MITSUBISHI ELECTRIC RESEARCH LABORATORIES
http://www.merl.com

Graph-Drawing Contest Report

Peter Eades, Joe Marks, Stephen North

TR96-24 December 1996

Abstract

This report describes the the Third Annual Graph Drawing Contest, held in conjunction with the 1996 Graph Drawing Symposium in Berkeley, California. The purpose of the contest is to monitor and challenge the current state of the art in graph-drawing technology.

Proceedings of the 1996 Graph Drawing Symposium

MERL – A MITSUBISHI ELECTRIC RESEARCH LABORATORY
http://www.merl.com

Graph-Drawing Contest Report

Peter Eades
Univ. of Newcastle

Joe Marks
MERL

Stephen North
AT&T Research

TR-96-24 October 1996

Abstract

This report describes the the Third Annual Graph Drawing Contest, held in conjunction with the 1996 Graph Drawing Symposium in Berkeley, California. The purpose of the contest is to monitor and challenge the current state of the art in graph-drawing technology.

1. First printing, TR96-24, October 1996.

1 Introduction

Text descriptions of the four graphs for the 1996 contest can be found on the World Wide Web at URL `www.research.att.com/conf/gd96/contest.html`. Graph A represents a finite automaton used in a natural-language processing system. Graph B represents the calls made between a set of telephone numbers. Graph C is an artificial graph that was designed as a special challenge for standard algorithms. Graph D represents the structure and content of a fragment of the World Wide Web. An effective graph drawing had to communicate not only the edge connections between vertices, but also any vertex- or edge-attribute values peculiar to the graph. Thus the main judging criterion was one of information visualization.

Approximately 35 graphs were submitted by the contest deadline. The winners were selected by a panel of judges, and are shown below.

2 Winning submissions and honorable mentions

2.1 Graph A

This directed graph contains 1,096 nodes and 1,691 edges. Each node is either a terminal or a nonterminal node, and each edge is labeled with a single character. It depicts part of a finite automaton used in a natural-language processing system. Our intention was to award separate prizes for the best overall drawing of this graph and for the best distorted drawing that emphasized a particular node.

However, only four submissions (two each for the regular and distorted views) were received, and the judges felt that none of them was good enough to win. But because of the challenge offered by this graph, the judges awarded special honorable mentions to Gilles Paris (paris@ireq.ca) of IREQ Institut de recherche d'Hydro-Quebec, Canada, and to Falk Schreiber and Carsten Friedrich ([schreibe, friedric]@fmi.uni-passau.de) of Universität Passau, Germany. Paris submitted three-dimensional color drawings of the graph. Schreiber and Friedrich did not draw the graph explicitly, but instead decompiled it by listing all the words that could be spelled out by traversing the graph's edges.

2.2 Graph B

This graph contains 111 nodes and 193 edges. It was extracted from a large telephone-call database by a utility that finds connected components of graphs in external storage. Graphs like this are used by the police in the investigation of telephone fraud and other criminal activities. For obvious reasons, random numbers were substituted for real numbers. However, the area codes are actual area codes for the United States and Canada.

The winning drawing for Graph B, shown in Figure 1, was submitted by Ulrich Fößmeier and Michael Kaufmann ([foessmei, mk]@informatik.uni-tuebingen.de) of Universität Tübingen. An initial drawing was generated by an algorithm for finding partially layered representations

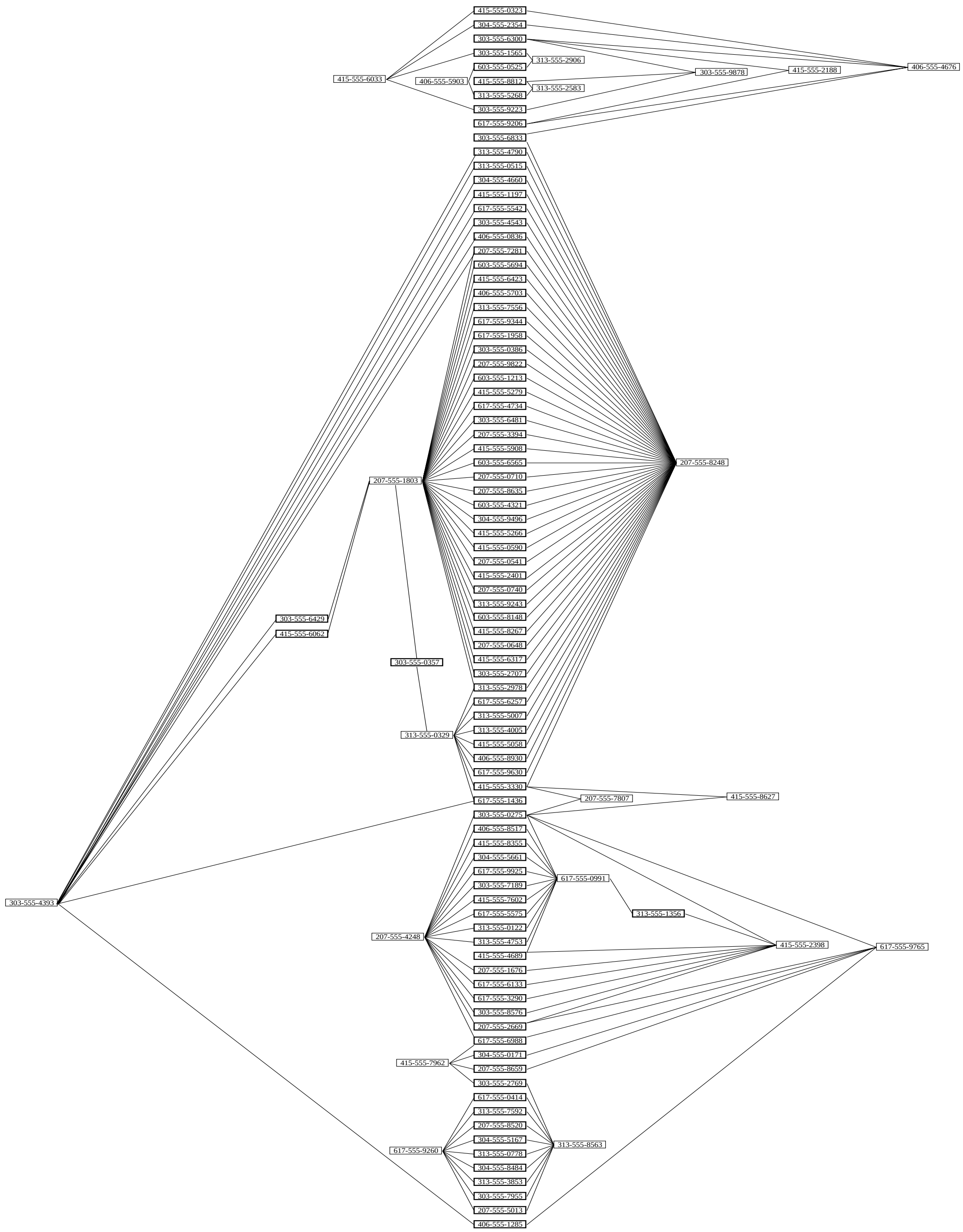

Figure 1: Winner, Graph B.

of planar bipartite graphs.[1] The final version of the drawing was refined manually.

An honorable mention for this graph was awarded to François Bertault (Francois.Bertault@-loria.fr) of CRIN/INRIA-Lorraine, France. His drawing is shown in Figure 2. The layout algorithm used was a spring method. Node positions were adjusted manually, and nodes are color-coded according to the area code of the corresponding telephone number.[2]

An honorable mention was also awarded to Vladimir Batagelj and Andrej Mrvar ([vladimir.-batagelj, andrej.mrvar]@uni-lj.si) from the University of Ljubljana, Slovenia, for the drawing in Figure 3. This layout was obtained by a program that positions vertices on a rectangular net so as to minimize edge crossings. Nodes were repositioned manually. Color coding and a key (not shown) associate nodes with area codes and telephone numbers, respectively.

2.3 Graph C

Unlike the other graphs, Graph C was contrived without reference to a real-world application. It contains 65 nodes and 125 edges. The winning drawing was submitted by Vladimir Batagelj and Andrej Mrvar ([vladimir.batagelj, andrej.mrvar]@uni-lj.si) from the University of Ljubljana, Slovenia. It appears in Figure 4. The graph was first partitioned into two parts automatically, and then each part was drawn using an energy-minimization approach. Some manual editing of the planar portion of the graph was also done.

The three honorable mentions (Figures 5-7) have approximately the same visual structure as the winning drawing. Figure 5 is the work of Falk Schreiber and Carsten Friedrich ([schreibe, friedric]@fmi.uni-passau.de) of Universität Passau, Germany. The layout results from a spring method. Figure 6 is due to Günter Rote (rote@opt.math.tu-graz.ac.at) from the Technische Universität Graz, Austria. The layout techniques used to produce the drawing were not described in the submission. Lastly, Figure 7 was submitted by François Bertault (Francois.Bertault@loria.fr) of CRIN/INRIA-Lorraine, France. A spring algorithm was used to separate the graph into two components. The layout of the planar component was found by first computing a planar embedding, and then applying a spring method that conserves planarity. The grid component was also handled by the spring method. Finally, the curved edges were added by hand.

2.4 Graph D

This directed graph contains 180 nodes and 229 edges. It represents some of AT&T's WWW sites and their contents. Each node represents either a URL, a text label, or an image; the node type can be inferred from the node's text label. So although the graph is relatively small, the node-attribute data make for a challenging visualization task.

The two best submissions for this graph took basically the same approach, which is to allow the user to view subsets of the graph interactively. Figure 8 contains a screen snap-shot from the winning system, developed by Falk Schreiber and Carsten Friedrich ([schreibe,

[1] Graph B was in fact the inspiration for developing this algorithm.

[2] To obtain a color hard copy or a PostScript version of this report, please contact Joe Marks (marks@merl.com).

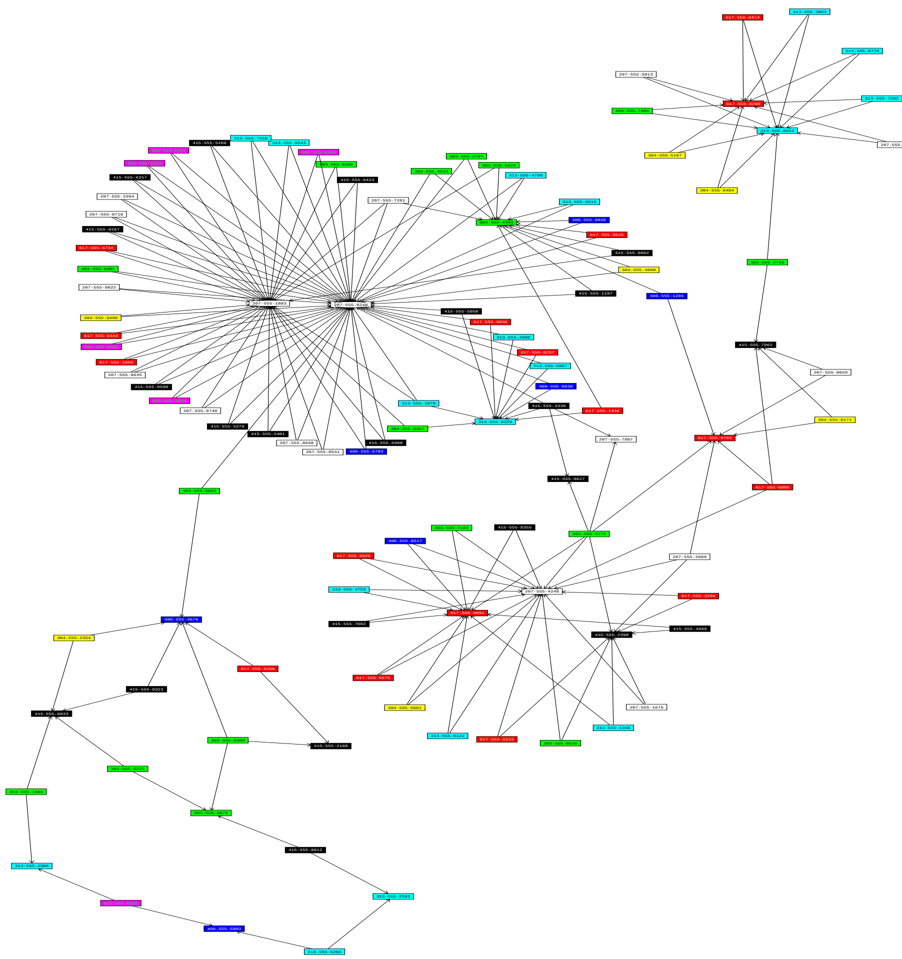

Figure 2: Honorable mention, Graph B (original in color).

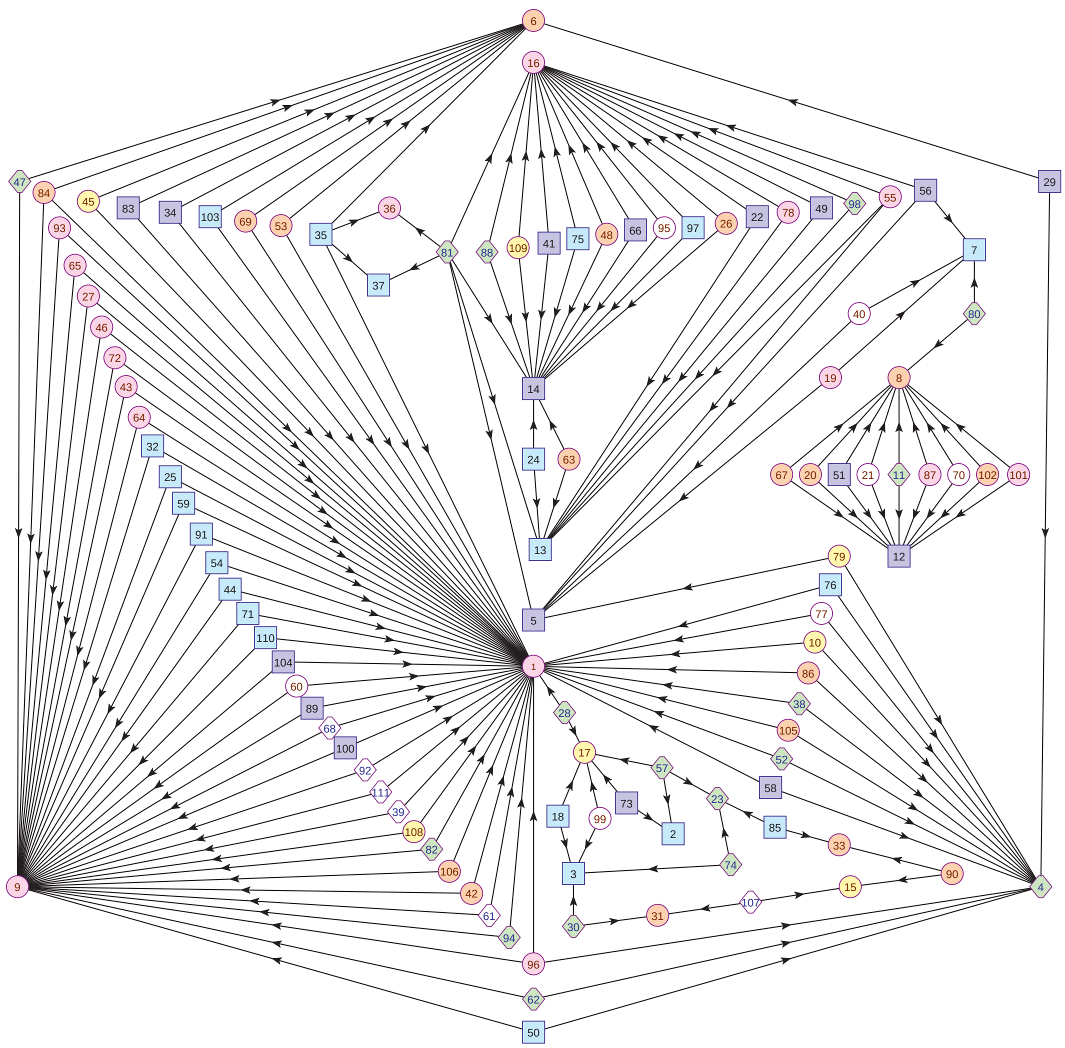

Figure 3: Honorable mention, Graph B (original in color).

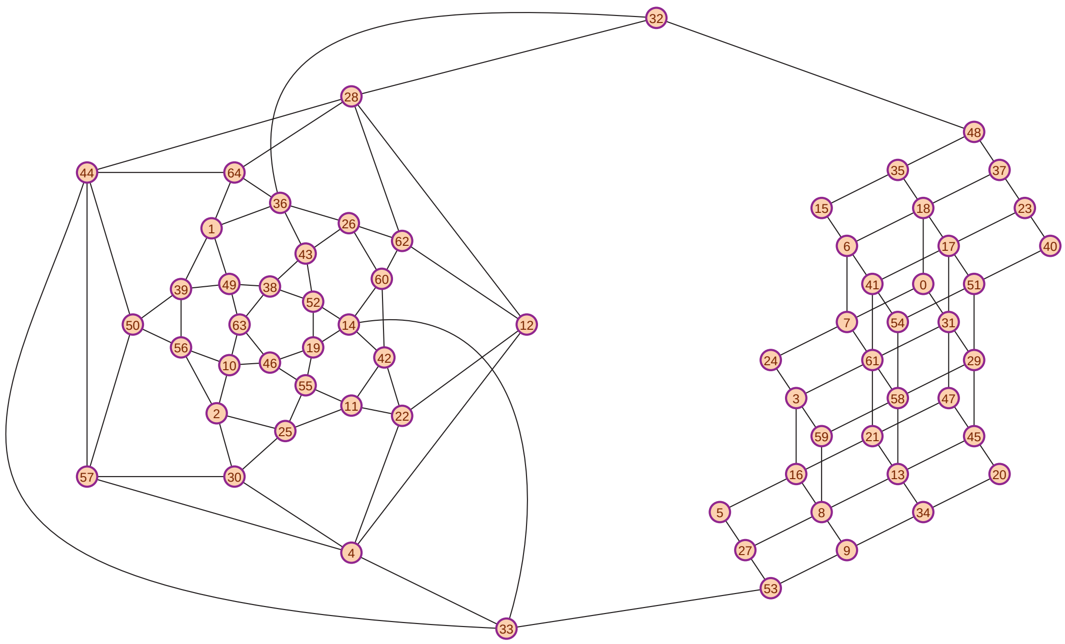

Figure 4: Winner, Graph C (original in color).

friedric]@fmi.uni-passau.de) of Universität Passau, Germany. They made the following modifications to the graph before computing layouts:

1. Node clusters were identified initially using a spring method.
2. Nodes that were referenced from different clusters and which had no successor were duplicated in each of the clusters.
3. Nodes whose labels had the prefix "`http://www.att.com/`" were displayed as an AT&T icon, which eased the text-labeling task considerably.
4. Some nodes with exactly one predecessor and one successor were replaced with a labeled edge.
5. Clusters that were connected to the rest of the graph via just one node were made into subgraphs. Nodes for these subgraphs were displayed large AT&T icons in the top-level graph. Clicking on these nodes causes the subgraphs to be displayed.

The subgraphs were drawn automatically (for the most part) by a Sugiyama algorithm. The main graph was drawn using a spring method, with subsequent modification by hand.

The drawing in Figure 9 was submitted by Thomas Kamps, Jörg Kleinz, and Thomas Reichenberger ([kamps, kleinz, reichen]@darmstadt.gmd.de) from IPSI, GMD Darmstadt, Germany. They also made similar structural changes to the graph to enable it to be visualized and explored interactively. All layouts were computed using a spring method, with the exception of the drawing of the curved edges and the label abbreviation, which were done by hand. A screen shot of their system is shown in Figure 9.

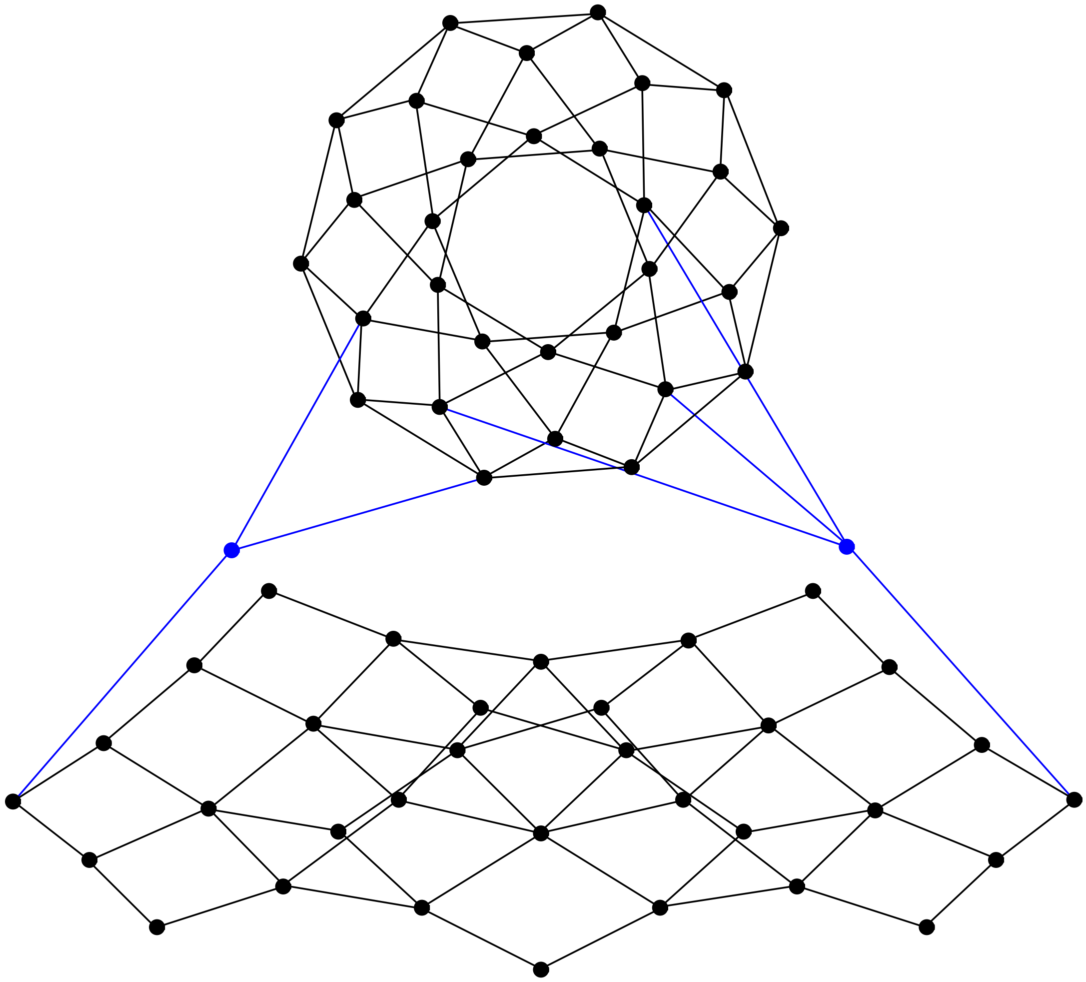

Figure 5: Honorable mention, Graph C (original in color).

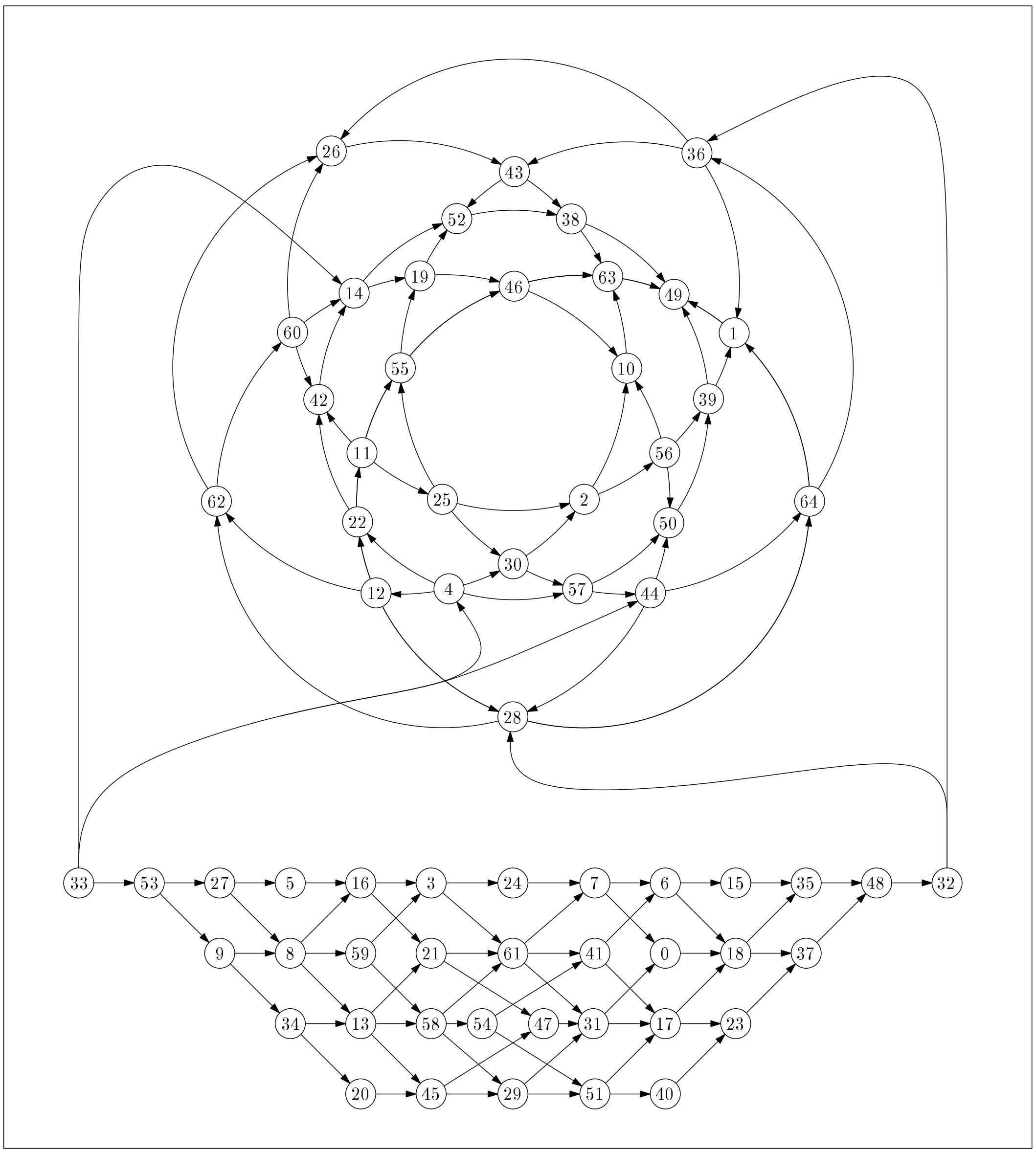

Figure 6: Honorable mention, Graph C.

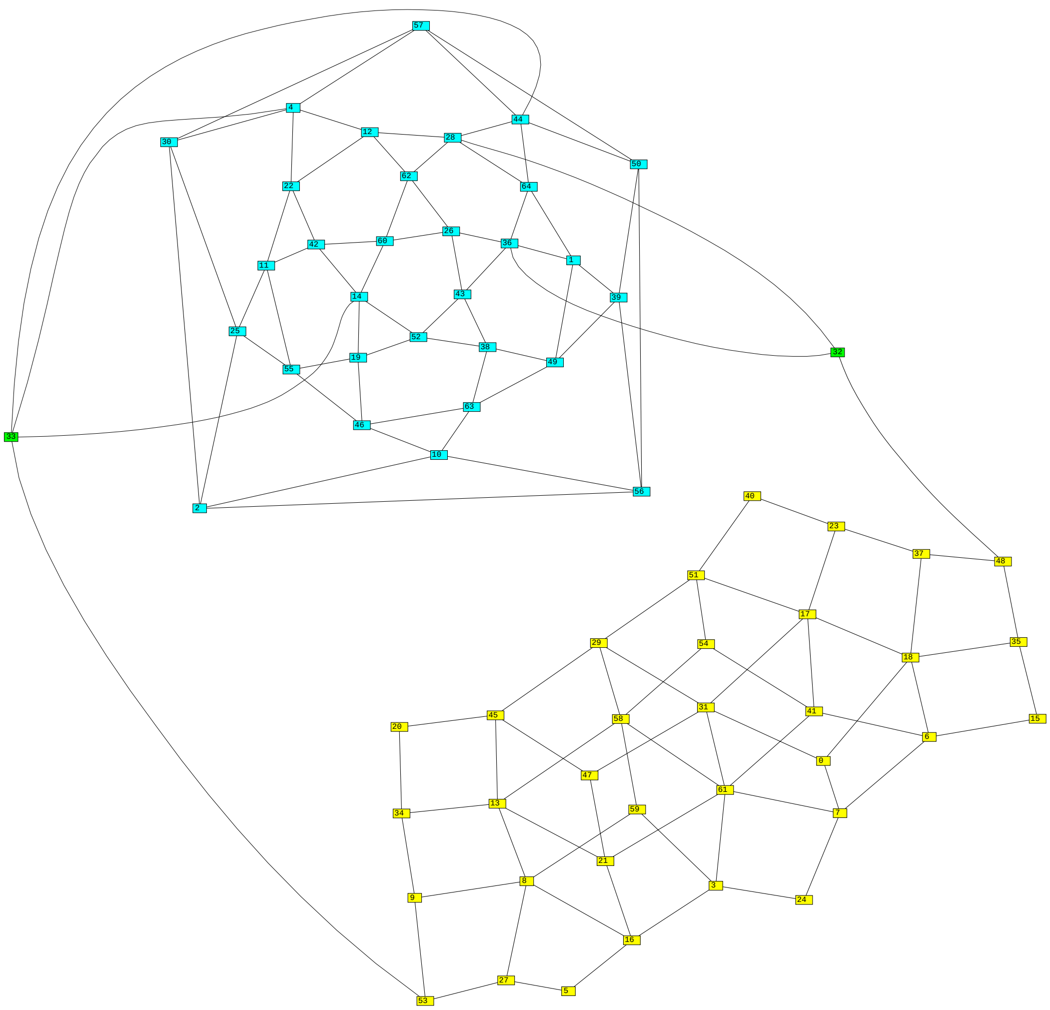

Figure 7: Honorable mention, Graph C (original in color).

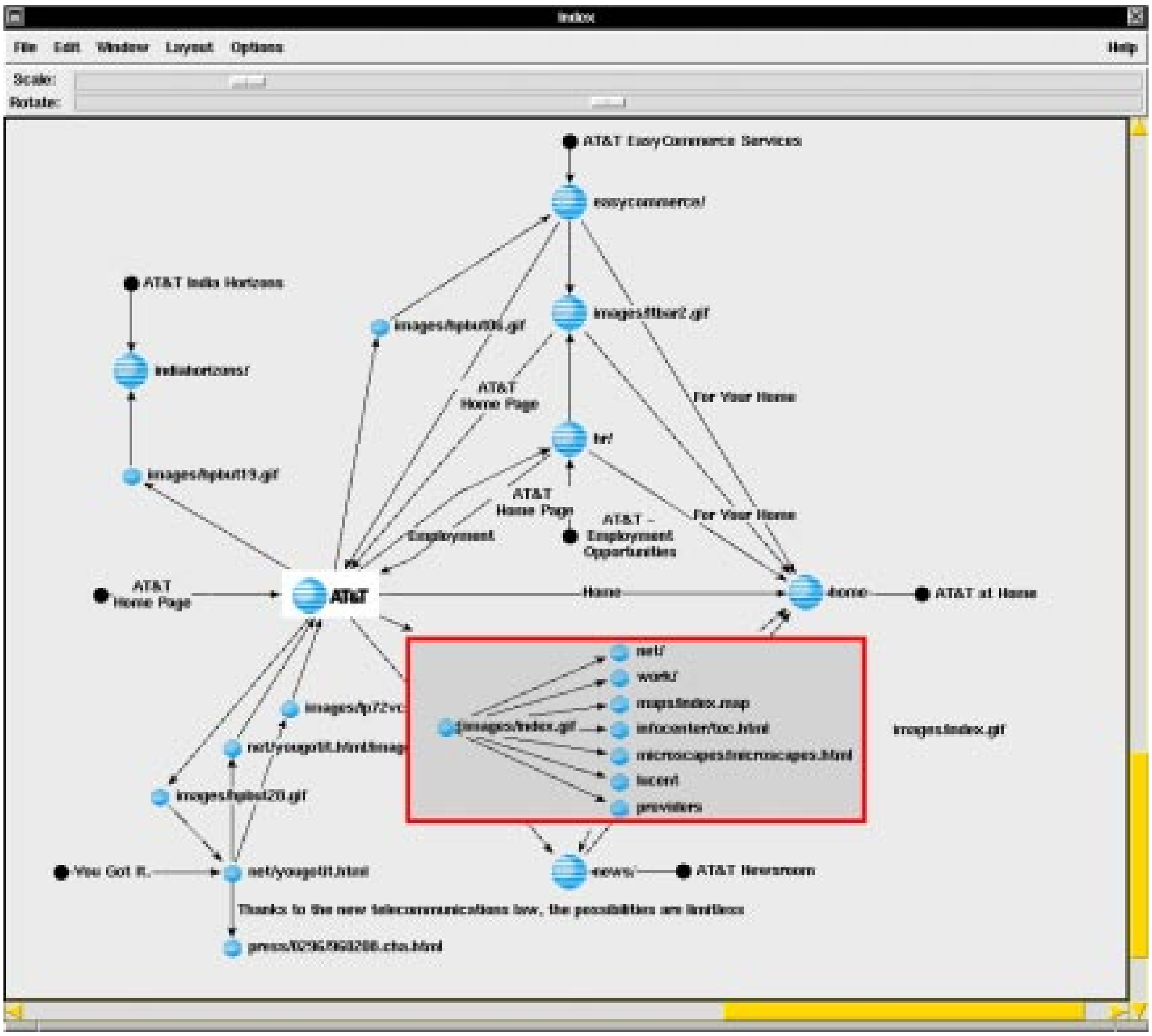

Figure 8: Winner, Graph D.

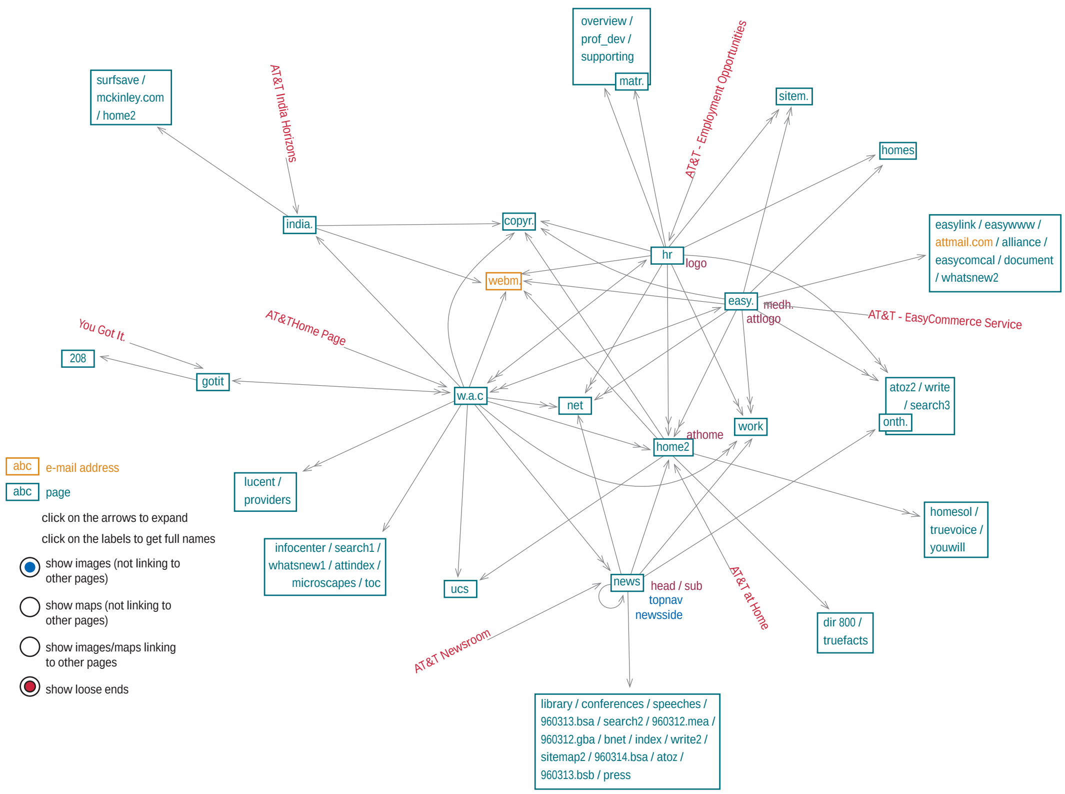

Figure 9: Honorable mention, Graph D (original in color).

3 Observations and Conclusions

Our first observation is that Graph A proved to be too challenging. It has 5 to 15 times as many nodes as the other graphs, and it also has labeled edges, which are not handled well by most current graph-drawing systems. We had hoped that the graph would serve to showcase the capabilities of distorted-view graph drawing, but no entries of this kind were submitted. Nevertheless, the graph may serve well as a near-term challenge for the next generation of graph-drawing software and may return in future contests.

The widespread use of spring methods among the better submissions is our next observation. A majority of the winning or honorable-mention drawings made use of the spring concept. Spring methods were used not only for producing final layouts, but also for initial exploration of graph structure. The insights gained from this exploration sometimes suggested other, non-spring algorithms for producing the final layout. The widespread use of the spring method as an investigatory layout technique seems to be new, and worthy of note.

A third observation is the lack of success achieved by orthogonal-edge drawings and three-dimensional drawings. In the former case, this year's results may be anomalous: in the two previous contests, orthogonal-edge drawings have figured prominently among the prize winners [1, 2]. However, no three-dimensional drawing has ever been awarded a prize in any of the three contests to date (we are not counting the special honorable mention given to a three-dimensional drawing of this year's Graph A – see above). The sample – a total of 11 graphs – may be too small to draw any strong conclusions,[3] but what evidence there is suggests that static three-dimensional graph drawings are not very effective at all.

As in previous years, the winners and honorable mentions often combined automatic layout and manual fine-tuning, which the rules allow. We suspect that the extent of manual modification and the editing tools used to do it vary greatly from one submission to the next, but we have had no good way of accurately classifying and quantifying post factum editing.

Lastly, we note how well interaction was used to visualize Graph D. Three-dimensional graph drawing may be a very good idea if the third dimension is temporal, not spatial! A graph that would be near impossible to explore and comprehend as a single drawing was made quite accessible in two well-designed interactive contexts that use a discrete "expand/contract" metaphor for navigating the graph.

The two final observations lead to our main conclusion, which is that future graph-drawing contests need to encourage and better accommodate interactive graph-drawing systems. Existing two-dimensional methods can be made more effective in well-designed interactive systems; interactivity may be essential for making three-dimensional graph drawing useful. We are investigating the possibility of introducing a separate category of video submissions next year as a way to foster research into interactive graph drawing.

[3]To be fair, we note that contest judging is done from static page-size drawings (color or grayscale, as appropriate), which certainly does not capture the full effect of using an interactive three-dimensional viewer.

4 Acknowledgments

Sponsorship for this contest was provided by AT&T Research, Fujitsu, MERL–A Mitsubishi Electric Research Laboratory, and Tom Sawyer Software. Takao Nishizeki, Yanni Tollis, and Sue Whitesides assisted with the judging. Graph A was contributed by Emmanuel Roche and Yves Schabes of MERL, and Graphs B and D was contributed by Eleftherios Koutsofios of AT&T. Patrick Garvan from the University of Newcastle helped to devise Graph C.

References

[1] P. Eades and J. Marks. Graph-drawing contest report. In R. Tamassia and I. G. Tollis, editors, *Lecture Notes in Computer Science: 894 (Proceedings of the DIMACS International Workshop on Graph Drawing '94)*, pages 143–146, Berlin Heidelberg, October 1994. Springer-Verlag.

[2] P. Eades and J. Marks. Graph-drawing contest report. In F. J. Brandenburg, editor, *Lecture Notes in Computer Science: 1027 (Proceedings of the Symposium on Graph Drawing GD '95)*, pages 224–233, Berlin Heidelberg, September 1995. Springer-Verlag.