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LAYOUTS FOR
GRAPH DRAWING CONTESTS
1995-2001

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Layouts for Graph Drawing Contests 1995-2001

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Graph drawing contests

Since 1994 graph drawing contests are organized as a part of the Graph Drawing Conferences. The rules and data are described on Internet and participants send their drawings till the specified date. They can use any technique to get layouts of graphs. The primary judging criterion is how well the drawings convey the information in the graphs: vertex identifiers, vertex types, and vertex interconnectivity. A secondary criterion is the degree to which manual editing was employed to produce the layout: the less manual intervention, the better.

The purpose of the contests is to monitor and challenge the current state of the art in graph-drawing technology.

Data (vertices and lines) for 3 or 4 graphs are given each year. A winning entry for each graph is chosen by a panel of experts.

In this paper we collected our submissions to the contests in the years 1995–2001. They are available also at

<http://vlado.fmf.uni-lj.si/pub/gd/gd95.htm>

and the original data (and their versions in Pajek format) at

<http://vlado.fmf.uni-lj.si/pub/networks/data/gd/gd.htm>

There you will find also pictures in some (dynamical) graphical formats (VRML, SVG) that can not be adequately reproduced in the paper form.

Layouts for Graph Drawing Contest 1995

In 1995 the Graph Drawing Conference was held in Passau and the contest was organized by Peter Eades and Joe Marks. Rules and data are described at:

<http://www.uni-passau.de/agenda/gd95/contest.html>

Graph A95

- First layout was obtained automatically using our program COORD (positioning vertices on the rectangular net so that the number of crossings of lines is as low as possible).
- Manual editing was performed to reposition vertices using our graph picture editor DRAW.

Graph B95

- Analysing graph B using our program RELCALC two central vertices were found (1 and 34).
- Feasible positions for vertices were generated (two families of concentric circles).
- Vertices 1 and 34 were fixed in the centre of the concentric circles mentioned.
- Other vertices were automatically positioned around using program COORD so that the total length of the lines was minimized.
- Layout was then edited manually using DRAW to reposition vertices to minimize crossings (concentric circles cannot be seen any more).

The layout was awarded the honorable mention.

Graph C95

- First layout was obtained automatically using our program ENERGEN (minimisation of ENERGY).
- Some manual editing using DRAW was performed to reposition vertices.

The layout was awarded the first prize.

See: <http://vlado.fmf.uni-lj.si/pub/gd/gd95.htm>

The complete report of the contest is available in [6] and:

<http://www.merl.com/reports/TR95-14/index.html>

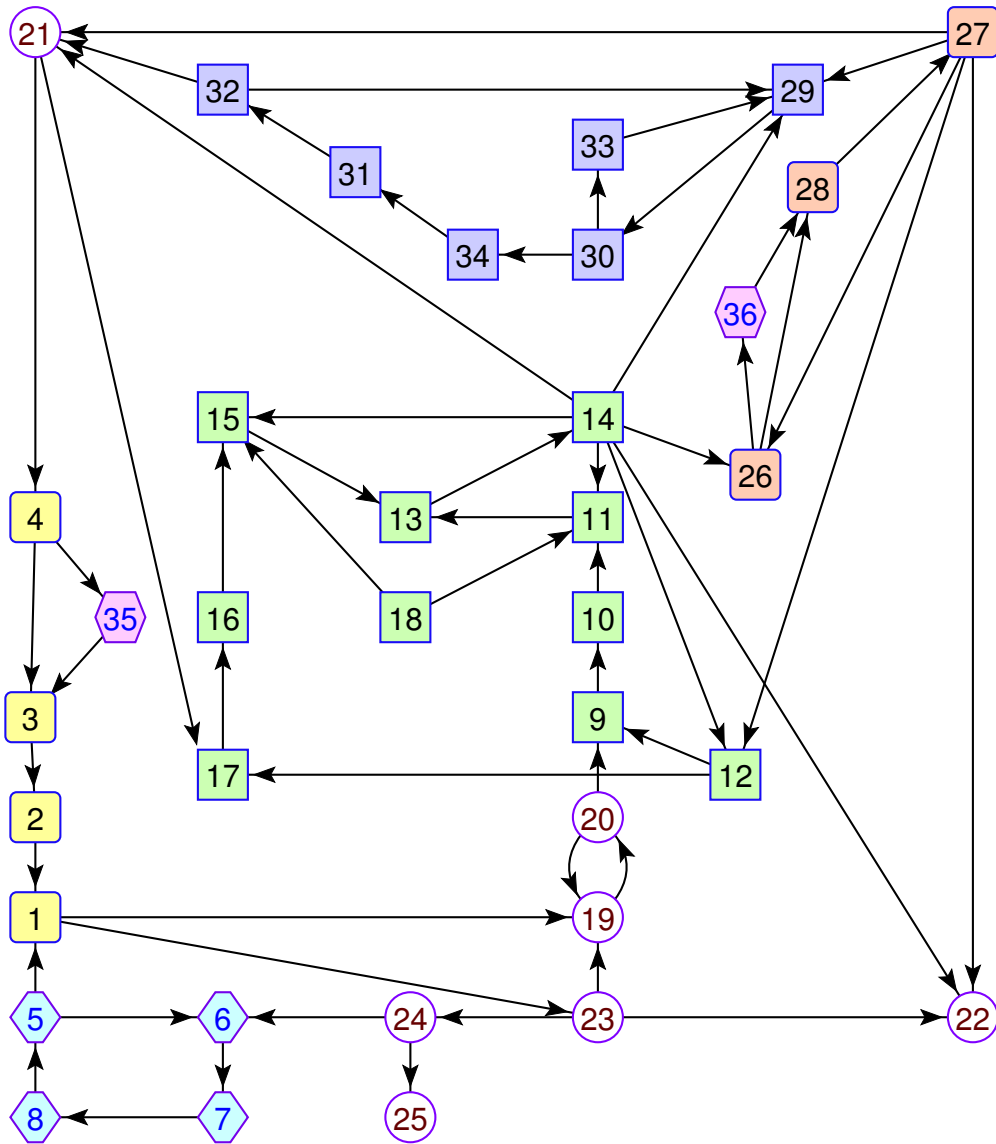


Figure 1: Graph A95.

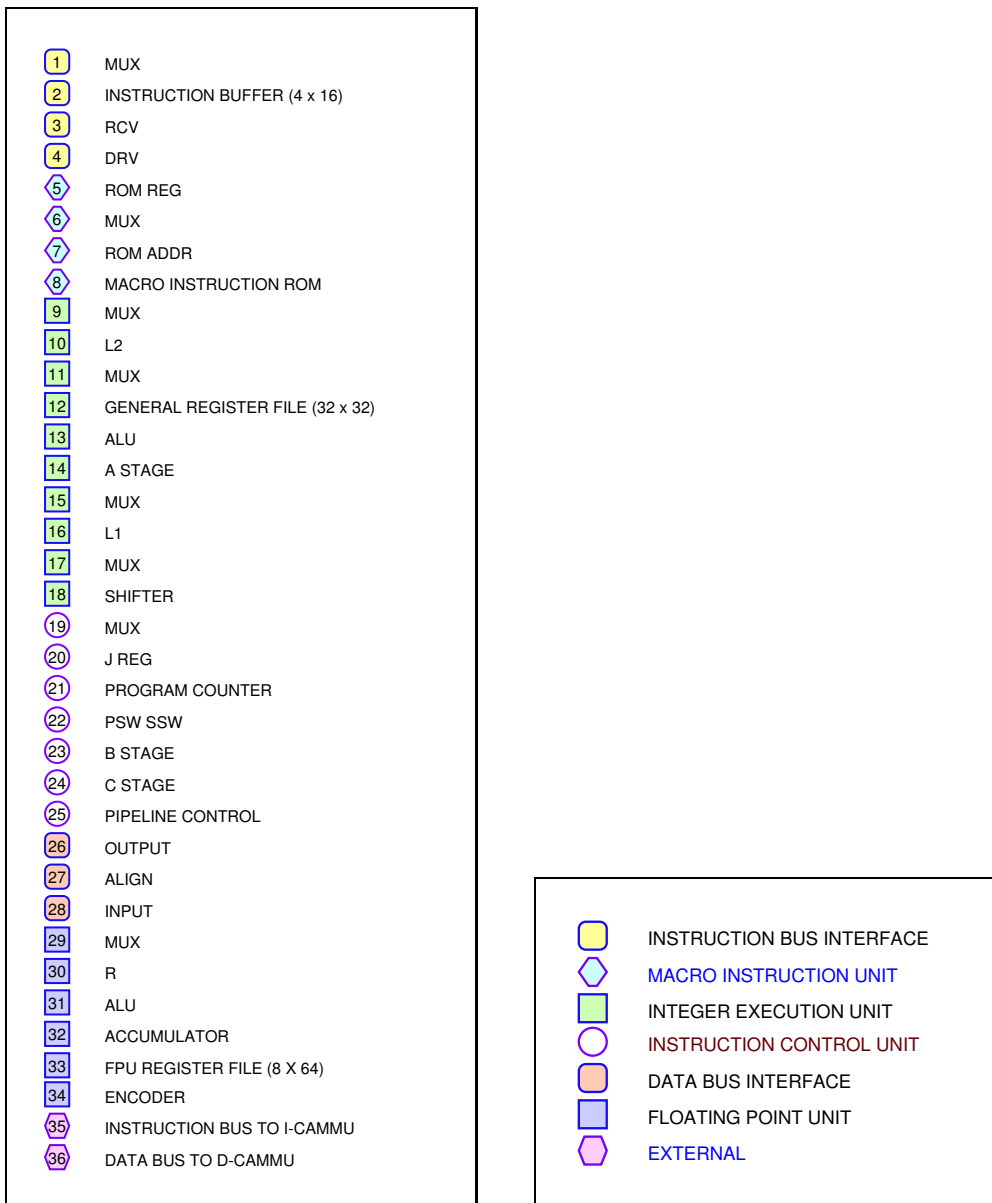


Figure 2: Graph A95 descriptions.

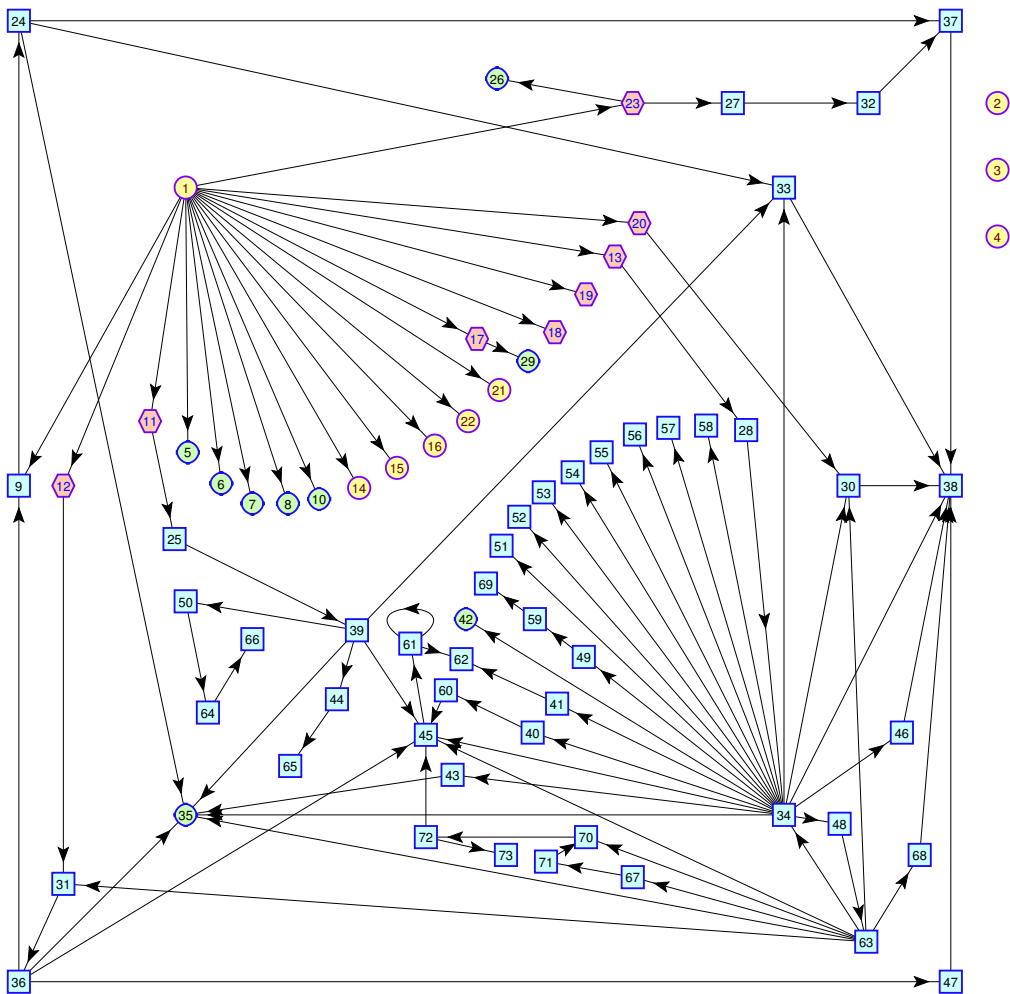


Figure 3: Graph B95 (*honorable mention*).

1	graphics.c:GRDisplayPoint	38	X11/X.h:XID
2	long1.c:GRDisplayPoint	39	X11/Xlib.h:struct Xlib_h_57
3	long2.c:GRDisplayPoint	40	X11/Xlib.h:ScreenFormat
4	short.c:GRDisplayPoint	41	X11/Xlib.h:struct Xlib_h_22
5	X11/X.h:GCFont	42	X11/Xlib.h:Status
6	gremlin.h:dby_to_win	43	X11/Xlib.h:struct Xlib_h_21
7	X11/X.h:GXxor	44	X11/Xlib.h:XCharStruct
8	X11/X.h:GCFunction	45	X11/Xlib.h:XExtData
9	X11/Xlib.h:XGCValues	46	X11/X.h:KeySym
10	gremlin.h:dbx_to_win	47	X11/X.h:GCContext
11	graphics.c:text_pf	48	X11/Xlib.h:Screen
12	main.c:pix_gc	49	X11/Xlib.h:XModifierKeymap
13	main.c:display	50	X11/Xlib.h:XFontProp
14	X11/Xlib.h:XChangeGC	51	<void>:struct _XrmHashBucketRec
15	X11/Xlib.h:XCopyPlane	52	<void>:struct _XKeytrans
16	/usr/include/strings.h:strlen	53	<void>:struct _XIMFilter
17	main.c:Artmode	54	<void>:struct _XExten
18	main.c:SUN_YORIGIN	55	<void>:struct _XContextDB
19	main.c:SUN_XORIGIN	56	<void>:struct _XFreeFuncs
20	main.c:pix_sw	57	<void>:struct _XSQEvent
21	X11/Xlib.h:XDrawString	58	<void>:struct _XDisplayAtoms
22	/usr/include/stdio.h:sprintf	59	X11/Xlib.h:struct Xlib_h_20
23	icons/icon.littlepoint:littlepoint_pm	60	X11/Xlib.h:struct Xlib_h_7
24	X11/Xlib.h:struct Xlib_h_3	61	X11/Xlib.h:struct _XExtData
25	X11/Xlib.h:XFontStruct	62	X11/Xlib.h:XPointer
26	icondata.c:mpr_static	63	X11/Xlib.h:struct Xlib_h_6
27	gremlin.h:PMRec	64	X11/Xlib.h:struct Xlib_h_56
28	X11/Xlib.h:Display	65	X11/Xlib.h:struct Xlib_h_55
29	gremlin.h:FALSE	66	X11/X.h:Atom
30	X11/X.h:Window	67	X11/Xlib.h:Depth
31	X11/Xlib.h:GC	68	X11/X.h:Colormap
32	gremlin.h:struct PMRec	69	X11/X.h:KeyCode
33	X11/X.h:Font	70	X11/Xlib.h:Visual
34	X11/Xlib.h:struct _XDisplay	71	X11/Xlib.h:struct Xlib_h_5
35	X11/Xlib.h:Bool	72	X11/Xlib.h:struct Xlib_h_4
36	X11/Xlib.h:struct _XGC	73	X11/X.h:VisualID
37	X11/X.h:Pixmap		

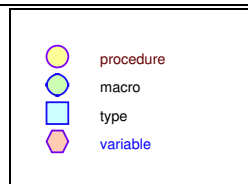


Figure 4: Graph B95 descriptions.

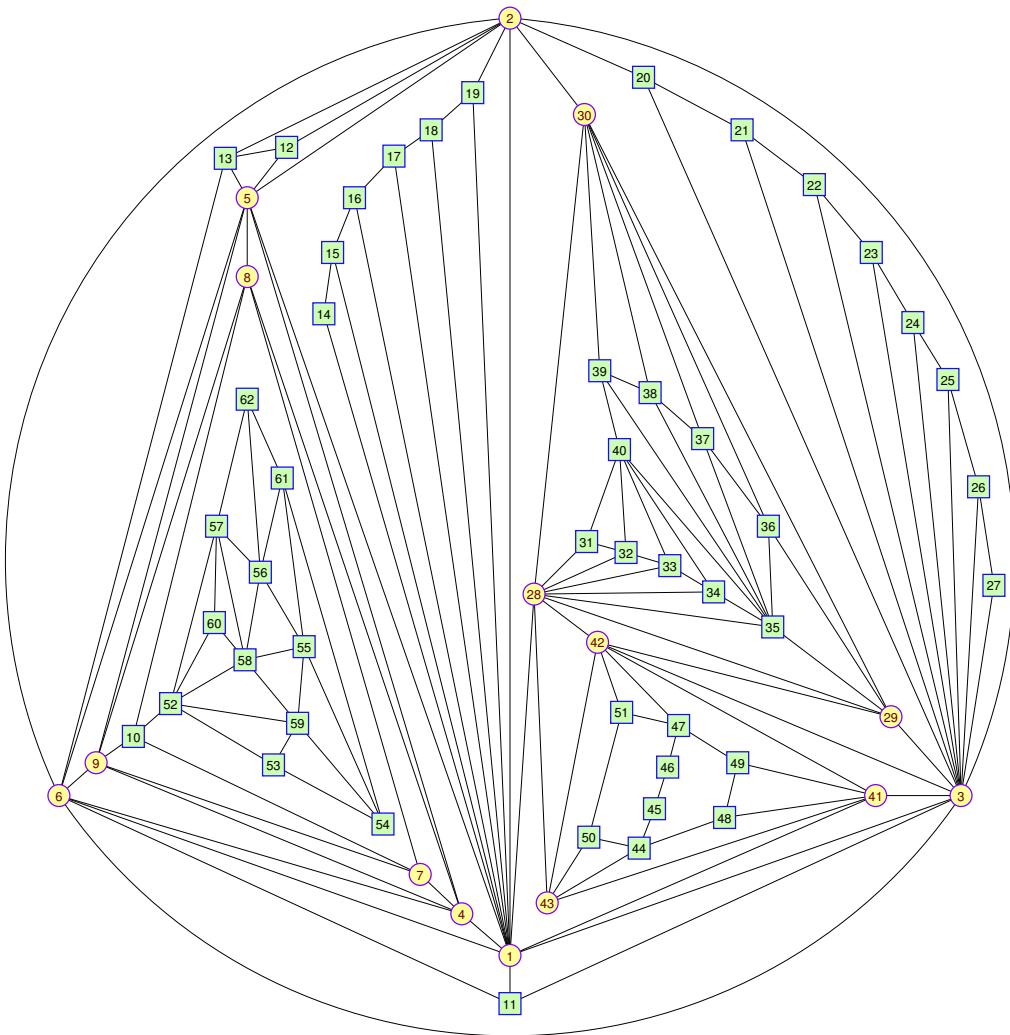


Figure 5: Graph C95 (*first prize*).

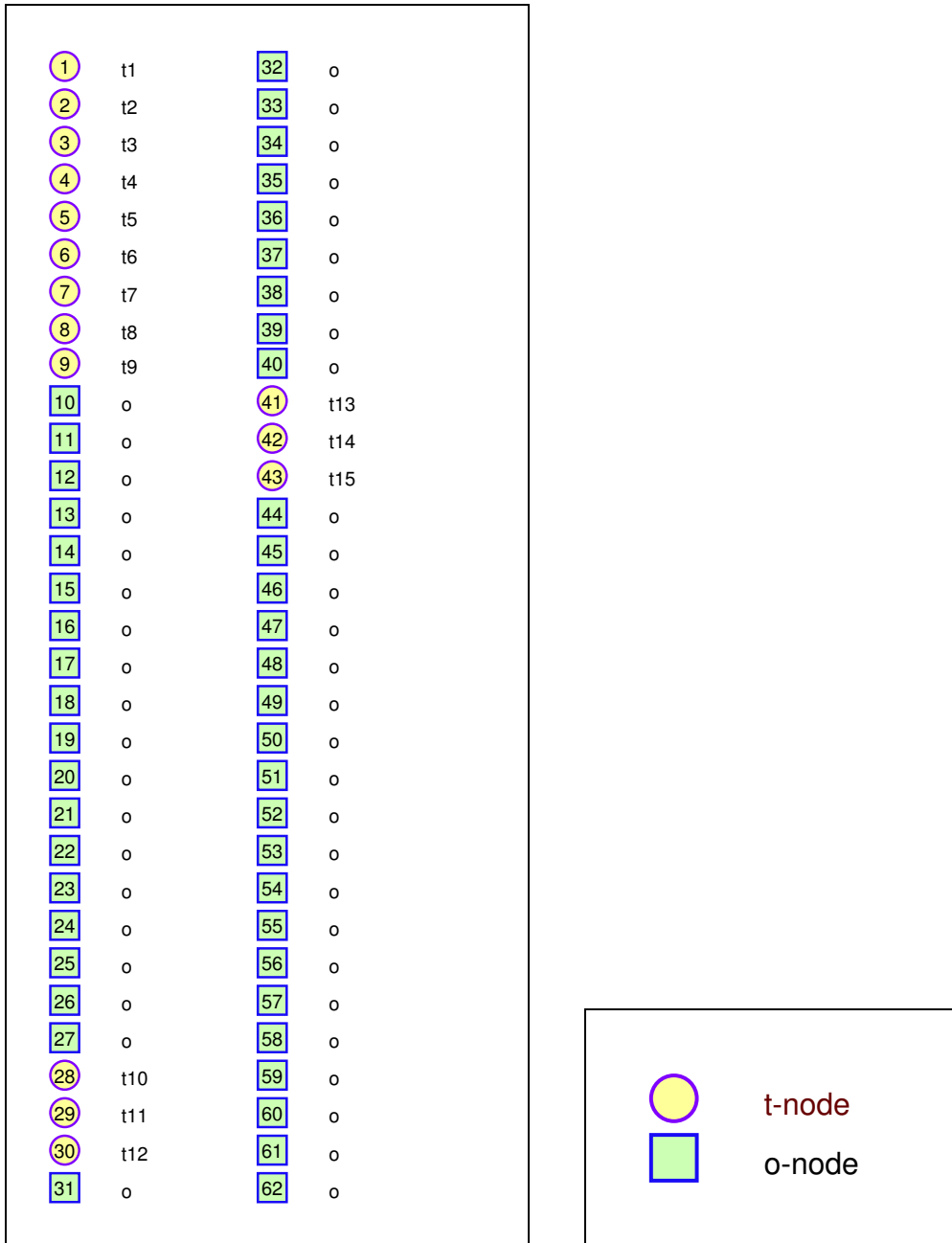


Figure 6: Graph C95 descriptions.

Layouts for Graph Drawing Contest 1996

In 1996 Graph Drawing Conference was held in Berkeley, and the contest was organized by Peter Eades, Joe Marks, and Stephen North. Rules and data are described at:

<http://portal.research.bell-labs.com/orgs/ssr/people/north/contest.html>

Graph B96

- First layout was obtained automatically using our program COORD. (positioning vertices on the rectangular net so that the number of crossings of lines is as low as possible).
- Manual editing was performed to reposition vertices using our graph picture editor DRAW.

The layout was awarded the honorable mention.

Graph C96

- Analysing graph C using our program RELCALC two parts and 2 connecting vertices were found.
- Each part was handled separately using our program ENER (minimisation of energy). One part consists of a lattice structure, and the second of a planar graph of cylindrical symmetries. This spatial picture was realized in VRML (produced from the description in our graph description language NetML based on SGML).
- Some manual editing was done for planar representation.

The layout was awarded the first prize.

Graph D96

- Analysing graph D using program RELCALC 17 important vertices of 'kernel graph' were found.
- The first layout for these 17 vertices was obtained automatically using program COORD.
- Other vertices were added to the obtained picture.
- Some manual editing using DRAW was performed to reposition vertices to avoid crossings.

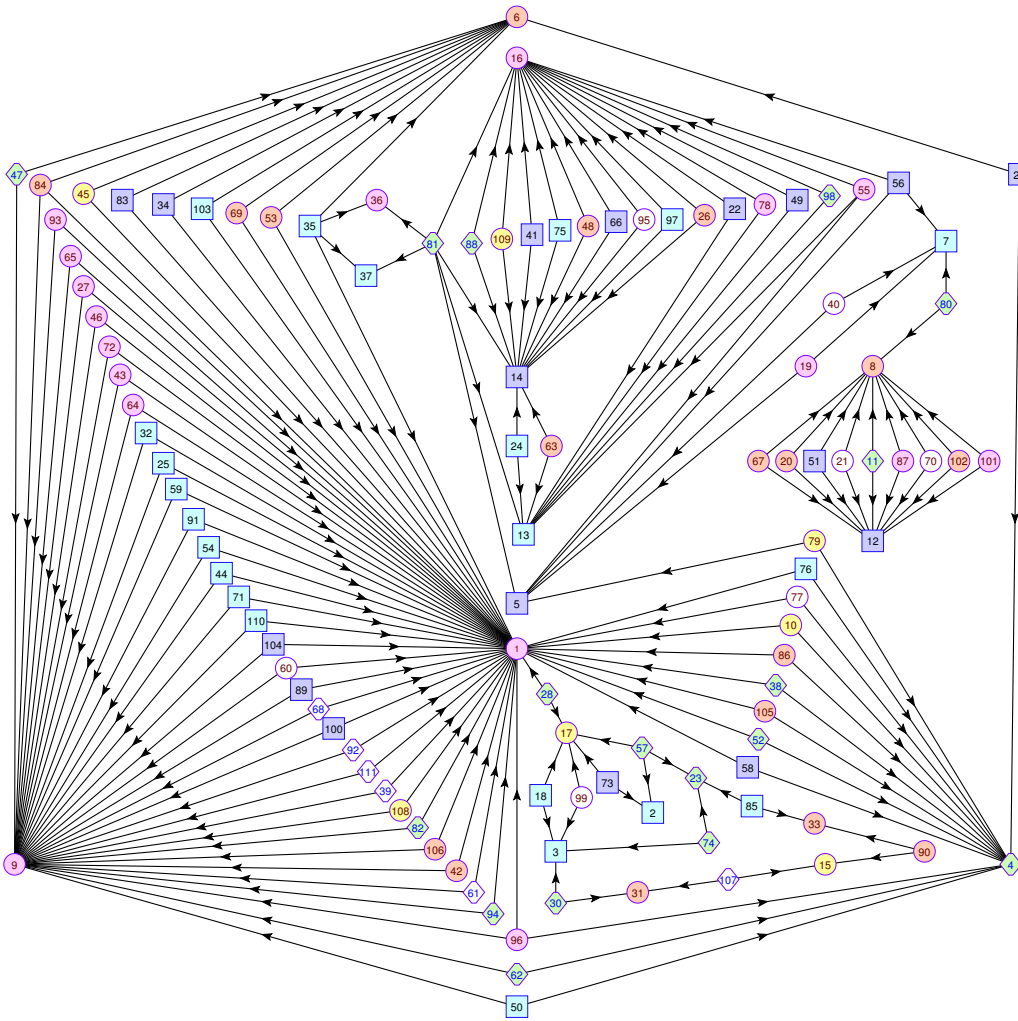


Figure 7: Graph B96 (*honorable mention*).

See: <http://vlado.fmf.uni-lj.si/pub/gd/gd96.htm>

The complete report of the contest is available in [10] and:

<http://www.merl.com/reports/TR96-24/index.html>









	207-555
	415-555
	303-555
	617-555
	313-555
	406-555
	304-555
	603-555

Figure 8: Graph B96 types.

1	207-555-8248	38	303-555-4543	75	415-555-7602
2	415-555-2188	39	603-555-8148	76	415-555-1197
3	415-555-6033	40	304-555-0171	77	304-555-4660
4	303-555-4393	41	617-555-9925	78	207-555-1676
5	617-555-9765	42	313-555-9243	79	406-555-1285
6	313-555-0329	43	207-555-0740	80	303-555-2769
7	415-555-7962	44	415-555-2401	81	303-555-0275
8	313-555-8563	45	406-555-8930	82	303-555-6481
9	207-555-1803	46	207-555-0541	83	617-555-6257
10	406-555-0836	47	303-555-0357	84	313-555-2978
11	303-555-7955	48	313-555-4753	85	415-555-8812
12	617-555-9260	49	617-555-6133	86	313-555-0515
13	415-555-2398	50	415-555-6062	87	207-555-8520
14	617-555-0991	51	617-555-0414	88	303-555-7189
15	406-555-5903	52	303-555-2707	89	617-555-4734
16	207-555-4248	53	313-555-4005	90	313-555-5268
17	406-555-4676	54	415-555-0590	91	415-555-5279
18	415-555-0323	55	207-555-2669	92	603-555-1213
19	207-555-8659	56	617-555-6988	93	207-555-9822
20	313-555-3853	57	303-555-6300	94	303-555-0386
21	304-555-8484	58	617-555-5542	95	304-555-5661
22	617-555-3290	59	415-555-5266	96	207-555-7281
23	303-555-9878	60	304-555-9496	97	415-555-8355
24	415-555-4689	61	603-555-4321	98	303-555-8576
25	415-555-6317	62	303-555-6429	99	304-555-2354
26	313-555-0122	63	313-555-1356	100	617-555-1958
27	207-555-0648	64	207-555-8635	101	207-555-5013
28	303-555-6833	65	207-555-0710	102	313-555-7592
29	617-555-1436	66	617-555-5575	103	415-555-5058
30	303-555-1565	67	313-555-0778	104	617-555-9344
31	313-555-2906	68	603-555-6565	105	313-555-4790
32	415-555-8267	69	313-555-5007	106	313-555-7556
33	313-555-2583	70	304-555-5167	107	603-555-0525
34	617-555-9630	71	415-555-5908	108	406-555-5703
35	415-555-3330	72	207-555-3394	109	406-555-8517
36	207-555-7807	73	617-555-9206	110	415-555-6423
37	415-555-8627	74	303-555-9223	11	603-555-5694

Figure 9: Graph B96 labels.

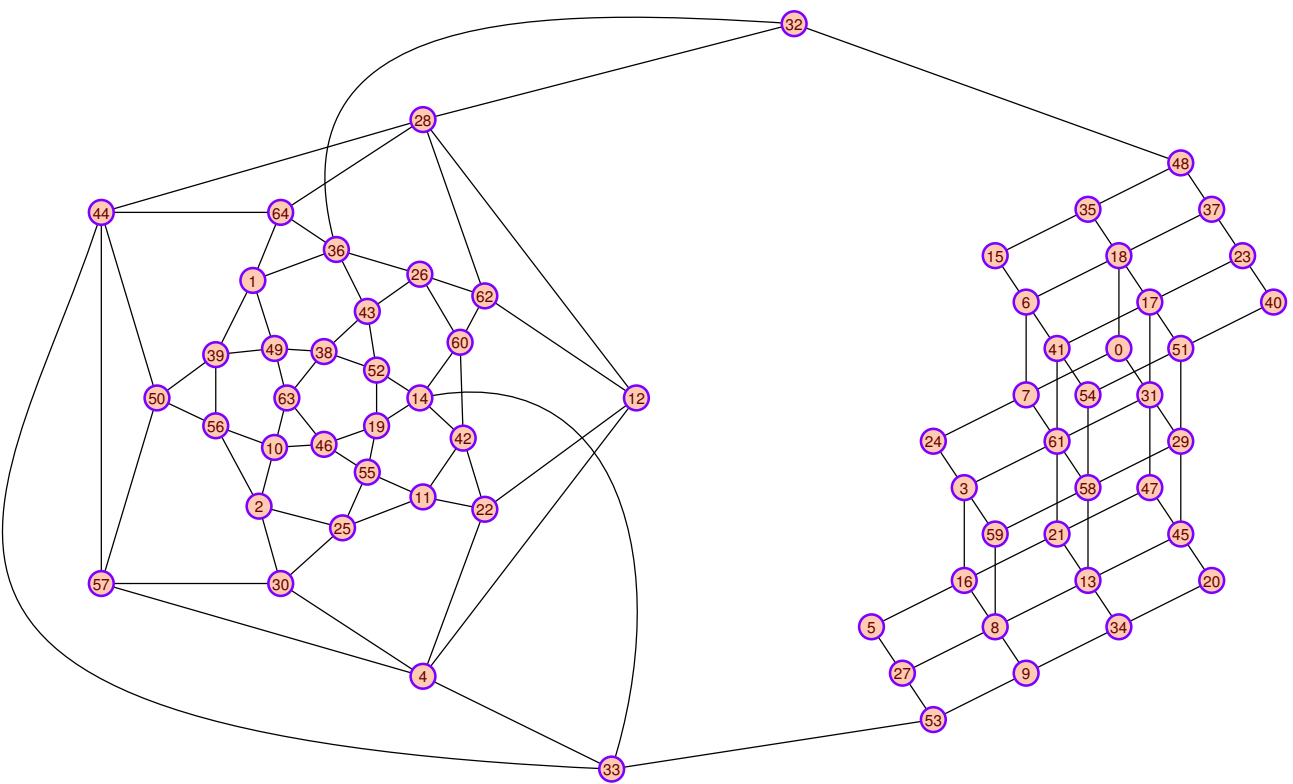


Figure 10: Graph C96 (*first prize*).

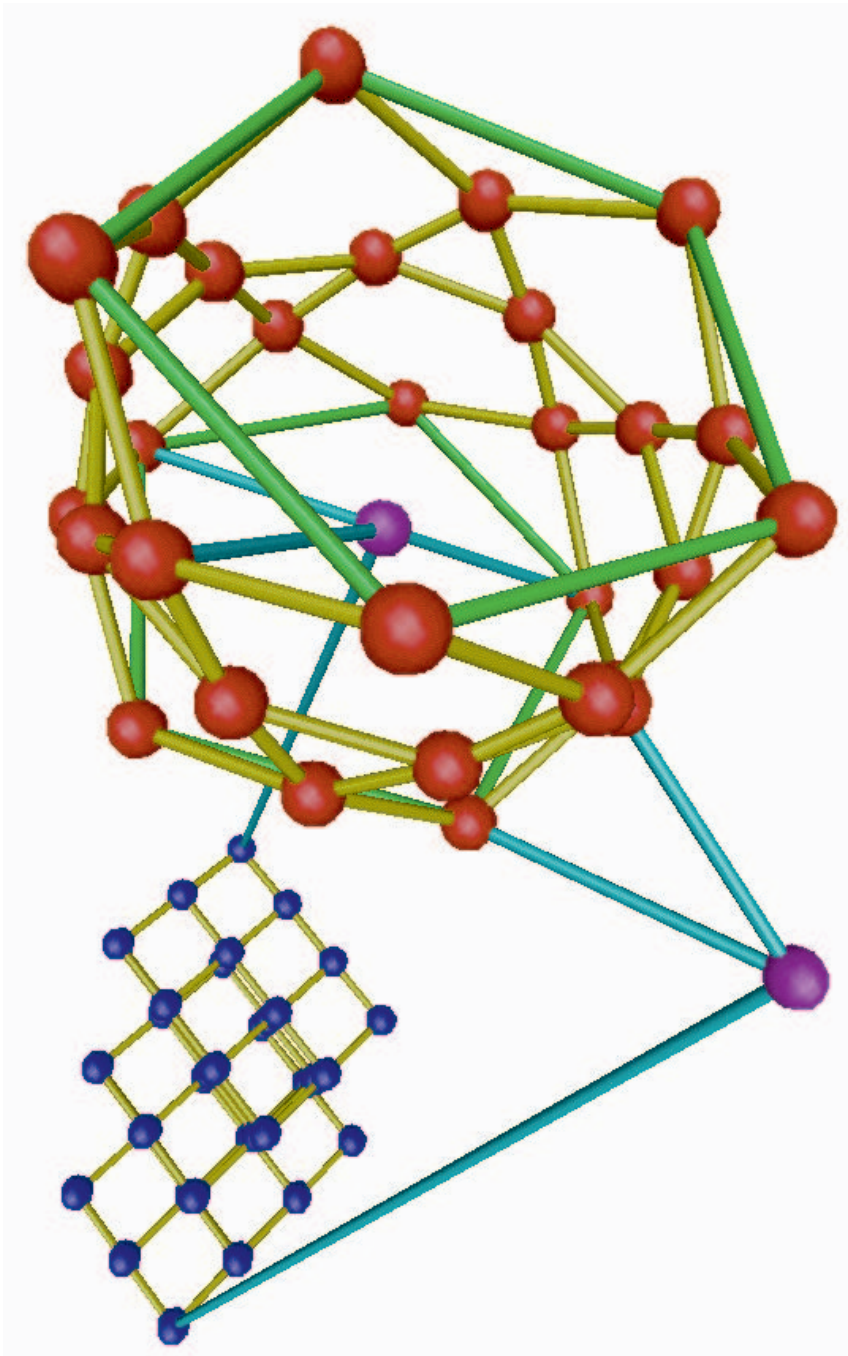


Figure 11: Graph C96 / VRML snapshot.

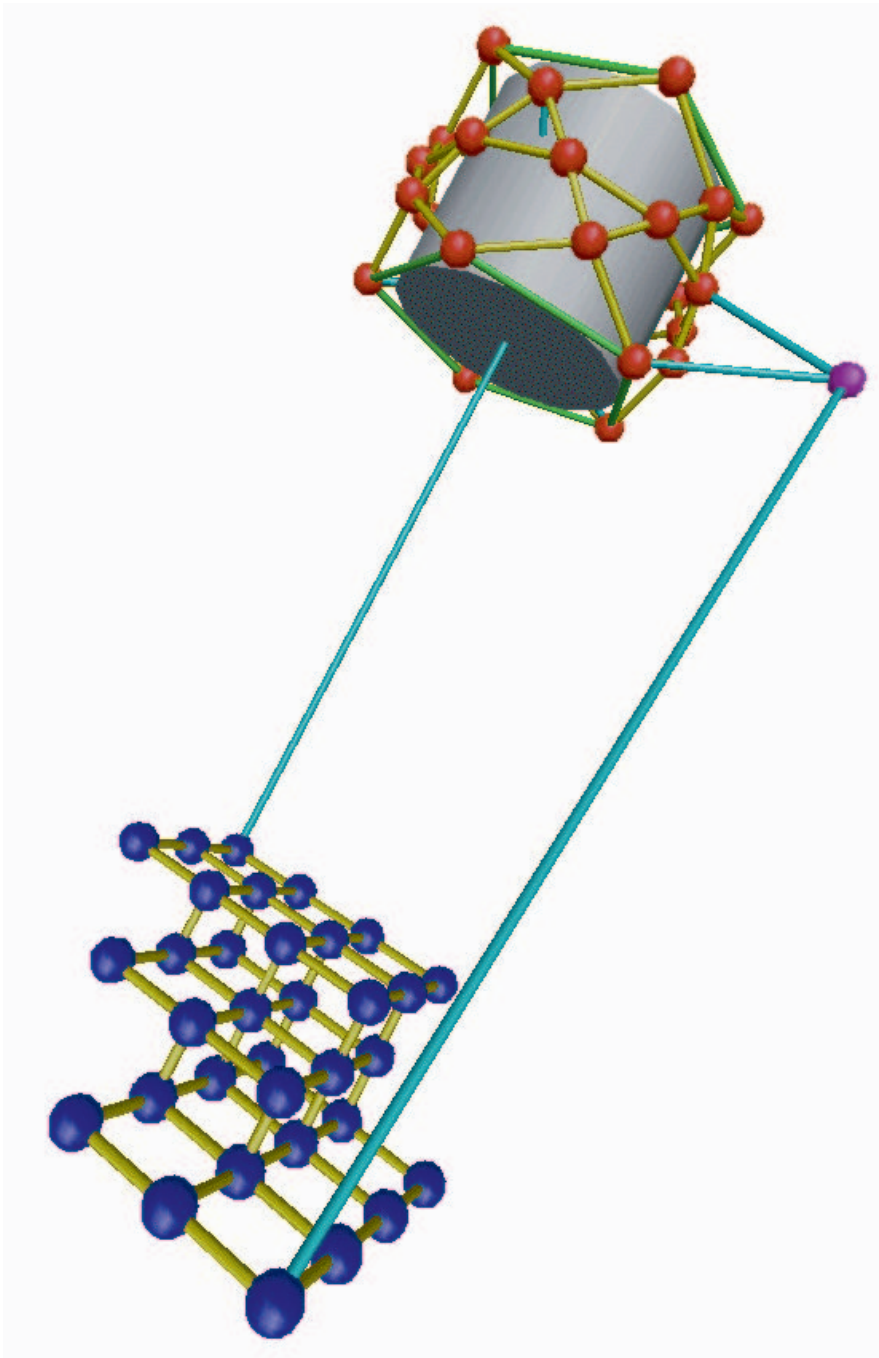


Figure 12: Graph C96 with cylinder / VRML snapshot.

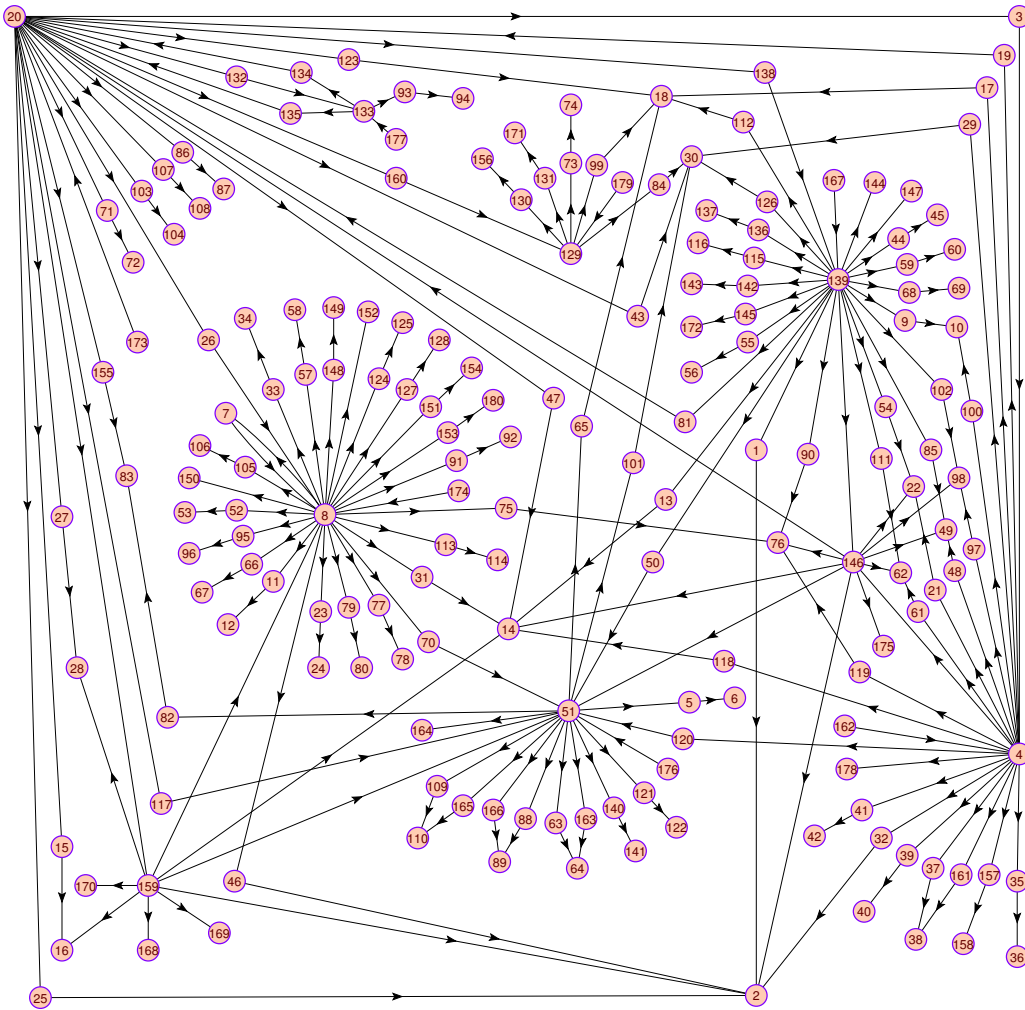


Figure 13: Graph D96.

1	For Your Business	37	label1	73	Surfing for Savings?	109	You Will	145	http://www.att.com/easycommerce/images/w
2	http://www.att.com/work/	38	http://www.att.com/hr/employmentmatrix	74	http://www.att.com/indiahorizons/connect	110	http://www.att.com/youwill/	146	http://www.att.com/images/tbar2.gif
3	Employment	39	label2	75	On The Go	111	Write To Us	147	http://www.att.com/images/itlogo_6the.gif
4	http://www.att.com/hr/	40	http://www.att.com/hr/employmentprof_de	76	http://www.att.com/onthego/	112	Copyright	148	http://www.att.com/news/_images/topnav
5	800 number	41	label3	77	Now shipping: Windows NT developer's kit	113	AT&T WorldNet Service officially availab	149	http://www.att.com/maps/topnav.map
6	http://www.tdfrhs.att.net/d800	42	http://www.att.com/hr/employmentsupport	78	http://www.att.com/press/0396/960312.gba	114	http://www.att.com/press/0396/960314.bsa	150	http://www.att.com/news/images/newshead
7	News for the Month	43	webmaster@att.com	79	Business Network	115	Calendar	151	http://www.att.com/news/images/news/side
8	http://www.att.com/news/	44	AT&T EasyLink Services (SM)	80	http://www.att.com/bnet/	116	http://www.att.com/easycommerce/easycomc	152	http://www.att.com/news/images/news/subg
9	AT&T Corporate Server Team	45	http://www.att.com/easycommerce/easylink	81	AT&T Home Page	117	Home	153	http://www.att.com/news/images/news/newsheads
10	http://www.att.com/homes/	46	For Your Business	82	AT&T Universal Card	118	On The Net	154	http://www.att.com/news/images/news/side.map
11	Library	47	Net	83	http://www.att.com/ucs/	119	On The Go	155	http://www.att.com/images/hpau20.gif
12	http://www.att.com/library/	48	AT&T A-Z	84	webmaster@att.com	120	For Your Home	156	http://www.mckinley.com/
13	On The Net	49	http://www.att.com/atoz	85	AT&T A-Z	121	calling plan	157	http://www.att.com/hr/employment/images/
14	http://www.att.com/net/	50	For Your Home	86	Search	122	http://www.att.com/hr/truefacts.html	158	http://www.att.com/hr/employment/trav.map
15	Lucent Technologies	51	http://www.att.com/home	87	http://www.att.com/search.html	123	Copyright	159	http://www.att.com/images/index.gif
16	http://www.att.com/lucent	52	CHI to offer AT&T and Unisource voice an	88	TrueVoice	124	AT&T A-Z	160	http://www.att.com/images/hpau19.gif
17	Copyright	53	http://www.att.com/press/0396/960313.bsa	89	http://www.att.com/hr/truevoice.html	125	http://www.att.com/news/_/atoz.html	161	http://www.att.com/hr/employment/images/
18	http://www.att.com/copyright.html	54	Site Map	90	On The Go	126	webmaster@att.com	162	AT&T - Employment Opportunities
19	AT&T Home Page	55	AT&T Easy World Wide Web (SM)	91	Home Page	127	Sonet T155 service gets first additrop m	163	http://www.att.com/images/homesoku.gif
20	http://www.att.com/	56	http://www.att.com/easycommerce/easywww	92	http://www.att.com/index.html	128	http://www.att.com/press/0396/960313.bsb	164	http://www.att.com/images/athome.gif
21	Site Map	57	Search	93	Thanks to the new telecommunication's law	129	http://www.att.com/indiahorizons/	165	http://www.att.com/images/youwill2.gif
22	http://www.att.com/sitemap	58	http://www.att.com/news/_/search.html	94	http://www.att.com/press/0296/960208.cha	130	http://www.att.com/indiahorizons/images/	166	http://www.att.com/images/youwill.gif
23	Conferences	59	Wenik@attmail.com	95	Write To Us	131	http://www.att.com/indiahorizons/images/	167	AT&T EasyCommerce Services
24	http://www.att.com/news/conferences.html	60	mailto:tslenik@attmail.com	96	http://www.att.com/news/_/write.html	132	http://www.att.com/images/hpau28.gif	168	http://www.att.com/maps/index.map
25	Work	61	Write To Us	97	Search	133	http://www.att.com/net/yougott.html	169	http://www.att.com/infocenter/toc.html
26	label0	62	http://www.att.com/write/	98	http://www.att.com/search/	134	http://www.att.com/images/g72cv.gif	170	http://www.att.com/microscopes/microscap
27	Globe	63	Home Solutions	99	Copyright	135	http://www.att.com/net/yougott.html/ima	171	http://www.att.com/indiahorizons/home.ht
28	http://www.att.com/providers	64	http://www.att.com/home/homesol.html	100	AT&T Corporate Server Team	136	http://www.att.com/easycommerce/images/t	172	http://www.att.com/easycommerce/whatnew
29	webmaster@att.com	65	Copyright	101	webmaster@att.com	137	http://www.att.com/easycommerce/document	173	AT&T Home Page
30	mailto:webmaster@att.com	66	New U transceiver chips enable lower cos	102	Search	138	http://www.att.com/images/hpau06.gif	174	AT&T Newsroom
31	On The Net	67	http://www.att.com/press/0396/960312.mea	103	What's New!	139	http://www.att.com/easycommerce/	175	http://www.att.com/maps/bar2.map
32	For Your Business	68	AT&T Global Alliance Marketing	104	http://www.att.com/whatsnew.html	140	http://www.att.com/images/bar.gif	176	AT&T at Home
33	Speeches Online	69	http://www.att.com/easycommerce/alliance	105	Site Map	141	http://www.att.com/maps/bar.map	177	You Got It.
34	http://www.att.com/news/speeches	70	For Your home	106	http://www.att.com/news/_/sitemap.html	142	http://www.att.com/easycommerce/images/h	178	http://www.att.com/hr/employment/images/
35	label0	71	InfoCenter	107	Index	143	http://www.att.com/easycommerce/home.map	179	AT&T India Horizons
36	http://www.att.com/hr/employment/overvie	72	http://www.att.com/infocenter	108	http://www.att.com/infocenter/attindex.h	144	http://www.att.com/easycommerce/images/m	180	http://www.att.com/press/

Figure 14: Graph D96 labels.

Layouts for Graph Drawing Contest 1997

In 1997 Graph Drawing Conference was held in Rome and the contest was organised by Peter Eades, Joe Marks, and Stephen North. Rules and data are described at:

<http://portal.research.bell-labs.com/orgs/ssr/people/north/contest.html>

Graph A97

- First layout was obtained automatically using `draw/eigenvalues` option in program `Pajek`. Manual editing was used to reposition vertices in the grid to obtain orthogonal layout in plane.

The layout was awarded the first prize.

- Manual editing in 3D was performed to get orthogonal embeddings in space: minimal, symmetric and cube.

Graph B97

- Analysing graph B using our program `MODEL` we obtained (almost) regular partition in 3 classes. The third class contains only vertex `Harmony Central`. The second class, represented by squares, contains 11 vertices that are connected only to the vertices in the class 1 (represented by circles). Vertices in class 1 are also connected to other vertices in the same class. We first drew all vertices in the class 1 in the center and vertices in class 2 separately – using class shrinking and circular drawing options in `Pajek`. Afterward we manually moved vertices of class 1 connected to only one vertex of class 2 close to this vertex. Finally we manually arranged the remaining vertices of class 1.
- We transformed given similarities s on arcs to dissimilarities $d = \frac{1}{1+s}$ and applied Ward's hierarchical clustering method to the obtained dissimilarity matrix. We produced a clustering into 12 clusters, shrank the graph using `Pajek`, and draw the obtained skeleton minimizing the number of crossings. Finally we manually arranged the vertices of original graph.

The layout was awarded the first prize.

See also

<http://vlado.fmf.uni-lj.si/pub/gd/gd97.htm>

The complete report is available in [7] or at

<http://www.merl.com/reports/TR97-16/index.html>

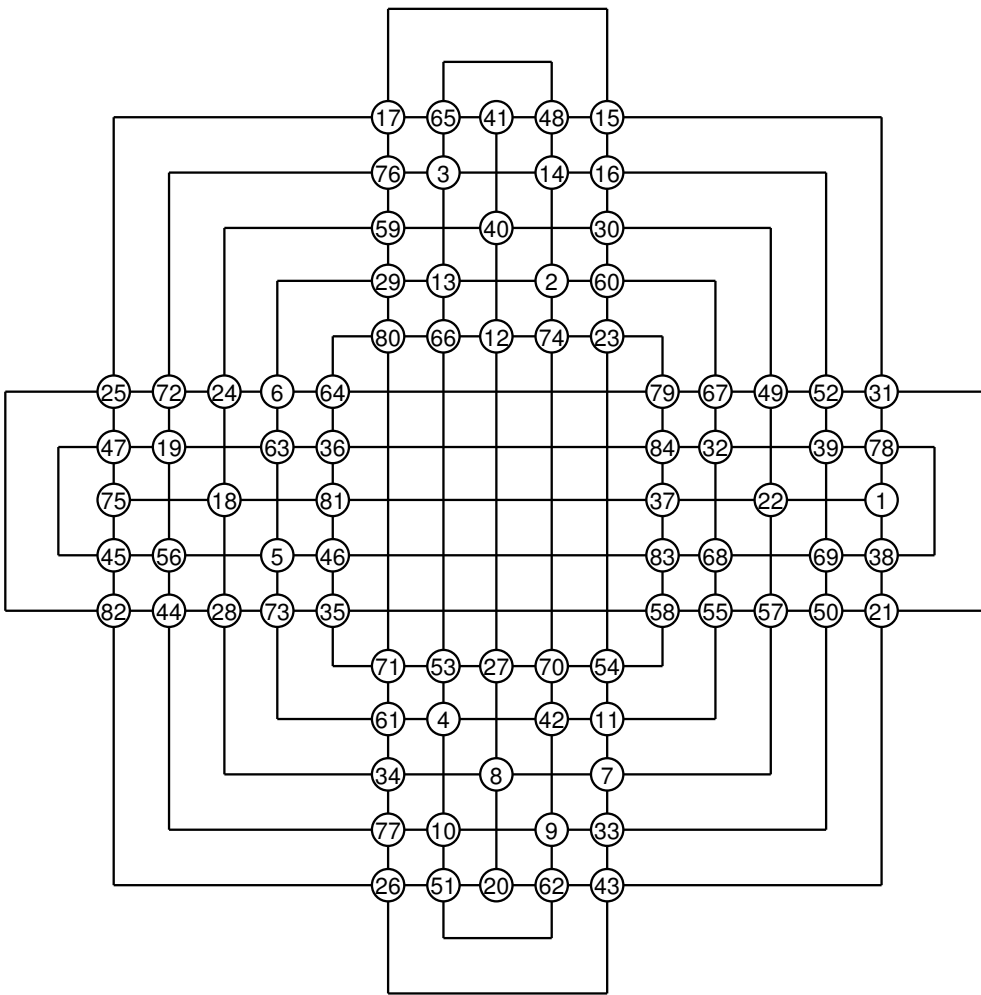


Figure 15: Graph A97 – orthogonal layout in plane (*first prize*).

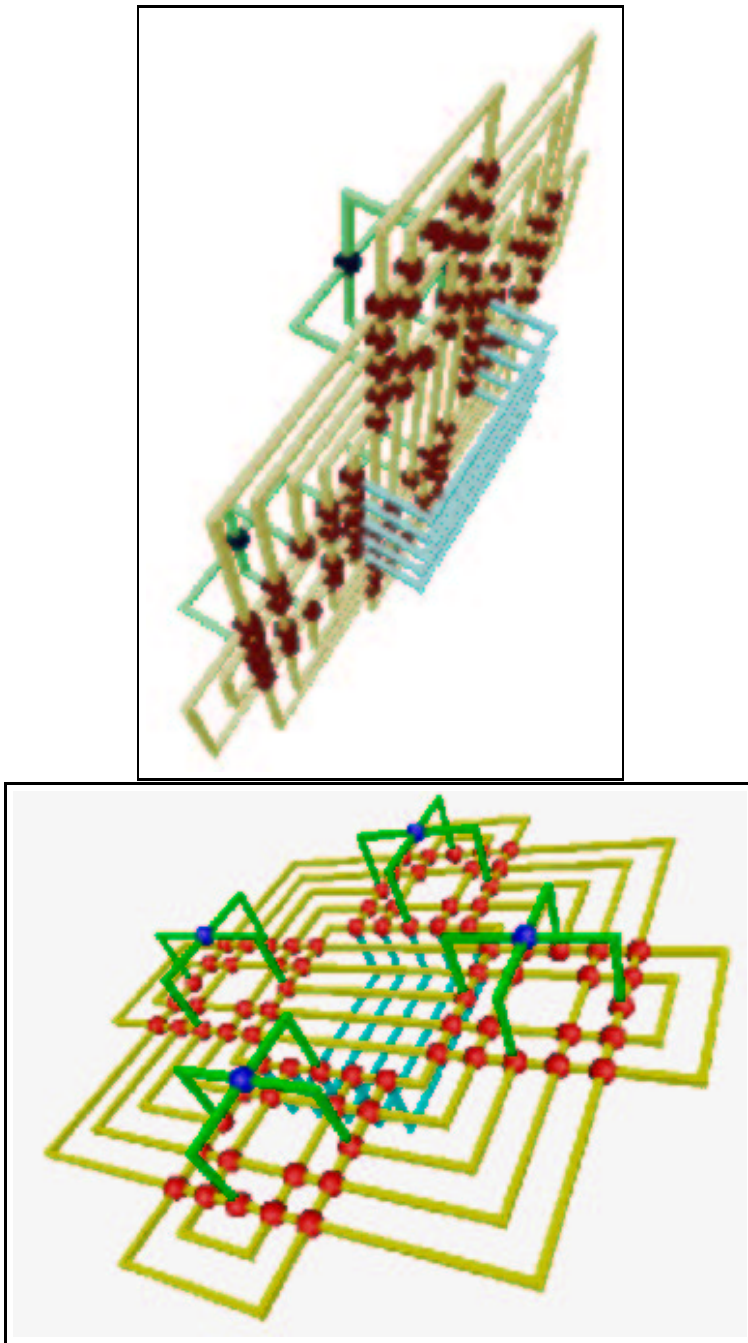


Figure 16: Graph A97 – 3D minimal / VRML snapshot.

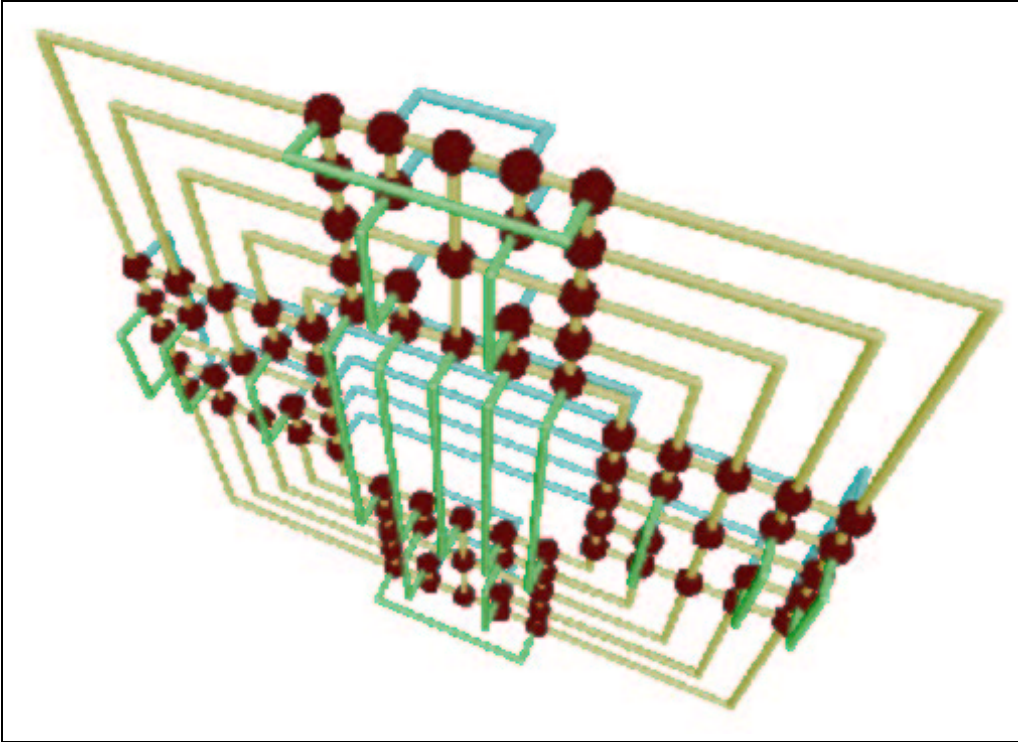


Figure 17: Graph A97 – 3D symmetric / VRML snapshot.

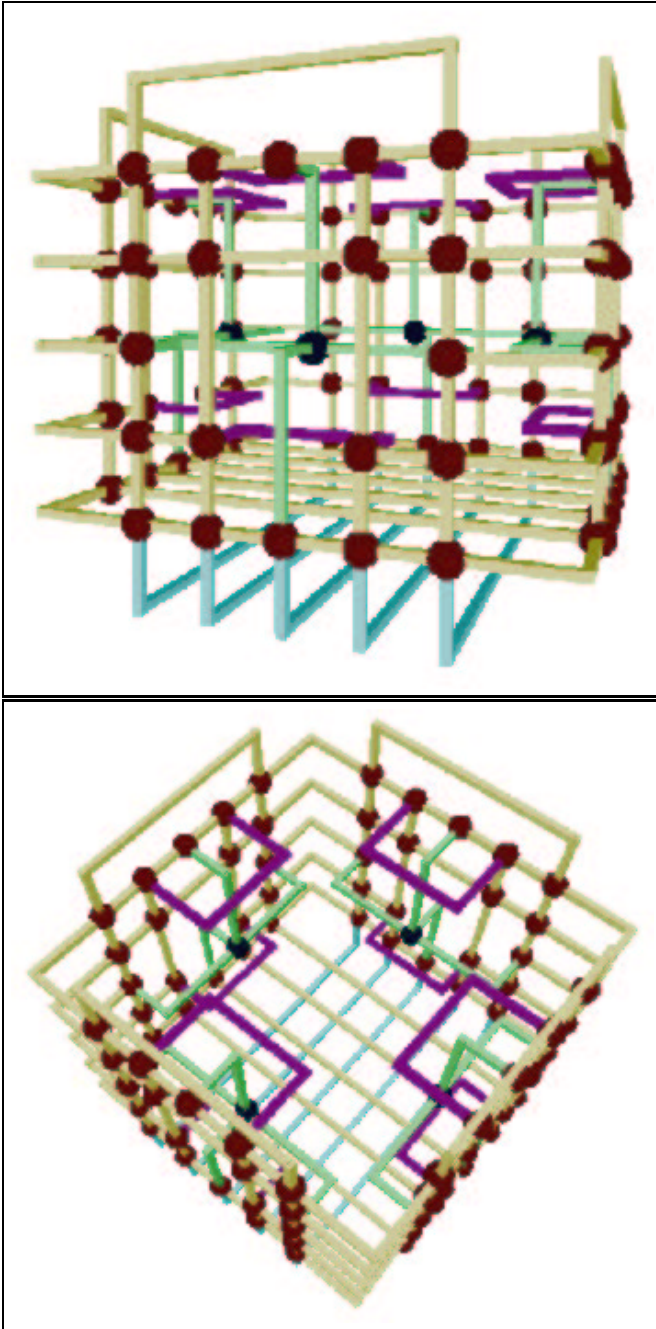


Figure 18: Graph A97 – 3D cube / VRML snapshot.

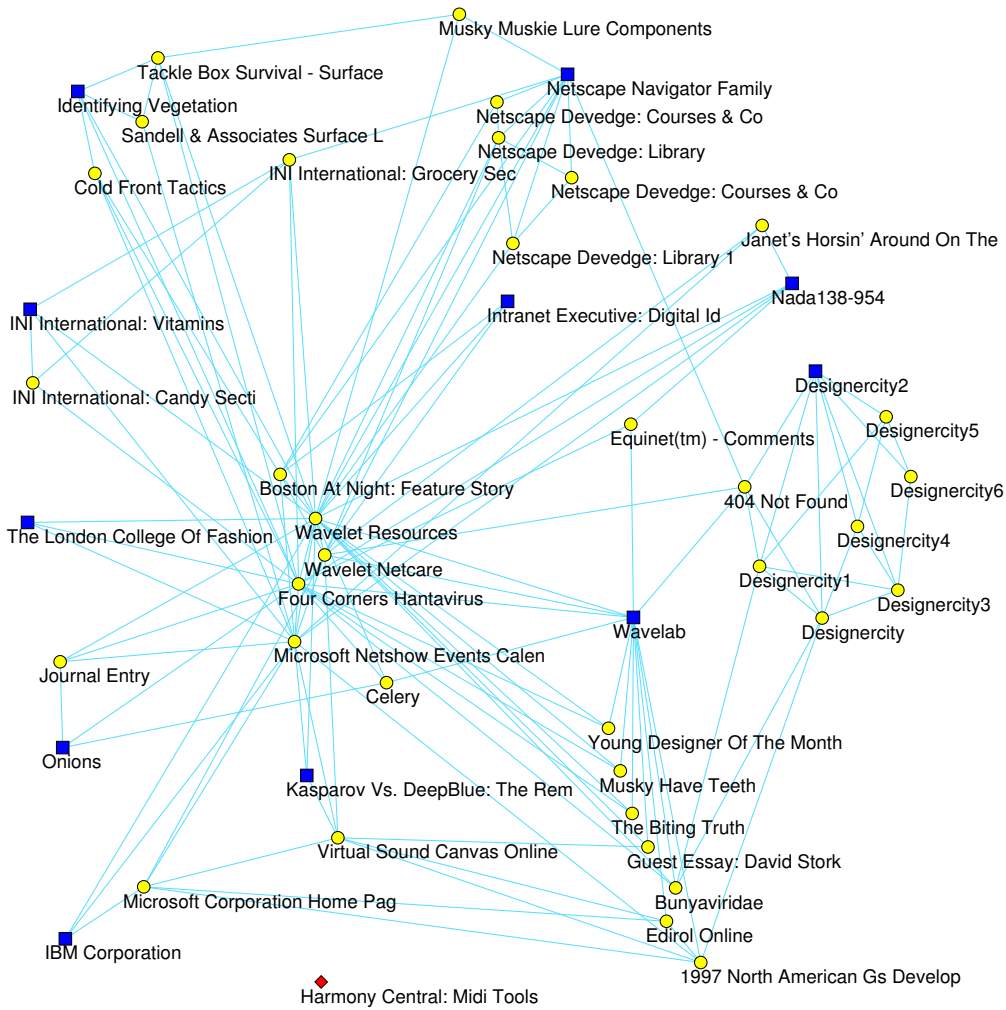


Figure 19: Graph B97 – regular equivalence.

CLUSE – ward [0.0, 4.80]
Graph B / GD'97

Sep- 8-1997

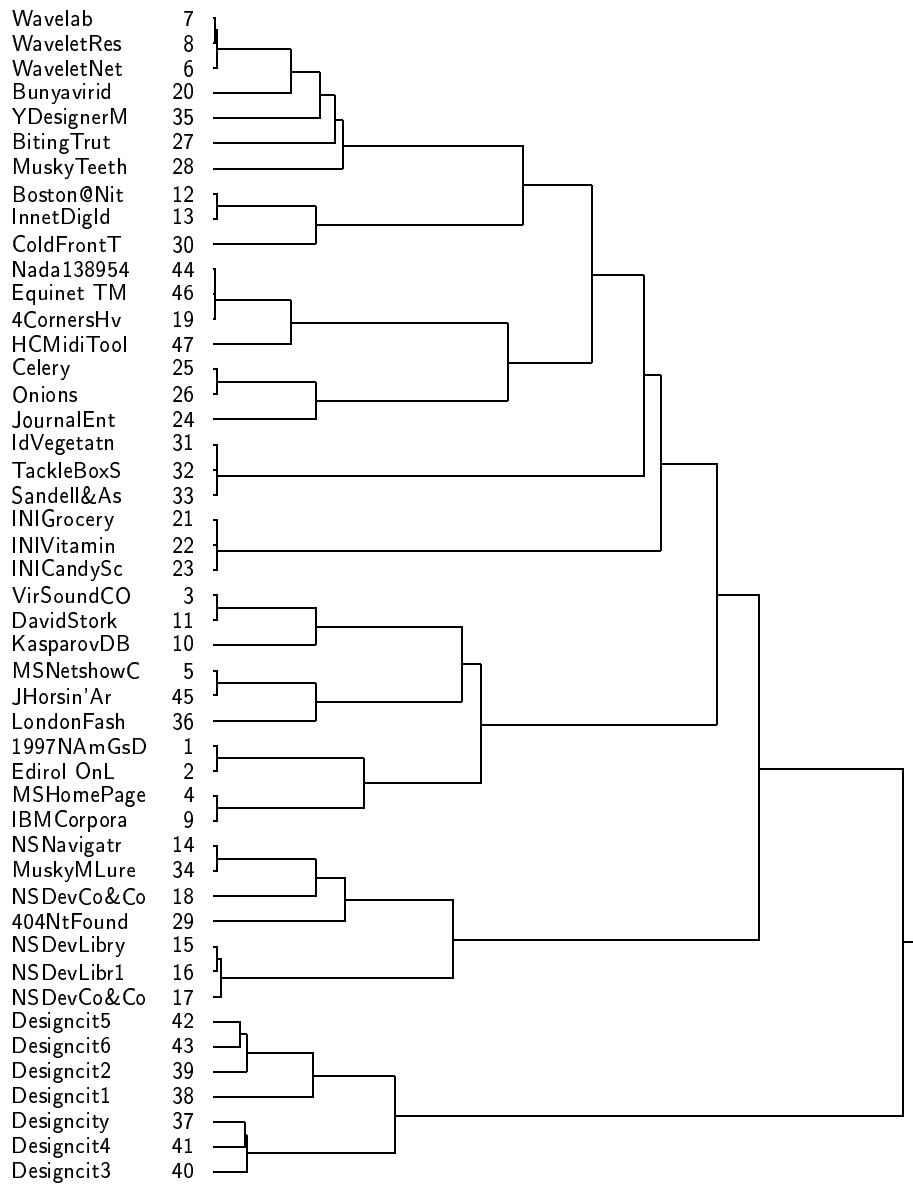


Figure 20: Graph B97 – Dendrogram for Ward's method.

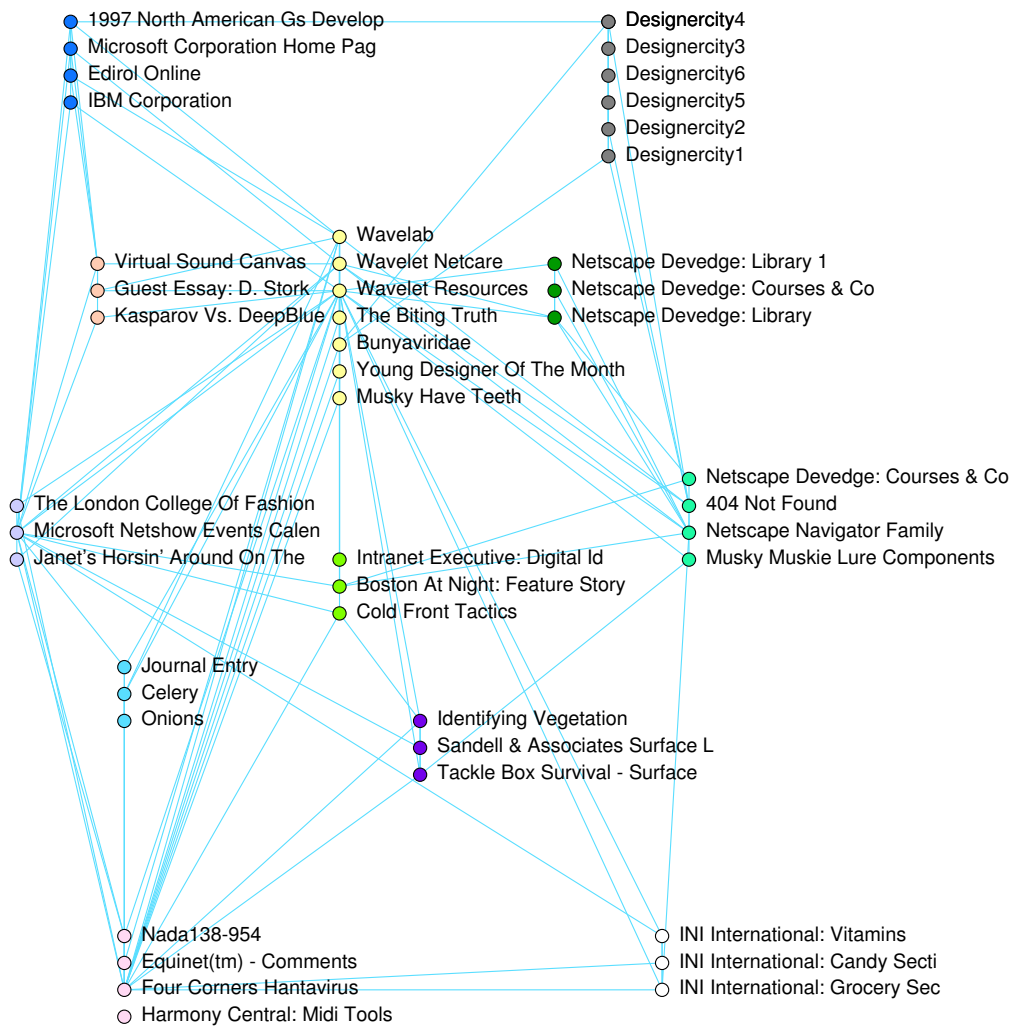


Figure 21: Graph B97 – Ward's clustering (*first prize*).

Layouts for Graph Drawing Contest 1998

In 1998 Graph Drawing Conference was held in Montreal and the contest was organised by Peter Eades, Joe Marks, Petra Mutzel, and Stephen North. Rules and data are described at:

<http://gd98.cs.mcgill.ca/contest/>

All work was done using our program package `Pajek`, which is freely available at:

<http://vlado.fmf.uni-lj.si/pub/networks/pajek/>

Graph A98

The data for graph A consist of addition and deletion operations that specify how the graph changes over time. In our solution addition and deletion operations were performed using macro language which is recognized by program package `Pajek`. Then we used `Microsoft Camcorder` (free software) to record the process. Selected layouts in three different time points are shown.

Graph B98

Symmetries in graph (with some exceptions) can easily be noticed. We started the drawing using the layout obtained using Fruchterman-Reingold spring embedder. Later we used manual editing to maximize symmetries and made some displacements according to different sizes and shapes of nodes. `Pajek` was used to do all the work.

The layout was awarded the first prize.

Graph C98

Using spring embedders we could not get any nice layouts. Analysing graph we found that it is a symmetric cubic graph. Later we used eigenvectors approach and computed eigenvectors of neighbourhood matrix that correspond to the largest eigenvalue (which is multiple). In this way we got nice symmetric picture in space (3D). According to symmetries (equivalences) some of the nodes are drawn on the same positions and some are overlapping when selecting the certain view to see the symmetries. Since some vertices are overlapping we built a list of overlapping vertices drawn in different colors:

Graph D98

There were no data available for this graph. The participants could send any picture that is inspired or related to graph drawing. We decided to generate graph from dictionary and sent some interesting subgraph of it.

Table 1: Overlapping vertices in graph C98

Group	Color	Vertices
1.	Yellow	13, 76
2.	Green	9, 12, 33,106
3.	Pink	39, 65, 88,112
4.	Blue	5, 20, 51, 63
5.	Fuchsia	68, 75, 85, 92
6.	White	36, 99
7.	Orange	21, 42
8.	Purple	23, 24, 55, 89
9.	NavyBlue	30, 44, 54, 57
10.	TealBlue	3, 11, 43,101
11.	OliveGreen	1, 18, 64, 74, 91,103,104,107
12.	Gray	19, 26, 47, 59
13.	Black	17, 40, 70, 79
14.	Maroon	48, 53
15.	LightGreen	25, 32, 35, 60, 66, 71, 73,105
16.	Cyan	10,102
17.	Yellow	2, 22, 81, 90
18.	Green	14, 58, 61, 83
19.	Pink	4, 15, 46, 52, 77, 78,109,110
20.	Blue	7, 8, 27, 41
21.	Fuchsia	6, 50, 67, 96
22.	White	82, 84, 95, 97
23.	Orange	31, 80
24.	Purple	16, 29, 98,108
25.	NavyBlue	38, 72, 86, 87
26.	TealBlue	37, 45
27.	OliveGreen	28, 62, 93,111
28.	Gray	34, 49, 56,100
29.	Black	69, 94

Large graph can be generated from words in a dictionary. We constructed a graph in which two words are connected iff one can be obtained from the other by changing single character (e. g. WORK – WORD) or by adding/deleting one character (e.g. EVER – FEVER). Then we took english words graph-drawing-contest, find all shortest paths between graph and drawing and between drawing and contest, draw the obtained graph using layers option in Pajek (layers are determined by distance from drawing). Additionally we added two puzzles:

- one difficult: find shortest paths alone,

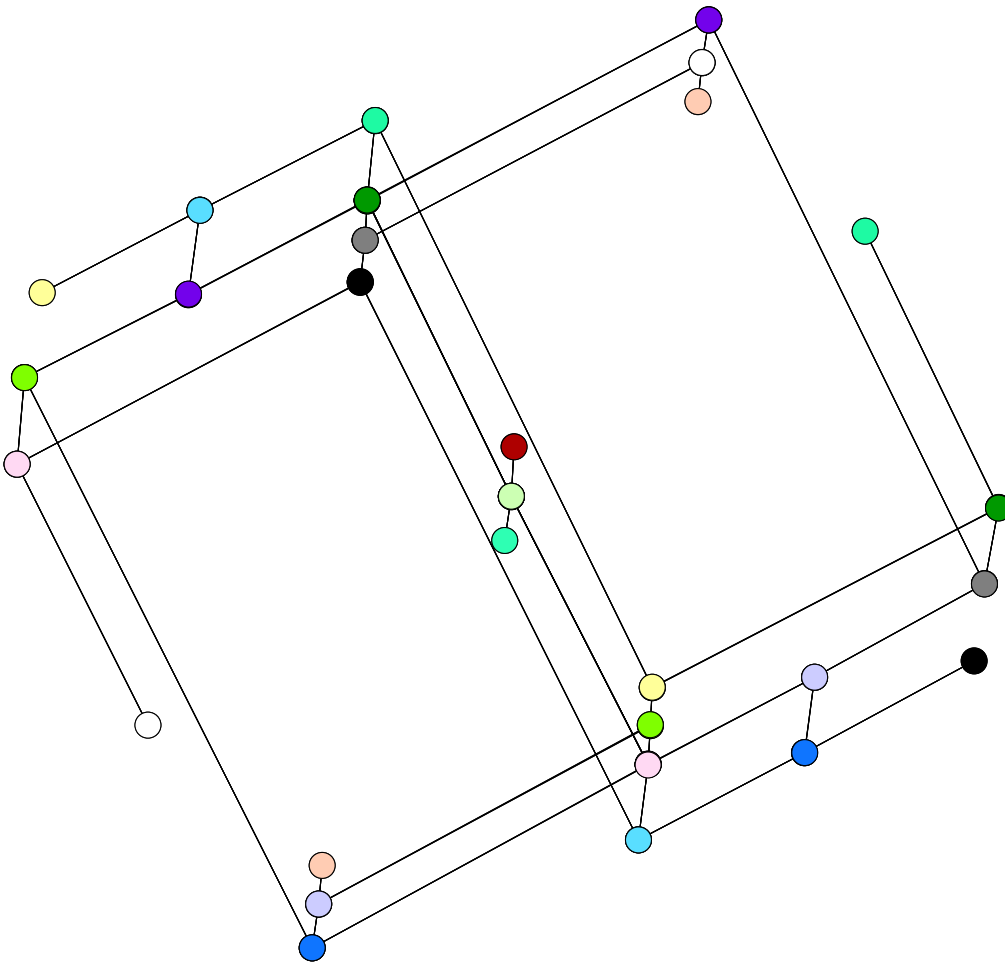


Figure 22: Graph C98.

- one easy: find only missing words on the paths.

See also: <http://vlado.fmf.uni-lj.si/pub/gd/gd98.htm>

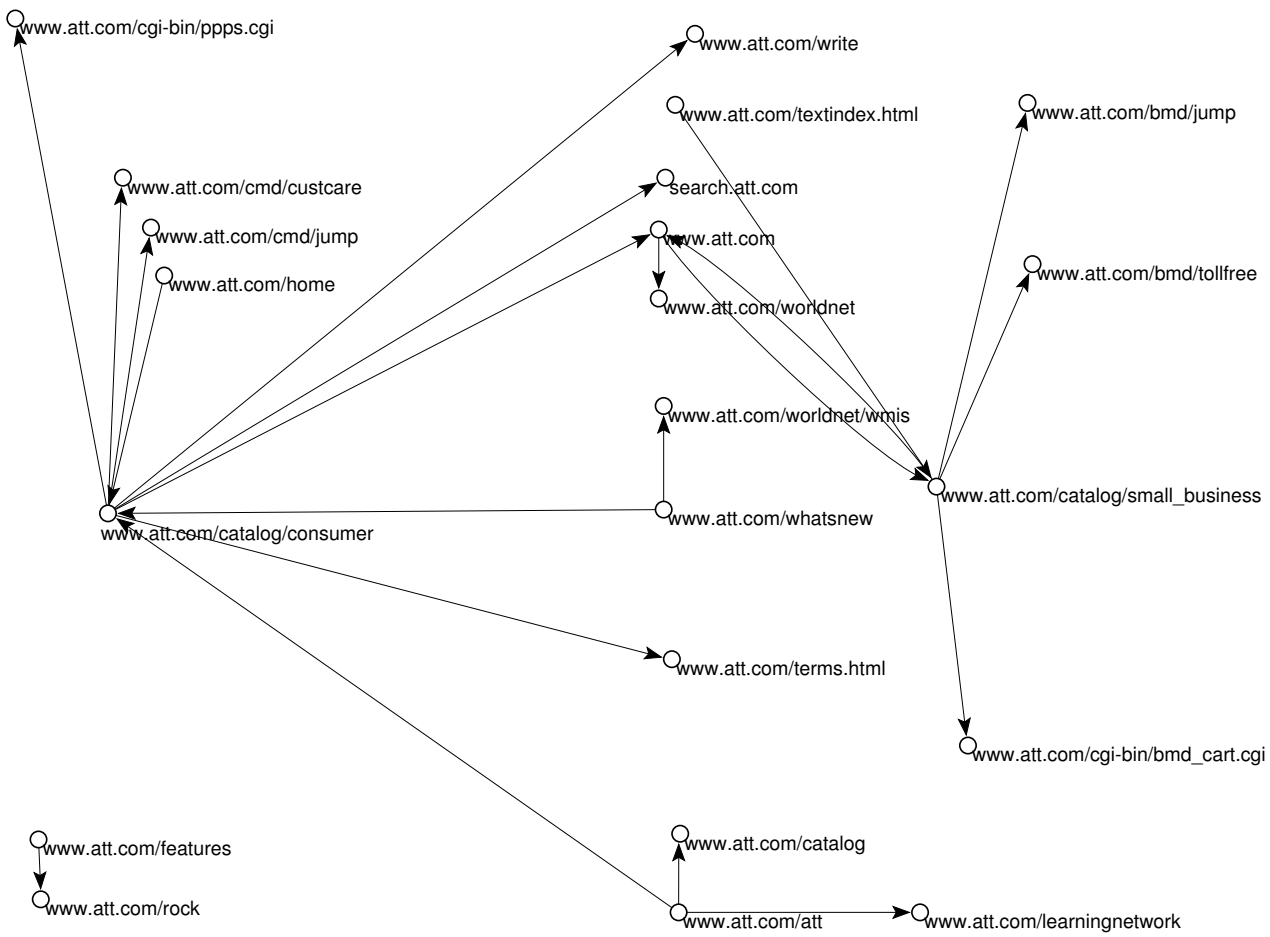


Figure 23: Graph A98, after executing deletion:
 delete www.att.com -> www.att.com/catalog/consumer
 (23 operations executed).

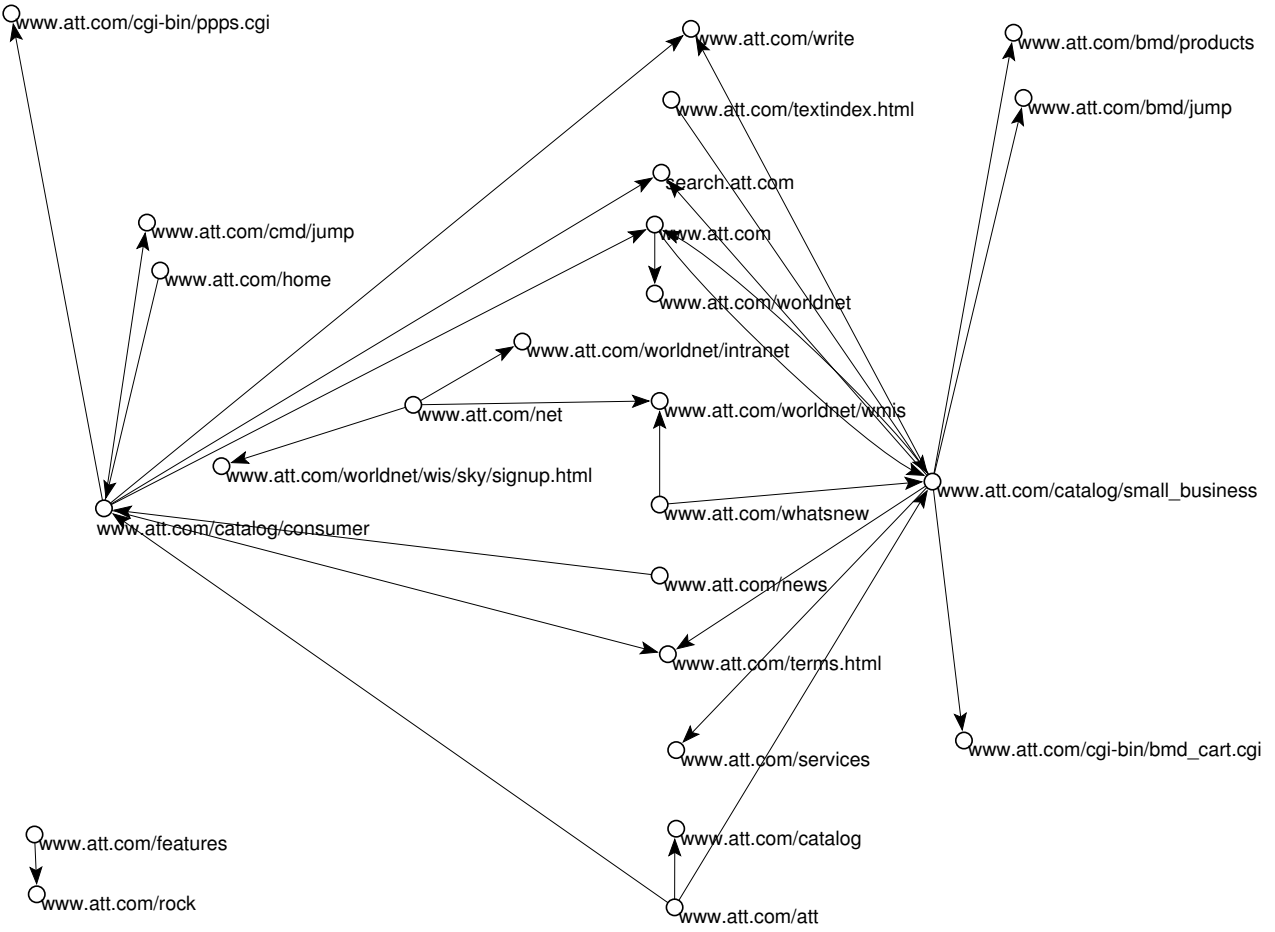
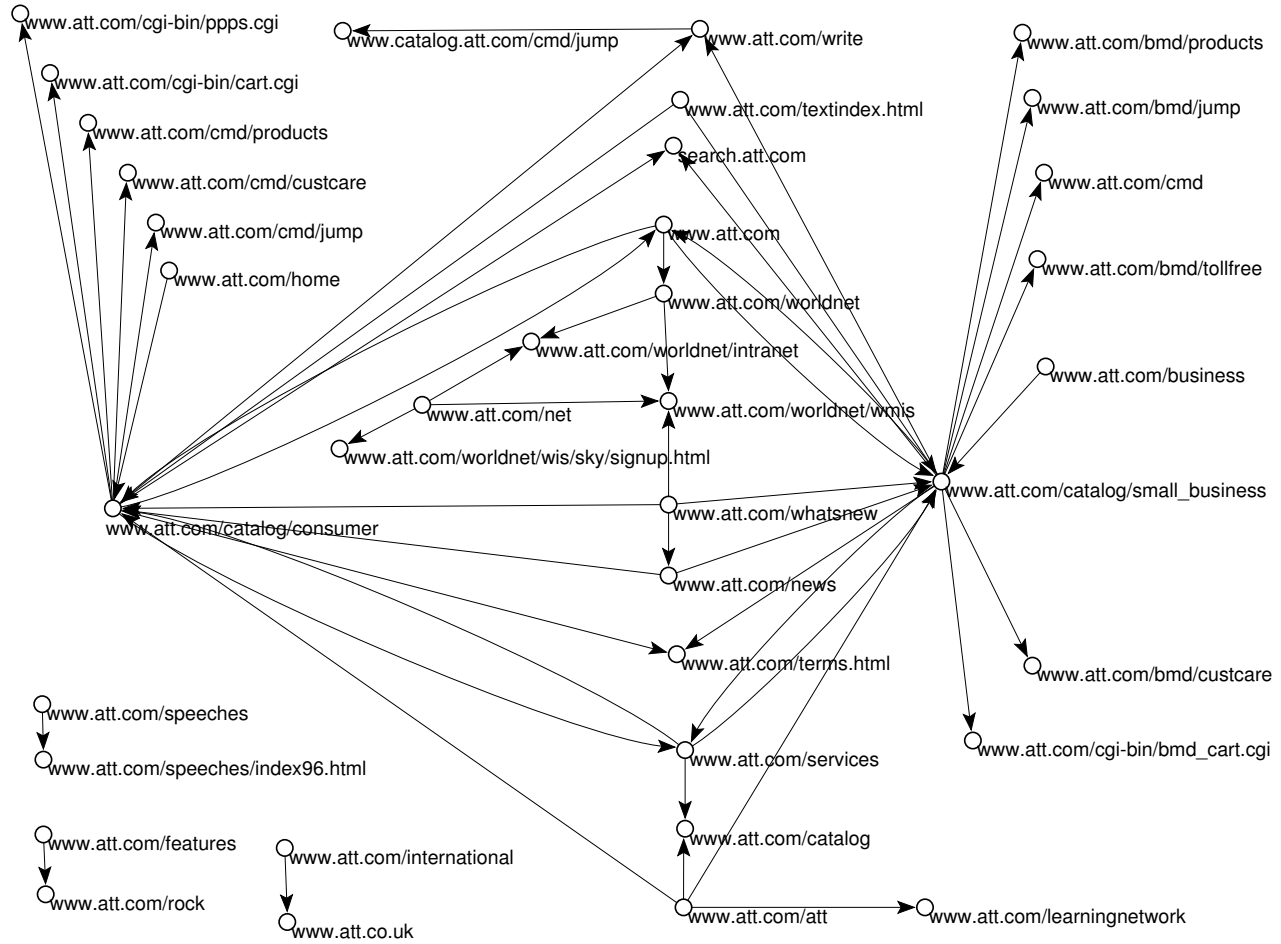


Figure 24: Graph A98, after executing deletion: delete www.att.com/whatsnew -> www.att.com/catalog/consumer (38 operations executed).

Figure 25: Graph A98, after all additions/deletions done (65 operations executed).



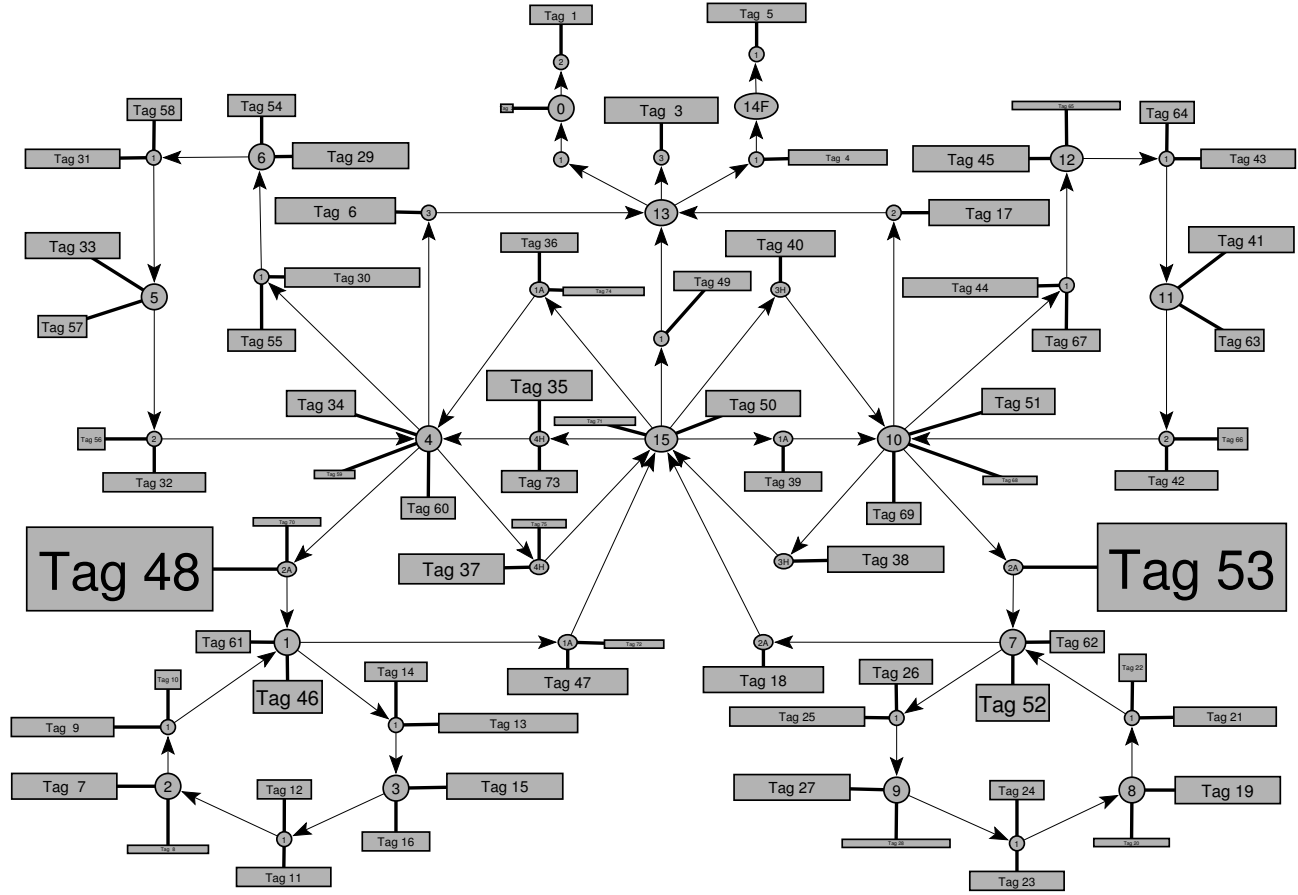


Figure 26: Graph B98 (*first prize*).

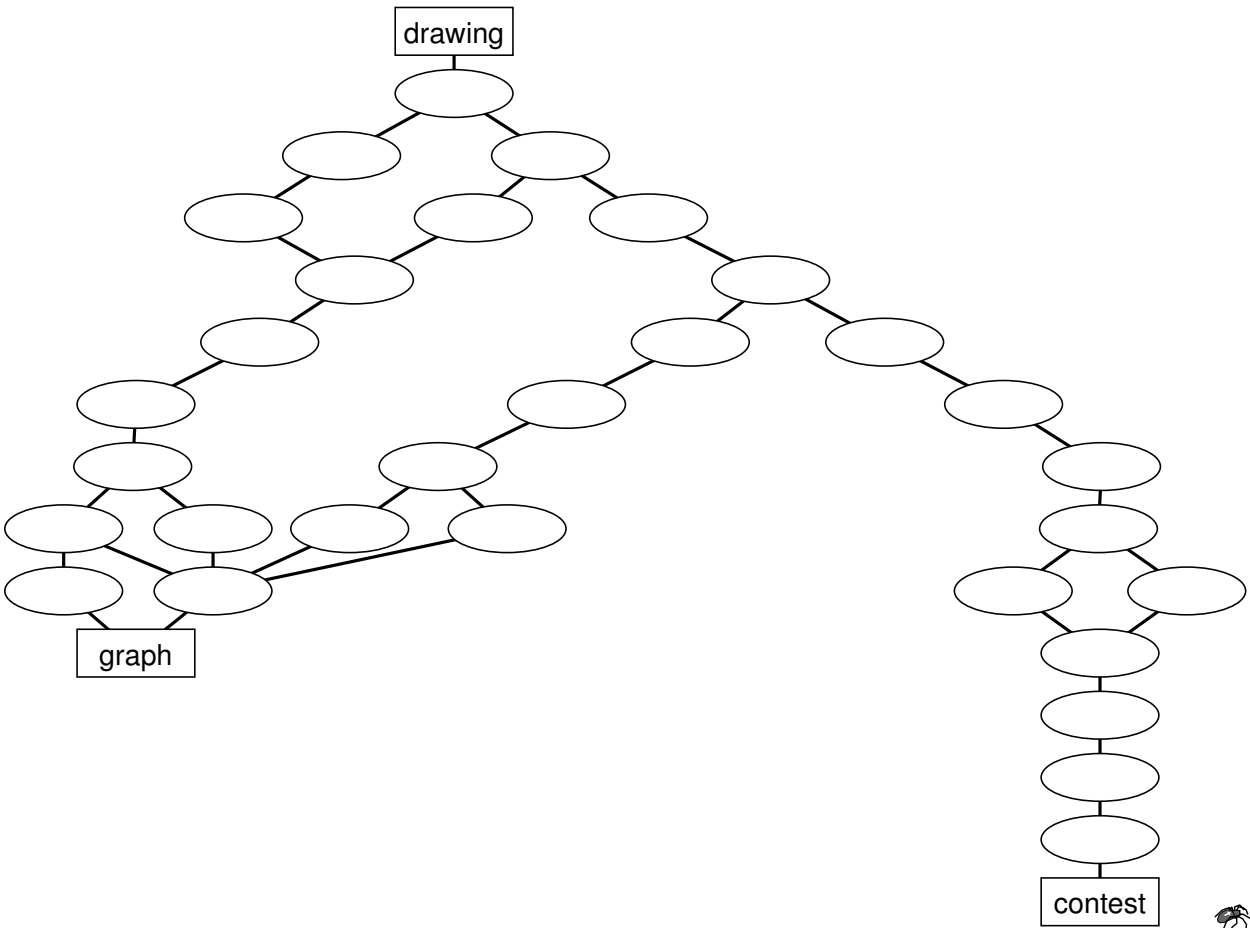


Figure 27: Graph D98: Difficult puzzle.

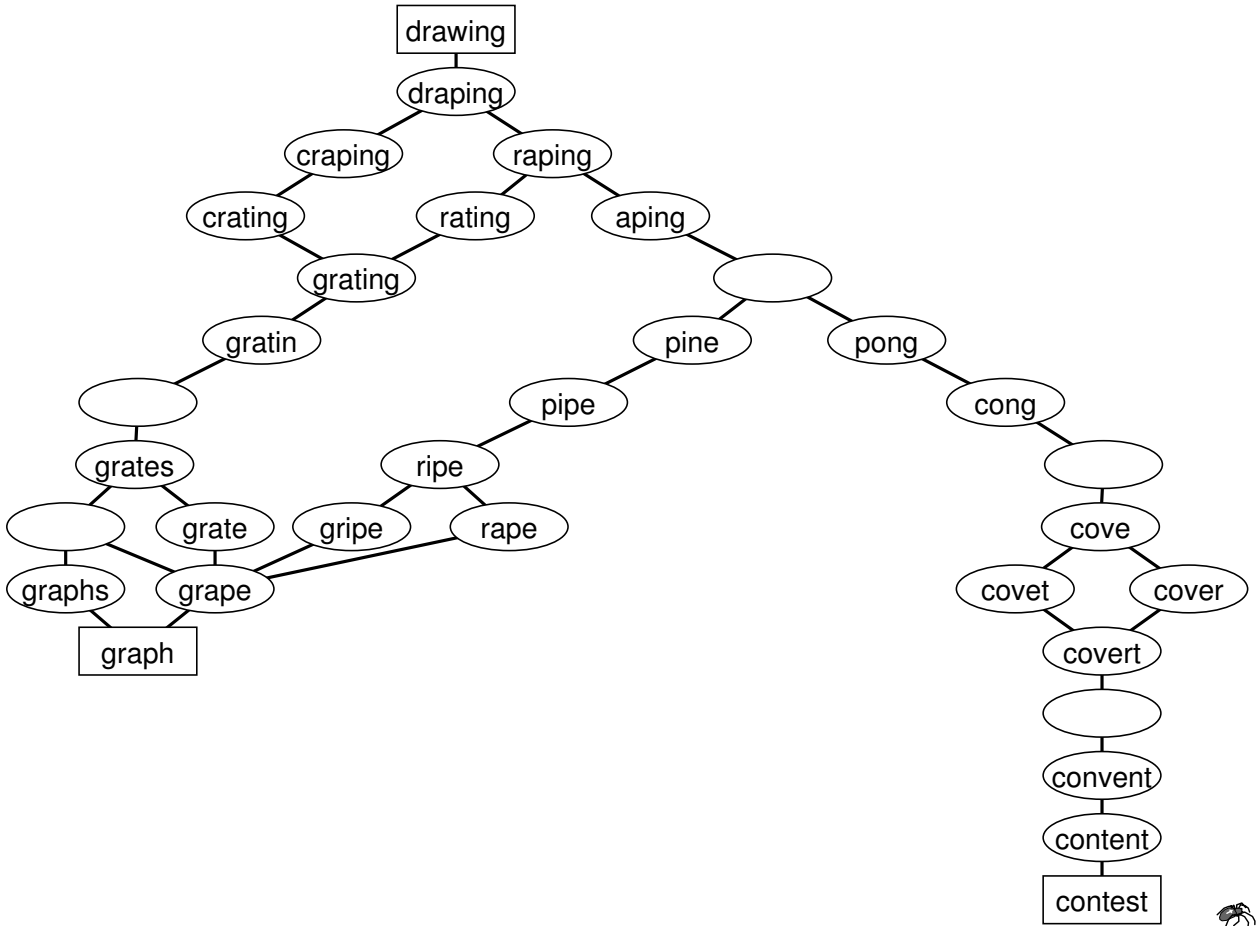


Figure 28: Graph D98: Easy puzzle.

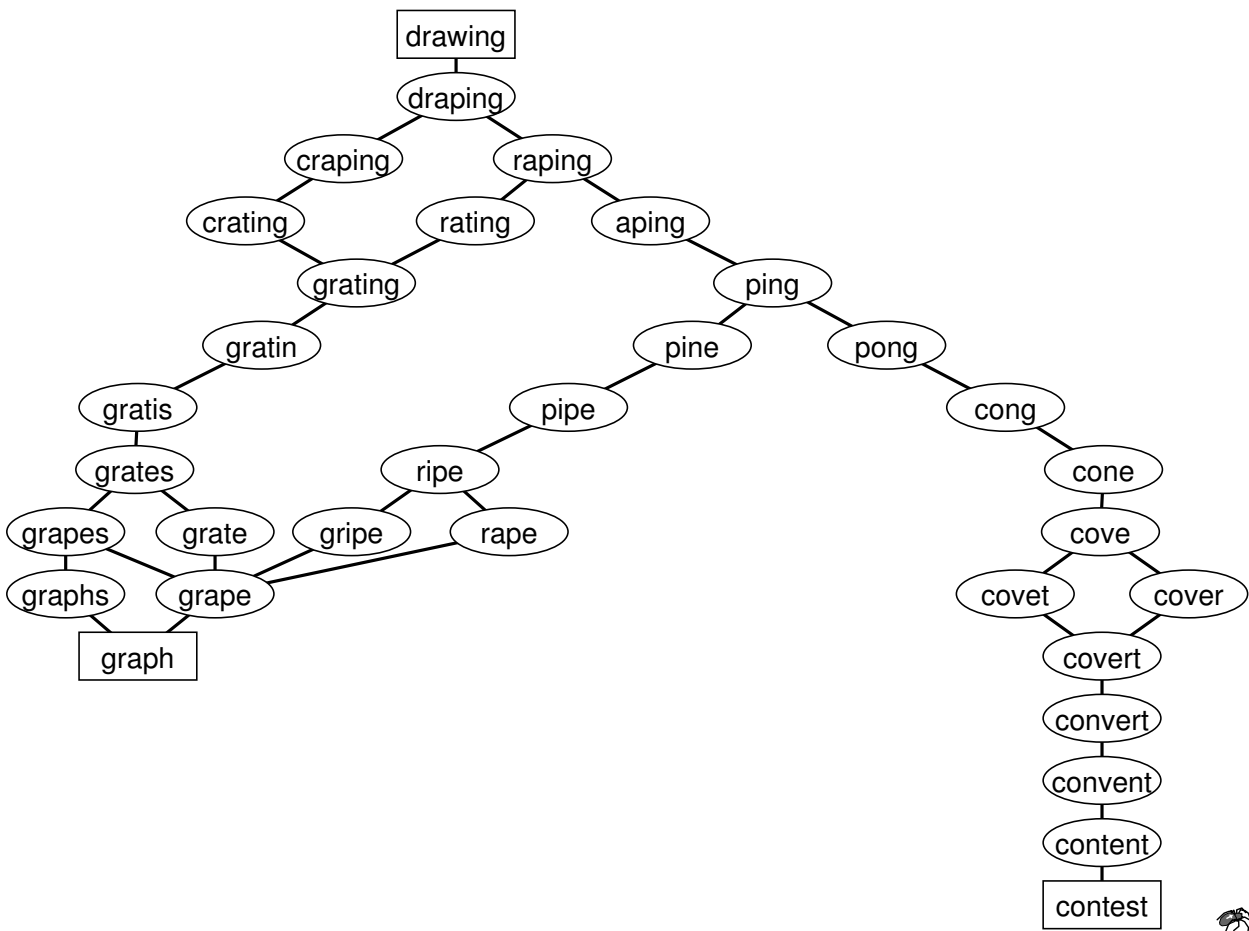


Figure 29: Graph D98: Solution.



Layouts for Graph Drawing Contest 1999

In 1999 Graph Drawing Conference was held in Stirin (Czech Republic) and the contest was organised by Franz Brandenburg, Michael Juenger, Joe Marks, Petra Mutzel, and Falk Schreiber. Rules and data are described at:

[http://www.ms.mff.cuni.cz/acad/kam/conferences/GD99/
contest/rules.html](http://www.ms.mff.cuni.cz/acad/kam/conferences/GD99/contest/rules.html)

All work was done using our program package Pajek, which is freely available at:

<http://vlado.fmf.uni-lj.si/pub/networks/pajek/>

Graph A99

Graph data were transformed to Pajek format, which enables to handle graph changes over time. The following coding of actors is used:

- Shapes
 - circle: =f= female
 - triangle: =m= male
 - yellow box: =b= female+male (Ernst+Lisl Wiesenhuber)
 - green box: =a= women+grandchildren (Julia von der Marwitz)
 - black diamond: =w= widowed
 - pink diamond: =d= divorced marriage
 - orange diamond: =m= still existing marriage
 - empty: =i= invisible node (white)
- Sizes
 - 0.8 - big
 - 0.4 - small
 - 0.6 - artificial
- Colors
 - =y= unactive characters (yellow)
 - =a= 2 persons in 2 different colors (green)
 - =b= active characters (blue)
 - =d= divorced marriage (pink)

- =w= characters that never showed up personally (white)
 - =m= still existing marriage (orange)
 - =g= already dead characters (grey)
 - =w= widowed (black)
- Border widths
 - =p= picture - border width = 2
 - =s= symbol - border width = 0.5

Drawing of the current situation We started the drawing using the layout obtained by Kamada-Kawai spring embedder. Later we used manual editing to arrange them on rectangular net.

Development of the graph over time We used the Pajek option for drawing graphs in different time points. Only time points where at least one vertex or one line changes according to last layout were drawn (e.g. 1, 2, 4, 5,...). After each change time the layout of the new graph was optimized starting with the previous positions.

The layout was awarded the first prize.

Graph B99

We used eigenvectors approach and computed eigenvectors of Laplacean matrix that correspond to the 1st, 2nd and 5th largest eigenvalue. No additional manual editing was used on the obtained spatial picture. Suitable view was selected to get planar EPS picture. Picture was exported to formats for the following 3D viewers: VRML (CosmoPlayer), kinemages (Mage), and MDLMOLfile (Chime).

The layout was awarded the second prize.

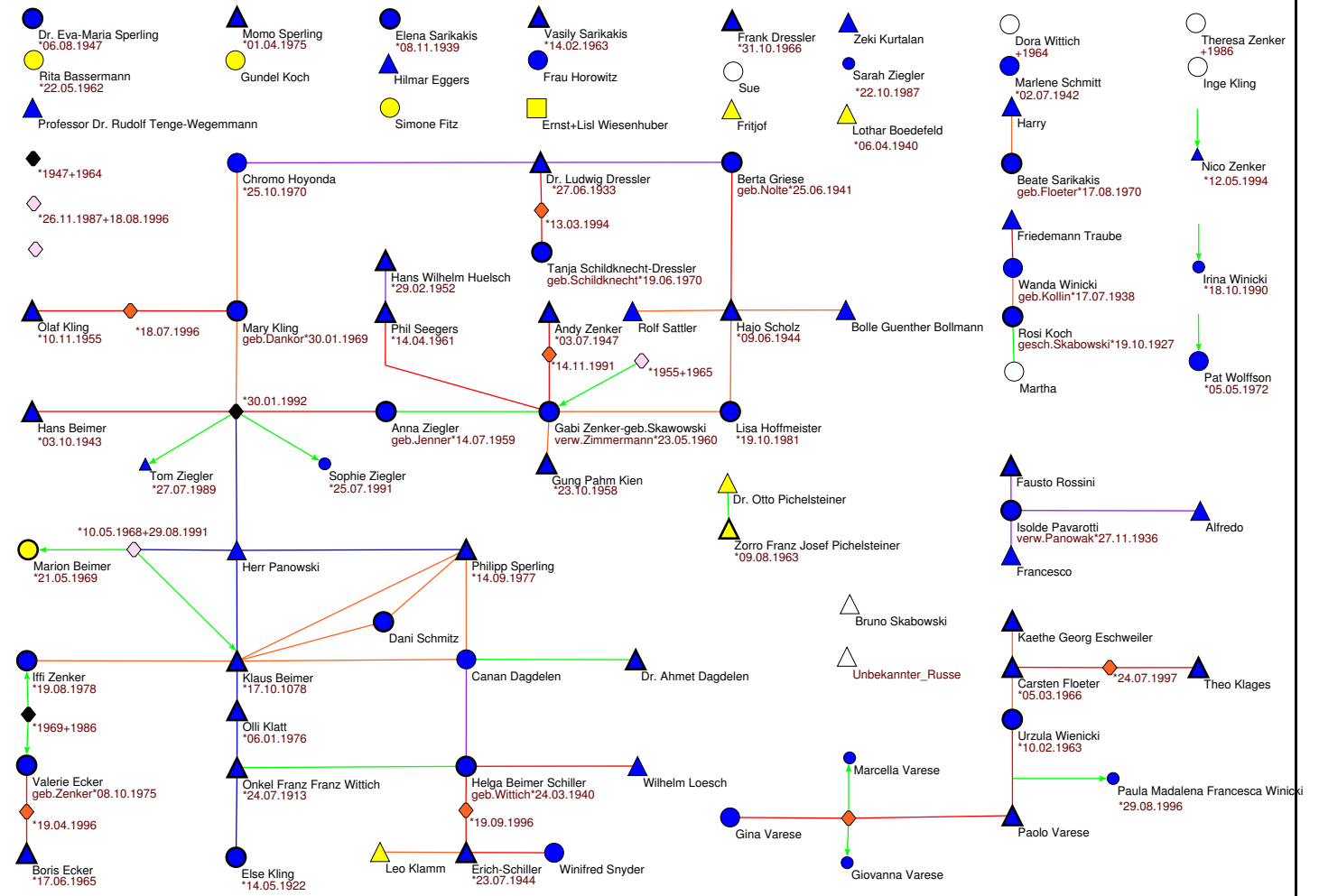
Graph C99

We started the drawing using the layout obtained by Fruchterman-Reingold spring embedder. Later we used manual editing to maximize 'rectangularity' and made some displacements to accommodate for different sizes of nodes.

See: <http://vlado.fmf.uni-lj.si/pub/gd/gd99.htm>.

The complete report of the contest is available in [8].

Figure 30: Graph A99, current situation.



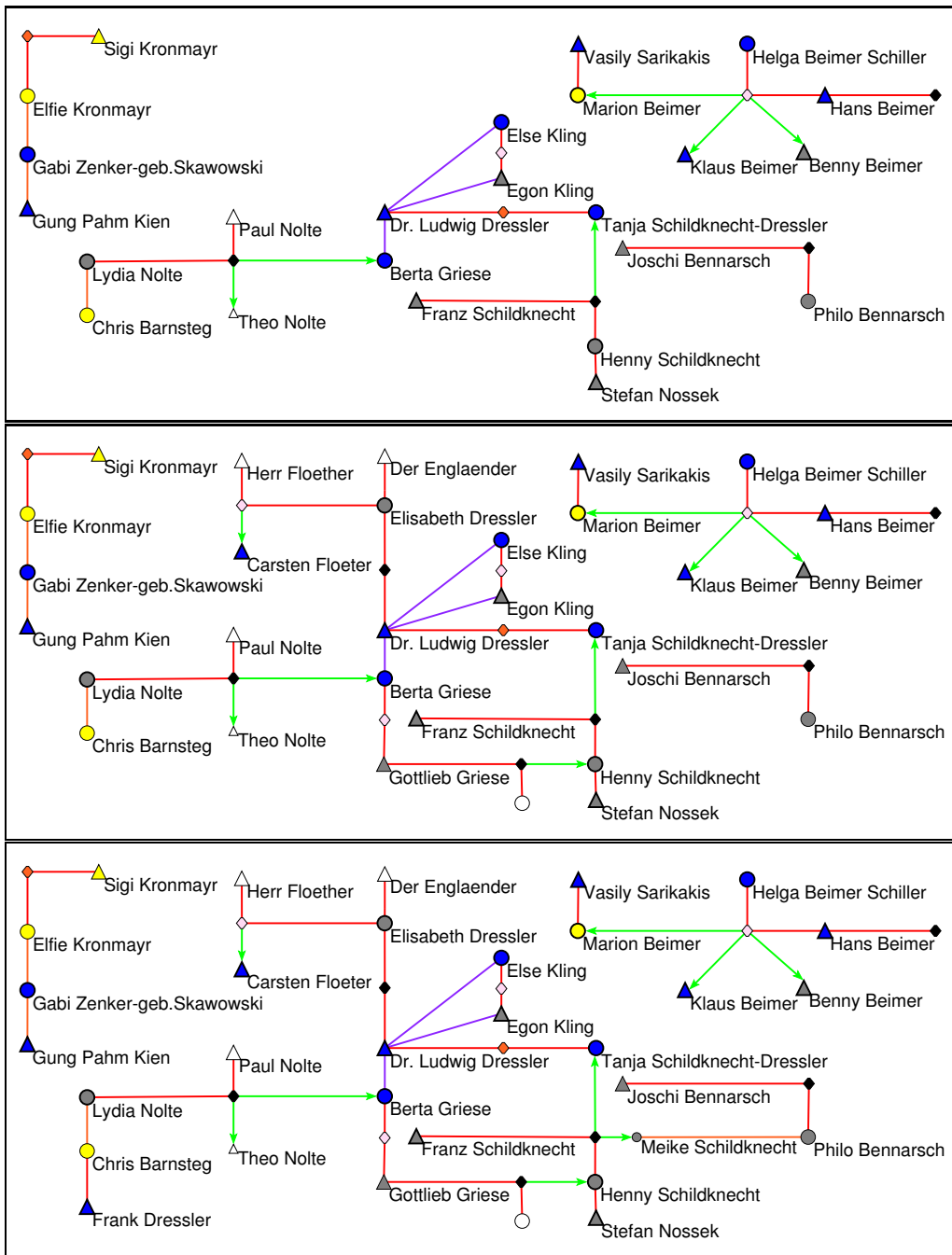


Figure 31: Graph A99, time points 5, 6 and 7 (*first prize*).

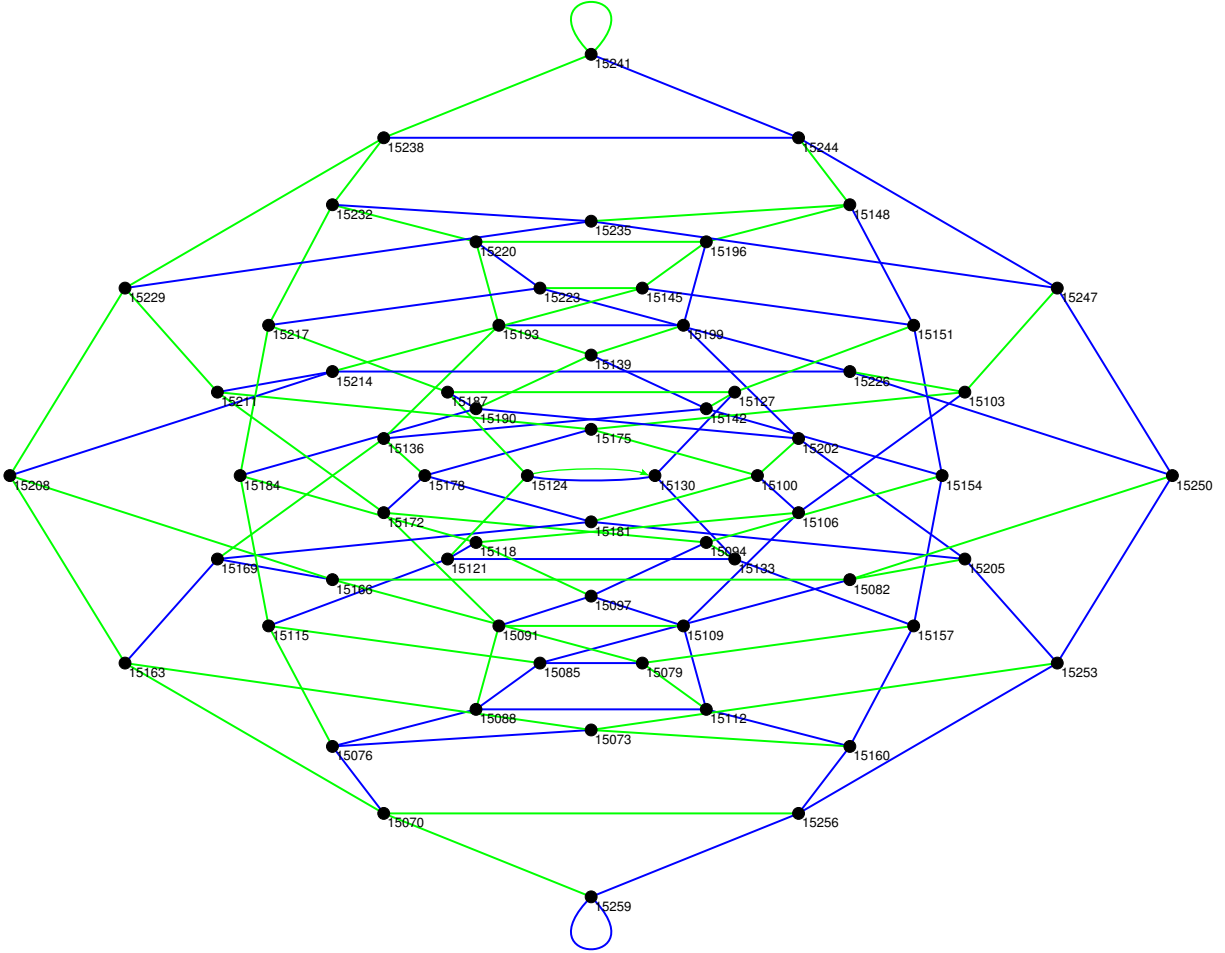


Figure 32: Graph B99 (*second prize*).

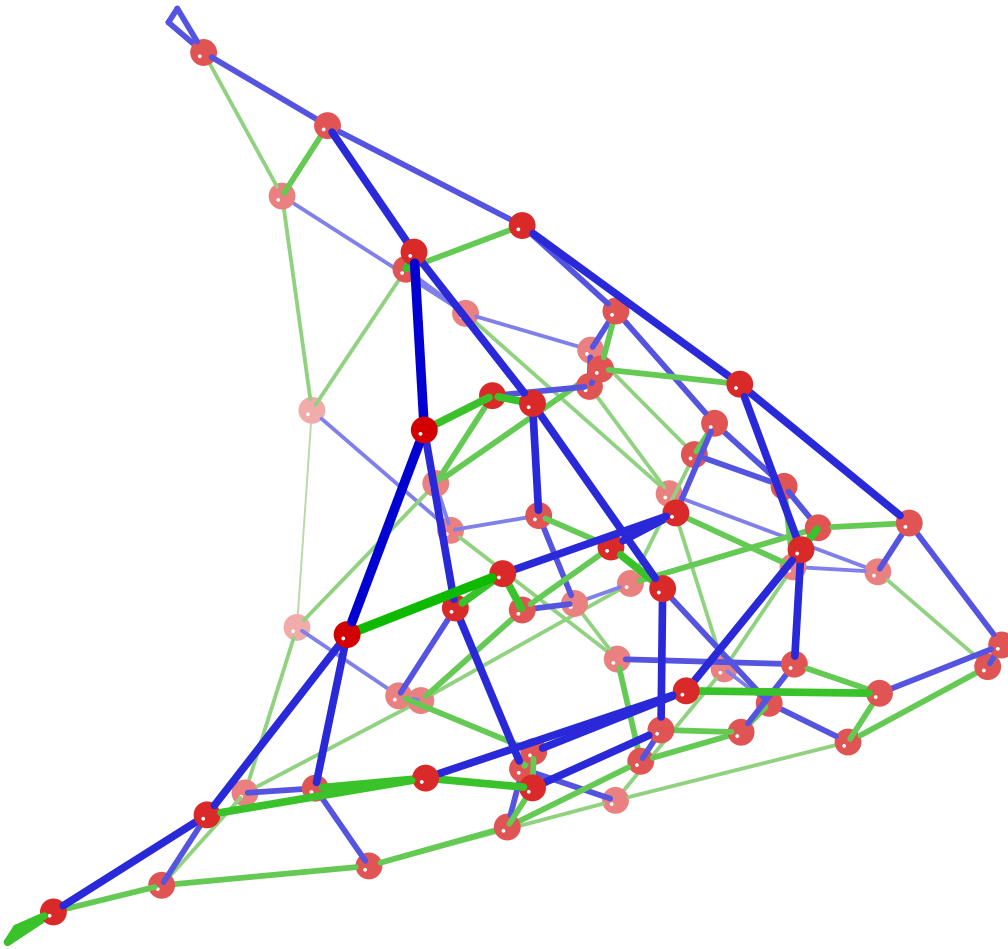


Figure 33: Graph B99 – general view.

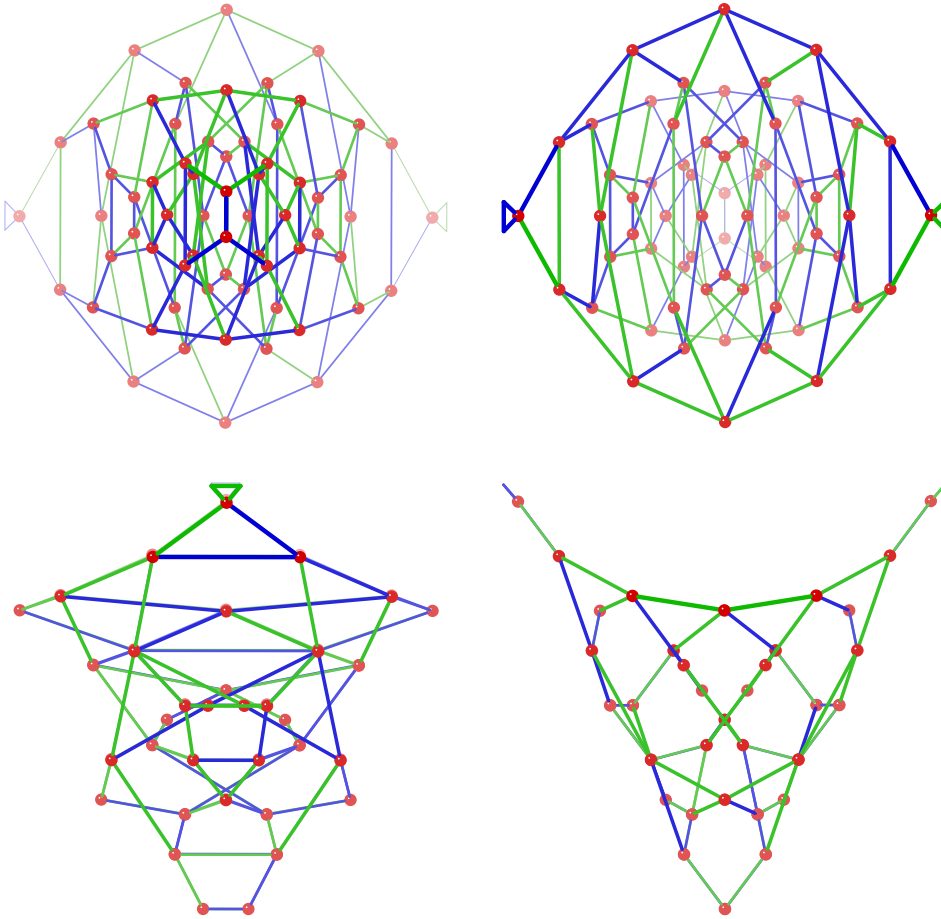


Figure 34: Graph B99 – different views.

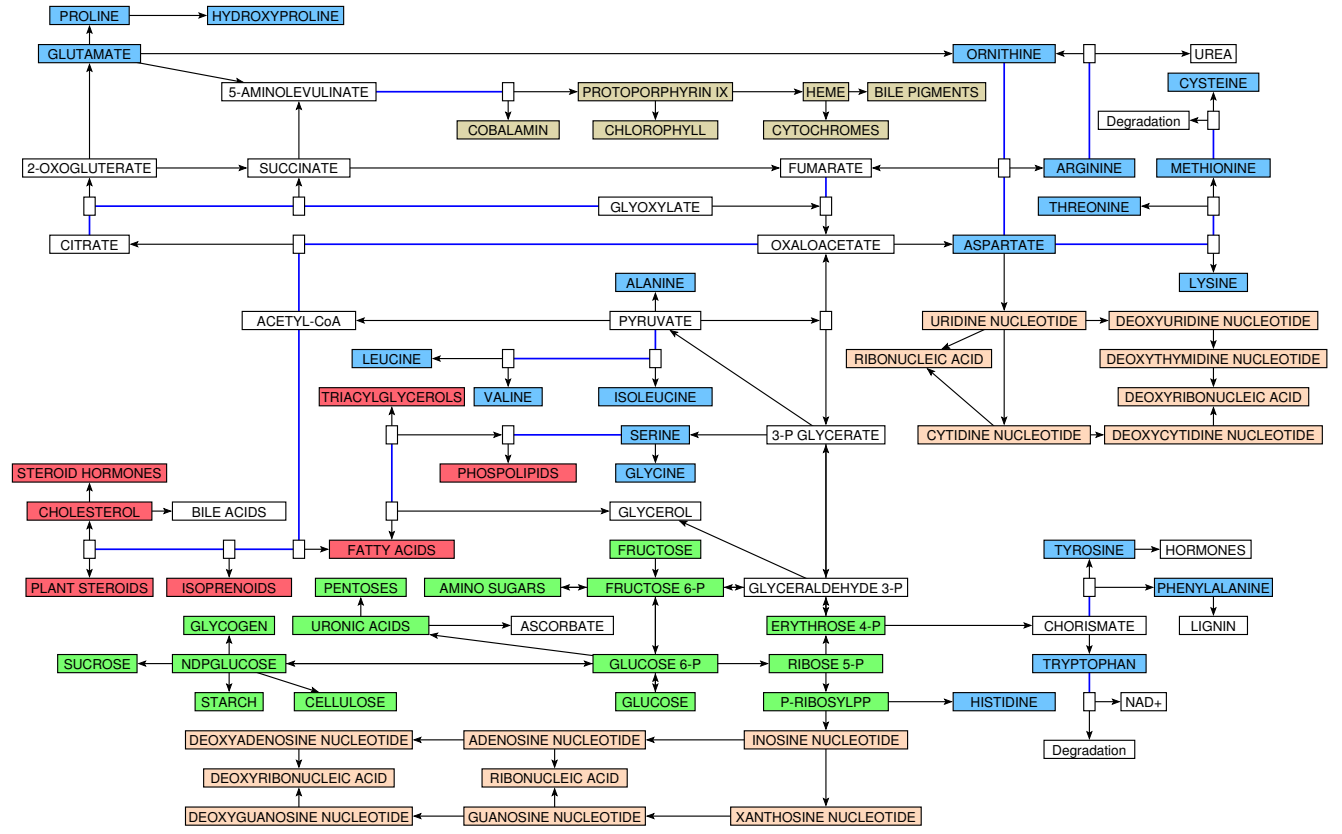
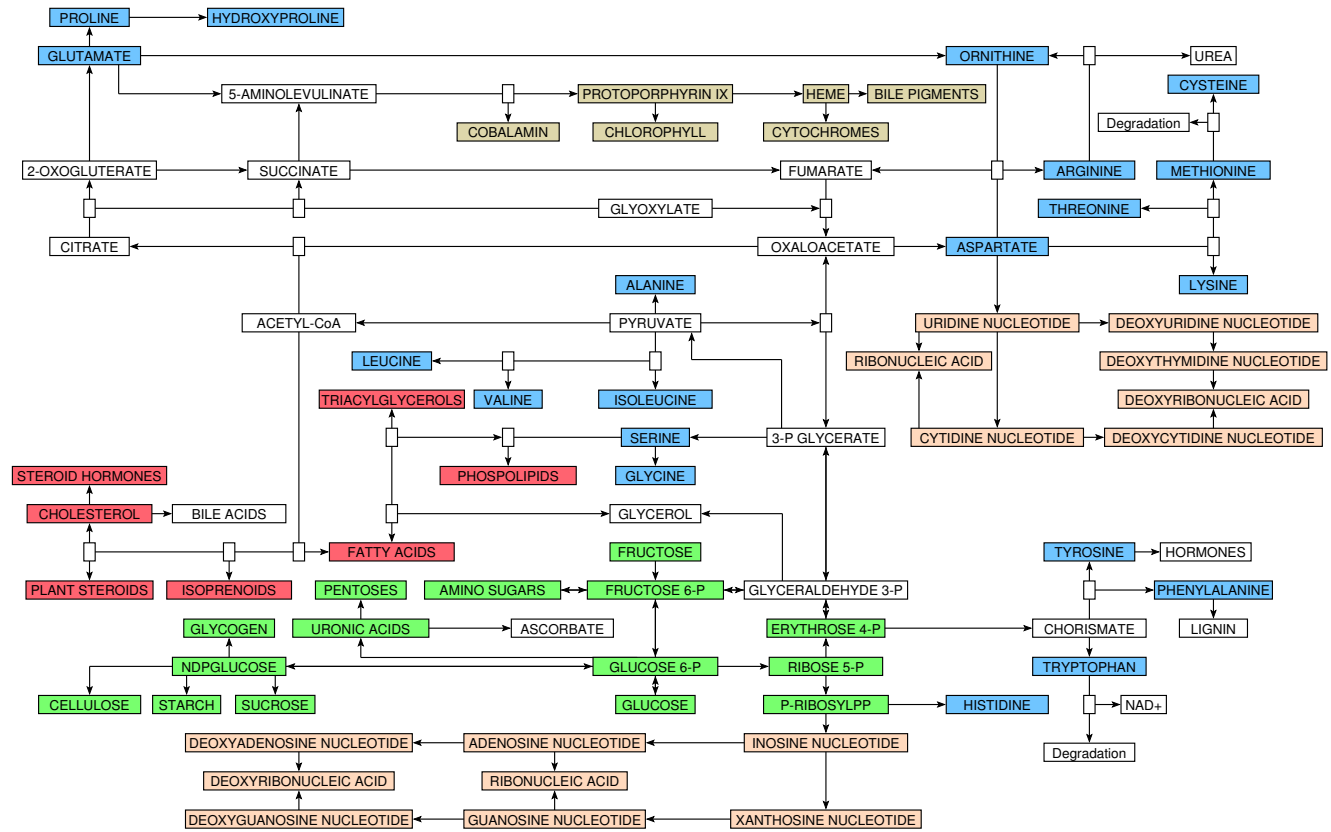


Figure 35: Graph C99.

Figure 36: Graph C99 - orthogonal layout.



Layouts for Graph Drawing Contest 2000

In 2000 Graph Drawing Conference was held in Colonial Williamsburg (USA) and the contest was organised by Franz Brandenburg. Rules and data are described at:

<http://www.infosun.fmi.uni-passau.de/GD2000/index.html>

Graph A00

Graph A00 was proposed by M. Himsolt.

First we found out that graph consists of 26 weakly connected components. After removing loops from the graph we got acyclic graph. On the acyclic graph we used standard algorithms to compute layers and position vertices into layers in order to minimize total length of lines. Some manual repositioning of vertices was used to avoid some line crossings. Vertices having loops are drawn as ellipses other as rectangles. Since graph consists of several components and labels are very small, some additional layouts of parts of network (top, middle and bottom) containing some components are shown.

We also produced pictures of this graph in Scalable Vector Graphics (SVG) format besides EPS pictures (see <http://vlado.fmf.uni-lj.si/pub/gd/gd00.htm>).

Graph B00

Graphs B00-A and B00-B were proposed by Ulrik Brandes.

The essential part of both graphs A and B are the green vertices. But there are too many arcs among them to produce a clear picture.

We first tried with circular presentation. To reveal internal structure of green subgraph and to determine the ordering of vertices on the circle we computed d_2 on the green subgraph and applied TSP (Travelling Salesman Problem) algorithm on this matrix.

$$d_2(u, v) = \frac{|N(u) \oplus N(v)|}{|N(u) \cup N(v)|} \quad (1)$$

$N(v)$ is the *neighborhood* of vertex $v \in V$:

$$N(v) = \{u \in V : (v : u) \in E\}$$

(\oplus denotes the symmetric difference, \cup denotes union)

Since there can exist different clusters inside the green set of vertices we extended the d_2 matrix with some additional vertices with equal distance to all green vertices. Some vertices were repositioned manually according to connections to yellow and blue vertices on the circular net. From obtained pictures we can see that neighbouring vertices have similar patterns of arcs. Vertices having loops are drawn as boxes (vertices 5 and 11 in graph A) other as circles. Different gray colors are used to show the frequency of contact:

- Black: 1 - weekly
- 75% Gray: 2 - biweekly
- 50% Gray: 3 - monthly
- 25% Gray: 4 - quarterly

The ordering of green vertices obtained by TSP algorithm we used also in matrix representation of graphs A and B. It seems that the matrix representation is more appropriate for dense (parts of) graphs. In the matrix representation the same shadowing is used as in the graph layout.

The layout was awarded the first prize.

The complete report of the contest is available in [9].

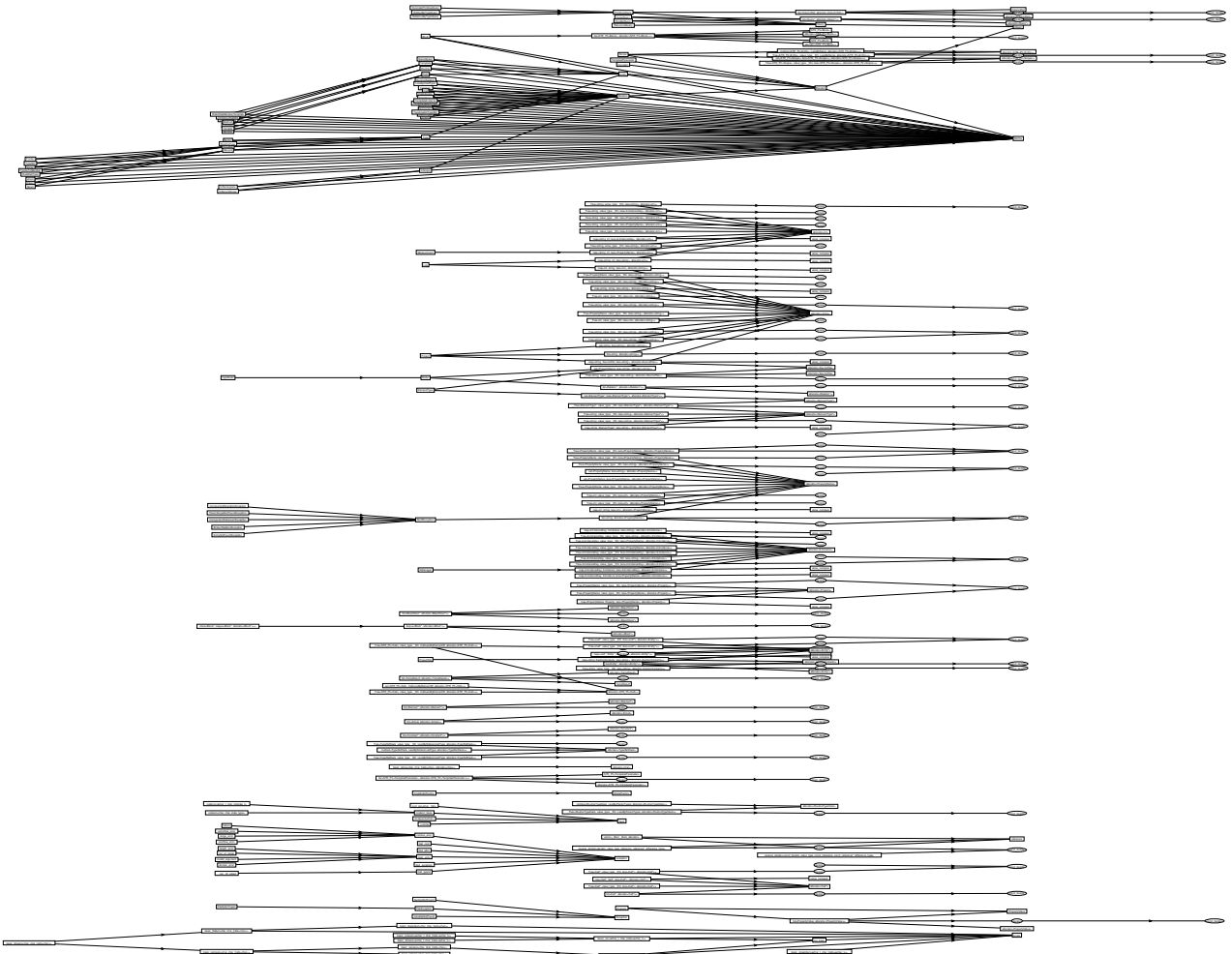


Figure 37: Complete layout of Himsoit graph A00.

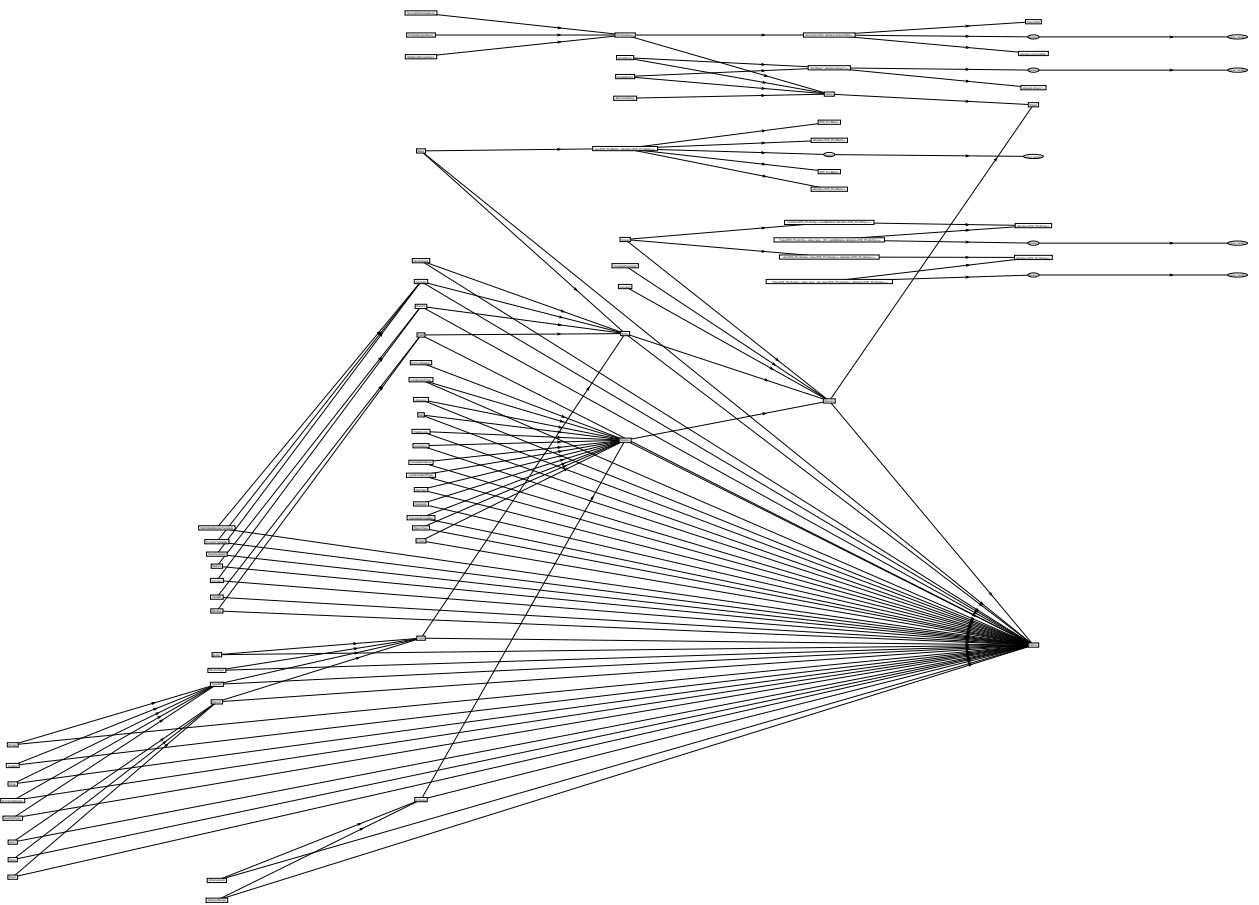


Figure 38: Upper part of Himsolt graph A00.

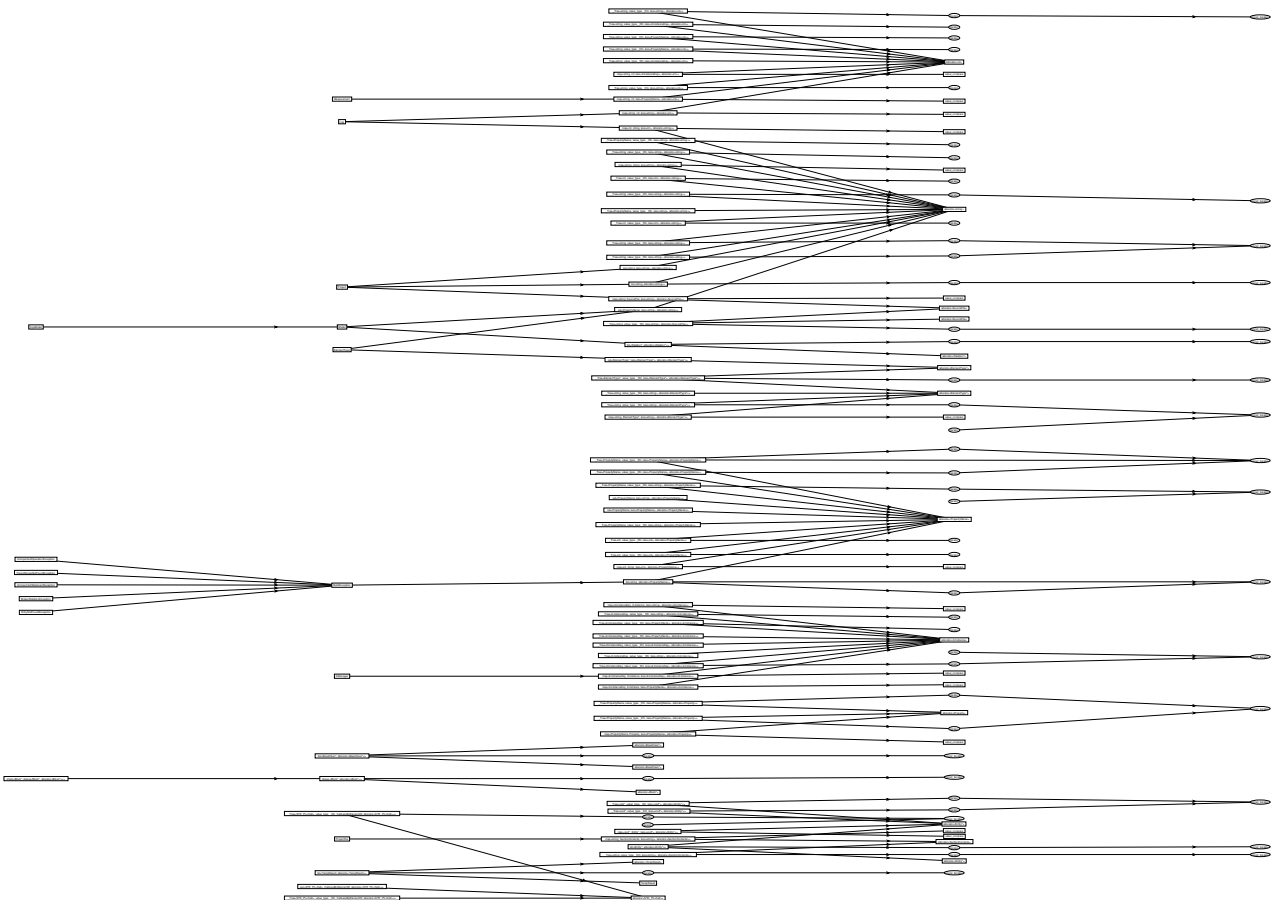


Figure 39: Middle part of Himsoft graph A00.

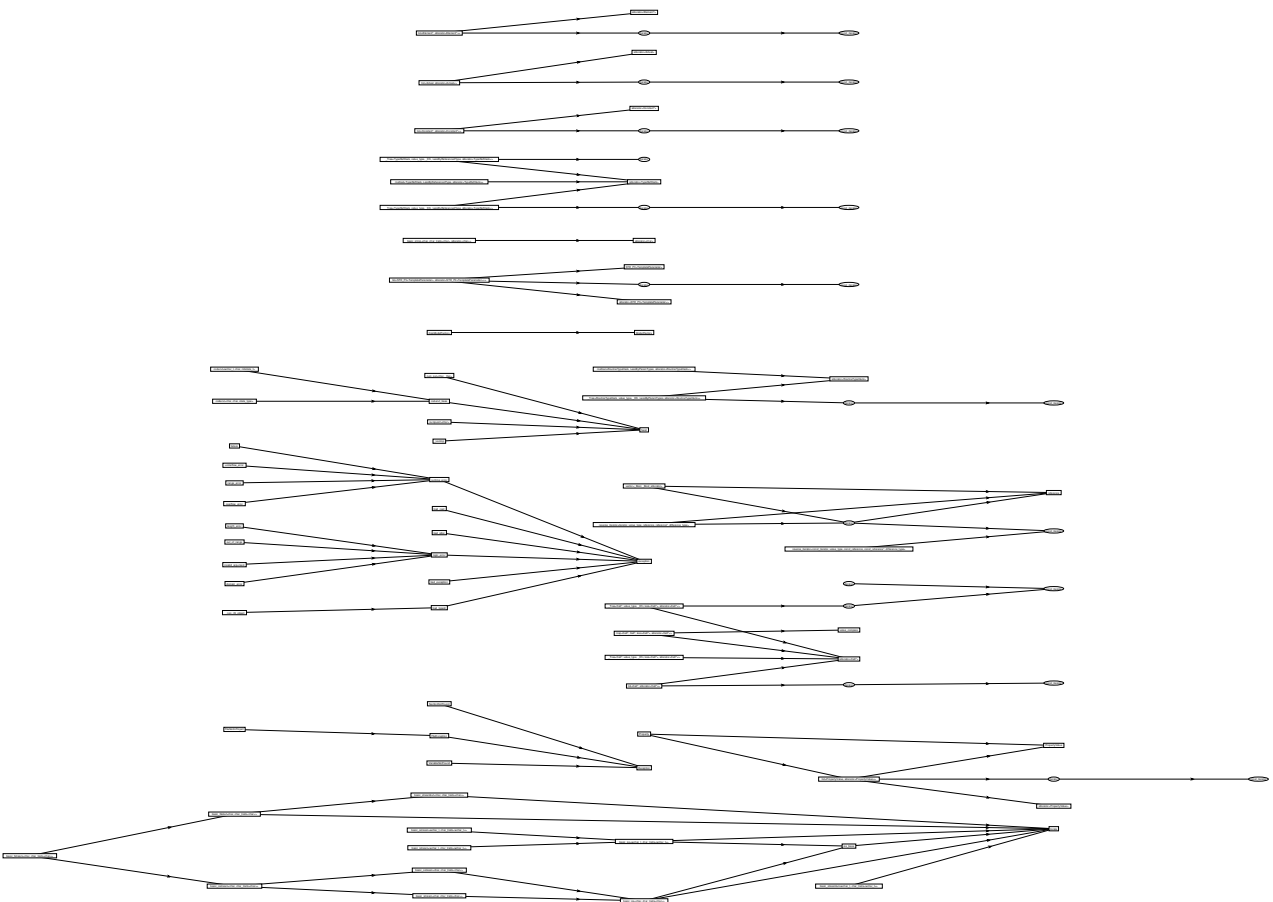


Figure 40: Bottom part of Himholtz graph A00.

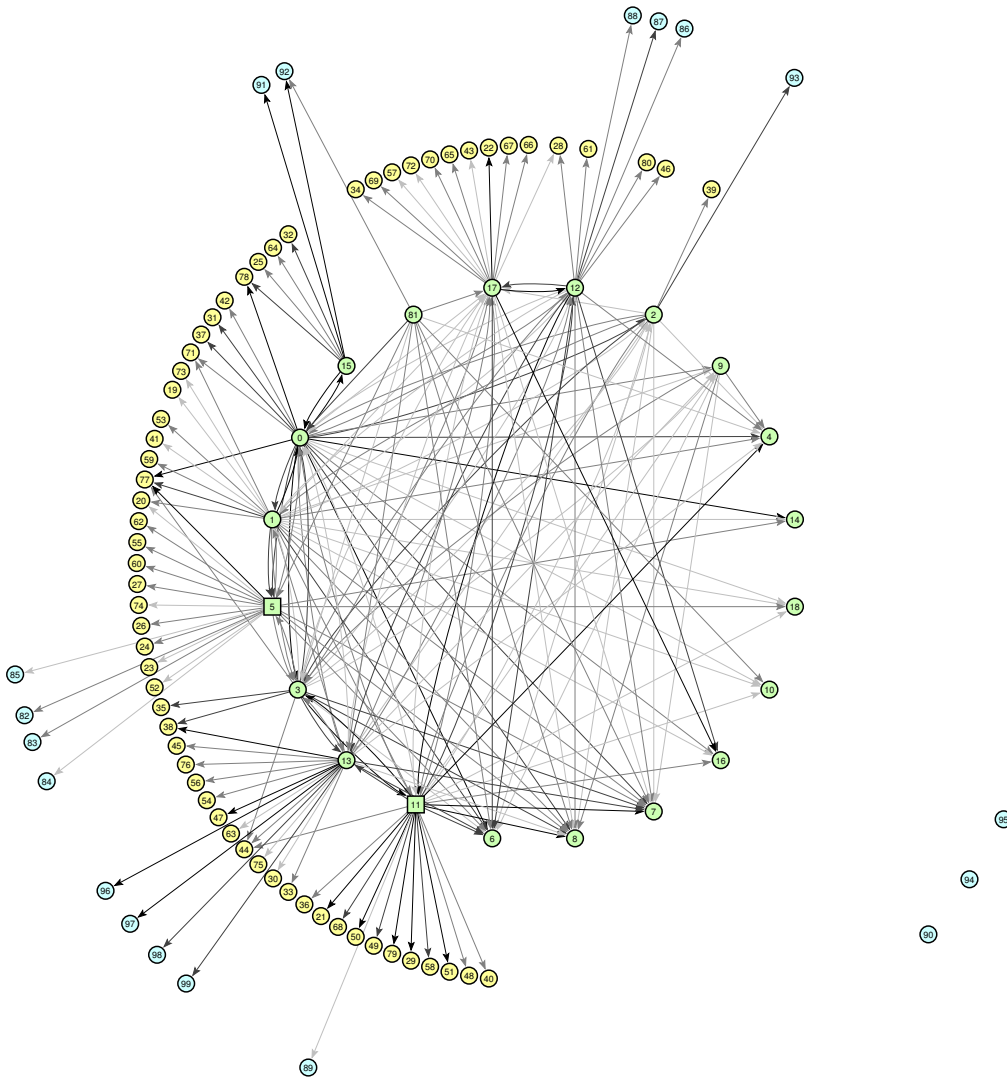


Figure 41: Graph B00-A - circular layout (*first prize*).

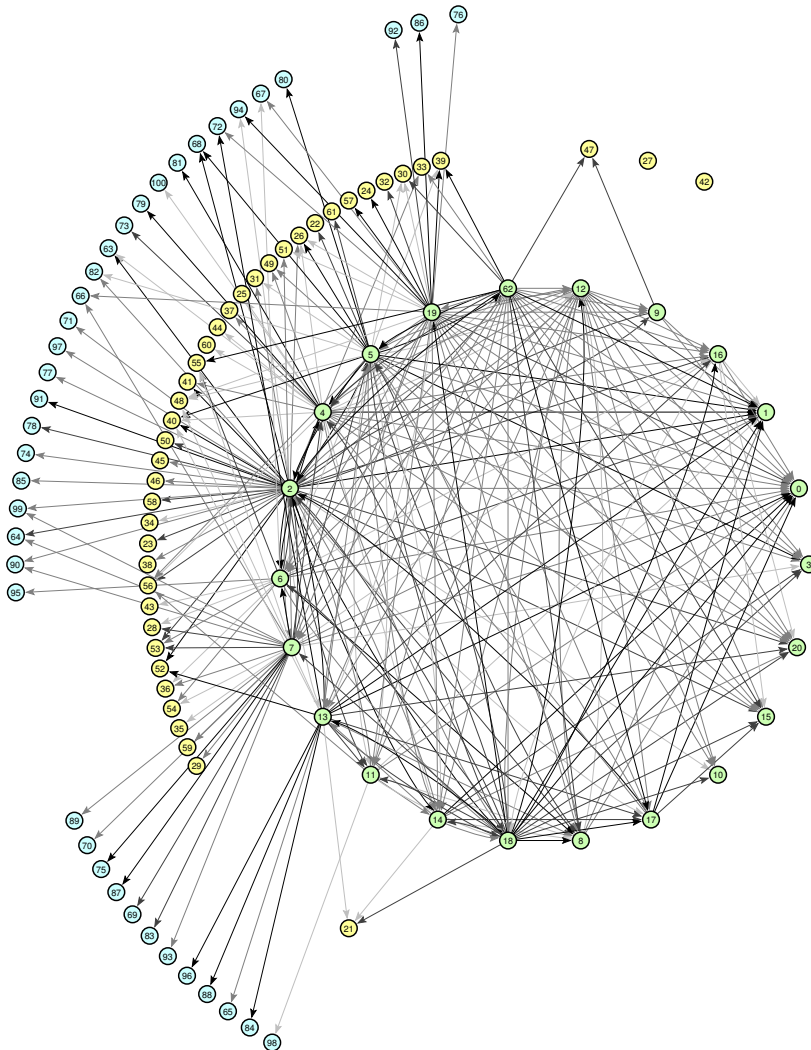


Figure 42: Graph B00-B - circular layout.

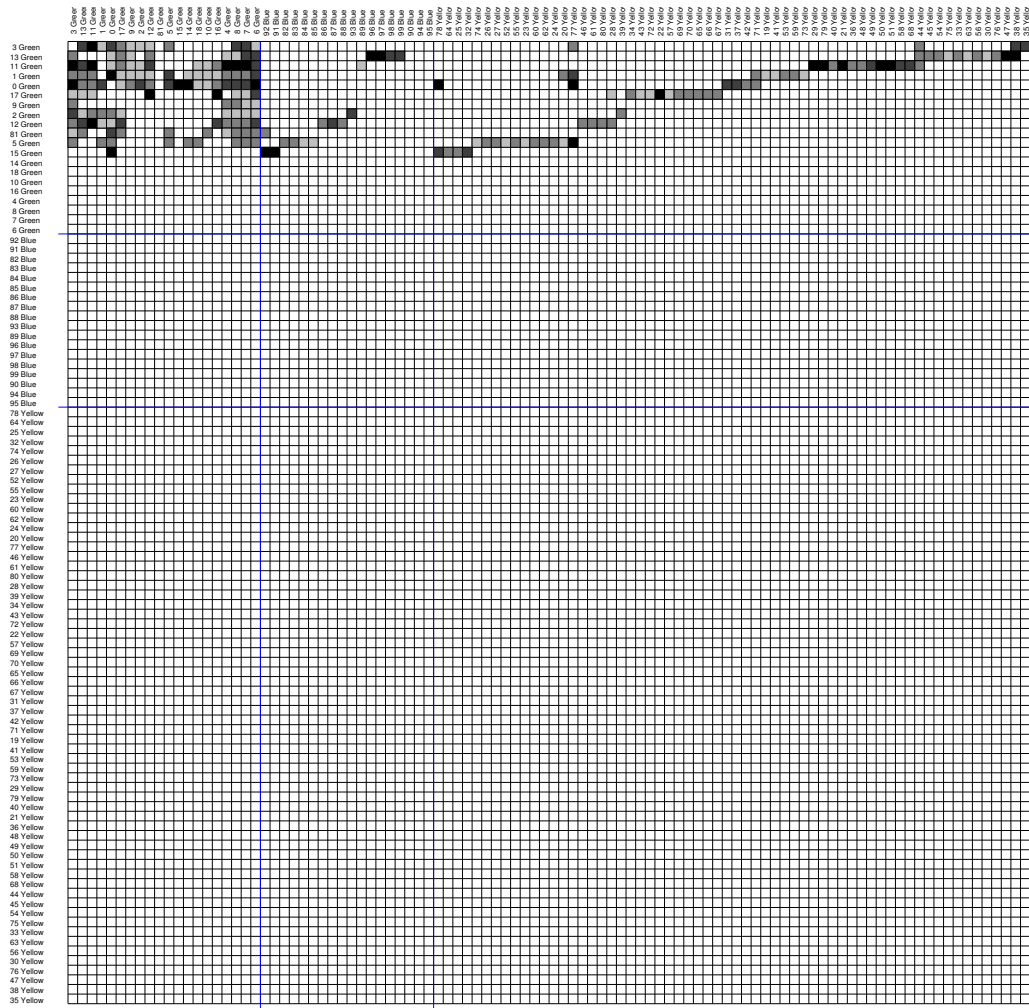


Figure 43: Matrix representation of graph B00-A.

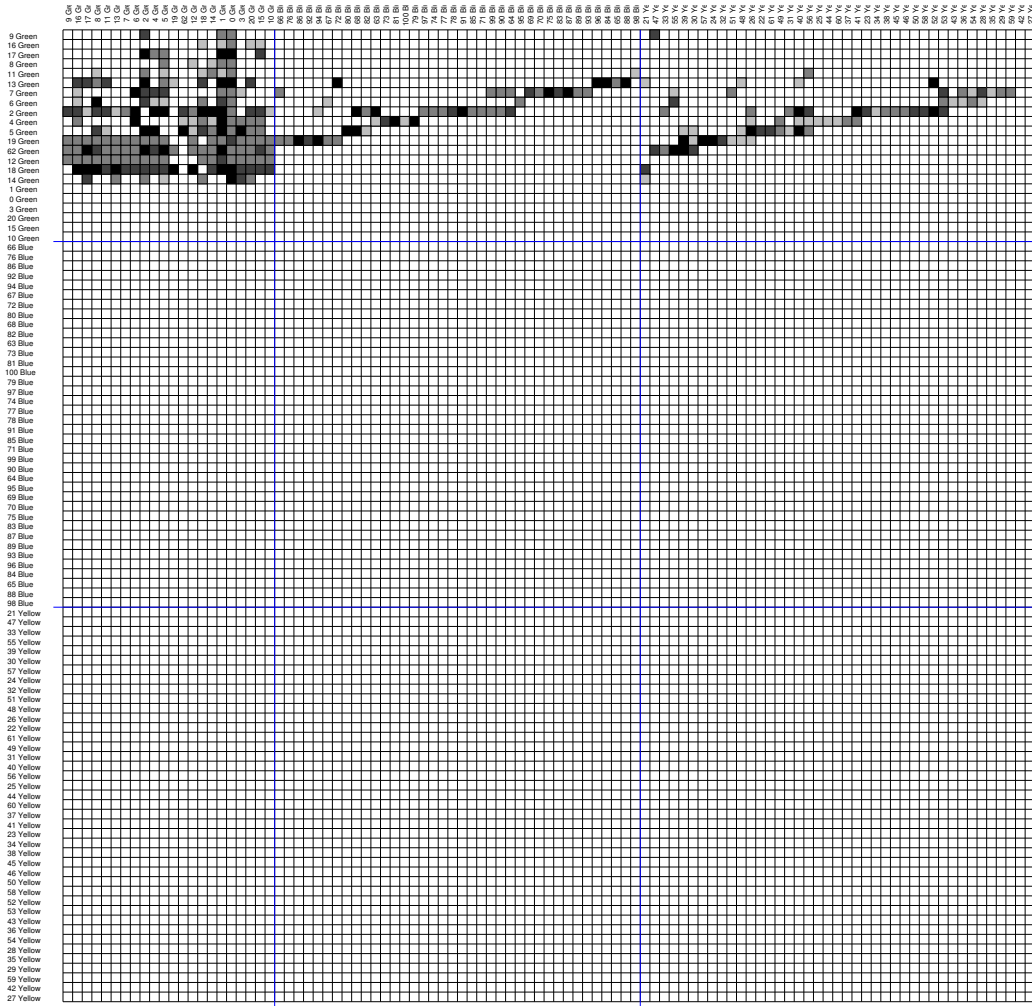


Figure 44: Matrix representation of graph B00-B.

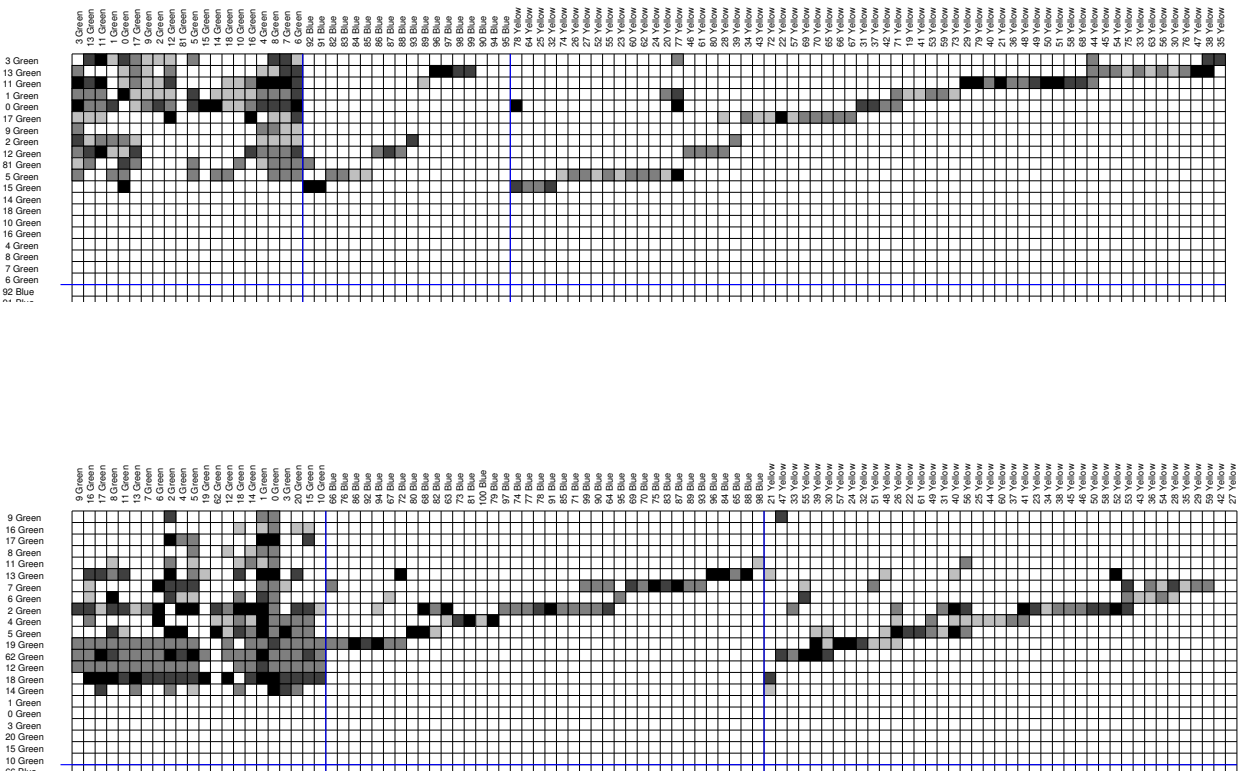


Figure 45: Matrix representation of non empty part of graphs B00-A and B00-B.

Layouts for Graph Drawing Contest 2001

In 2001 Graph Drawing Conference was held in Vienna and the contest was organised by Franz Brandenburg. Rules and data are described at:

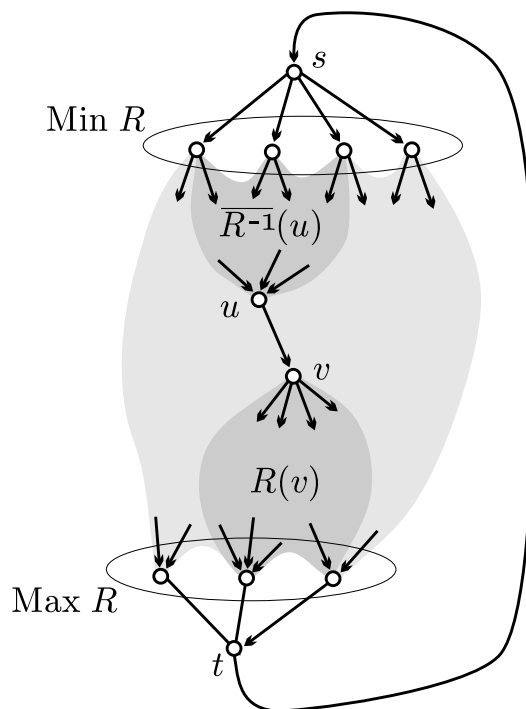
<http://www.ads.tuwien.ac.at/gd2001/>

Graph A01

In a given set of units E (articles, books, works, ...) we introduce a *citing* relation $R \subseteq E \times E$

$$xRy \equiv y \text{ cites } x$$

which determines a *citation network* (E, R) . A citing relation is usually *irreflexive*, $\forall x \in E : \neg xRx$, and (almost) *acyclic*, $\forall x \in E \forall k \in \mathbf{N}^+ : \neg xR^kx$. The citation network is *standardized* by adding, if necessary, artificial *source* vertex s and *sink* or *terminal* vertex t and the arc (t, s) (see figure).



An approach to the analysis of citation network is to determine for each unit / arc its *importance* or *weight*. These values are used afterwards to determine the essential substructures in the network. Hummon and Doreian (1989, 1990) [1, 2, 3] proposed three methods of assigning weights $w : R \rightarrow \mathbb{R}_0^+$ to arcs:

- NPCC method: $w_1(u, v) = |\overline{R}^{-1}(u)| \cdot |\overline{R}(v)|$
- Paths count method: $w_2(u, v) = N(u, v)$, where $N(u, v)$ denotes the number of different paths from Min R to Max R (or from s to t) through the arc (u, v)
- SPLC method: $w_3(u, v) = N'(u, v)$, where $N'(u, v)$ equals to $N(u, v)$ from paths count method over the network (E, R') , $R' := (R \cup \{s\}) \times (E \setminus \{s, t\})$

The last two methods are efficiently (Batagelj, 1991, 1994) [4] implemented in Pajek and can be applied also on (very) large acyclic networks. Let $N^-(v)$ denotes the number of different paths from s to v , and $N^+(v)$ denotes the number of different paths from v to t . Then $N(u, v) = N^-(u) \cdot N^+(v)$, $(u, v) \in R$.

N and N' are flows in the network since they obey the *Kirchoff's node law*:

For every node v in a citation network (E, R) in standard form it holds

$$\text{incoming flow} = \text{outgoing flow}$$

Therefore the *total flow* through the citation network equals $N(t, s)$. This gives us a natural way to normalize the weights

$$w(u, v) = \frac{N(u, v)}{N(t, s)} \Rightarrow 0 \leq w(u, v) \leq 1$$

If C is a minimal cut-set it also holds

$$\sum_{(u,v) \in C} w(u, v) = 1$$

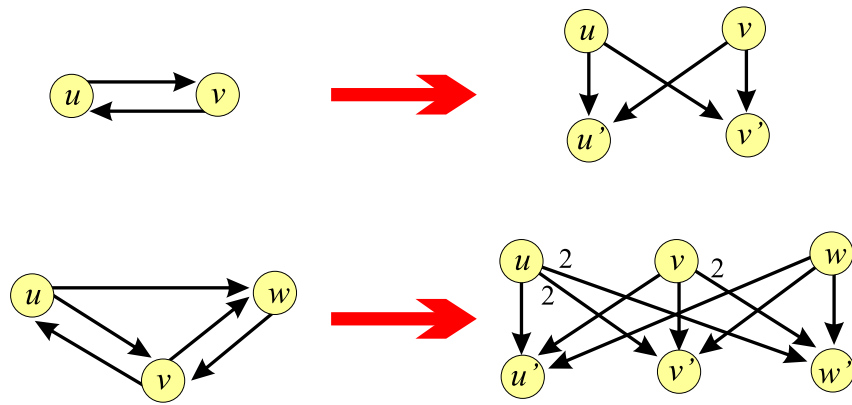
We can assign weights also to vertices

$$w(v) = \frac{N^-(v) \cdot N^+(v)}{N(t, s)}$$

References

Layouts of graph A

In graph A the relation is the reverse of the citing relation. The original graph A has 311 vertices. It has 6 weak components. Searching for strong components (testing acyclicity) it turns out that the graph A is not acyclic. A large strong component was generated by an erroneous arc (GD94/143 Eades, GD98/423 Eades). After reversing it 4 small strong components remained, corresponding to mutual references { GD94/286 Garg, GD94/298 Papakostas }, { GD94/328 Di Battista, GD94/340 Bose, GD94/352 ElGindy }, { GD95/8 Alt, GD95/234 Fekete } and { GD95/140 Chandramouli, GD95/300 Heath } . To obtain an acyclic graph, required by citations analysis method, we applied the following 'preprint' transformation:



Each paper from a strong component is duplicated with its 'preprint' version. The papers inside strong component cite preprints.

The pictures were exported as nested partitions into SVG format that allows interactive display of different *slices* – subgraphs induced by arcs with weights larger than a threshold value. These pictures are available at

<http://vlado.fmf.uni-lj.si/pub/GD/GD01.htm>.

In the paper form we can present only some snapshots.

The first picture displays complete network after 'preprint' transformations (320 vertices). The vertices are put in layers (vertical position and color of vertices) according to the years of publication. The placement of vertices inside the layer was determined by local optimization. The width and the color density of an arc and the size of a vertex are proportional to their citation weights.

The second and the third picture display the main parts (*slices*) of the citation network at threshold values 0.02 and 0.05. The red arcs belong to the 'main path'.

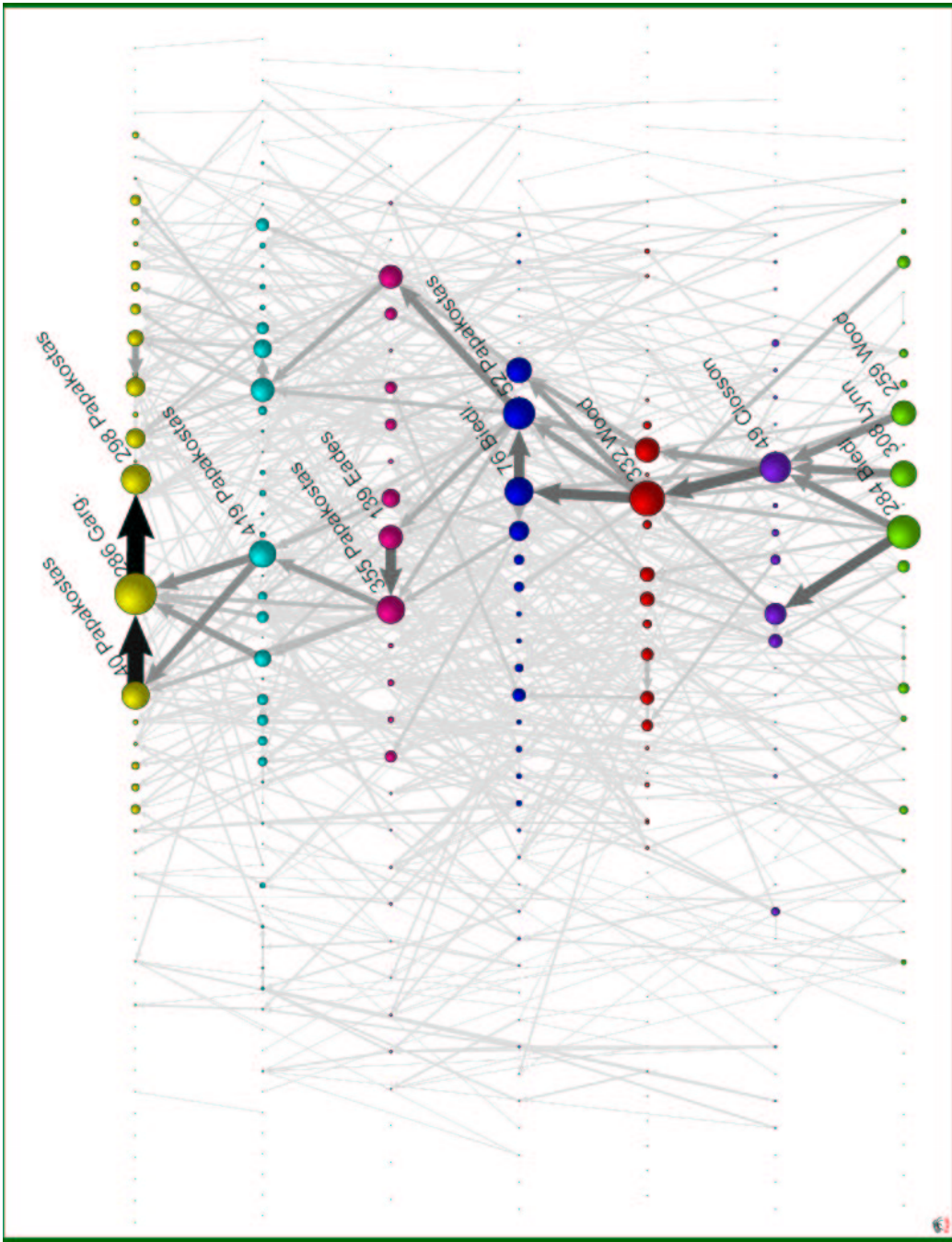


Figure 46: Graph A – complete graph.

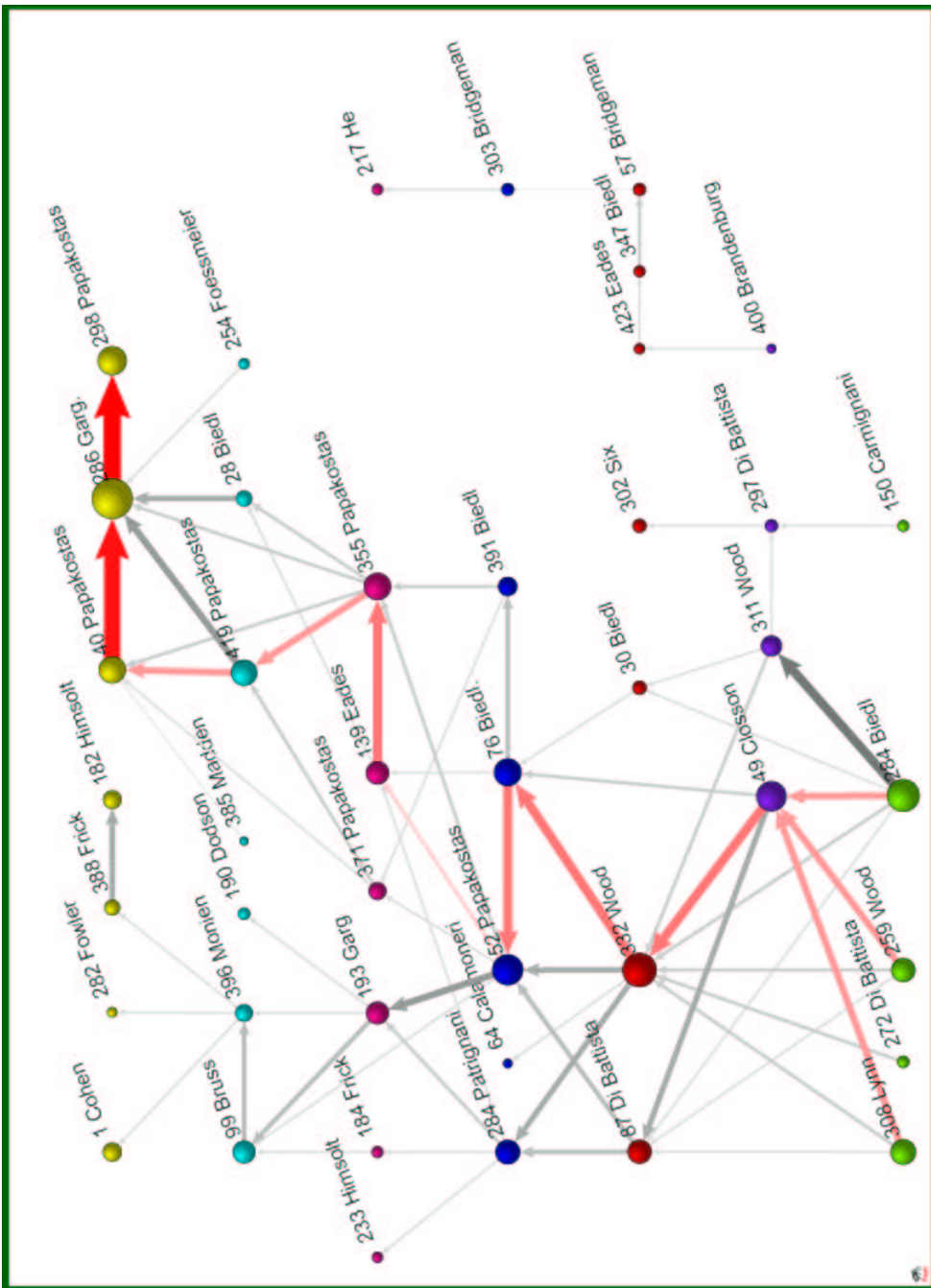


Figure 47: Graph A – level 0.02.

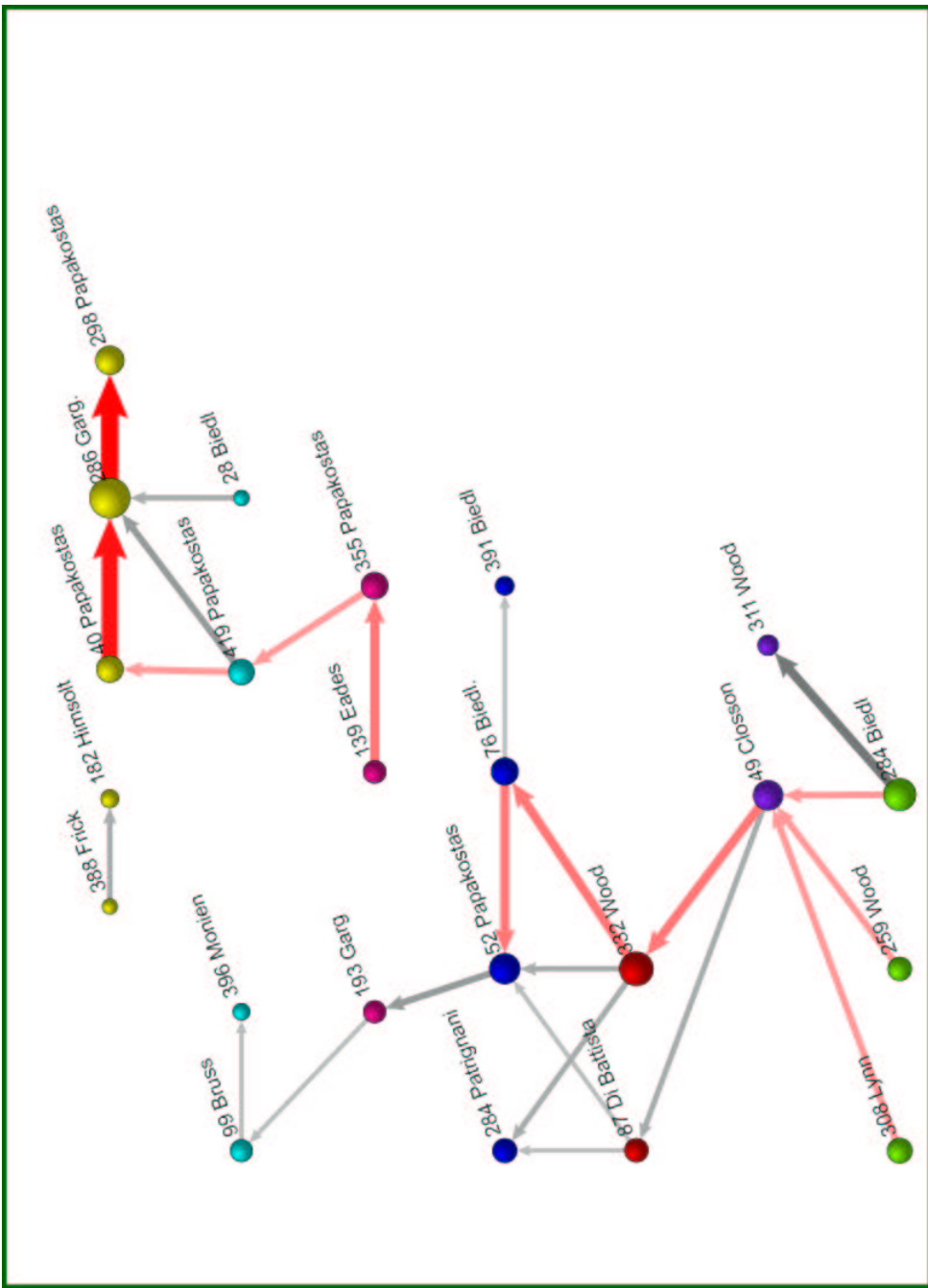


Figure 48: Graph A – level 0.05.

Graph B

To obtain the 'central symmetric' picture of graph B energy drawing was used, followed by manual grid positioning of vertices. To save the space the lower part of the picture was manually mirrored across the vertical axis.

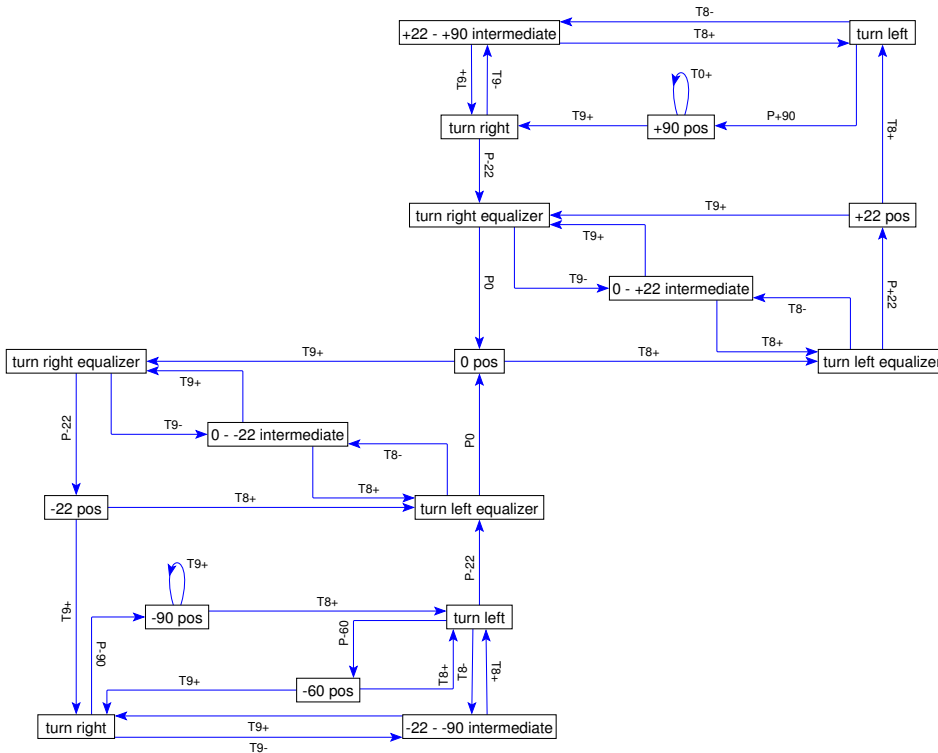


Figure 49: Graph B – 'central symmetric'.

Graph C

Graph C is an acyclic directed graph. Such graphs can be topologically sorted. The corresponding adjacency matrix has zero lower triangle and diagonal. Since the graph is rather dense we decided to use the matrix representation to visualize the graph structure. Layers are represented by blocks divided by blue lines.

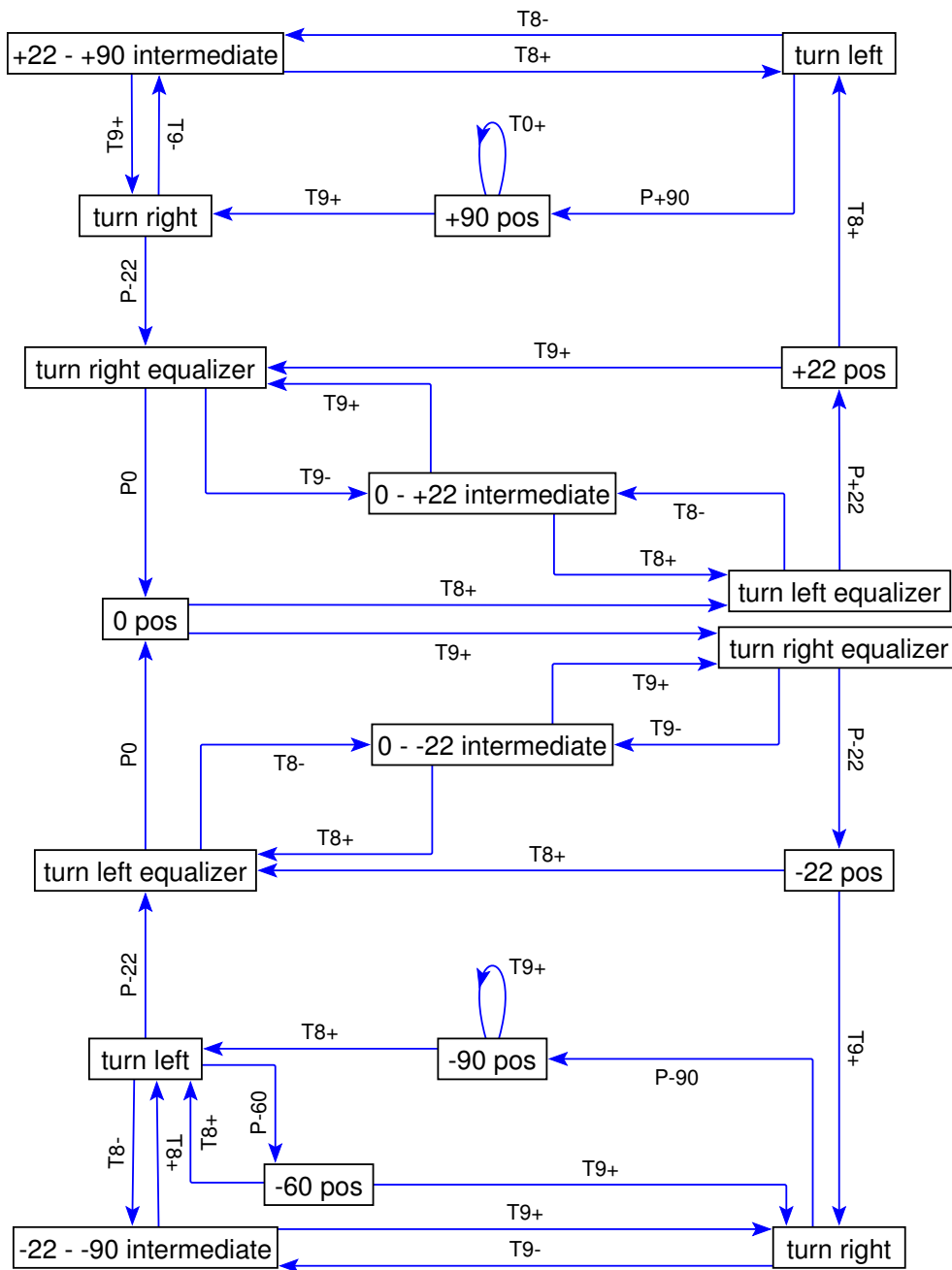


Figure 50: Graph B – mirror.

Pajek - shadow [0.00, 1.00]

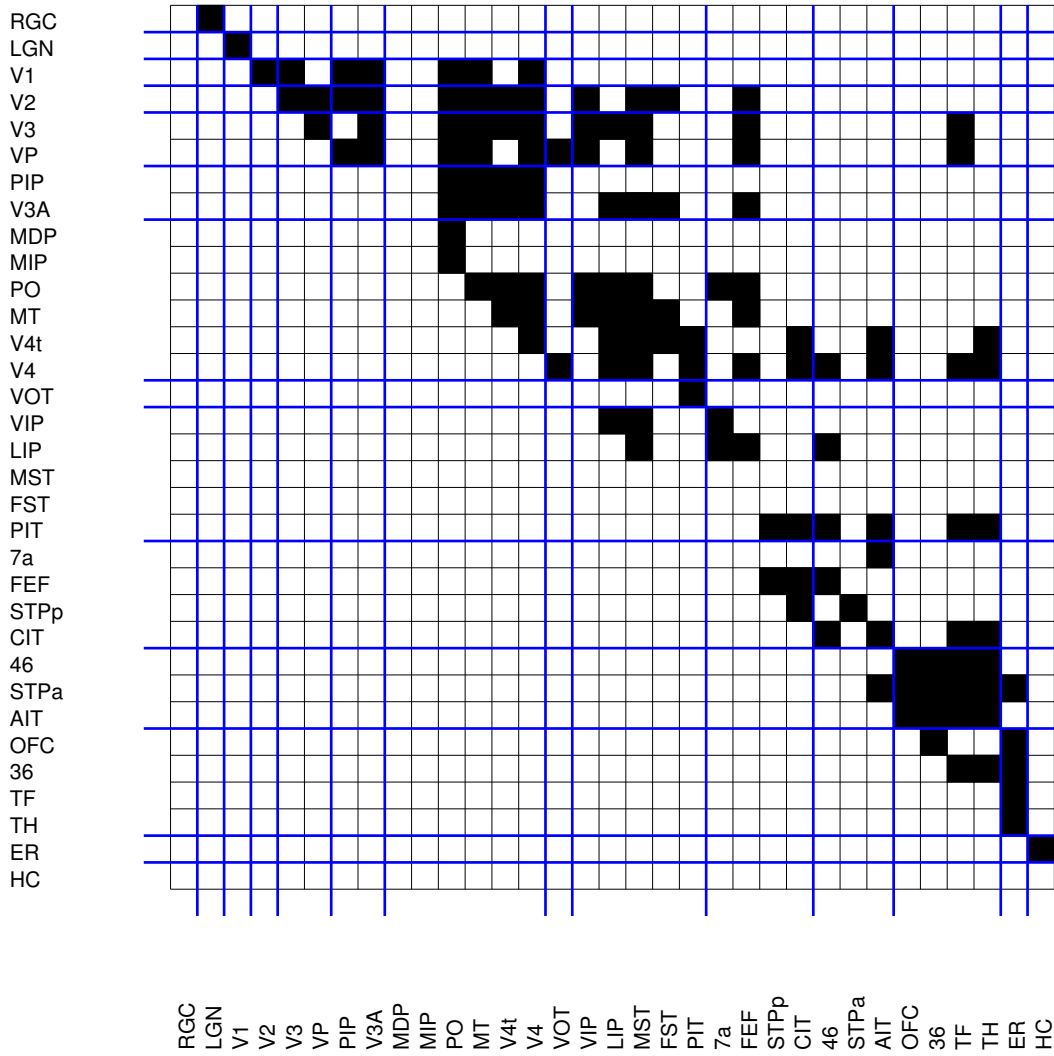


Figure 51: Graph C – matrix representation.

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