How connected are you?
Putting some network science in your life

Hugo Touchette
National Institute for Theoretical Physics (NITheP)
Stellenbosch
Internet

UUNET’s North America Internet network

For more information visit www.uunet.com
Internet
IP connection map, 15 Jan 2005 (wiki)
Other networks
Other networks
Other networks
Other networks
Facebook

Brendan Griffen

Kris Krüg
Football graphs

- With Javier Lopez Pena (now at kickdex)
- http://www.maths.qmul.ac.uk/~ht/footballgraphs/
Bits of graph theory

Degree: \( d_i = \# \text{ links from } i \)

Degree sequence
\( d = (1,3,2,2,2) \)

Adjacency matrix

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Degree distribution

\[ \text{Degree distribution graph} \]
Degree distribution
Types of graphs

**Random**
- Social networks
- Electricity grid
- Gene networks
- Between ordered and random

**Small world**

**Scale free**
- Internet
- Sexual partners
- Airline connections
- Scientific citations
- Highly connected nodes (hubs)
Small world networks

- Re-wire link with probability $p$
- Create **bridges**
- Small distance
- High clustering

Watts & Strogatz, Nature 1998
Kevin Bacon game

Kevin Bacon is the centre of the entertainment world!

https://oracleofbacon.org
Kevin Bacon game

Kevin Bacon is the centre of the entertainment world!

https://oracleofbacon.org

Jay Sanders
Centrality

- Most connected = highest degree
- Most central = most effect if removed
- Centrality = Link to many connections

- Different centrality measures $C = F(A)$
  - Betweenness
  - Pagerank
  - Degree centrality
Examples

- Communication servers (39 stars)
- Power grid (310 circles)
- Failure probability with 14 servers down

Examples

- Left: Betweenness centrality
- Right: Correlation of centrality-activity

Porta et al., Environ. & Planning 2009
Current research

Maths + physics + computer science + social sciences

- Community detection
  - Identification
  - Recommendations (Facebook, Amazon, etc.)

- Evolving networks
  - City growth
  - Urban planning

- Dynamics on networks
  - Disease spreading
  - Google search
  - Daily commute
LONDON IN MOTION

One day of public transit travel for 3.1 million Londoners, inferred using complete sets of data from the Oyster farecard and the iBus vehicle-location system.