

Graph representations

V - number of vertices (nodes), E - number of edges

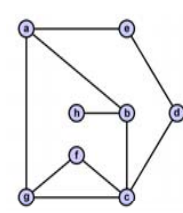
Edge array - size: E

Adjacency matrix - size: $V * V$

Adjacency lists - size: $V + E$

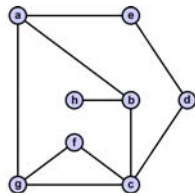
“pure” representations

Adjacency matrix



	a	b	c	d	e	f	g	h
a	0	1	0	0	1	0	1	0
b	1	0	1	0	0	0	0	1
c	0	1	0	1	0	1	1	0
d	0	0	1	0	1	0	0	0
e	1	0	0	1	0	0	0	0
f	0	0	1	0	0	0	1	0
g	1	0	1	0	0	0	0	0
h	0	1	0	0	0	0	0	0

Adjacency List



a: b e g
 b: c h
 c: b g
 d: c e
 e: a d
 f: c g
 g: a c f
 h: b

Representation properties

V - number of vertices

E - number of edges


	matrix	list	edge array
space	V^2	$V+E$	E
find edge	1	V	E
insert edge	1	1	1
path v to w ?	V^2	$V+E$	$E \lg V$

Graph processing software tools

- **GUI programs:** Pajek, yED, UCINET
- **Command line programs:** graphviz, R, statnet
- **Software Libraries:** LEDA, networkx, igraph
- **Input:** user input (mouse-clicks) or files
- **Most file formats are text, graph formats**
- **Output:** images or data files
- **Focus:** visualization or graph algorithms

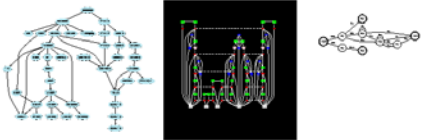
Graphviz

command line graph visualizer – the language itself is called **dot**



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Graphviz - Graph Visualization Software



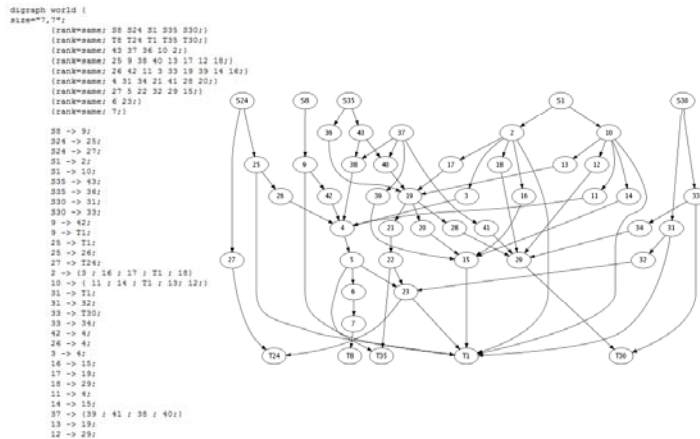
Graph Visualization

Graph visualization is a way of representing structural information as diagrams of abstract graphs and networks. Automatic graph drawing has many important applications in software engineering, database and web design, networking, and in visual interfaces for many other domains.

Graphviz is open source graph visualization software. It has several main graph layout programs. See the [gallery](#) for some sample layouts. It also has web and interactive graphical interfaces, and auxiliary tools, libraries, and language bindings.

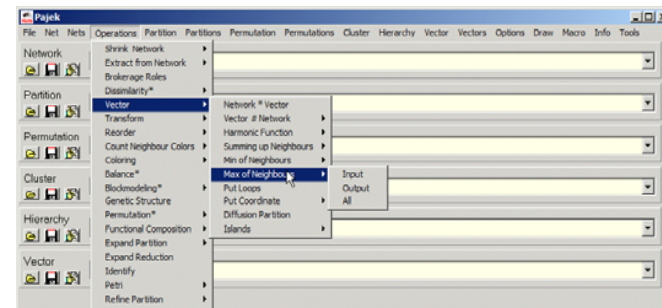
The [Mac OS X edition of Graphviz](#), by Glen Low, won two 2004 Apple Design Awards.

Graphviz example



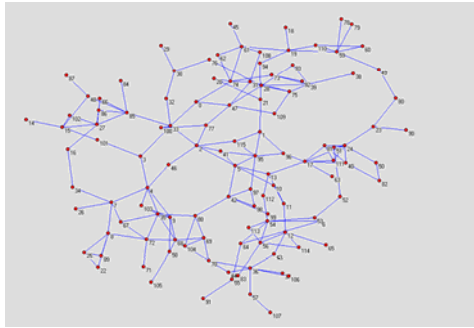
Pajek

Windows program for visualization and analysis of large networks



Pajek input and output

```
*Vertices 116
1 "0" ic Black
2 "1" ic Black
3 "2" ic Black
4 "3" ic Black
5 "4" ic Black
...
116 "115" ic Black
*Edges
1 34
1 48
2 96
2 97
2 116
3 6
3 42
3 47
3 70
3 116
4 5
4 34
4 102
5 8
5 10
5 47
6 11
6 42
7 55
7 65
8 9
8 69
11 12
12 13
14 6
...
```

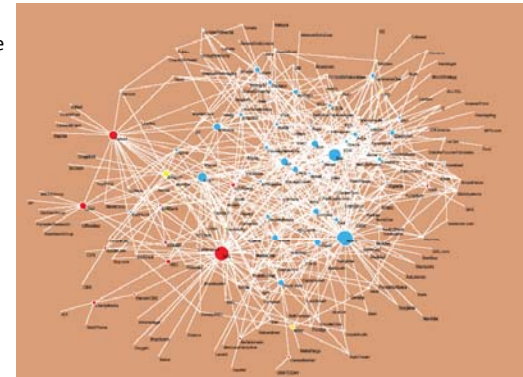


Basic layout circular, easy to change to energy-minimizing layout.

More sophisticated Pajek example: strategic alliances among companies

red - content,
blue - infrastructure
yellow - commerce

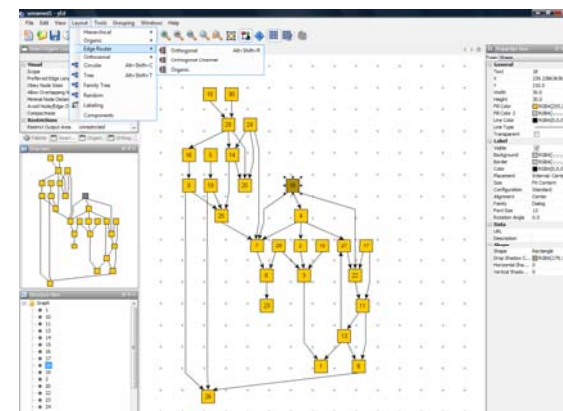
Figure by
Valdis Krebs



yED - yFiles

yED (editor) is free but yFiles costs \$\$\$
<http://www.yworks.com>

yED – Excellent Layout



Cytoscape – biology oriented

The screenshot shows the Cytoscape website's download page. At the top, there's a navigation bar with links: Home, Introduction, Downloads, Plugins, Community, All releases, New team, Links, Top Tutorials, and Help. The main content area has a large image of a network graph. Below it, there's a section for 'Download Cytoscape 2.6.1' with a 'Download Cytoscape 2.6.1' button. To the right, there's a 'Manual' section with a 'Download Manual' button. Below the main content, there's a 'Getting Help' section with a 'Need help getting started with Cytoscape?' link. The bottom of the page has a 'Cytoscape 2.6.1' section with a 'Download Cytoscape 2.6.1' button.

UCINET – social science oriented

Description <http://www.analysetech.com/ucinet/description.htm>



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Description

Capabilities

UCINET is a comprehensive package for the analysis of social network data as well as other 1-mode and 2-mode data. Can read and write a multitude of differently formatted text files, as well as Excel files. Can handle a maximum of 32,767 nodes (with some exceptions) although practically speaking many procedures get too slow around 5,000 - 10,000 nodes. Social network analysis methods include centrality measures, subgroup identification, role analysis, elementary graph theory, and permutation-based statistical analysis. In addition, the package has strong matrix analysis routines, such as matrix algebra and multivariate statistics.

Integrated with UCINET is the [InVista](#) program for drawing diagrams of social networks. In addition, the program can export data to MAGE and Pajek.

Trial Version / Purchase

UCINET

can be [downloaded](#) and used free for 60 days. For longer use, individual students pay \$40, faculty, schools & government pay \$150, and corporations pay \$250. In addition, generous volume discounts / site licenses are available. Click [here](#) for ordering information.

Python – Networkx graph library

Uses Graphviz for graph visualization

The screenshot shows the NetworkX website's download page. At the top, there's a navigation bar with links: Home, Search, Download, Developer Site, and Documentation. The main content area has a large image of a network graph. Below it, there's a section for 'Download NetworkX' with a 'Download NetworkX' button. To the right, there's a 'Manual' section with a 'Download Manual' button. Below the main content, there's a 'Getting Help' section with a 'Need help getting started with NetworkX?' link. The bottom of the page has a 'NetworkX 2.0' section with a 'Download NetworkX 2.0' button.

A networkx example

```
2 import networkx as nx
3
4 # generate a few different types of random graphs
5 er = nx.erdos_renyi_graph( 100, 0.1 )
6 ws = nx.watts_strogatz_graph( 100, 10, 0.2 )
7 ba = nx.barabasi_albert_graph( 100, 2 )
8
9 # collect them in a list
10 allgen = [ er, ws, ba ]
11
12 # print various network measures
13 for graph in allgen:
14     avg = nx.cluster.average_clustering( graph )
15     diam = nx.distance.diameter( graph )
16     cent = nx centrality.betweenness centrality(graph)
17     print 'Avg=%4.2f, Diameter=%d, BCentral=%s' % (avg, diam, cent)
18
```



```
Avg=0.10, Diameter=4, BCentral=[0: 0.016015371933121809, 1: 0.0039172788090537005,
Avg=0.39, Diameter=4, BCentral=[0: 0.037242946115432697, 1: 0.023804532988251741, :
Avg=0.15, Diameter=6, BCentral=[0: 0.17685572133217217, 1: 0.0, 2: 0.2989597792701:
```

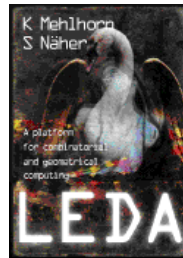
LEDA

Library of efficient data types - written in C++
free versions / \$150 for the academic license

You can buy the Leda Guide from Amazon
(also available free on the web)

High performance, professional product,
covers much more than just graphs.

So abstract that it feels like a
high level programming language



LEDA example

```
#include <LEDA/graph.h>
#include <LEDA/basic_graph_alg.h>
using namespace leda;

int main() {
    graph G;
    list<node> dfs_res ;

    node n0 = G.new_node ();
    ...
    G.new_edge (n0,n1);
    ...
    dfs_res = DFS (G, n0, n5);

    forall (node, dfs_res)
        G.print_node(node);
}
```

igraph software library

The igraph library SourceForge

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Introduction

igraph is a free software package for creating and manipulating undirected and directed graphs. It includes implementations for classic graph theory problems like minimum spanning trees and network flow, and also implements algorithms for some recent network analysis methods, like community structure search.

The efficient implementation of igraph allows it to handle graphs with millions of vertices and edges. The rule of thumb is that if your graph fits into the physical memory then igraph can handle it.

igraph can be installed in several forms:

- igraph as a C library is useful if you want to use it in your C/C++ projects, or want to implement your own network analysis or model in C/C++ using the data structures and functions igraph provides.
- igraph as an R package. You can use igraph as an extension package to The GNU R project for Statistical Computing. The flexibility of the R language and its richness in statistical methods add a great deal of productivity to igraph, with a very small speed penalty.
- igraph as a Python extension module. This way you can combine igraph with the huge set of Python functions and modules available, and the ease of the Python language, with a small speed penalty.
- igraph as a Ruby extension. If you like the Ruby language, then this might be the right choice for you.

Latest version: 0.5.2
[Release notes](#)

