Intro to Graphs

NetworkX

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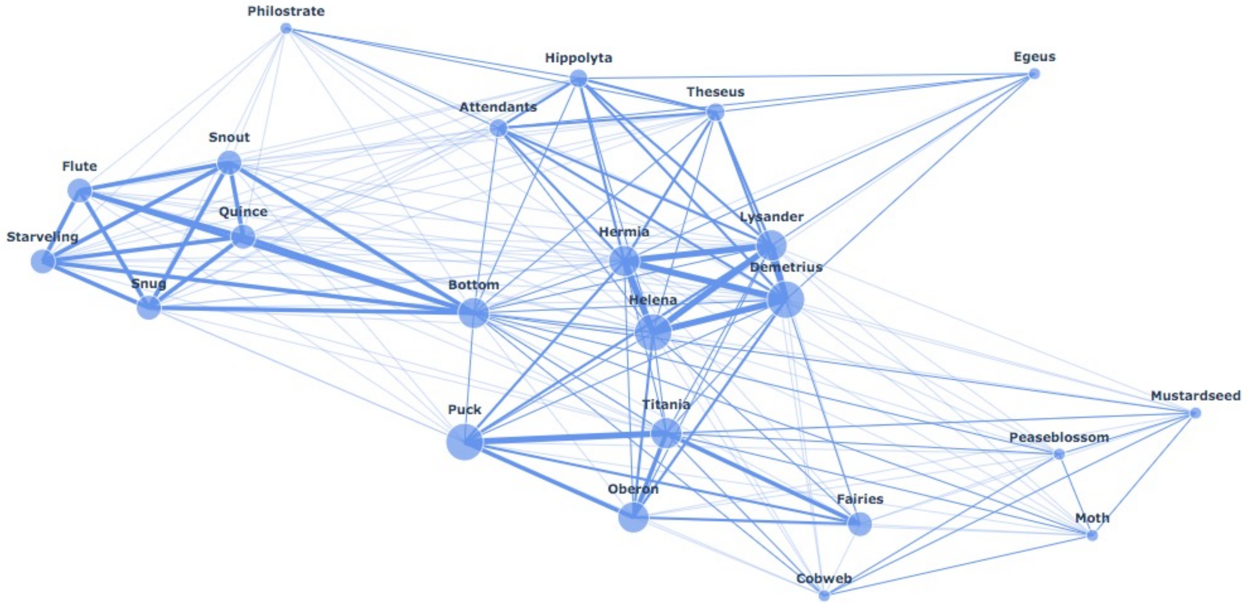


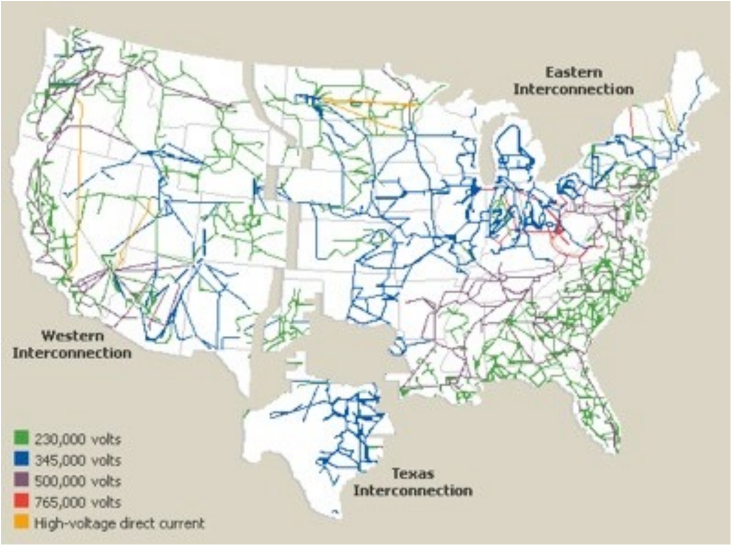
INTRODUCTION TO NETWORKX

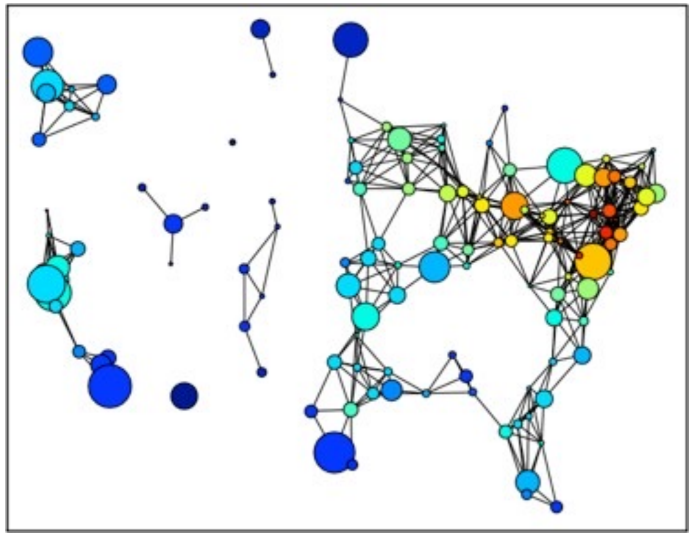
Introduction to NetworkX - network analysis

- Vast amounts of network data are being generated and collected
- Sociology: web pages, mobile phones, social networks
- Technology: Internet routers, vehicular flows, power grids

How can we analyse these networks?

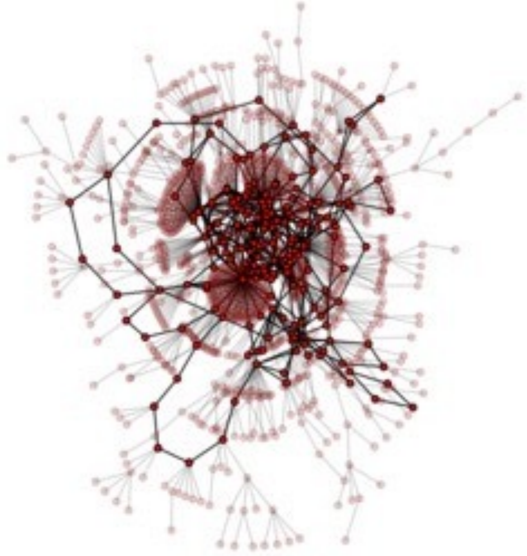
Python + NetworkX!



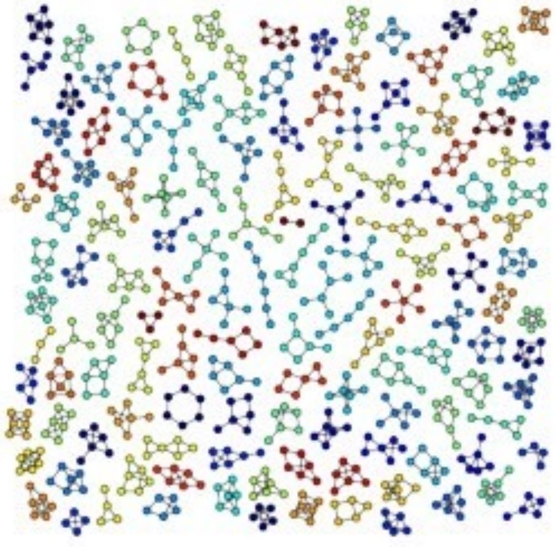


Introduction to NetworkX

“Python package for the creation, manipulation and study of the structure, dynamics and functions of complex networks.”



- Data structures for representing many types of data in the form of graphs
- Nodes can be any (hashable) Python object, edges can contain arbitrary data
- Flexibility ideal for representing networks found in many different fields
- Easy to install on multiple platforms
- Online up-to-date documentation
- First public release in April 2005



Introduction to NetworkX - design requirements

- Tool to study the structure and dynamics of social, biological, and infrastructure networks
- Ease-of-use and rapid development
- Open-source tool base that can easily grow in a multidisciplinary environment with non-expert users and developers
- An easy interface to existing code bases written in C, C++, and FORTRAN
- To painlessly slurp in relatively large nonstandard data sets

Introduction to NetworkX - object model

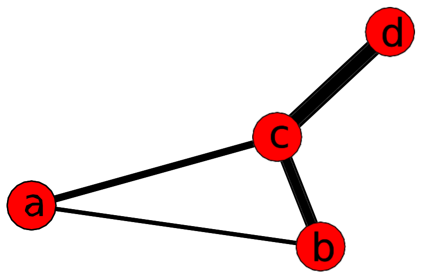
NetworkX defines no custom node objects or edge objects

- node-centric view of network
- nodes can be any hashable object, while edges are tuples with optional edge data (stored in dictionary)
- any Python object is allowed as edge data and it is assigned and stored in a Python dictionary (default empty)

Introduction to NetworkX - quick example

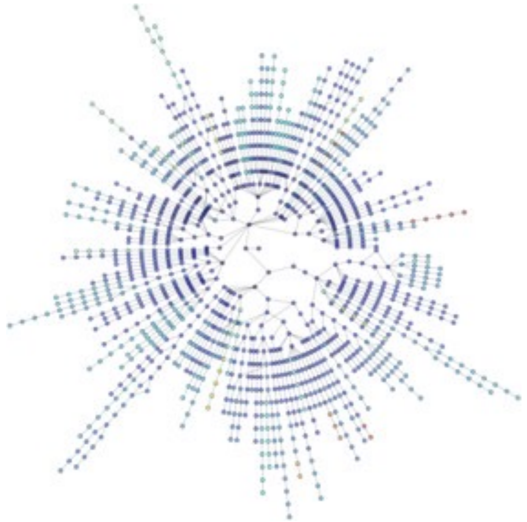
- Search for the shortest path in a weighted and unweighted network:

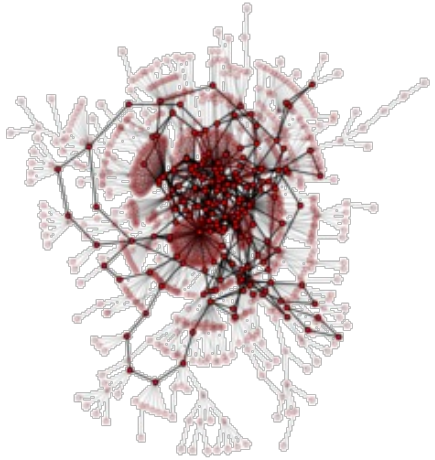
```python
import networkx as nx
g = nx.Graph()
g.add_edge("a","b",weight=1)
g.add_edge("b","c",weight=100)
g.add_edge("a","c",weight=1)
g.add_edge("c","d",weight=1)
print(nx.shortest_path(g,"b","d"))
print(nx.dijkstra_path(g, "b", "d", weight='weight'))
```

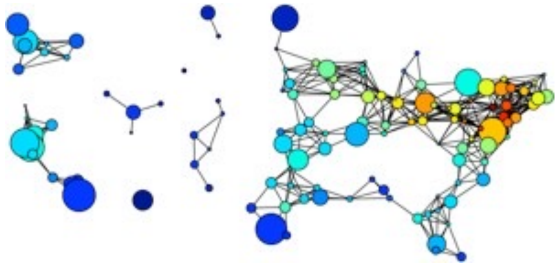


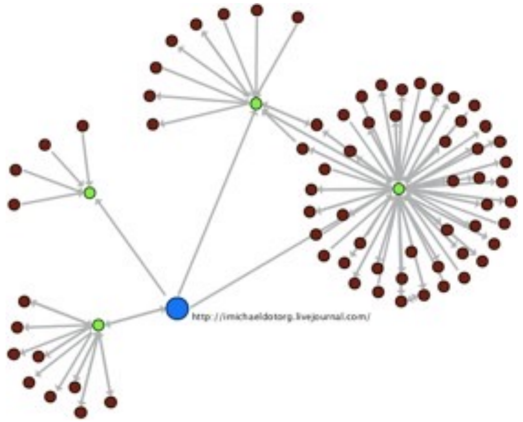
Introduction to NetworkX - drawing and plotting

- It is possible to draw small graphs within NetworkX and to export network data and draw with other programs (i.e., GraphViz, matplotlib)



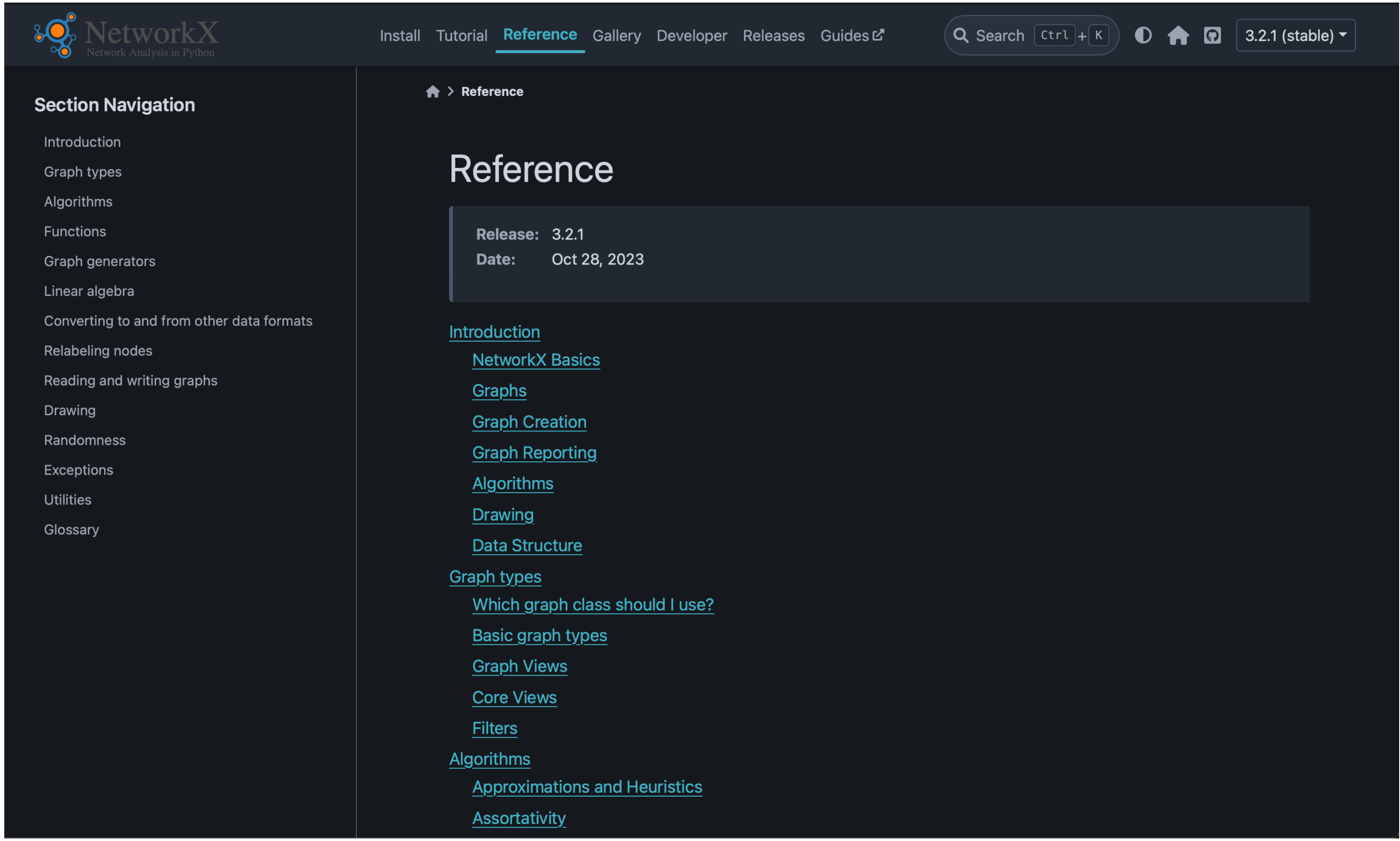






Introduction to NetworkX - official website

- https://networkx.org/



GETTING STARTED WITH PYTHON AND NETWORKX

Getting started – import NetworkX

- NetworkX supports many different graph types, like:
  - `nx.Graph()` – undirected
  - `nx.DiGraph()` – directed
  - `nx.MultiGrap()` – supports multiple edges between nodes
  - `nx.MultiGrap()` – directed multigraph
- Also provide implementation of notable graphs (like heawood)

```python
import networkx as nx
import math
import flet as ft

g = nx.heawood_graph()
print(g.nodes, g.edges)

g.add_node(math.cos)  # cosine functionx
g.add_node(ft.Text("Pippo"))
g.add_edge("math.cos", 3)
print(g.nodes, g.edges)
```

Getting started – build a graph

- Nodes could be (almost) anything
  - Numbers, strings
  - Objects
  - Functions
  - Flet containers
- Edges connect nodes (even heterogeneous)
- Nodes and edges could have attributes

```python
import networkx as nx
import math
import flet as ft

g = nx.Graph()
g.add_edge(1, 2)  # default edge data=1
g.add_edge(2, 3, weight=0.9)  # specify edge data

g.add_edge('y', 'x', function=math.cos)
g.add_node(math.cos)  # any hashable can be a node

elist = [(1, 2), (2, 3), (1, 4), (4, 2)]
g.add_edges_from(elist)
elist = [('a', 'b', 5.0), ('b', 'c', 3.0), ('a', 'c', 1.0), ('c', 'd', 7.3)]
g.add_weighted_edges_from(elist)
g.add_node(ft.Text("Pippo"))

print(g.nodes())
print(g.edges())
print(g.get_edge_data('a','b'))
```

Getting started – Data Structure

- A graph is essentially a "dictionary of dictionaries of dictionaries"
- The keys are the nodes
- Indeed, `g[n]` yields a dictionary where keys are all the nodes connected with n (adjacency) and values are the edges params (like weight)

```
import networkx as nx

g = nx.Graph()
g.add_edge(1, 2)  # default edge data=1
g.add_edge(2, 3, weight=0.9)  # specify edge data

elist = [(1, 2, 1), (2, 3, 1), (1, 4, 1), (4, 2, 1),
         ('a', 'b', 5.0), ('b', 'c', 3.0), ('a', 'c', 1.0), ('c', 'd', 7.3)]
g.add_weighted_edges_from(elist)

print(g[2])
```

```
{1: {'weight': 1}, 3: {'weight': 1}, 4: {'weight': 1}}

Process finished with exit code 0
```

Getting started – Data Structure

- `g[u][v]` yields the edge attributes
- `n in g` tests if node `n` is in `g`
- `for n in g:` iterates through the graph
- `for nbr in g[n]:` iterates through the neighbors of n
- Data struct for direct graphs is only slightly more complex (two dics, one for successors and one for predecessors)
- You can also use `g.nodes()` and `g.edges()` to get corresponding data
- Edges can have arbitrary attributes

```
import networkx as nx

g = nx.Graph()
g.add_edge(1, 2)  # default edge data=1
g.add_edge(2, 3, weight=0.9)  # specify edge data

elist = [(1, 2, 1), (2, 3, 1), (1, 4, 1), (4, 2, 1),
         ('a', 'b', 5.0), ('b', 'c', 3.0), ('a', 'c', 1.0), ('c', 'd', 7.3)]
g.add_weighted_edges_from(elist)
g.add_edge(2,5,arbitraryAttr = "foo")

print(g[2])
print("---------")
print(g['a']['b'])
print("---------")
print('e' in g)
print("---------")
for n in g:
    print (n)
print("---------")
for nbr in g[2]:
    print(nbr)
print("---------")
print(g[2][5]['arbitraryAttr'])
```

Getting started – Directed and Multi

- Graphs can be directed, therefore differentiating neighbors in predecessors and successors
- Two nodes can have more than one edge

```
import networkx as nx

dg = nx.DiGraph()
dg.add_weighted_edges_from([(1,4,0.5), (3,1,0.75)])

print([s for s in dg.successors(1)])
print([p for p in dg.predecessors(1)])

mg = nx.MultiGraph()

mg.add_weighted_edges_from([(1,2,.5), (1,2,.75),
(2,3,.5)])

print(mg[1][2])
```

Getting started - graph operators

Classic graph operations

- `subgraph(G, nbunch)` - induce subgraph of G on nodes in nbunch
- `union(G1,G2)` - graph union
- `disjoint_union(G1,G2)` - graph union assuming all nodes are different
- `compose(G1,G2)` - combine graphs identifying nodes common to both
- `complement(G)` - graph complement
- `create_empty_copy(G)` - return an empty copy of the same graph class
- `convert_to_undirected(G)` - return an undirected representation of G
- `convert_to_directed(G)` - return a directed representation of G

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