DataScience for Development and Social Change, 2015

Science

Getting information from your datasets. Truthfully.

Machine Learning

- Build a model that extract patterns from data
- Use those patterns to predict missing or future data
- Do it automatically

(part of artificial intelligence)

Example Uses

- Search engines: producing results tailored to you
- Spam filters: learning what should go into your spam folder (and not)
- Handwritten character recognition: recognizing “a”
- Gap-filling: estimating missing data values
- Prediction

Why Use Machine Learning?

- You don’t have all the features you want in your data.
  - Some features don’t exist
  - Some features have missing data
- You want to predict an outcome (eg. loan default) based on previous examples

Machine Learning Areas

- Classification: predict classes
- Regression: predict numerical values
- Clustering: predict group membership
- Dimension reduction: deciding which factors (e.g. age, sex, education, location, chickens) are most important in a prediction

Classification

Classification is the allocation of a piece of information to a category (e.g. male, female, other).

- Often need to automate this:
  - e.g. huge dataset, specialist knowledge (e.g. Tagalog, non-obvious connections), regularly-updated data etc.

Classification: Practice

- Which of these people are male or female?
  1. She previously worked at Kings College London.
  2. Bayani advises the UN on the use of drones.
  3. Kim is a leading scholar on text classification.
  4. His work on sand eels is renowned.
  5. Diwata Jones.
  6. He works closely with Sandra Smith and her work on fish.

Classification: Practice

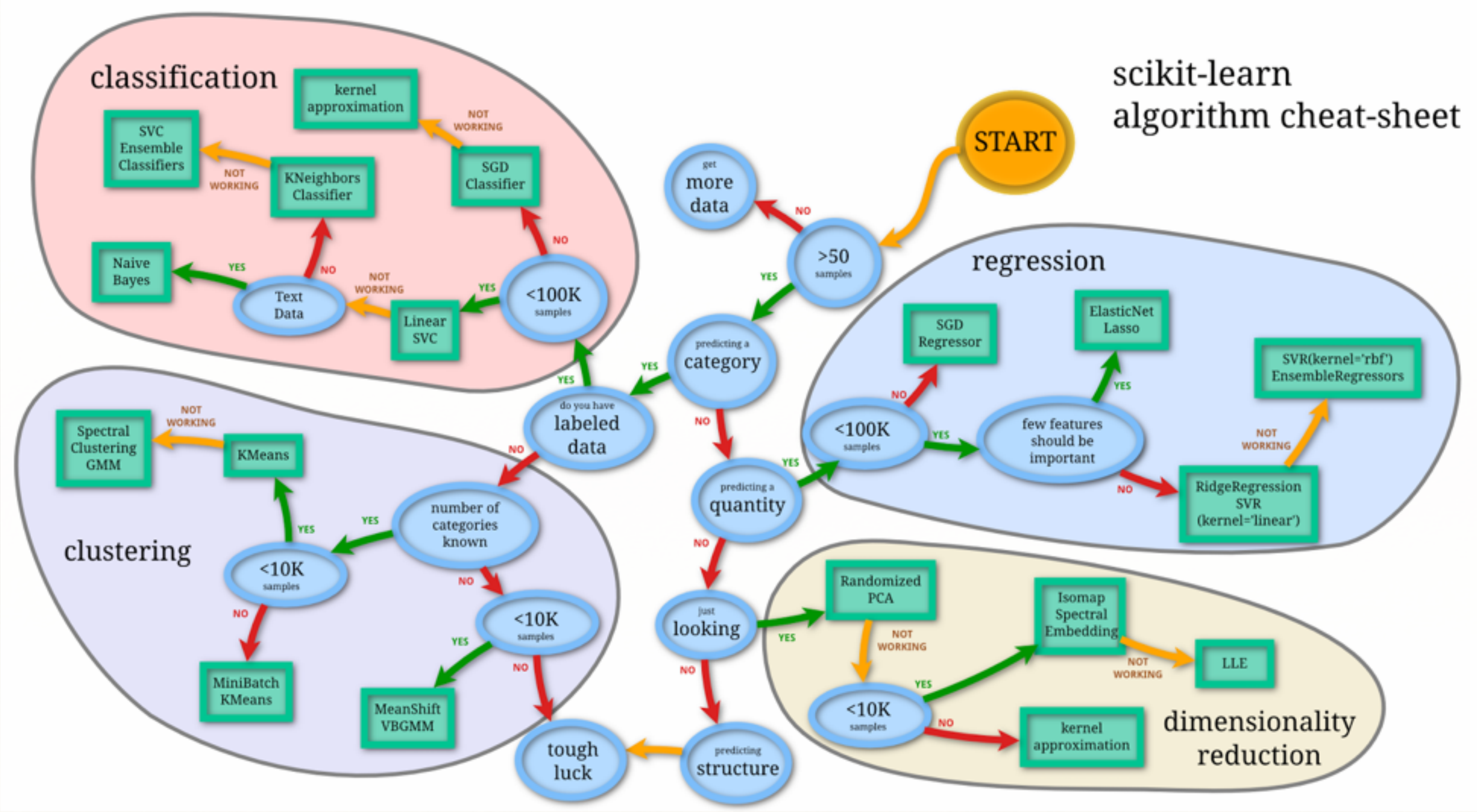
1. Female: “She” at start of description.
2. Male: male first name (look in babynames.ch)
3. Unknown: “Kim” is male or female first name.
4. Male: “His” at start of description.
5. Female: female first name (look in babynames.ch)
6. Male: “He” at start of description, but note the “her” later in the text.

- Alternative gender classification methods include:
  - GenderAnalyzer: guesses gender of writer (has API)
  - Name endings: Names ending in a, e and i are more likely to be female, while names ending in k, o, r, s and t are more likely to be male

The Scikit.learn Library

- Python library
- Contains most common machine learning algorithms
- import sklearn

Scikit.Learn Algorithms



The Iris Dataset

Fisher's *Iris* Data

Sepal length	Sepal width	Petal length	Petal width	Species
5.1	3.5	1.4	0.2	*I. setosa*
4.9	3.0	1.4	0.2	*I. setosa*
4.7	3.2	1.3	0.2	*I. setosa*
4.6	3.1	1.5	0.2	*I. setosa*
5.0	3.6	1.4	0.2	*I. setosa*
5.4	3.9	1.7	0.4	*I. setosa*
4.6	3.4	1.4	0.3	*I. setosa*
5.0	3.4	1.5	0.2	*I. setosa*



Reading in the Iris Dataset

- import numpy as np
- from sklearn import datasets

- iris = datasets.load_iris()
- iris_X = iris.data
- iris_Y = iris.target
- print("Iris dataset: {}".format(iris))
- print("Xs: {}".format(iris_X))
- print("Ys: {}".format(iris_Y))
- print("Unique Y values: {}".format(np.unique(iris_Y)))

Training and Test sets

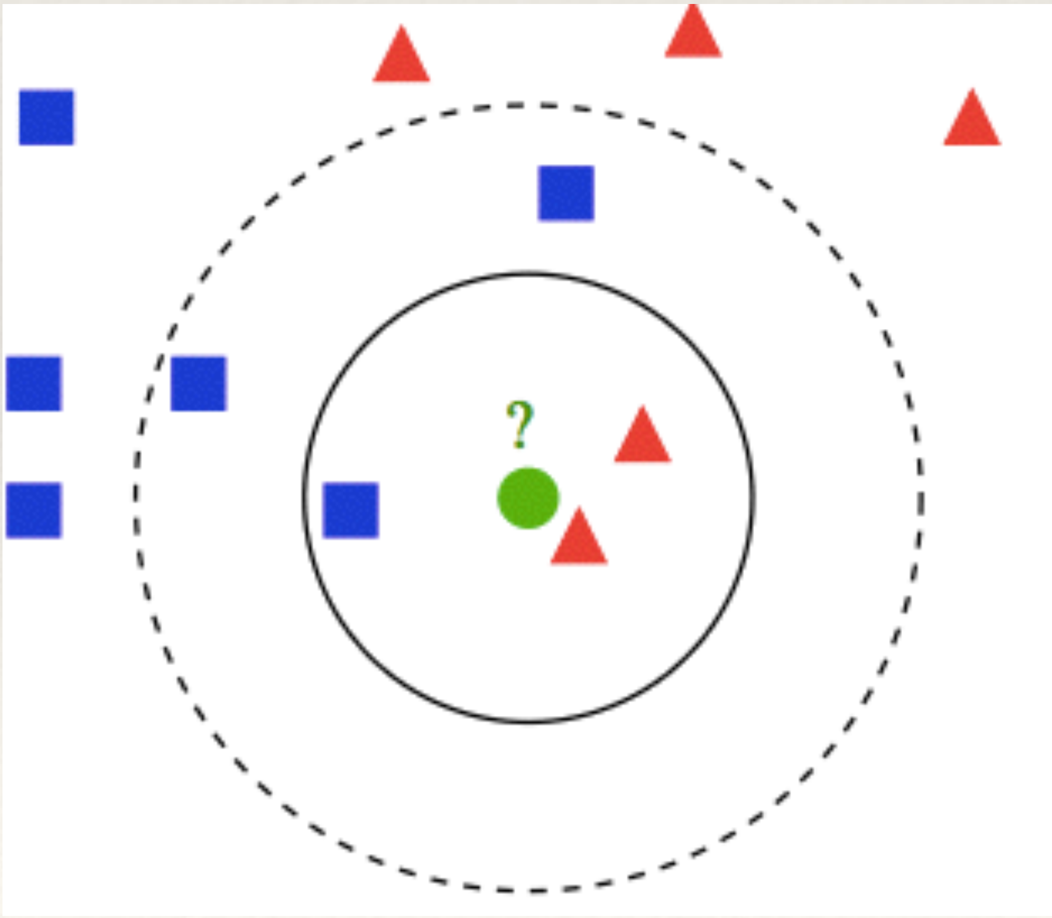
- “Training set”: a set of pre-classified examples, for the classifier to learn from
- “Test set”: a smaller set of pre-classified examples, for the classifier to check its predictions

Split the Iris data into train and test

```
ntest=10
np.random.seed(0)
indices = np.random.permutation(len(iris_X))
iris_X_train = iris_X[indices[:-ntest]]
iris_Y_train = iris_Y[indices[:-ntest]]
iris_X_test  = iris_X[indices[-ntest:]]
iris_Y_test  = iris_Y[indices[-ntest:]]
print("{} training points, {} test points".format(len(iris_X_train),
    len(iris_X_test)))
```

The kNN classifier

- "k Nearest Neighbours"
  - Look at the k closest points to an unknown point
  - The class of the unknown point is the class of most of those "neighbors"

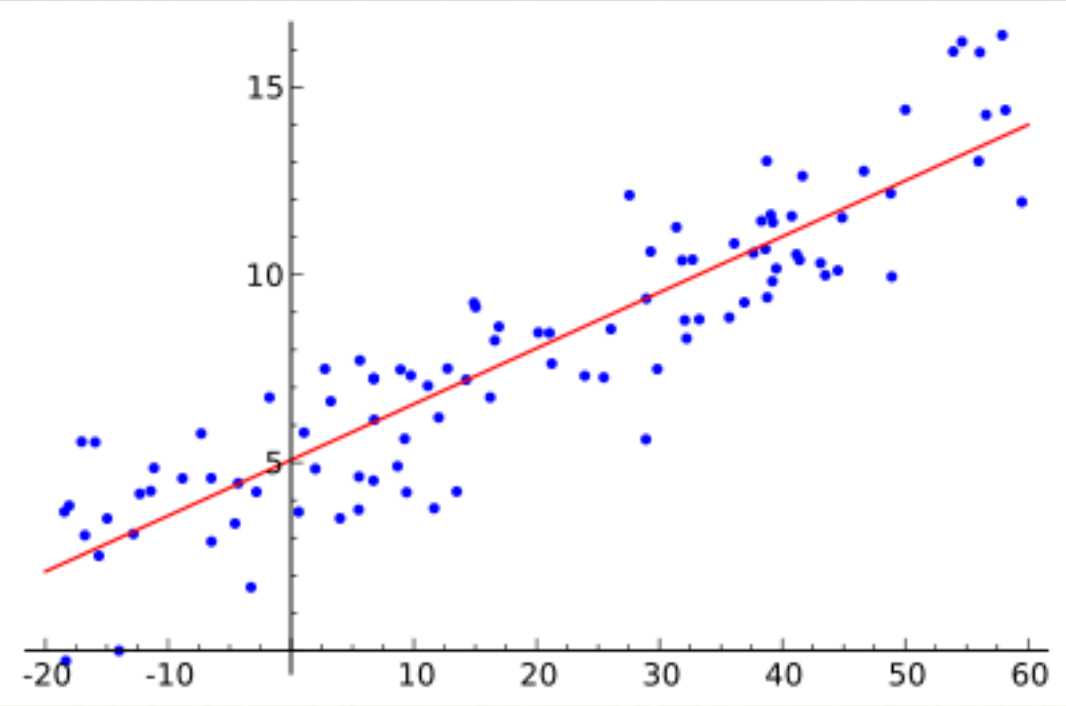


kNN on the Iris Dataset

```
from sklearn.neighbors import KNeighborsClassifier


knn = KNeighborsClassifier()
knn.fit(iris_X_train, iris_Y_train)
predicted_classes = knn.predict(iris_X_test)


print("kNN predicted classes: {}".format(predicted_classes))
print("Real classes: {}".format(iris_Y_test))
```

Regression

- Finds the best-fit line between points
- Because: you need to know the relationship between 2 or more features
- Needs:
  - data points, in 2 or more dimensions
  - “best-fit” equation, e.g. city-block metric, least-squares, edit distance etc



The Diabetes Dataset

```
import matplotlib.pyplot as plt

import numpy as np

from sklearn import datasets, linear_model


# Load the diabetes dataset

# 442 people: diabetes, age, sex, weight, blood pressure etc

diabetes = datasets.load_diabetes()
```

Diabetes Training and Test Sets

- # Use only one feature
- diabetes_X = diabetes.data[:, np.newaxis]
- diabetes_X_temp = diabetes_X[:, :, 2]

- # Split the data into training/testing sets
- diabetes_X_train = diabetes_X_temp[:-20]
- diabetes_X_test = diabetes_X_temp[-20:]

- # Split the targets into training/testing sets
- diabetes_y_train = diabetes.target[:-20]
- diabetes_y_test = diabetes.target[-20:]

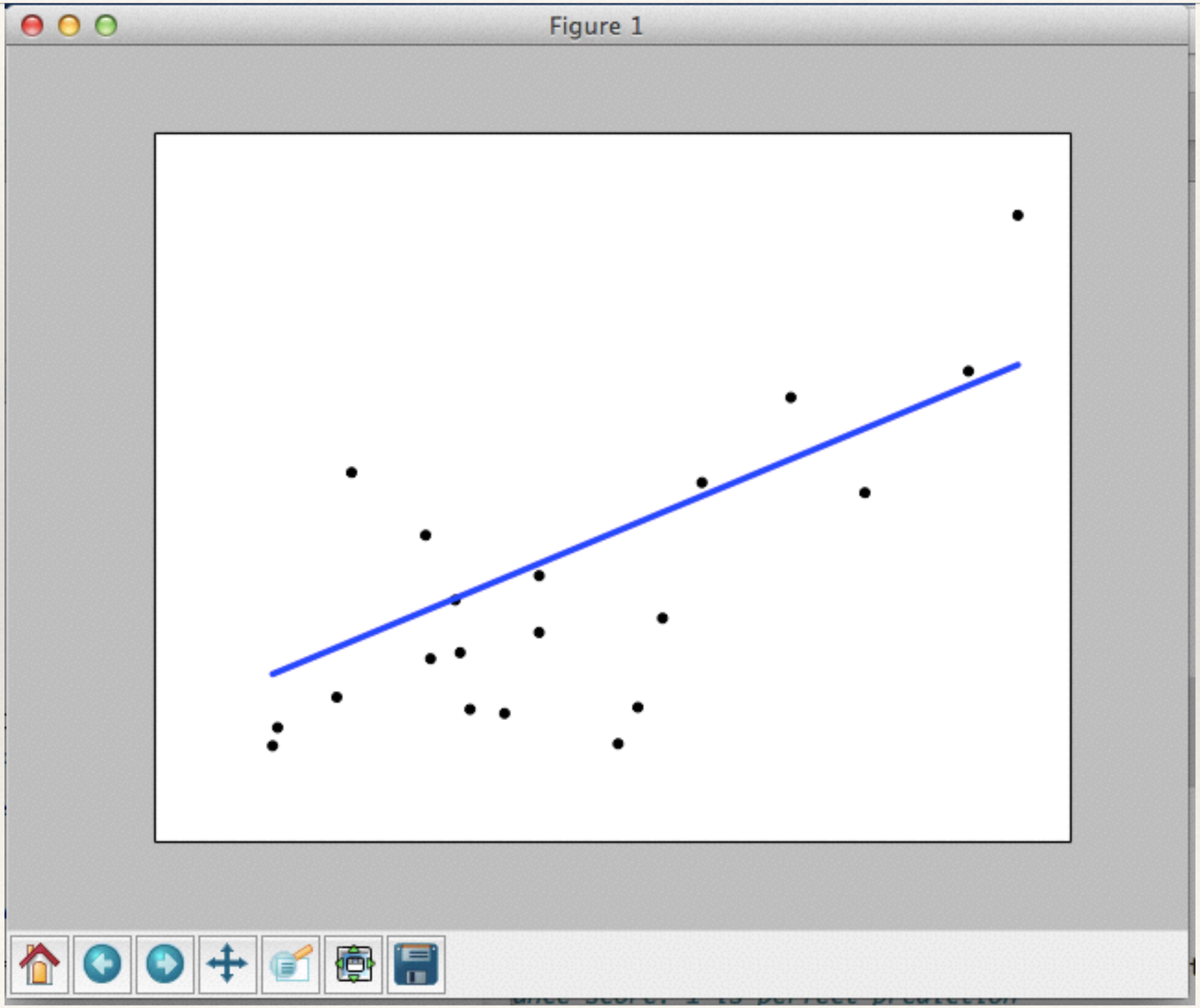
Do the Linear Regression

```
#from sklearn import datasets, linear_model

# Create linear regression object
regr = linear_model.LinearRegression()

# Train the model using the training sets
regr.fit(diabetes_X_train, diabetes_y_train)
```

Look at your results

```
import matplotlib.pyplot as plt

plt.scatter(diabetes_X_test, diabetes_y_test,  color='black')

plt.plot(diabetes_X_test, regr.predict(diabetes_X_test),
color=‘blue', linewidth=3)

plt.xticks(())

plt.yticks(())

plt.show()
```

Results



How Good was the Model?

```
# The coefficients
print('Coefficients: \n', regr.coef_)
# The mean square error
print("Residual sum of squares: %.2f"
      % np.mean((regr.predict(diabetes_X_test) - diabetes_y_test) ** 2))
# Explained variance score: 1 is perfect prediction
print('Variance score: %.2f' % regr.score(diabetes_X_test,
diabetes_y_test))
```

Logistic Regression

- Because: you want to predict the class of a datapoint
- Uses the logistic function ('S" shaped curve) to separate datasets.
- Examples: predict whether person will be diabetic, given their BMI
- http://blog.yhathq.com/posts/logistic-regression-and-python.html

Unsupervised Learning

- Supervised learning:
  - We ‘teach’ the computer how to do a task
  - E.g. we tag male/female names until the machine can do this reliably (i.e. low number of misclassifications) for itself
- Unsupervised learning:
  - The computer learns for itself, without teaching
  - E.g. the computer separates a dataset into classes of closely-related data points, without being told what or where these are

Clustering

- Divide a dataset up into n related “clusters” or classes
  - **Because**: you want to know if groups exist in your data (so you can investigate further / use characteristics of those groups to advantage)
  - **Issue**: knowing “n”
  - **Algorithms**: k-means (and many many others)
  - **Python module**: sklearn.cluster

k-Means Algorithm

- Divides a dataset into k groups, where the datapoints in each group are closer to each other, than to datapoints in other groups
- Issue: you have to choose “k”

k-Means with the Iris Dataset

```
from sklearn import cluster, datasets

iris = datasets.load_iris()

k_means = cluster.KMeans(3)
k_means.fit(iris.data)

print("Generated labels: {}".format(k_means.labels_))
print("Real labels: {}".format(iris.target))
```

Dimension Reduction

- For classification to work, you need a feature set that's useful, e.g.
  - First names
  - First name endings
  - Personal pronouns in text
  - Not: department (e.g. Engineering)
- Dimension reduction helps you choose that feature list

Network Analysis

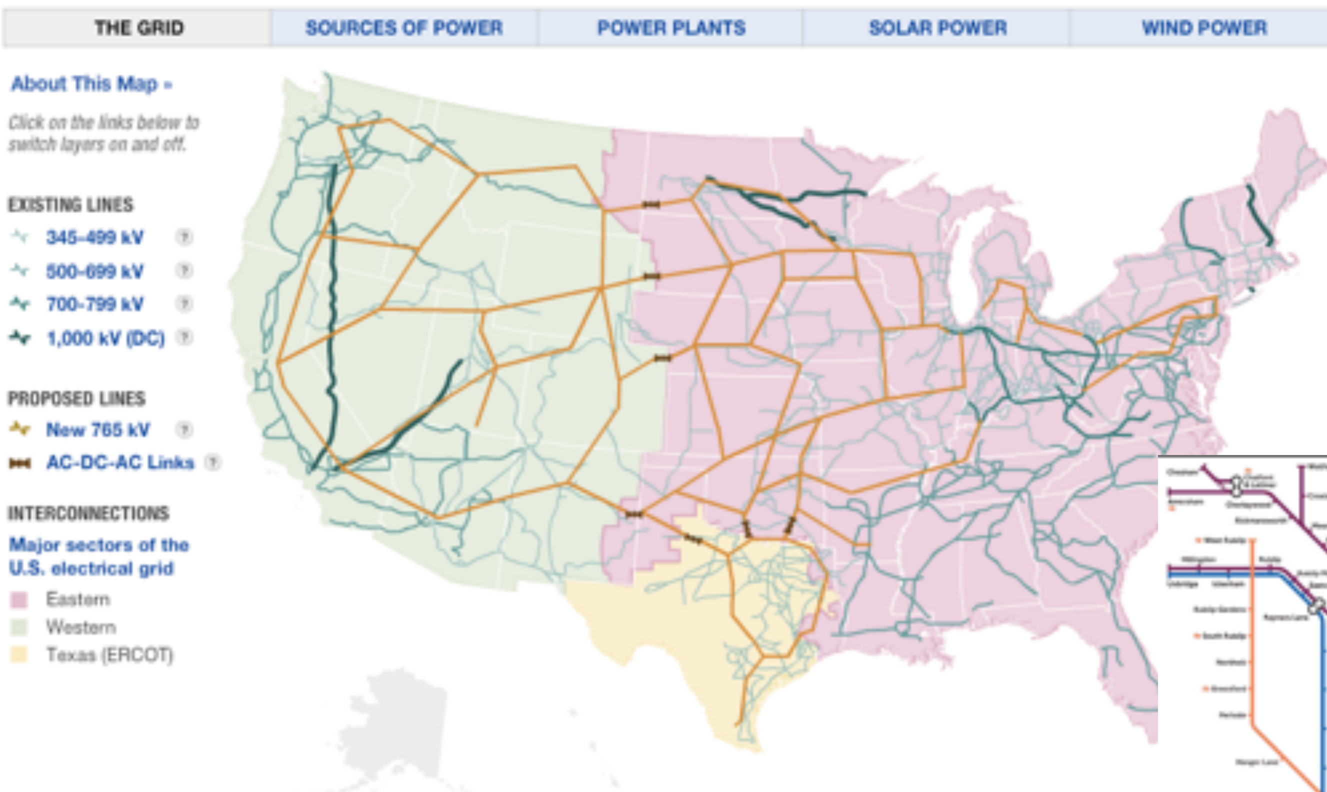
- What is a network?
- What features does a network have?
- What analysis is possible with those features?
- How do we explain that analysis?

“Network”

“A group of interconnected people or things”
(Oxford English Dictionary)

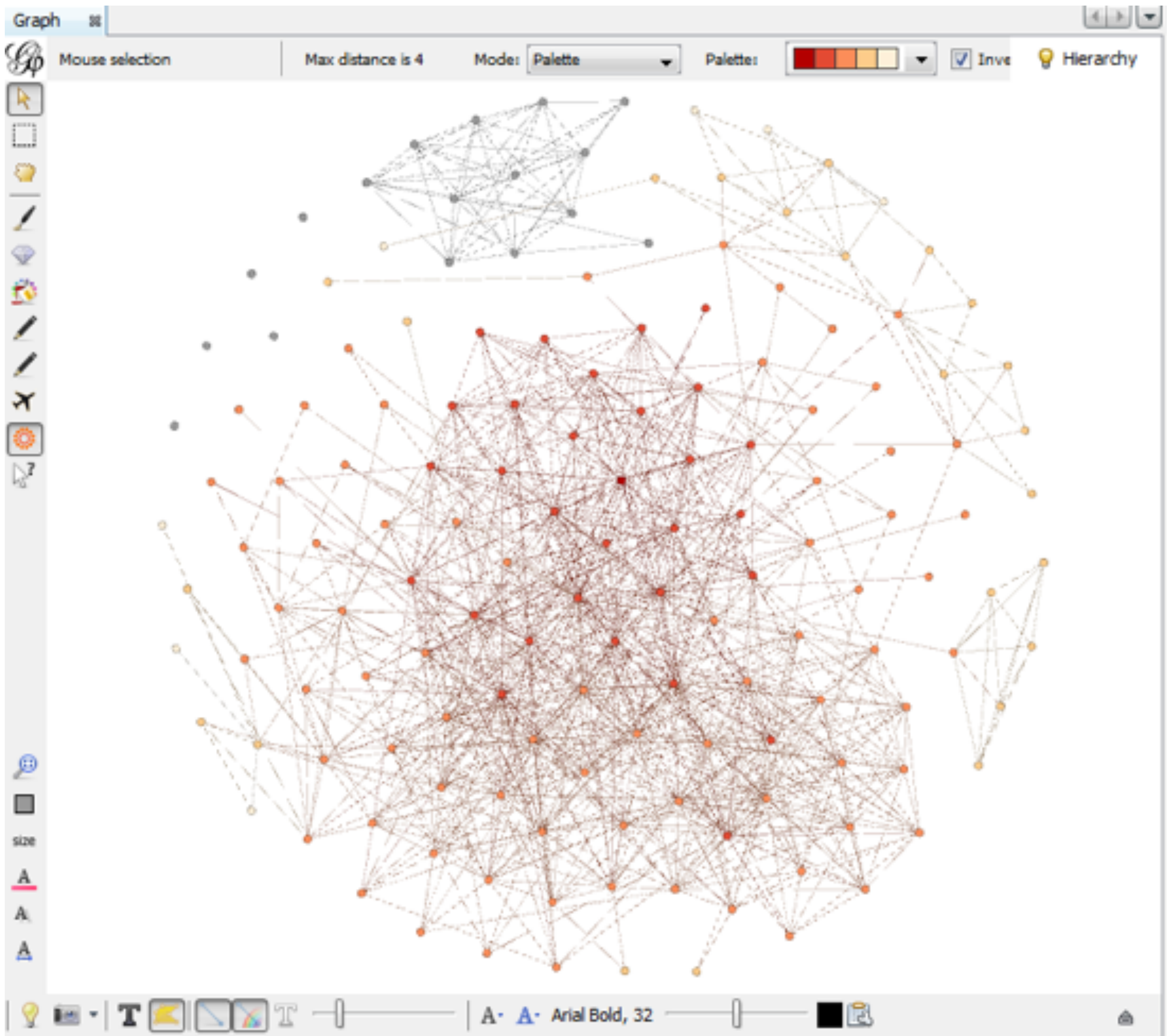
Use networks to understand, use and explain **relationships**

Infrastructure Networks



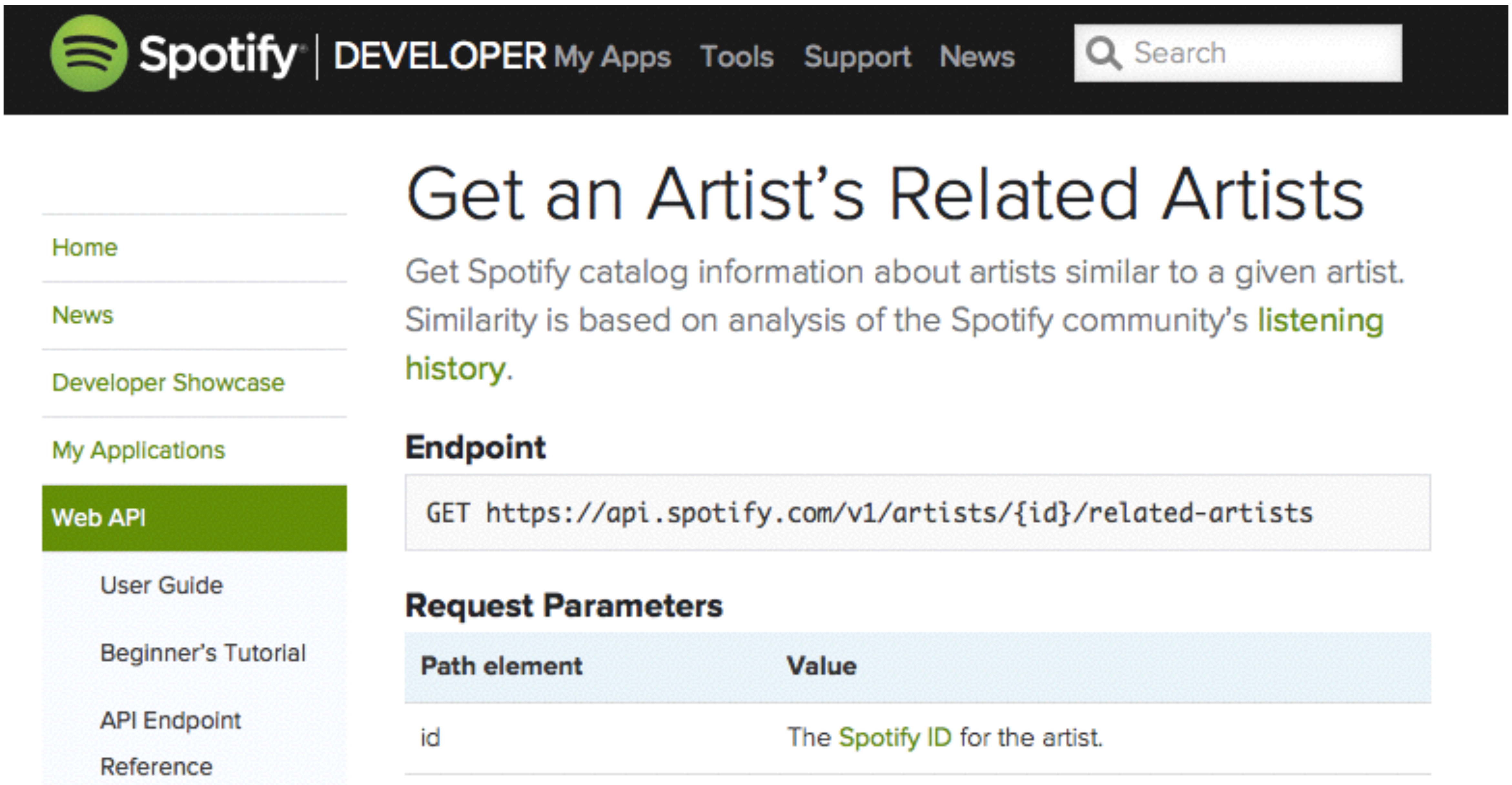
NPR: Visualising the US Power Grid
Transport for London: London Underground Map

Social Networks



(Sara's Facebook friends, in Gephi)

Songs



Spotify API reference

Words

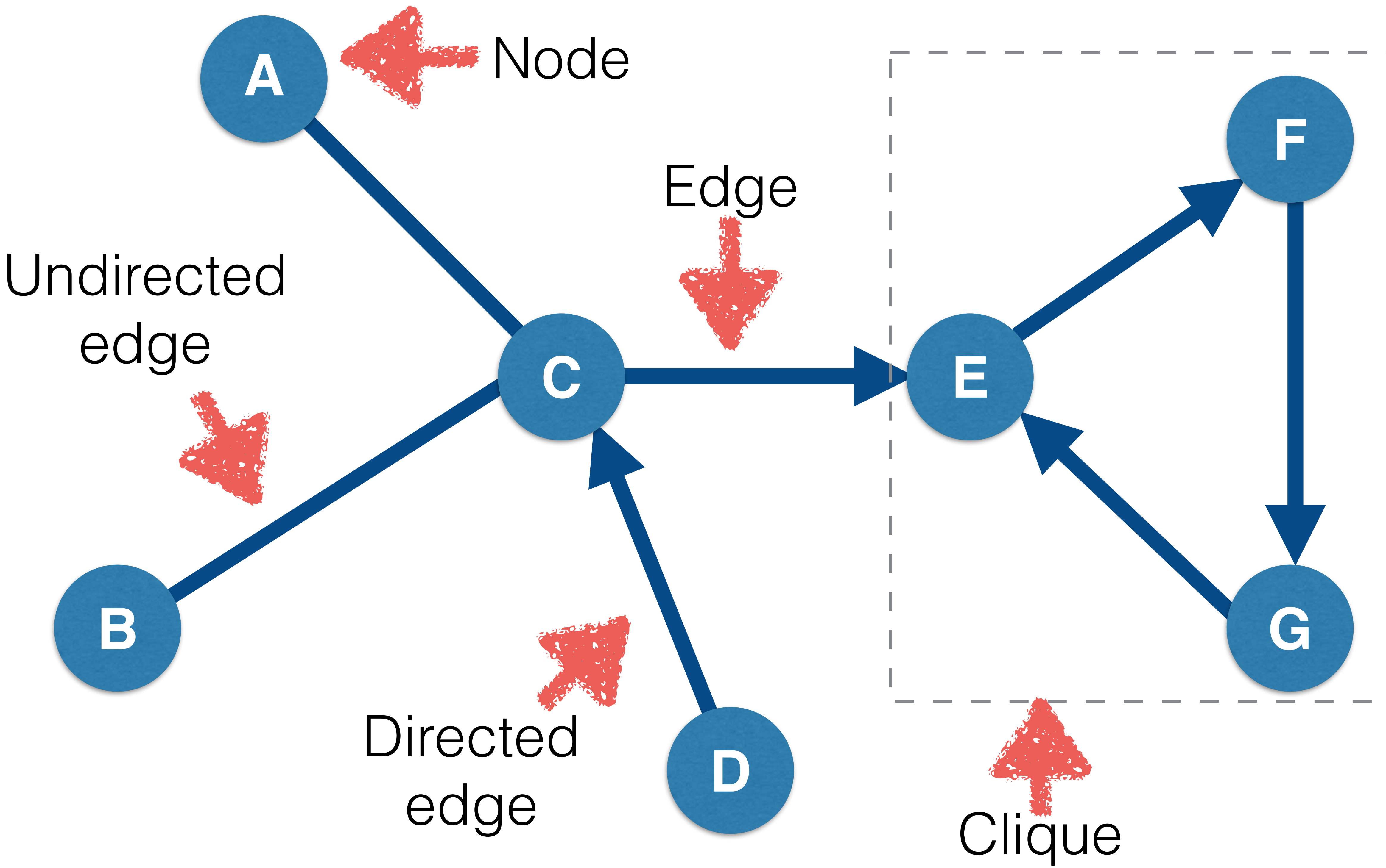
	bank	career	education	employment	example	experience	Florida	home	human	insurance	job	jobs	monster.com	office	opening	opportunities
bank	--															
career		--														
education		1	--													
employment	3		2	--												
example			35		--											
experience			42		35	--										
Florida				9			--									
home				7				--								
human	1								--							
insurance	1		2	6		2				--						
job	28	2	4	4			4	1	2	3	--					
jobs	1	1	4	16			6				17	--				
monster.com											1		--			
office				8				2			3			--		
opening											30	30			--	
opportunities		3		20						1	24	15			30	--

(Wise blogpost on word co-occurance matrices)

Network Analysis

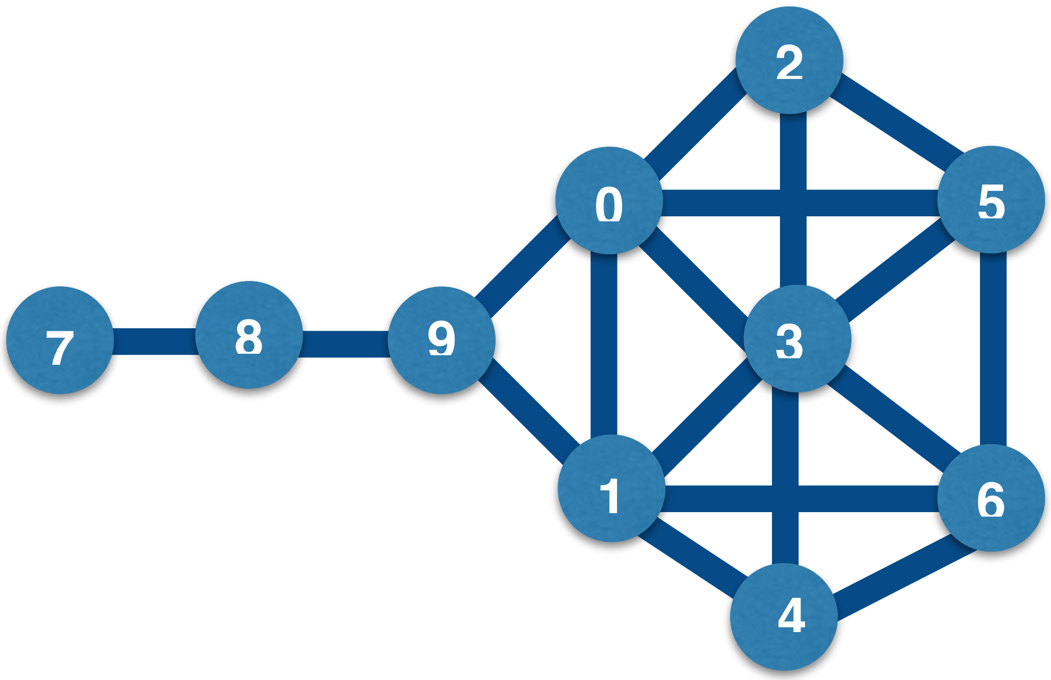
Use networks to understand, use and explain **relationships**

Network Features



Network Representations

- **Diagram**



- **Adjacency matrix**

```
[[ 0,  1,  1,  1,  0,  0,  0,  0,  0,  1],
 [ 1,  0,  0,  1,  1,  0,  1,  0,  0,  1],
 [ 1,  0,  0,  1,  0,  1,  0,  0,  0,  0],
 [ 1,  1,  1,  0,  1,  1,  1,  0,  0,  0],
 [ 0,  1,  0,  1,  0,  0,  1,  0,  0,  0],
 [ 0,  0,  1,  1,  0,  0,  1,  0,  0,  0],
 [ 0,  1,  0,  1,  1,  1,  0,  0,  0,  0],
 [ 0,  0,  0,  0,  0,  0,  0,  0,  1,  0],
 [ 0,  0,  0,  0,  0,  0,  0,  1,  0,  1],
 [ 1,  1,  0,  0,  0,  0,  0,  0,  1,  0]]
```

- **Adjacency list**

```
{0: [1, 2, 3, 9], 1: [0, 9, 3, 4, 6], 2: [0, 3, 5], 3: [0, 1, 2, 4, 5, 6],
 4: [1, 3, 6], 5: [2, 3, 6], 6: [1, 3, 4, 5], 7: [8], 8: [9, 7], 9: [8, 1, 0]}
```

- **Edge list**

```
{(0,1),(0,2),(0,3),(0,9),(1,3),(1,4),(1,6),(1,9),(2,3),(2,5),(3,4),
 (3,5),(3,6),(4,6),(5,6),(7,8),(8,9)}
```

- **Maths**

```
G = (V,E,e)
```

The NetworkX Library

- Python network analysis library

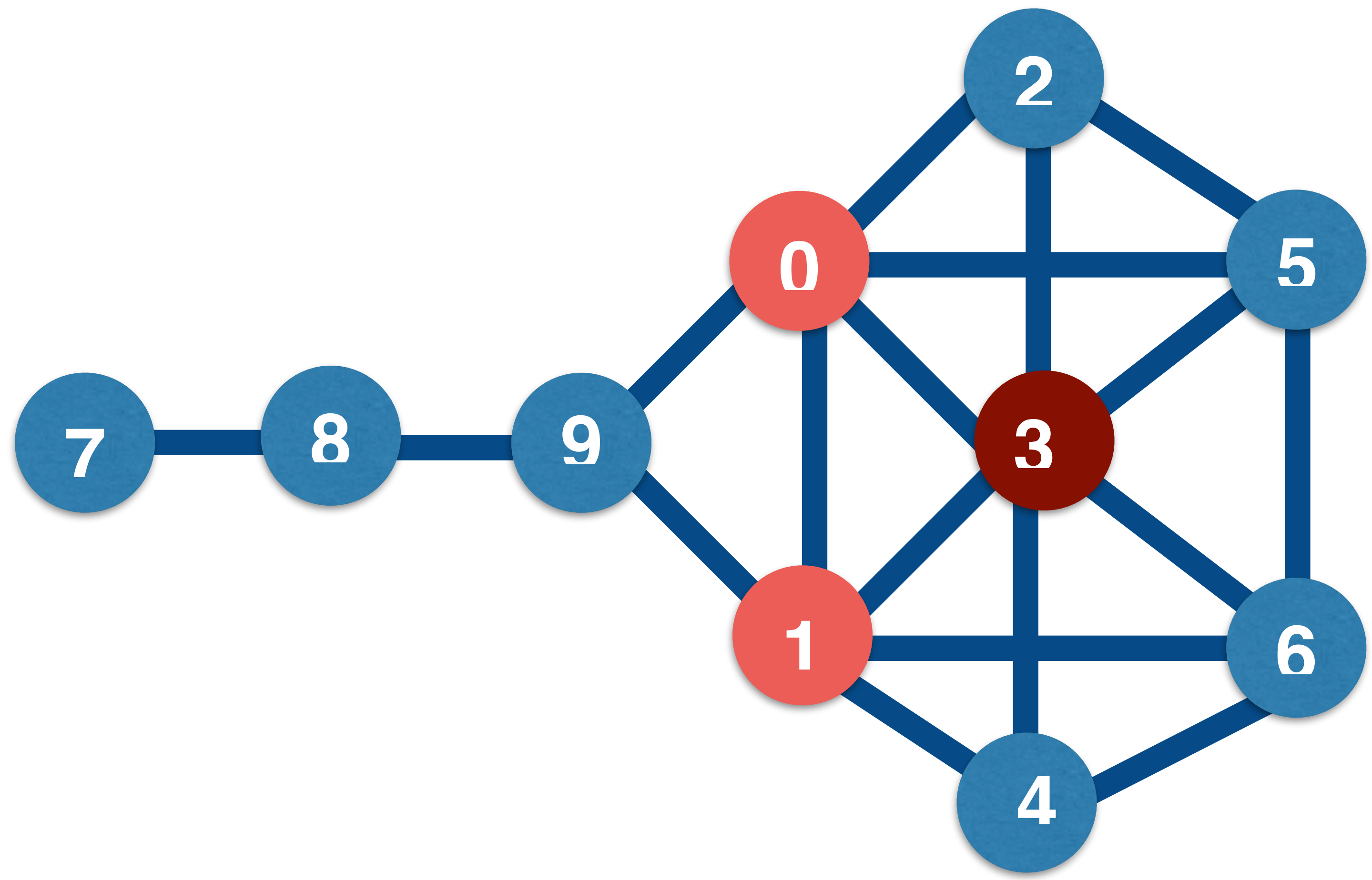
```
import networkx as nx

edgelist = {(0,1),(0,2),(0,3),(0,9),(1,3),(1,4),(1,6),
(1,9),(2,3),(2,5),(3,4),(3,5),(3,6),(4,6),(5,6),(7,8),
(8,9)}

G = nx.Graph()
for edge in edgelist:
 G.add_edge(edge[0], edge[1])
```

Node Centrality

- Finding the most “important”/“influential” nodes
  - i.e. how “central” is a node to the network

Degree centrality: “who has lots of friends?”

3	0.666
0	0.555
1	0.555
5	0.444
6	0.444
2	0.333
4	0.333
9	0.333
8	0.222
7	0.111

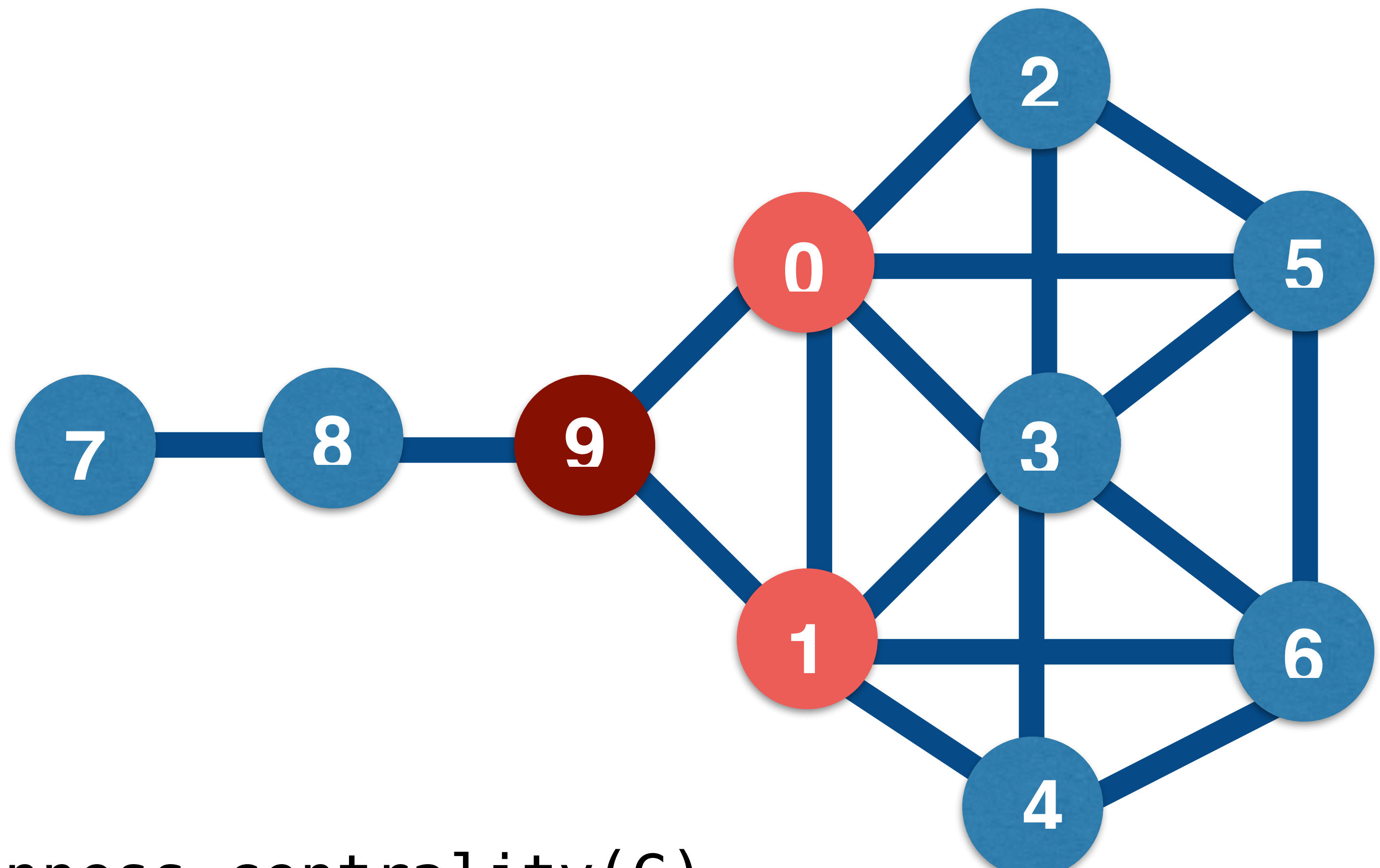



```
nx.degree_centrality(G)
```

= number of edges directly connected to n

Betweenness centrality: "who are the bridges"?

9	0.38
0	0.23
1	0.23
8	0.22
3	0.10
5	0.02
6	0.02
2	0.00
4	0.00
7	0.00

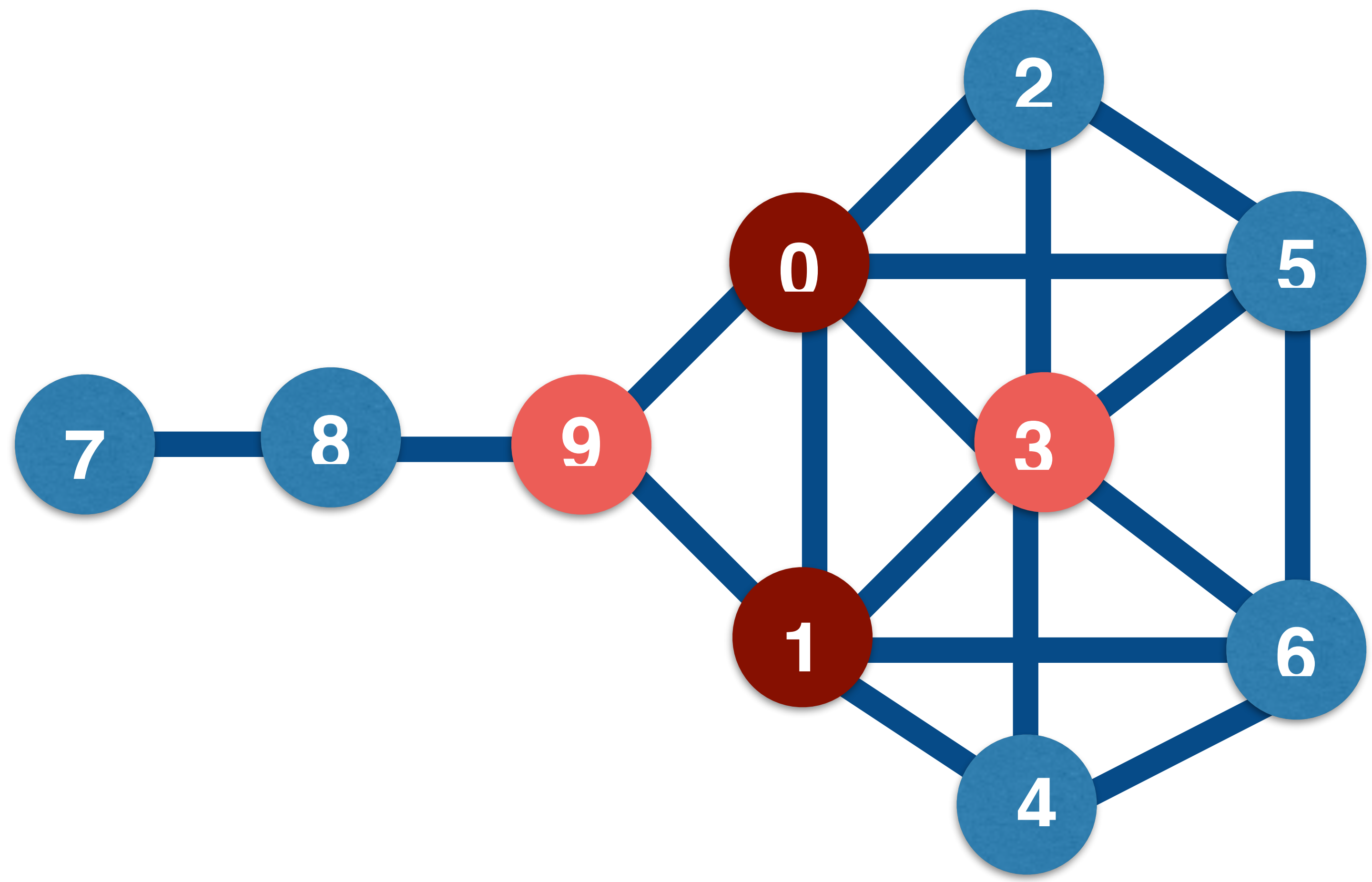



```
nx.betweenness_centrality(G)
```

= (number of shortest paths including n / total number of shortest paths) / number of pairs of nodes

Closeness centrality: “who are the hubs”?

0	0.64
1	0.64
3	0.60
9	0.60
5	0.52
6	0.52
2	0.50
4	0.50
8	0.42
7	0.31

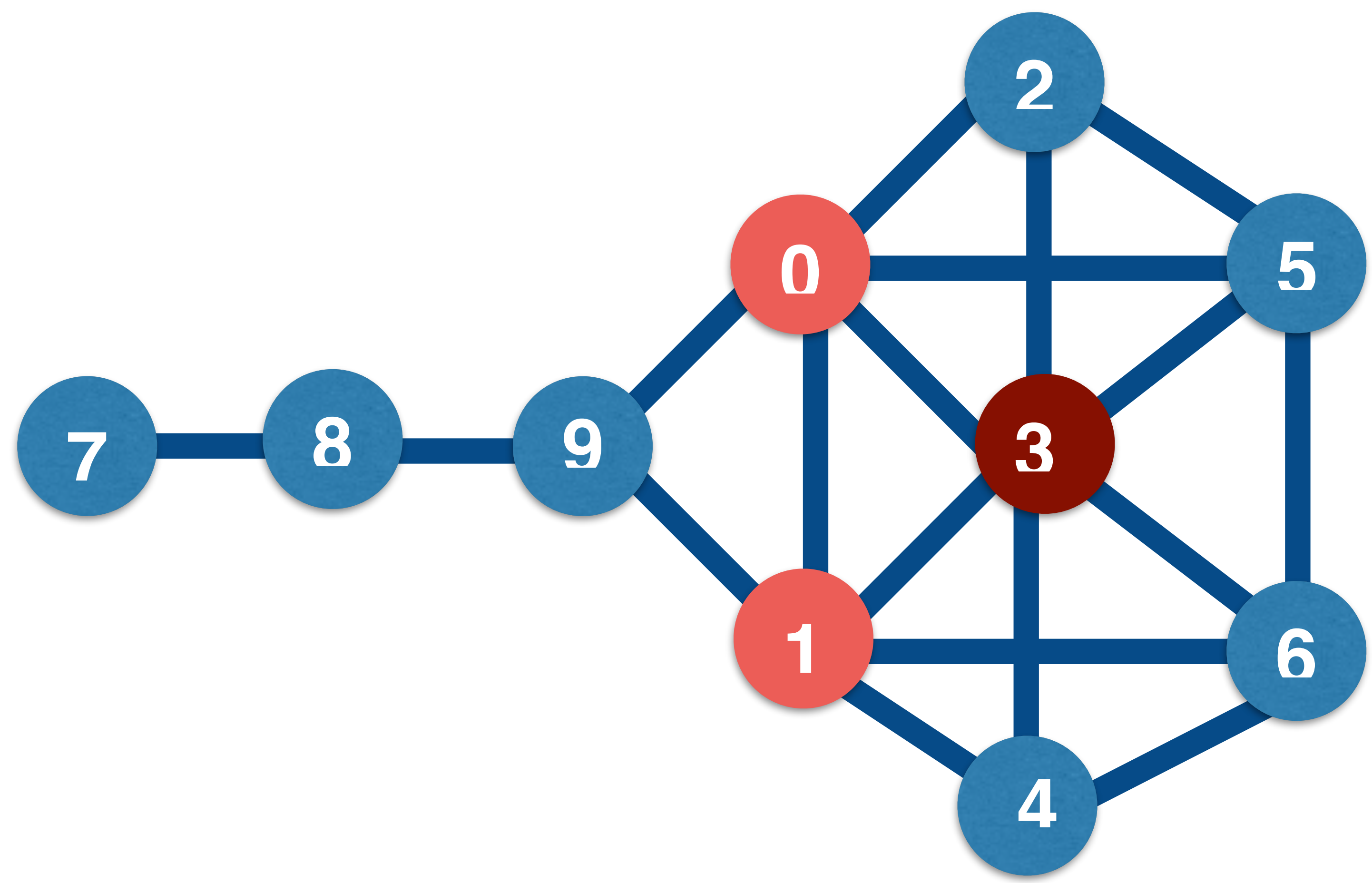



```
nx.closeness_centrality(G)
```

= sum(distance to each other node) / (number of nodes-1)

Eigenvalue centrality "who has most network influence"?

3	0.48
0	0.39
1	0.39
5	0.35
6	0.35
2	0.28
4	0.28
9	0.19
8	0.04
7	0.01



`nx.eigenvector_centrality(G)`

Network properties

- Characteristic path length: average shortest distance between all pairs of nodes
- Clustering coefficient: how likely a network is to contain highly-connected groups
- Degree distribution: histogram of node degrees

Community Detection

"Are there groups in this network?"

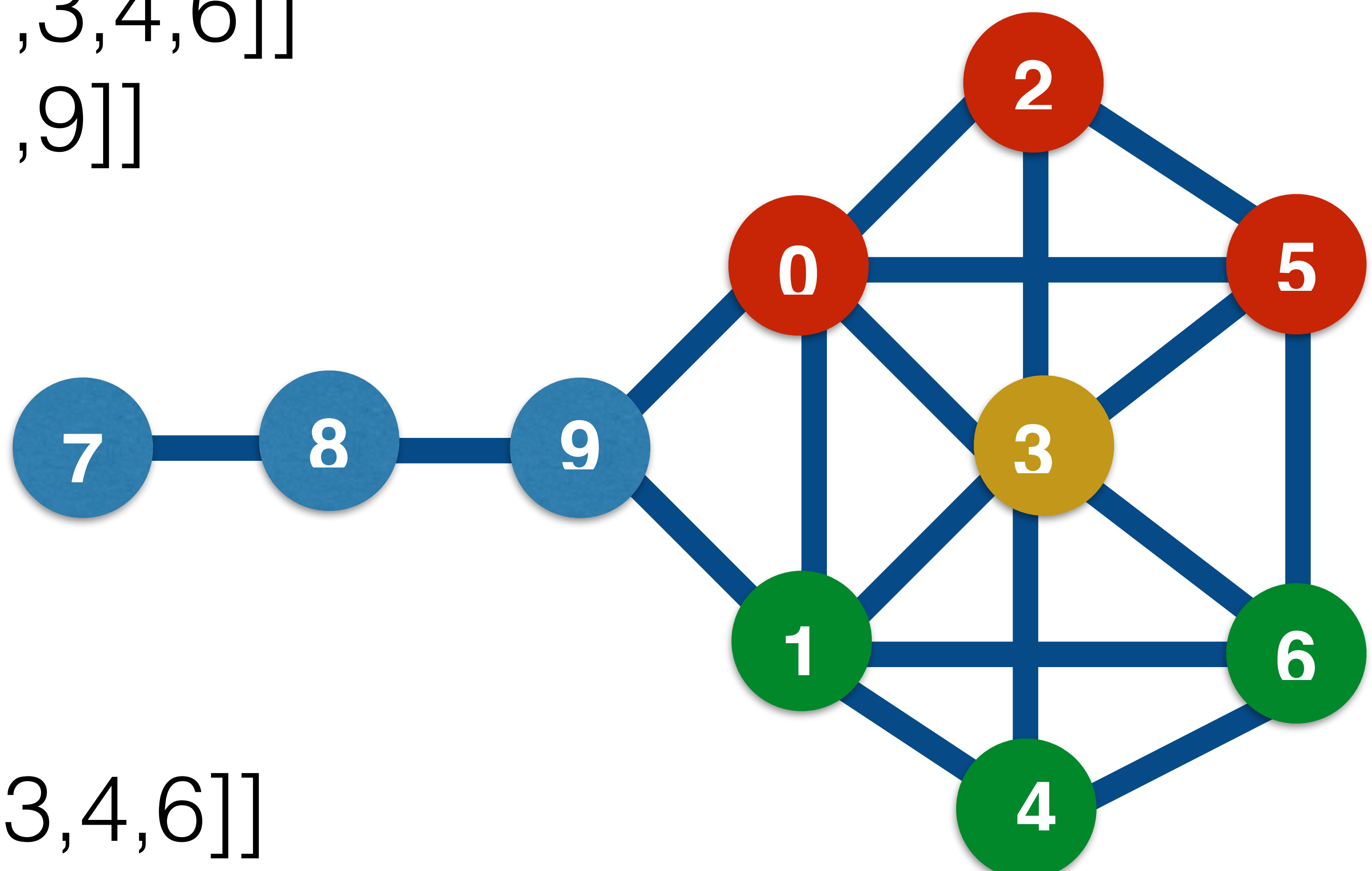
"What can I do with that information?"

Disconnected Networks

- Not all nodes are connected to each other
- Connected component = every node in the component can be reached from every other node
- Giant component = connected component that covers most of the network

Cliques and K-Cores

4-cliques: [[0,2,3,5],[1,3,4,6]]
3-cliques: [[0,1,3],[0,1,9]]
2-cliques: [[7,8],[8,9]]



3-cores: [[0,2,3,5], [1,3,4,6]]
2-core: [0,1,2,3,4,5,6,9]

```
nx.find_cliques(G)
nx.k_clique_communities(G, 3)
```

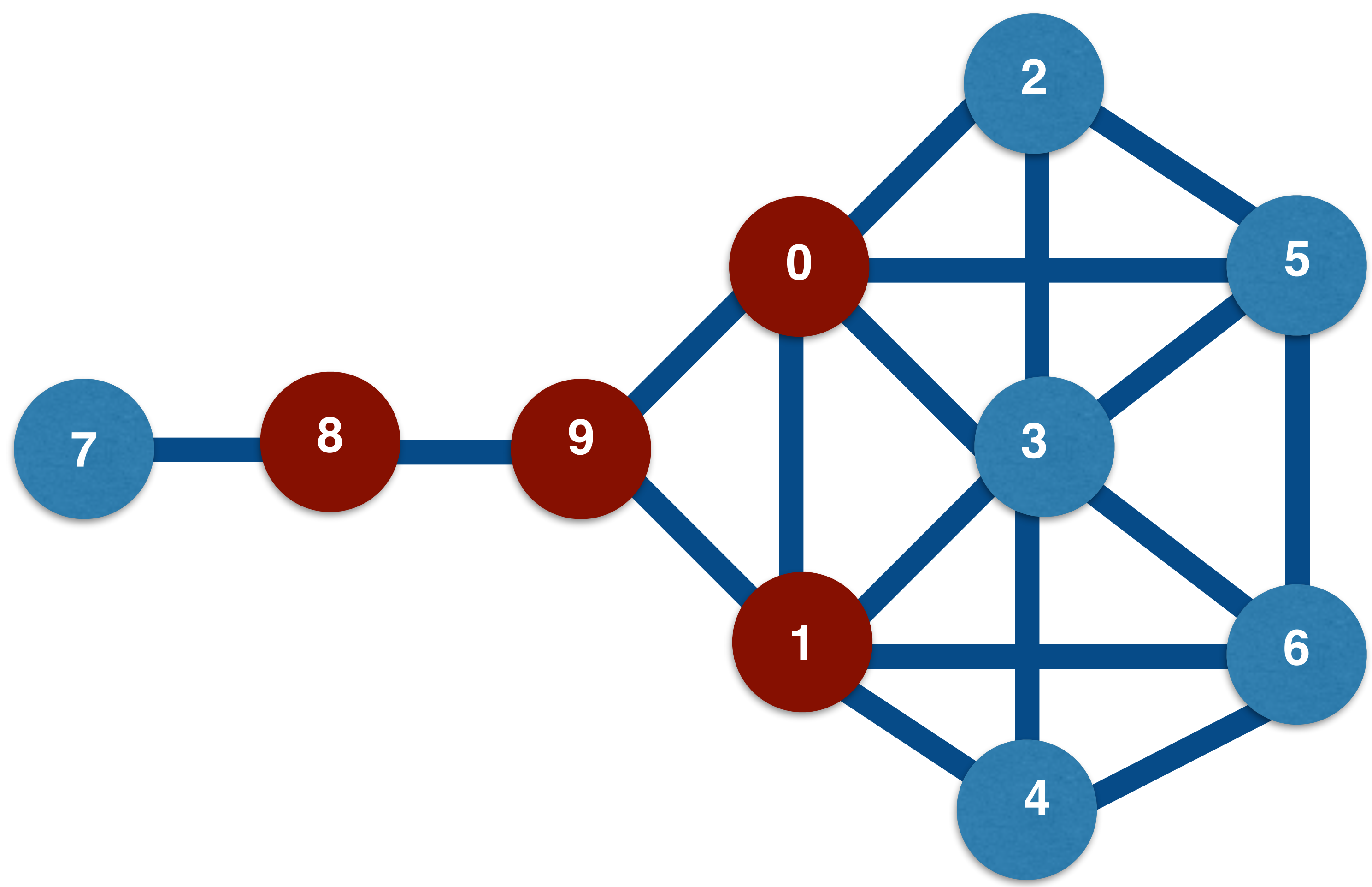
Other Clique methods

- N-clique: every node in the clique is connected to all other nodes by a path of length n or less
- P-clique: each node is connected to at least p% of the other nodes in the group.

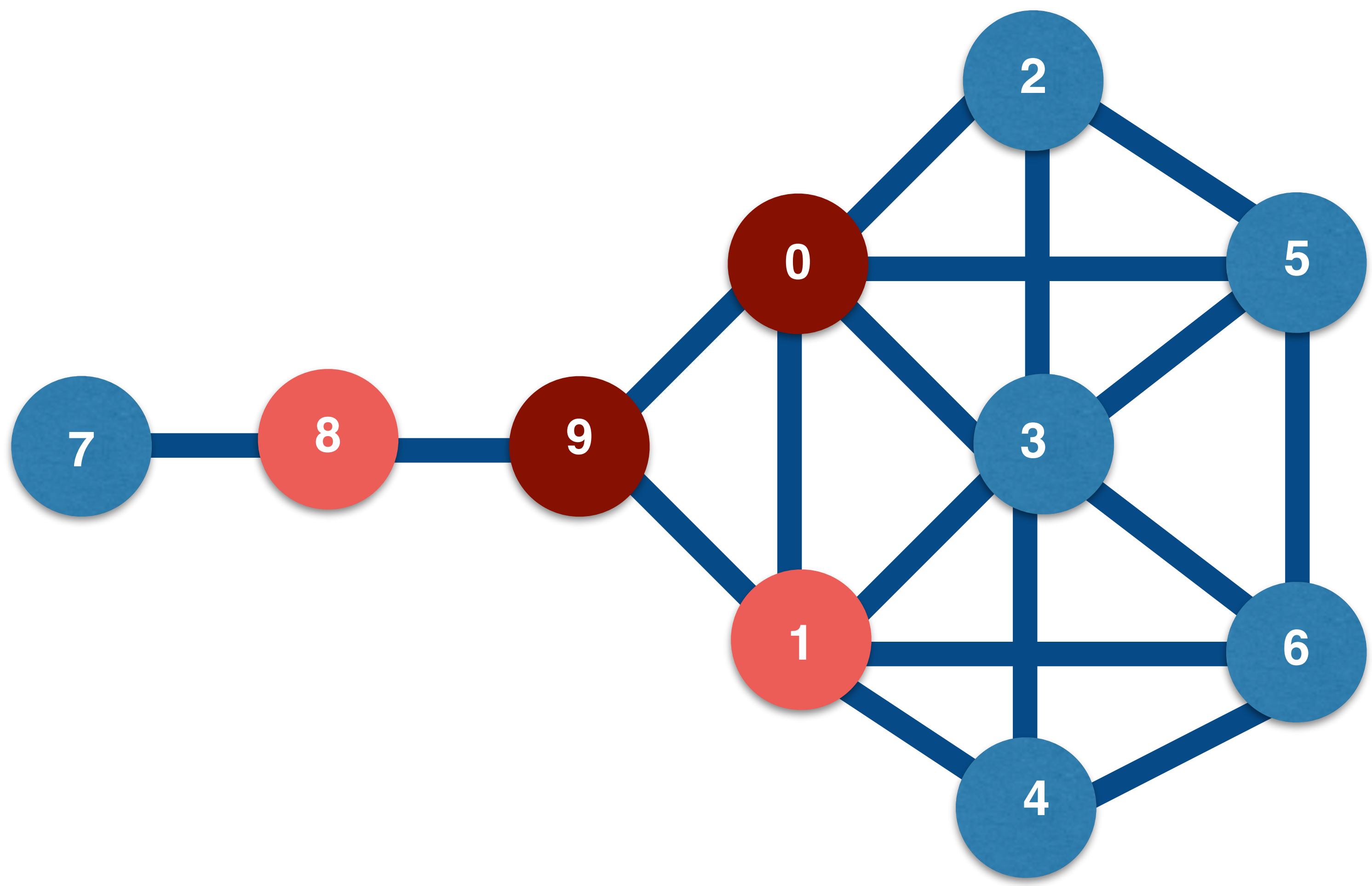
Network Effects

Predict how information or states (e.g. political opinion or rumours) are most likely to move across a network

Diffusion (Simple contagion)

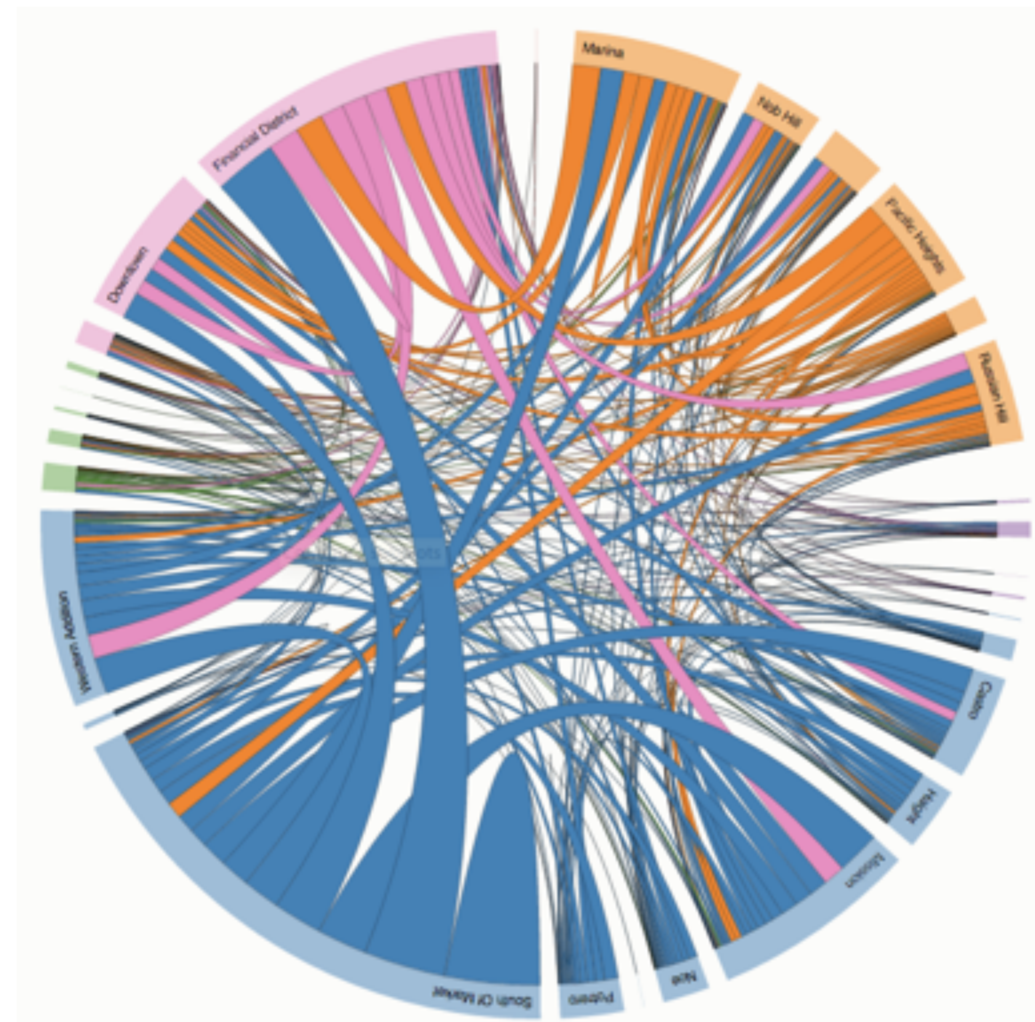


Complex contagion



Describing Networks

Network diagram



Edge bundling

bl.ocks.org/mbostock/4062045
http://bost.ocks.org/mike/uberdata/
http://bl.ocks.org/mbostock/7607999

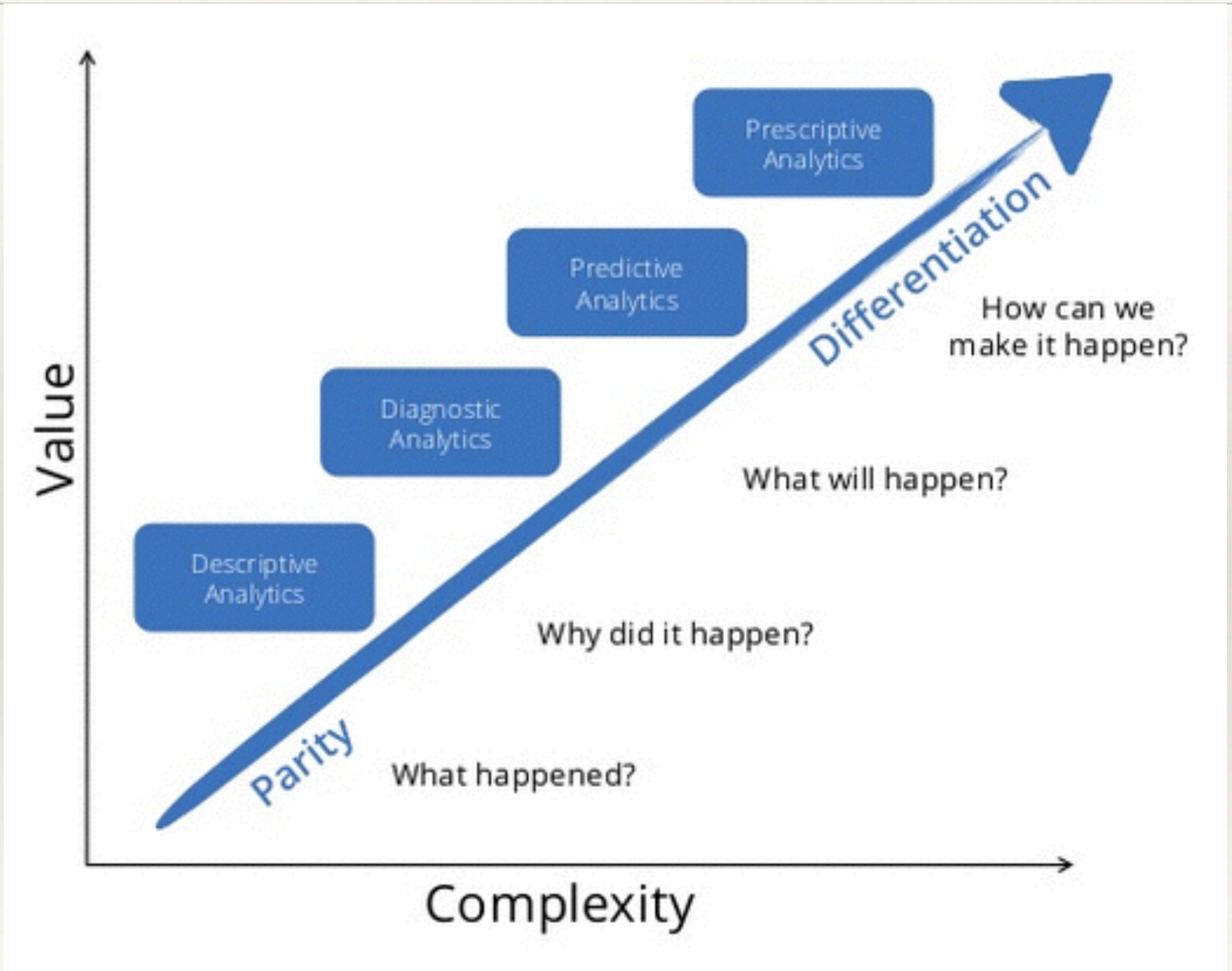
Network Analysis Tools

- Python libraries:
  - NetworkX
  - iGraph
  - graph-tool
  - Matplotlib (visualisation)
  - Pygraphviz (visualisation)
  - Mayavi (3d visualisation)

- Standalone tools:
  - SNAP
  - GUESS
  - NetMiner (free for students)
  - Gephi (visualisation)
  - GraphViz (visualisation)
  - NodeXL (excel add-on)

Longer list: http://en.wikipedia.org/wiki/Social_network_analysis_software

Moving Beyond Prediction



(Image: Ken Collier, Thoughtworks)

Continuing your Science journey

- http://scikit-learn.org/stable/index.html
- “An empirical classification of supervised learning algorithms”