and install Python 2.x:**

    http://www.python.org
- **Download the Snap.py for your platform:**

    http://snap.stanford.edu/snappy
  - Packages for Mac OS X, Windows, Linux (CentOS)
    - <u>OS must be 64-bit</u>
    - Mac OS X, 10.7.5 or later
    - Windows, install Visual C++ Redistributable Runtime
      http://www.microsoft.com/en-us/download/details.aspx?id=30679
- **Installation:**
  - Follow instructions on the Snap.py webpage

```
(sudo) python setup.py install
```

If you encounter problems, please report them to us or post to the mailing list

Snap.py: Important

- The most important step:
  Import the snap module!

```
$ python
>>> import snap
```

Snap.py Tutorial

- **On the Web:**
  http://snap.stanford.edu/snappy/doc/tutorial/index-tut.html
- **We will cover:**
  - Basic Snap.py data types
  - Vectors, hash tables and pairs
  - Graphs and networks
  - Graph creation
  - Adding and traversing nodes and edges
  - Saving and loading graphs
  - Plotting and visualization

Snap.py Naming Conventions (1)

Variable types/names:
- **...Int**: an integer operation, variable: **GetValInt()**
- **...Flt**: a floating point operation, variable; **GetValFlt()**
- **...Str**: a string operation, variable; **GetDateStr()**

Classes vs. Graph Objects:
- **T...:** a class type; **TUNGraph**
- **P...:** type of a graph object; **PUNGraph**

Data Structures:
- **...V:** a vector, variable **TIntV InNIdV**
- **...VV:** a vector of vectors (i.e., a matrix), variable **FltVV**
  - **TFltVV** ... a matrix of floating point elements
- **...H**: a hash table, variable **NodeH**
  - **TIntStrH** ... a hash table with **TInt** keys, **TStr** values
- **...HH**: a hash of hashes, variable **NodeHH**
  - **TIntIntHH** ... a hash table with **TInt** key 1 and **TInt** key 2
- **...Pr:** a pair; type **TIntPr**

Snap.py Naming Conventions (2)

- **Get...:** an access method, **GetDeg()**
- **Set...:** a set method, **SetXYLabel()**
- **...I:** an iterator, **NodeI**
- **Id:** an identifier, **GetUId()**
- **NId:** a node identifier, **GetNId()**
- **EId:** an edge identifier, **GetEId()**
- **Nbr:** a neighbor, **GetNbrNId()**
- **Deg:** a node degree, **GetOutDeg()**
- **Src:** a source node, **GetSrcNId()**
- **Dst:** a destination node, **GetDstNId()**

Basic Types in Snap.py (and SNAP)

- **`TInt`**: Integer
- **`TFlt`**: Float
- **`TStr`**: String

- Used primarily for constructing composite types
- In general no need to deal with the basic types explicitly
  - Data types are automatically converted between C++ and Python
  - An illustration of explicit manipulation:

```
>>> i = snap.TInt(10)
>>> print i.Val
10
```

- **Note:** do not use an empty string “” in TStr parameters

Snap.py Reference Documentation

For more information check out Snap.py Reference Manual
http://snap.stanford.edu/snappy/doc/reference/index-ref.html

Introduction

Next topic

Composite Types

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Enter search terms or a module, class or function name.

TInt

class **TInt**
class **TInt**(*val*)
class **TInt**(*SIn*)

Returns a new `TInt` initialized with the value specified by optional parameter *val*. If no value is given, the `TInt` object is initialized with the default value 0. If *SIn* is provided, the value is loaded from the binary stream *SIn*. In Snap.py, `TInt` is automatically converted to Python type `int`.

Below is a list of functions supported by the `TInt` class:

`Load(SIn)`
Loads the int from a binary stream *SIn*.

`Save(SOut)`
Saves the int to a binary stream *SOut*.

`Abs(val)`
A static method that returns the absolute value of *val*, an int.

`GetHexStr(val)`
A static method that returns a string with the hexidecimal representation of int *val*.

`GetInRng(val, min, max)`
A static method that returns int *val* if it is between *min* and *max*. If *val* is smaller than *min*, it returns *min*. If *val* is larger than *max*, it returns *max*.

`GetKiloStr(val)`
A static method that returns the int *val* as a kilo-formatted string. If *val* is less than 1000, it returns *val* as a string. If *val* is greater than or equal to 1000, it returns a string in form of 'x.yK', where x is some digit from 1-9 and y from 0-9.

`GetMegaStr(val)`
A static method that returns the int *val* as a mega-formatted string. If *val* is less than 1000000, it returns the equivalent of *GetKiloStr(val)*. If *val* is greater than or equal to 1000000, it returns a string in the form of 'x.yM', where x is some digit from 1-9 and y from 0-9.

SNAP C++ Documentation

SNAP User Reference Manual

http://snap.stanford.edu/snap/doc.html

Vector Types

- **Sequences of values of the same type**
  - New values can be added at the end
  - Existing values can be accessed or changed
- **Naming convention: T<value_type>V**
  - Examples: `TIntV, TFltV, TStrV`
- **Common operations:**
  - **`Add(<value>)`**: append a value at the end
  - **`Len()`**: vector size
  - **`[<index>]`**: get or set a value of an existing element
  - **`for i in V:`** iteration over the elements

Vector Example

```
v = snap.TIntV()

v.Add(1)
v.Add(2)
v.Add(3)
v.Add(4)
v.Add(5)

print v.Len()

print v[3]
v[3] = 2*v[2]
print v[3]

for item in v:
    print item
for i in range(0, v.Len()):
    print i, v[i]
```

Create an empty vector

Add elements

Print vector size

Get and set element value

Print vector elements

Hash Table Types

- **A set of (key, value) pairs**
  - Keys must be of the same types
  - Values must be of the same type
    - Value type can be different from the key type
  - New (key, value) pairs can be added
  - Existing values can be accessed or changed via a key
- **Naming: `T<key_type><value_type>H`**
  - **Examples:** `TIntStrH, TIntFltH, TStrIntH`
- **Common operations:**
  - **`[<key>]`**: add a new value or get or set an existing value
  - **`Len()`**: hash table size
  - **`for k in H`**: iteration over keys

Hash Table Example

```
h = snap.TIntStrH()

h[5] = "apple"
h[3] = "tomato"
h[9] = "orange"
h[6] = "banana"
h[1] = "apricot"

print h.Len()

print "h[3] =", h[3]

h[3] = "peach"
print "h[3] =", h[3]

for key in h:
    print key, h[key]
```

Create an empty table

Add elements

Print table size

Get element value

Set element value

Print table elements

Hash Tables: KeyID

- `T<key_type><value_type>H`
  - **`Key`:** item key, provided by the caller
  - **`Value`:** item value, provided by the caller
  - **`KeyId`:** integer, unique slot in the table, calculated by SNAP

KeyId	0	2	5
Key	100	89	95
Value	"David"	"Ann"	"Jason"

Pair Types

- **A pair of (value1, value2)**
  - Two values
    - type of **value1** could be different from the **value2** type
  - Existing values can be accessed
- **Naming:** **`T<type1><type2>Pr`**
  - **Examples:** `TIntStrPr`, `TIntFltPr`, `TStrIntPr`
- **Common operations:**
  - **`GetVal1`**: get value1
  - **`GetVal2`**: get value2

Pair Example

```
>>> p = snap.TIntStrPr(1,"one")
```

Create a pair

```
>>> print p.GetVal1()
1
>>> print p.GetVal2()
one
```

Print pair values

- **`TIntStrPrV`**: a vector of (integer, string) pairs
- **`TIntPrV`**: a vector of (integer, integer) pairs
- **`TIntPrFltH`**: a hash table with (integer, integer) pair keys and float values

Basic Graph and Network Classes

- **Graphs vs. Networks Classes:**
  - **`TUNGraph`**: undirected graph
  - **`TNGraph`**: directed graph
  - **`TNEANet`**: multigraph with attributes on nodes and edges
- Object types start with **P…**, since they use wrapper classes for garbage collection
  - **`PUNGraph, PNGraph, PNEANet`**
- Guideline
  - For class methods (functions) use **T**
  - For object instances (variables) use **P**

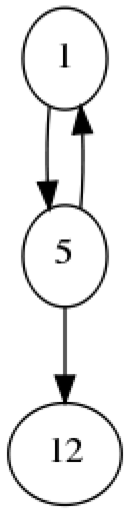
Graph Creation

```
G1 = snap.TNGraph.New()

G1.AddNode(1)
G1.AddNode(5)
G1.AddNode(12)

G1.AddEdge(1,5)
G1.AddEdge(5,1)
G1.AddEdge(5,12)

G2 = snap.TUNGraph.New()
N1 = snap.TNEANet.New()
```

Directed graph

Add nodes before adding edges

Undirected graph, directed network



G1

Graph Traversal

Node traversal

```
for NI in G1.Nodes():
    print "node id %d, out-degree %d, in-degree %d"
      % (NI.GetId(), NI.GetOutDeg(), NI.GetInDeg())
```

Edge traversal

```
for EI in G1.Edges():
    print "(%d, %d)" % (EI.GetSrcNId(), EI.GetDstNId())
```

Edge traversal by nodes

```
for NI in G1.Nodes():
    for DstNId in NI.GetOutEdges():
        print "(%d %d)" % (NI.GetId(), DstNId)
```

Graph Saving and Loading

Save text

```
snap.SaveEdgeList(G4, "test.txt", “List of edges")
```

Load text

```
G5 = snap.LoadEdgeList(snap.PNGraph,"test.txt",0,1)
```

Save binary

```
FOut = snap.TFOut("test.graph")
G2.Save(FOut)
FOut.Flush()
```

Load binary

```
FIn = snap.TFIn("test.graph")
G4 = snap.TNGraph.Load(FIn)
```

Text File Format

- **Example file:** `wiki-Vote.txt`
  - Download from http://snap.stanford.edu/data

```
# Directed graph: wiki-Vote.txt
# Nodes: 7115 Edges: 103689
# FromNodeId    ToNodeId
0       1
0       2
0       3
0       4
0       5
2       6
…
```

Load text

```
G5 = snap.LoadEdgeList(snap.PNGraph,"test.txt",0,1)
```

Plotting in Snap.py

- **Plotting graph properties**
  - Gnuplot: http://www.gnuplot.info
- **Visualizing graphs**
  - Graphviz: http://www.graphviz.org
- **Other options**
  - Matplotlib: http://www.matplotlib.org

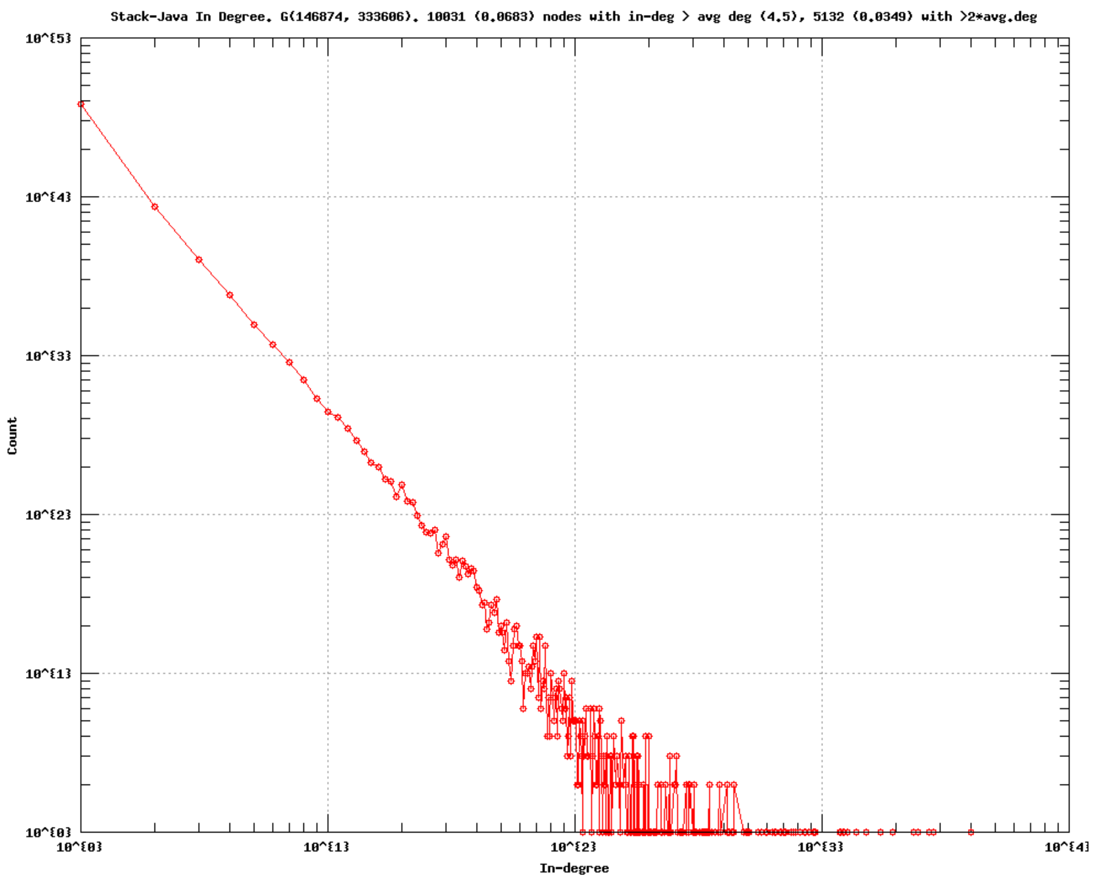
Plotting with Snap.py

- **Install Gnuplot:** http://www.gnuplot.info/

- Make sure that the directory containing wgnuplot.exe (for Windows) or gnuplot (for Linux, Mac OS X) is in your environmental variable **$PATH**

Plotting with Snap.py

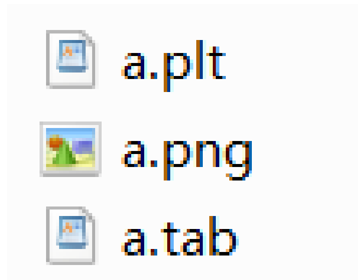
```
import snap
G = snap.LoadEdgeList(snap.PNGraph, "qa.txt", 1, 5)
snap.PlotInDegDistr(G, "Stack-Java", "Stack-Java In Degree")
```



Graph of Java QA on StackOverflow: in-degree distribution

Snap.py + Gnuplot

- **Snap.py** generates three files:



  - **.png** or **.eps** is the plot
  - **.tab** file contains the data (tab separated file)
  - **.plt** file contains the plotting commands

Drawing Graphs

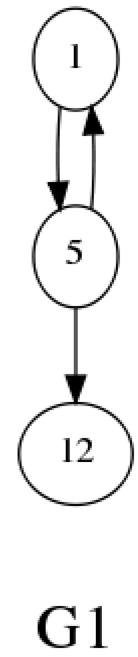
- **InstallGraphViz:** http://www.graphviz.org/

- Make sure that the directory containing GraphViz is in your environmental variable **$PATH**

Drawing Graphs with Snap.py

```
G1 = snap.TNGraph.New()

G1.AddNode(1)
G1.AddNode(5)
G1.AddNode(12)

G1.AddEdge(1,5)
G1.AddEdge(5,1)
G1.AddEdge(5,12)
```

Create graph




```
NIdName = snap.TIntStrH()
NIdName[1] = "1"
NIdName[5] = "5"
NIdName[12] = "12"
```

Set node labels

Draw

```
snap.DrawGViz(G1, snap.gvlDot, "G1.png", "G1", NIdName)
```

Network Analytics with Snap.py

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CS224W, Autumn 2015 **September, 2015**

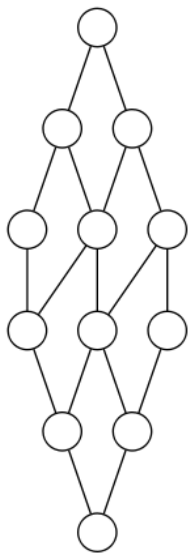
Overview of Network Analytics

- **How to get a network**
  - From a **real-world dataset**
  - Generate a **synthetic network**
  - From an **existing network**
- **Calculate network properties**
  - **Quick summary** of network properties
  - **Global connectivity**: connected components
  - **Local connectivity**: node degrees
  - **Key nodes** in the network: node centrality
  - **Neighborhood connectivity**: triads, clustering coefficient
  - **Graph traversal**: breadth and depth first search
  - **Groups of nodes**: community detection
  - **Global graph properties**: spectral graph analysis
  - **Core nodes**: K-core decomposition

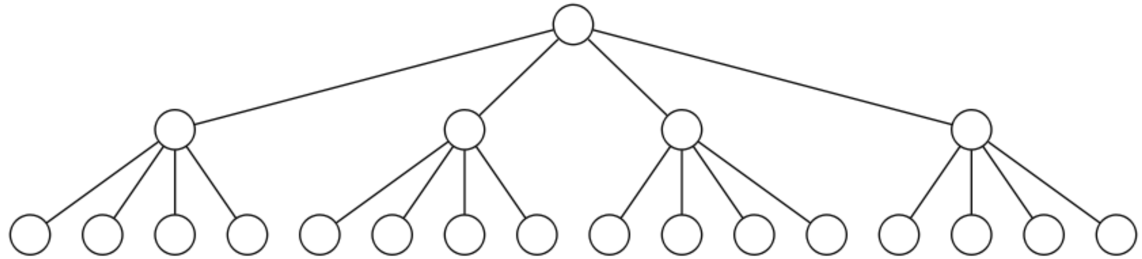
Basic Graph Generators

- **Complete, circle, grid, star, tree graphs**

```
GG = snap.GenGrid(snap.PUNGraph, 4, 3)
GT = snap.GenTree(snap.PUNGraph, 4, 2)
```



G-4-3

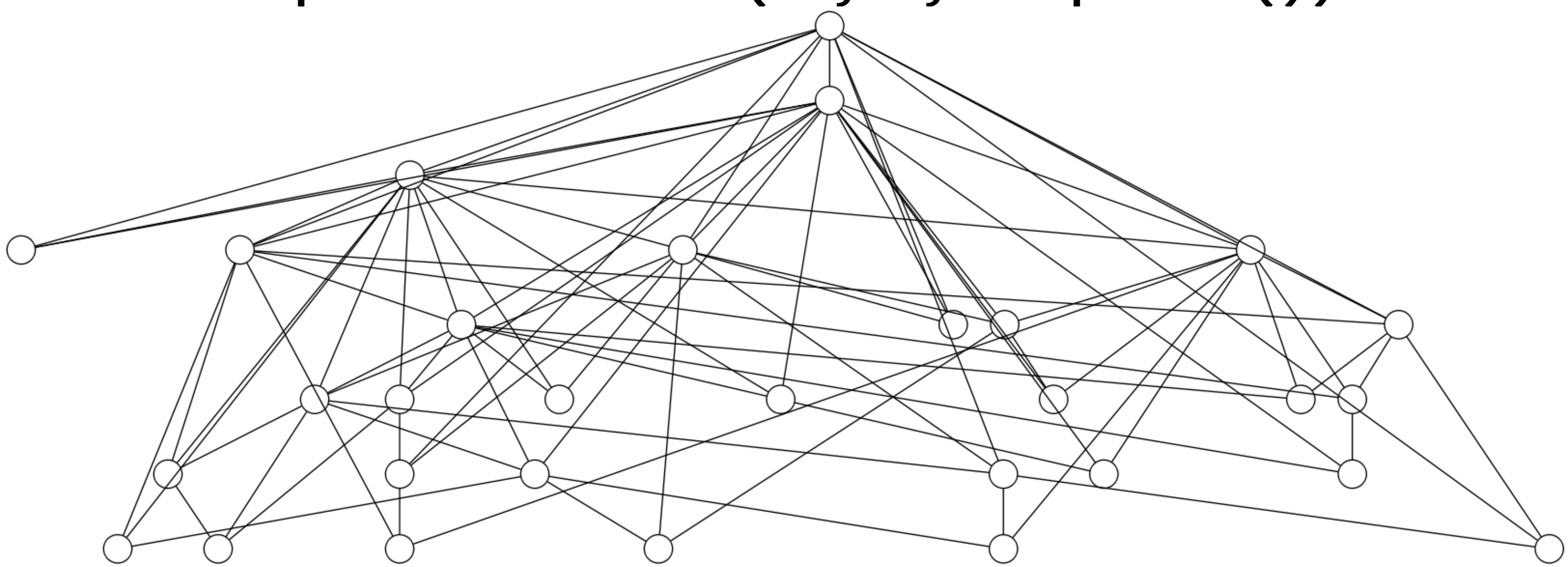


T-4-2

Advanced Graph Generators

- Erdos-Renyi, Preferential attachment
- Forest Fire, Small-world, Configuration model
- Kronecker, RMat, Graph rewiring

```
GPA = snap.GenPrefAttach(30, 3, snap.TRnd())
```



PA-30

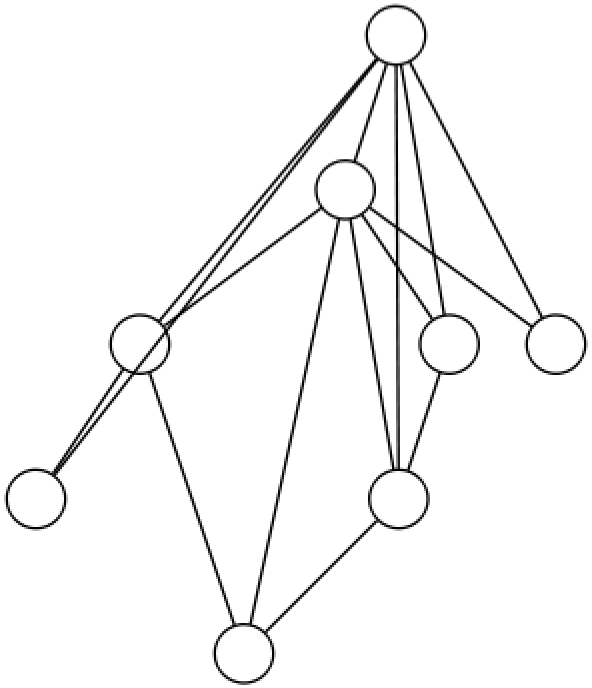
Subgraphs and Conversions

- Extract subgraphs
- Convert from one graph type to another

Get an induced subgraph on a set of nodes NIdV:

```
NIdV = snap.TIntV()
for i in range(1,9): NIdV.Add(i)

SubGPA = snap.GetSubGraph(GPA, NIdV)
```



SPA-8

Print Graph Information

```
G = snap.LoadEdgeList(snap.PNGraph, "qa.txt", 1, 5)
snap.PrintInfo(G, "QA Stats", "qa-info.txt", False)
```

Output:

```
QA Stats: Directed
  Nodes:                         188406
  Edges:                         415174
  Zero Deg Nodes:                0
  Zero InDeg Nodes:              108618
  Zero OutDeg Nodes:             38319
  NonZero In-Out Deg Nodes:      41469
  Unique directed edges:         415174
  Unique undirected edges:       415027
  Self Edges:                    26924
  BiDir Edges:                   27218
  Closed triangles:              46992
  Open triangles:                69426319
  Frac. of closed triads:        0.000676
  Connected component size:      0.886745
  Strong conn. comp. size:       0.025758
  Approx. full diameter:         13
  90% effective diameter:        5.751723
```

Connected Components

- **Analyze graph connectedness**
  - Strongly and Weakly connected components
    - Test connectivity, get sizes, get components, get largest
    - Articulation points, bridges
  - Bi-connected, 1-connected

```
MxWcc = snap.GetMxWcc(G)
print "max wcc nodes %d, edges %d" %
      (MxWcc.GetNodes(), MxWcc.GetEdges())
```

Get largest WCC

```
WccV = snap.TIntPrV()
snap.GetWccSzCnt(G, WccV)
```

Get WCC sizes

```
print "# of connected component sizes", WccV.Len()
for comp in WccV:
    print "size %d, number of components %d" %
        (comp.GetVal1(), comp.GetVal2())
```

Node Degrees

- **Analyze node connectivity**
  - Find node degrees, maximum degree, degree distribution
  - In-degree, out-degree, combined degree

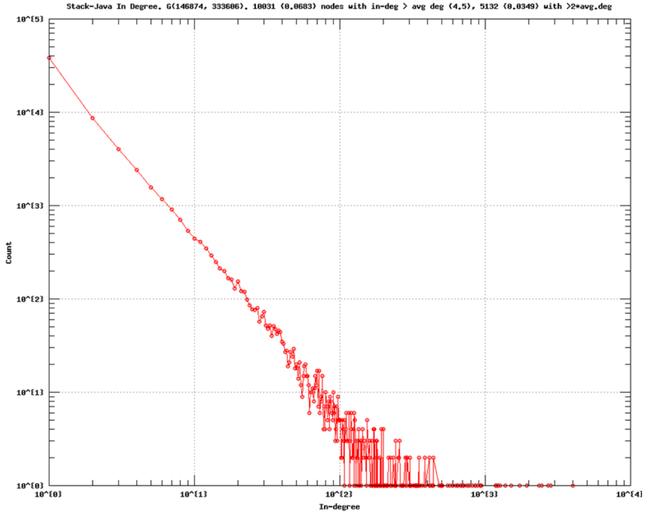
```
NId = snap.GetMxDegNId(GPA)
print "max degree node", NId

DegToCntV = snap.TIntPrV()
snap.GetDegCnt(GPA, DegToCntV)
for item in DegToCntV:
    print "%d nodes with degree %d" % (
        item.GetVal2(), item.GetVal1())
```

Get node with max degree

Get degree distribution

```
max degree node 1
13 nodes with degree 3
4 nodes with degree 4
3 nodes with degree 5
2 nodes with degree 6
1 nodes with degree 7
1 nodes with degree 9
2 nodes with degree 10
2 nodes with degree 11
1 nodes with degree 13
1 nodes with degree 15
```



Node Centrality

- **Find "importance" of nodes in a graph**
  - PageRank, Hubs and Authorities (HITS)
  - Degree-, betweenness-, closeness-, farness-, and eigen- centrality

```
PRankH = snap.TIntFltH()
snap.GetPageRank(G, PRankH)
```

Calculate node PageRank scores

```
for item in PRankH:
    print item, PRankH[item]
```

Print them out

Triads and Clustering Coefficient

- **Analyze connectivity among the neighbors**
  - # of triads, fraction of closed triads
  - Fraction of connected neighbor pairs
  - Graph-based, node-based

```
Triads = snap.GetTriads(GPA)
print "triads", Triads
```

Count triads

```
CC = snap.GetClustCf(GPA)
print "clustering coefficient", CC
```

Calculate clustering coefficient

Breadth and Depth First Search

- **Distances between nodes**
  - Diameter, Effective diameter
  - Shortest path, Neighbors at distance **d**
  - Approximate neighborhood (not BFS based)

```
D = snap.GetBfsFullDiam(G, 100)
print "diameter", D
```

Calculate diameter

```
ED = snap.GetBfsEffDiam(G, 100)
print "effective diameter", ED
```

Calculate effective diameter

Community Detection

- **Identify communities of nodes**
  - Clauset-Newman-Moore, Girvan-Newman
    - Can be compute time intensive
  - BigClam, CODA, Cesna (C++ only)

Clauset-Newman-Moore

```
CmtyV = snap.TCnComV()
modularity = snap.CommunityCNM(UGraph, CmtyV)

for Cmty in CmtyV:
    print "Community: "
    for NI in Cmty:
        print NI
print "The modularity of the network is %f" % modularity
```

Spectral Properties of a Graph

- **Calculations based on graph adjacency matrix**
  - Get Eigenvalues, Eigenvectors
  - Get Singular values, leading singular vectors

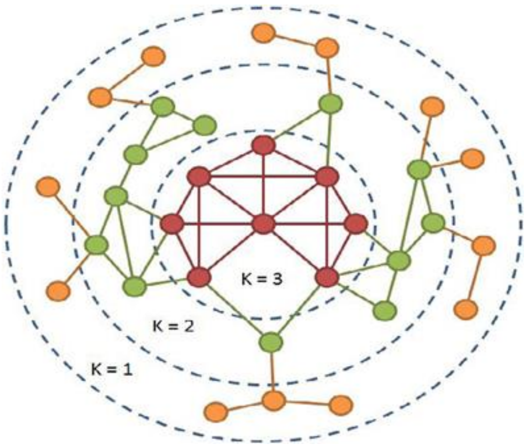
```
EigV = snap.TFltV()
snap.GetEigVec(G, EigV)

nr = 0
for f in EigV:
    nr += 1
    print "%d: %.6f" % (nr, f)
```

Get leading eigenvector

K-core Decomposition

- **Repeatedly remove nodes with low degrees**
  - Calculate K-core




```
Core3 = snap.GetKCore(G, 3)
```

Calculate 3-core

Snap.py Tutorial: Conclusion

- Q&A

- Thank you!

Contact information:
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