BiblioViz: A System for Visualizing Bibliography Information

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Abstract

The InfoVis 2004 contest led to the development of several bibliography visualization systems. Even though each of these systems offers some unique views of the bibliography data, there is no single best system offering all the desired views. We have thus studied how to consolidate the desirable functionalities of these systems into a cohesive design. We have also designed a few novel visualization methods. This paper presents our findings and creation: BiblioViz, a bibliography visualization system that gives the maximum number of views of the data using a minimum number of visualization constructs in a unified fashion.

Keywords: bibliography visualization, linked views, graph visualization, text and document visualization, applications of visualization, tables

1 Introduction

In the academic world, the citation databases in each field are very valuable resources to researchers. While text-based searching and browsing is used extensively to look up information in the databases, complex inter-relationships among papers, authors, research areas, and publication venues are best revealed with visual means. The InfoVis 2004 Contest (Plaisant, Fekete, Grinstein 2004) was dedicated to visualizing the bibliography of the field of information visualization. The contest attracted much attention and received many submissions.

The organizers of the InfoVis 2004 Contest selected four First Place winners and eight Second Place winners. Together, these twelve entries presented different visualization representations and systems, with various tradeoffs, strengths and weaknesses. Several other tools for visualizing bibliography information have also appeared over the years. Although these systems provide good visualizations of different aspects of the data, the user is still left with some unanswered questions:

- What are the similarities and differences, and advantages and disadvantages of each system?
- Which of these systems should I use for my needs?
- Is it possible or feasible to integrate the different methods offered by different systems?

We cannot construct a complete bibliography visualization system by simply putting together all the different visual representations presented by the contest entries. The sheer number of choices would lead to information glut and overwhelm the user. Our objective is to analyze the requirements of bibliography visualization and examine the different solutions presented, then to design and create a usable and comprehensive bibliography visualization system, drawing from the experience provided by these existing systems, to create a "best of all worlds" visualization.

We discuss the following issues involved in our analysis, design and construction of our bibliography visualization system, which we call BiblioViz:

1. the methodology and principles in building a usable and comprehensive bibliography visualization system,
2. the goal of bibliography visualization according to what users may want to discover,
3. the various existing systems and their contributions, and
4. our design, based on the principles we outlined and our analysis and integration of existing systems.

We describe the components of BiblioViz, and how we adapt various existing visual representations and visualization components to fit together. We also incorporate some novel visualization methods. We show that BiblioViz is intuitive despite having many different functionalities. Through a case study, we describe how users can utilize the various features of BiblioViz to create custom visualizations that help glean insights in the data.

2 Design Methodology and Principles

We take a systematic approach in our system design by considering the following factors.

2.1 Goal Driven

We consider the goals of the user so that we can tailor our system to help users draw the insights and knowledge they seek. Amar and Stasko (Amar & Stasko 2004) note that "there remains uncertainty about the ability of current systems to adequately support decision making," and therefore propose "a knowledge task-based framework" for designing information visualizations. We approach our design by first asking what information and relationships the user may be interested in visualizing, and also what insights and knowledge the user may gain out of visualization. Card et al. (Card, Mackinlay & Shneiderman 1999) mention that "the purpose of visualization is insight, not pictures." Our goal is to provide the best platform for users to "amplify cognition" (Card et al. 1999), and to help them to draw desired insights. The goals we came up with are listed in Section 3.

2.2 Problem Domain Specification

Our system aims to visualize bibliography information. To that end, BiblioViz expects the following data as input:

1. List of Papers (year, publication venue, title, keywords, research areas, primary research area, authors, abstract)
2. List of Publication Venues (name, year)
3. List of Authors (last name, first name)
4. List of Keywords (name, research area)
5. List of Research Areas (name)

BiblioViz currently does not take as input some aspects of publications, such as the month of publication venue, figures, captions and the textual content of the paper. This information can potentially be included and visualized in future versions of BiblioViz.

2.3 Visualization Minimization

In experiments performed by Klein et al. (Klein, Müller, Reiterer, Eibl 2002), they observed that "switching between completely different visualizations confused the users." We therefore cannot simply throw together all the different contest visualizations into one system; the sheer number of visualizations would surely overwhelm the user. Instead, we will analyze all the contest entries and distill the visualization metaphors down to the essentials needed for a system with a wide range of visualization capabilities. We will also give the user flexibility in choosing some properties of each visualization, such as the use of shapes, colors, etc., without changing the basic metaphor.

2.4 Analysis of Existing Work

We systematically analyze the existing visualization systems according to the goals we outlined for bibliography visualization. Mackinlay et al. (Mackinlay 1986, Mackinlay & Genesereth 1985) use the criteria of *expressiveness* and *effectiveness* to evaluate visual representations. Roth and Mattis (Roth & Mattis 1990) consider an additional criterion: the user's goal in using the visualization. We use these standards to evaluate various existing visual representations, to derive a set of necessary features for BiblioViz. In analyzing and evaluating existing work, as well as in determining the visual representations in BiblioViz, we consider whether a visualization expresses a relationship in the data, and how effectively it conveys this information. We also consider how useful this information may be to the user. Certainly, these criteria are subjective in their nature, so we use the best of our judgment, and the reader can verify the examples shown in this paper.

2.5 Linking and Extensibility

Although we minimize the number of different representations, there is still more than one representation, and we allow the user to show multiple views simultaneously. We allow linking (Becker & Cleveland 1987) when there are separate windows and different representations so that the user can have a cohesive view of the data.

Since Bibliography data is complex, there are many different ways to visualize the data. Although we have analyzed current systems and defined a set of relationships the user is interested in, there could potentially be additions to the data schema, or inventions of new visualization methods. Our system therefore needs to be able to accommodate these changes. We consider our system to be composed of separate modules: (1) data processing, (2) visual metaphor, (3) auxiliary graphics, and (4) layout algorithm. Each component has a well-defined interface to the others so that changes can be made to one component without affecting others. We currently support a few different visual representations and a few different layout algorithms. From a control panel, the user can choose which to display and use. In the future, if other visual representations and/or layout algorithms are added, we just need to insert new options. Within each visual representation, options are also provided to display additional graphical objects. Again, the current set of auxiliary graphical objects is not exhaustive, so in the future, new graphical objects may be incorporated and added as options.

3 Goals of Bibliography Visualization

In the InfoVis 2004 Contest, three tasks were proposed:

1. "Characterize the research areas and their evolution,"
2. "Where does a particular author fit within the research areas?" and
3. "What are the relationships between two or more of the authors?"

These questions serve as good guidelines for the goals of bibliography visualization. We will keep these goals in mind during the design and evaluation of the system.

4 Analysis of Existing Work

We analyzed the entries of the InfoVis Contest 2004. Some existing bibliography visualization tools such as Chen and Carr's work (Chen & Carr 1999) and Noel's work (Noel, Chu & Raghavan 2003) have heavily influenced some of the contest entries, so these works are not listed separately.

We notice that there are many similarities among the different visualizations presented. We can classify them under four broad categories shown below, listed with the visualizations that fall under each category.

- Table: PaperLens (Lee, Czerwinski, Robertson & Bederson 2004), Keyword Burst Table (Ke, Börner, Viswanath 2004), Time Slicer of IN-SPIRE (Wong, Hetzler, Posse, Whiting, Havre, Cramer, Shah, singhal, Turner & Thomas 2004), Paper Finder (Keim, Panse, Sips, Scheidewind, Barro 2004), One-For-All (Teoh & Ma 2004)
- Network:

  - 2D: Citation and Co-citation Network (Ke et al. 2004), Associative Information Visualizer (White, Lin & Buzydlowski 2004), Paper Finder (Keim et al. 2004), Citespace (Chen 2004)
  - 3D: WilmaScope (A. Ahmed, T. Dwyer, C. Murray, L. Song, and Y.X. Wu. 2004), van Ham (van Ham 2004), Tulip (Delest, Munzner, Auber, Domenger 2004)

- Node placement without network:
  - 2D: IN-SPIRE, (Wong et al. 2004) Associative Information Visualizer (White et al. 2004), MonkEllipse (Hsu, Farabaugh, McColgin, Stamper 2004)
  - 3D: InfoVisExplorer (Tyman, Gruetzmacher & Stasko 2004)

- Others: InterRing techniques (Yang, Ward & Rundensteiner 2002) used in Paper Finder (Keim et al. 2004), MonkEllipse (Hsu et al. 2004) (arrange papers chronologically, show paper details), Worms in WilmaScope (Ahmed et al. 2004)

Within each category, we find differences and commonalities.

In the Table category, we have found that all the tables assign time to an axis. This indicates a strong consensus that the Table View is very appropriate and effective for representing time-related information. Furthermore, all Table entries, with the exception of One-For-All, use the x-axis to represent time. In the Table View, some systems draw bar graphs (eg. INSPIRE), some draw line graphs (eg. Ke et al.) and others draw nodes (eg. One-For-All and Keim). Many visual methods incorporate color to show additional information (for example, One-For-All uses color to represent selected authors). Size is commonly used to show the importance of the node.

There are also many variations under the Network category. For example, Ke et al. uses color and size to represent number of citations. Keim also uses color. Xia Lin mixes all the attributes such as authors, keywords and documents, Keim uses a spring embedder to lay out the graph, showing co-author relationships, and CiteSpace superimposes citation bars on the network. Node/link color and size are used by many systems to show additional information. For example, one option in Ke et al. is to use size to represent the number of citations, and color to represent publication year. The different methods also vary in their effectiveness; for example, the large number of overlapping lines in WilmaScope may obscure some information.

Some systems such as MonkEllipse and PaperLens also provide Details on demand, displaying the full title, authors and other information of selected papers.

We find that the information conveyed by systems listed in the "Others" category can often be expressed equally effectively by the Table and Network Views. For example, Keim's use of InterRing to visualize co-authors, papers and year can also be shown in a network of authors, highlighting the appropriate author node, and using the appropriate color-coding (color-code the co-authors of the highlighted author) and text labeling (label the year of publication).

5 BiblioViz

We utilize our classification and analysis of current visualization tools to create a compact but comprehensive bibliography visualization system: BiblioViz. From our study, we discover that only two views–the Network View and Table View–are sufficient to cover the functionalities of the existing visual representations. The Network View is better able to visually convey relationships between objects, whereas the Table View is better at showing time-related information. We notice that several of the contest entries submitted pictures of both Table and Network Views, and that all the Table Views use time as one of the axes. Because the Network and Table views are very common visual metaphors, and because of our goal of minimizing visual representations (See Section 2), we select these two views to include in BiblioViz.

In addition, we find that displaying the details of a paper on demand, such as when the user clicks on a visual object, is a convenient and useful feature, following Shneiderman's (Schneiderman 1996) mantra, "Overview first, zoom and filter, then details on demand." In the Network View, the user can choose to show only the nodes without the links, and hence offer the same visualization as the methods listed in the "node placement without network" class in Section 4.

We then build additional options and visual features to enable BiblioViz to convey deeper and richer information. We describe how we fit the various visualization pieces so that they work cohesively and seamlessly together, and we also describe some novel techniques we introduce in BiblioViz. The InfoVis 2004 Contest dataset, composed of bibliography data in the field of Information Visualization, is used for the rest of the discussion and examples.

5.1 System Overview

BiblioViz consists of five parts: (1) Table View, (2) Network View, (3) Paper Details Panel, (4) Data Menu, and (5) User Control Panel. The user can click in the Table View display or the Network View display to highlight a particular paper, and the details of the paper are shown in the Paper Details Panel. BiblioViz also allows the user to pick data entities (authors, papers, research areas) from the Data Menu to view or to highlight. The User Control Panel allows the user to make dynamic queries into the data, and also to specify visualization parameters for the Table View and Network View. The Views are linked, so interaction with one has an appropriate visual effect on the other.

5.2 Table View

In the Table View, a 2D table is shown. The x-axis depicts time by year. The user can choose to show (1) publication venues, (2) authors, or (3) research areas on the y-axis. Figure 1 shows an author table, while Figure 2 shows a research area table. Each paper is represented as a rectangle and is placed into a cell in the table according to its attribute values in the x and y axes. Within each cell, the rectangles are stacked horizontally. Additionally, a rectangle can be colored by (1) publication venues, (2) authors, or (3) research areas. If a paper has multiple authors or belongs to multiple research areas, its rectangle is divided into multiple sections and colored accordingly. The height of each rectangle indicates its relative importance (how many times it is cited by other papers).

We use a focus+context method resembling Datelens (Bederson, Clamage, Czerwinski, Robertson 2004) for the table navigation. The user may select individual rows or columns to focus upon (see Figure 1). Those table entries will become larger while the surrounding entries become smaller, but still remain visible to provide the context.

One useful feature provided by the Table View is to allow the user to choose different methods of arranging the rows. For example, if research area is chosen as the y-axis, the user can choose to sort the research areas in terms of their importance, or to arrange them by their relationship with one another (related research areas placed close together via multidimensional scaling). The user can also highlight a certain paper by clicking on it, or by specifying it from a list. When a paper is selected, its border is highlighted in red, and its details are displayed on the side. Rather than draw lines connecting it with its citations, as in One-For-All, the cited papers are highlighted in a similar way in orange border color. This greatly reduces visual clutter while still allowing the user to visualize relationships.

Another feature provided by the Table View is to incorporate the keyword burst visualization offered by Ke et al. We arrange the periods chronologically as usual, but instead of just coloring periods of keyword burst, we show the actual papers in the periods. This provides the user richer visual information, while preserving the perception of the bursts. An example is shown in Figure 2.

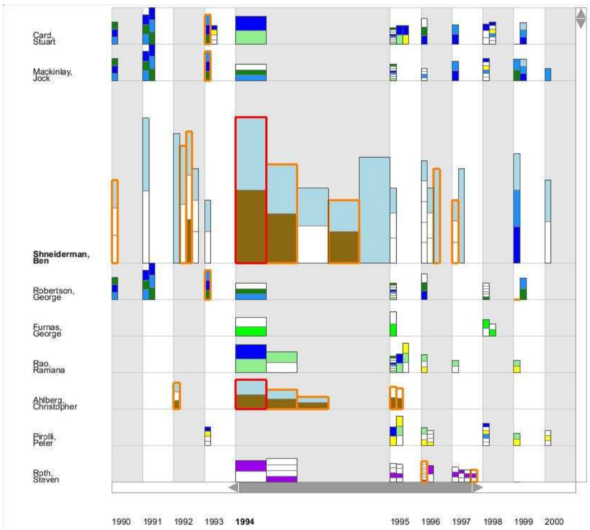

Figure 1: Table of Papers by Year (x-axis) and authors (y-axis). The authors are arranged by their importance. Each rectangle represents a paper. Each segment within a rectangle represents an author of the paper. Selected authors are color-coded.

5.3 Network View

The Network View consists of five components: (1) Filter, (2) Node Placement, (3) Highlight, (4) Rendering, and (5) Auxiliary Graphics.

For the Filter component, the user can choose to draw a network consisting of nodes representing authors, papers, publication venues or research areas. Within each network, the user can choose only to draw nodes representing the top n entities (authors, papers, publication venues or research areas), for example, the user may choose to display the 100 most-cited authors. BiblioViz also provides a menu for the user to select specific entities to display. This menu can be ordered alphabetically or arranged by the importance of the entity.

In the Node Placement component, BiblioViz supports several different layout algorithms. These are self-organizing maps (SOM) (Kohonen 1997), force-directed (Kamada, Kawai 1989), and centroid. SOM is good for arranging the nodes according to research area (see Figure 3). Force-directed is good for reducing edge lengths by placing collaborating authors or paper citation cliques close together (see Figure 4).

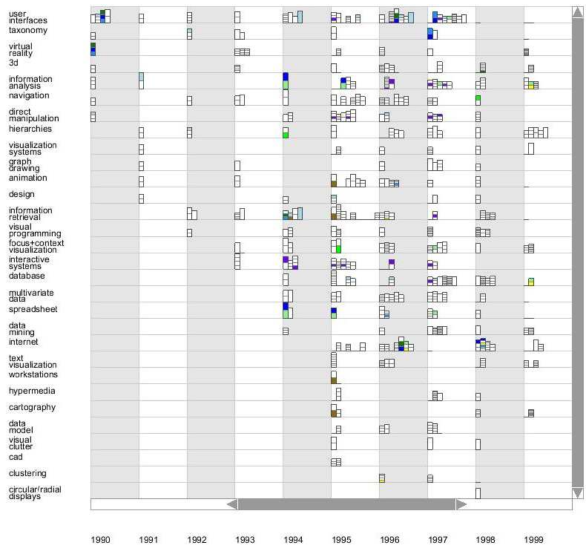

Figure 2: Table of papers by Year (x-axis) and research area (y-axis). The research areas are arranged by their burst in activity.

The centroid layout method is used in the dual-plane rendering mode, discussed below. It places nodes of one type above the centroid of its neighbors of another type.

The Highlight component allows the user to choose certain entities to focus on. This is done by clicking on the node representing the entity (author or paper). The user can also highlight an entity by selecting it from a menu. When an entity is highlighted, it is labeled and its links are drawn with increased thickness. This allows the user to see the highlighted entity clearly, in the context of the global information.

The Rendering component determines how the data is displayed as graphics. We provide two possible views of the network: 2D and 3D. In the Network View, there can be one or more planes. Each plane contains nodes representing one type of entity (author, paper, publication venue, or research area). Planes can be stacked above each other. The 2D view looks at the network plane(s) from the top, so if multiple planes exist, they will be blended into one. The 3D view looks at them from an oblique angle (see Figure 5). Cylinders, spheres, and lighting are used to enhance depth cues in the 3D view. Furthermore, on the same plane, tube arches are used to draw links, rather than straight lines, in order to give a better perception of the end-points of the links (Arcs or curved lines have been used effectively in the past, for example, in Wattenberg's Arc Diagrams (Wattenberg 2002) and InfoVis 2004 Contest entry One-For-All, but 3D arches have not been used in previous bibliography visualization systems.). Colors are mapped to categorical data, and non-highlighted objects are drawn in lighter colors. These graphical methods are used to enhance the *effectiveness* of the visualization. The mapping of color to nominal data, links and proximity for relationships, and size for (quantitative) importance, are all commonly used visual mappings, as they take advantage of the "automatic processing" (Card et al. 1999) ability of the human visual perception system.

The Auxiliary Graphics component helps to convey additional information. We allow the user to add some auxiliary graphical entities to the visualization. For example, the user can choose to show the density map of the SOM nodes similar to INSPIRE, except that in BiblioViz, this can be superimposed on the network display, providing contextual information. The circular nodes representing papers can also be segmented, so that each segment can be color-coded according to the authors of the paper, or the research areas of the paper, similar to One-For-All. In the 3D Network View, we also allow the user to optionally display a tower on top of each node (similar to the *citation landscape* used in CiteSpace). If the nodes represent authors, each segment in the tower can represent a paper written by the author, and color-coded according to the publication venue.

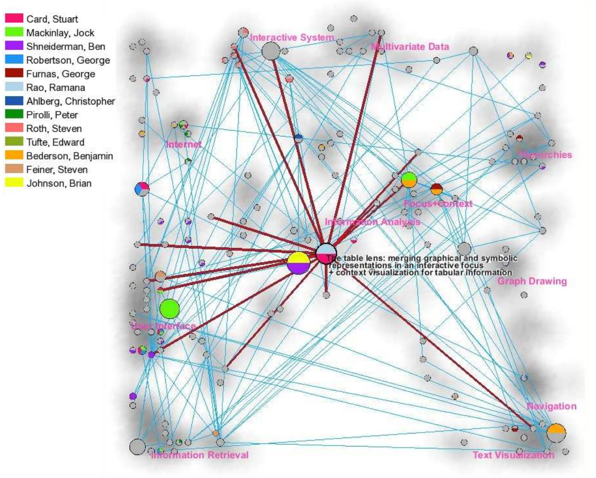

Figure 3: Network View of selected papers. Papers are placed by research areas using SOM.

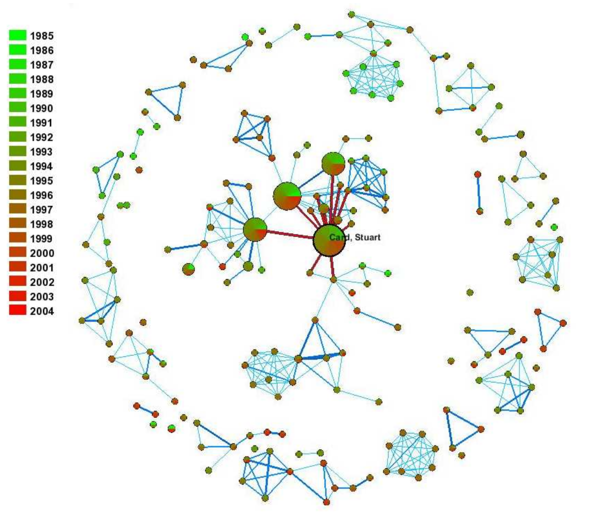

Figure 4: Network View of selected authors. Authors are placed according to their collaborations using force-directed layout methods.

The options in BiblioViz allow the user to balance information quantity against clarity. With the Filtering options, the user can choose how many nodes to show. More nodes show more information, but add to clutter. With the Highlight option, the desired important information can be made more obvious, while keeping a lot of information in the background as context. Similarly, the options to show or to hide auxiliary graphics such as links and towers also have the same trade-offs. With the Filter, Highlight and Auxiliary Graphics options, the user can have a wide variety of choices in making these trade-off decisions according to the knowledge desired.

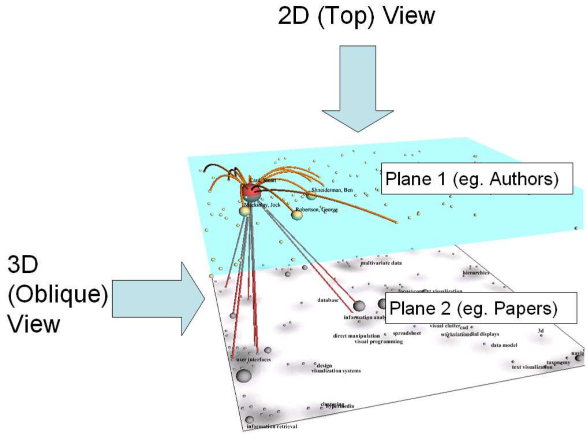

Figure 5: User can choose to view the network from the top (2D view) or from an oblique angle (3D view).

5.4 Linking the Components

The Table View and Network View can be displayed individually or simultaneously, selected by an option in the control panel. In the single view mode, the chosen View occupies the entire center region of the display. In double view mode, the Network View is shown above the Table View (see Figure 6). The two Views are linked, in that interacting with one will have an effect on the other. For example, clicking on a node in the Network View will highlight the node in both Views, as well as display the paper details.

With the combination of these two Views, many visualizations can be generated. For each View, the user can choose to arrange information by author, paper, publication venue, research area, etc. This leads to many possible visualizations per View, and even more visualizations when the two Views are combined.

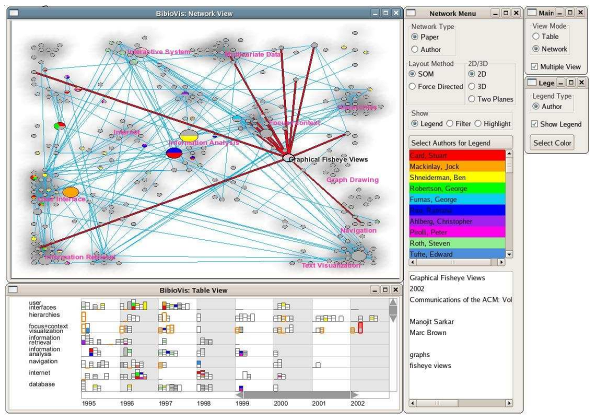

Figure 6: Double view mode layout. The Network View is shown above the Table View. Clicking on a node in one view will highlight the node in both views, as well as display the paper details.

6 Evaluation

In section 3, we listed the tasks of the InfoVis 2004 Contest. We considered these tasks to be the goals of our system. We will now go through and determine if these goals have been met.

Characterize the research areas and their evolution. The Network View is able to show the relationships between research areas well. Using an SOM, the node placement component arranges the nodes into clusters according to research area. Larger clusters indicate more developed research areas. Clusters which are closer together indicate related areas. The Table View is able to show the evolution of research areas due to its assignment of time on the x-axis. The user can select the keyword burst arrangement and see the progression of research area activity.

Where does a particular author fit within the research areas? For this task, we can use the Network View exclusively. We will display two planes; the bottom will contain nodes representing papers and the top will contain nodes representing authors. The paper nodes will be clustered according to research area by the SOM. Each author node will be placed above the centroid of the papers he or she has published. By clicking on and highlighting a particular author node, the user can easily see which papers he or she has written and in which research areas they belong.

*What are the relationships between two or more of the authors?*Again, the Network View is the most useful in relationship tasks. We can have a plane containing author nodes, arranged by a force-directed layout. We then select the specific authors we want to investigate either from a list or by clicking a node in the Network View. We can see the other authors who have collaborated with our selection through the edges. We can create another plane containing nodes representing papers, arranged by SOM, placed below the author plane. The papers are clustered according to research area, so now we can see which research areas are common to the authors we have selected.

We have demonstrated how our system can easily accomplish the InfoVis tasks.

7 A Case Study

We now narrate a typical user experience of BiblioViz.

First, the user starts with an overview of the entire dataset in the Table View (Figure 7). The x-axis is year of publication and the y-axis is author. There are too many papers visible, so we use the slider bars to display only the papers of the ten most widely cited authors in the last 20 years (Figure 8). We see that Stuart Card is deemed the most widely cited author in this period, followed by Jock Mackinlay and Ben Shneiderman. Looking at the color of the bars, we see the pattern of dark blue, blue, light blue appearing quite frequently in the works of Card, Mackinlay and Robertson. Indeed, they have collaborated on many papers together, likely due to the fact that they were colleagues at the Xerox Research Center.

We are interested in Ben Shneiderman, so we focus on his row by clicking on his name in the y-axis (Figure 9). The bars in his row become larger so we can more clearly see the collaborations in his papers. We are also interested in the year 1991, so we click on that year in the y-axis. The column corresponding to 1991 similarly becomes wider. We see that Shneiderman published one paper in 1991. We click on it and see from the paper details that it is "Treemaps: A Space-Filling Approach to the Visualization of Hierarchical Information Structures." From the highlighted borders, we can see that almost every other author in the table cites or is cited by this paper.

We then switch to the Network View of authors. The nodes are positioned using a force-directed graph layout algorithm. Since we have already highlighted Ben Shneiderman in the Table View, his node in the Network View is highlighted as well. We can see from the proximity and size of the nodes surrounding Shneiderman, that he has two very important authors closely connected to him. By clicking on the nodes, we see that they are Card and Mackinlay (Figure 10).

We then add another plane to the Network View. It contains paper nodes clustered by SOM into their research areas. The paper plane is placed below the author plane in 3D (Figure 11). Edges extend from Ben Shneiderman's node on the top plane to his papers on the bottom plane. We see that his main research areas are user interfaces, information retrieval and hierarchies. The tower on top of his node shows which publication venues have featured his work. We see from the orange disks that he has published six papers in the Conference on Human Factors in Computing Systems.

From our case study, we have shown that our system can be easily used to explore bibliography information.

8 Future Work

BiblioViz is designed to be extensible. We see several possibilities for extension: adding more (1) data, (2) visual representations, and (3) algorithms. Currently, BiblioViz does not look at the full text and figures/captions of the papers, and these can potentially be added in the future. New visual representations can also be added if they are able to more effectively express otherwise hidden knowledge in the data. Our strategy is to try to embed these additional visual representations into the current Table or Network Views, the way we have embedded citation links, segmented circles, arches and towers. This will reduce users' context-switching and confusion. If this is not possible, we have to add new views apart from the existing Table and Network Views. Other layout algorithms such as Pajek (Batagelj & Mrvar 2003), Galaxies (Wise, Thomas, Pennock, Lantrip, Pottier, Schur & Crow 1995) and BiblioMapper (Song 1998) can also be incorporated as options. This will change the position of the network nodes but will otherwise not alter the look of the current visualization.

The data that we worked with is small relative to other potential bibliography datasets. In order to fully test the robustness of our system, we need a larger dataset, perhaps on the order of several thousands of references.

While we solved the scalability problem in the Table View through the zoomable interface, we still need to address the problem in the Network View. As the number of nodes increases, so does the clutter. We need better methods to draw large graphs.

9 Conclusions

We have introduced a compact, comprehensive and extensible system for visualizing bibliography information. Our design has been driven by a set of goals we defined, and is based on the principle of minimal visual representations, and on our analysis of current visualization techniques.

We first defined a set of goals and inputs for bibliography visualization. We then analyzed and classified current bibliography visualization techniques. From our problem definition and analysis, we designed a system, BiblioViz, combining the features and capabilities of the different available techniques in a seamless, cohesive manner.

We condensed the numerous existing visual representations into only two views: the Table View and the Network View, link them together, and provide details on demand. We found that these two views can effectively express the many relationships contained in bibliography data. We limited the number of different views to prevent users from getting confused by too many different visual metaphors. We also chose the Table and Network Views because they

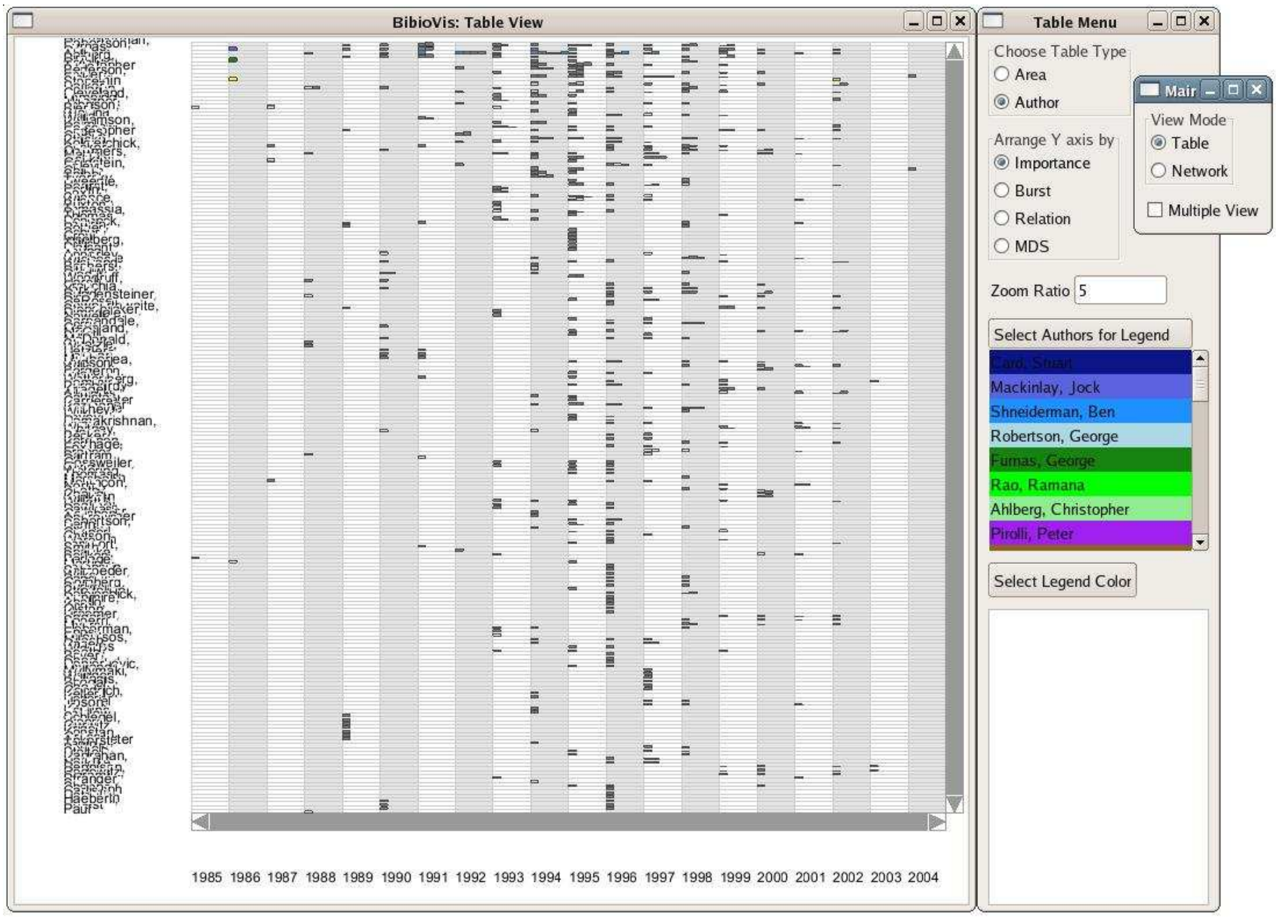

Figure 7: The Table View of authors, showing all authors in the dataset. There are too many authors and papers to discern detailed information, so we allow filtering and focus+context through the user interface.

are commonly used visual metaphors that users are familiar with. Within each View, we provide users with a wider range of options and auxiliary graphics so that users can create different visualizations tailored to explore different parts of the bibliography data schema, while keeping the same view paradigm.

For the Table View, we allow the user to choose the data entity to show on the y-axis, attribute values to display as colors, different methods of arranging the rows, the option to show citation links, and highlight certain data entities. This powerful set of features is not available in any previous package.

For the Network View, we allow 3D or 2D views, providing layout options (force-based, SOM). BiblioViz displays nodes representing single or multiple data types (papers, publication venues, authors, research areas) and their inter-relationships, and can super-impose SOM density maps, perform dynamic queries, and highlight individual data entities.

Using various combinations of options, the user has a good control over the type and amount of data to display and what to show in focus and context, and can create custom-made visualizations.

In BiblioViz, we introduced novel visual representations, such as multiple parallel network planes, arched links in the 3D Network View, segmented nodes in the Network View, super-imposition of SOM density maps on network displays, and keyword burst visualization with paper-nodes in the Table View. We have demonstrated these functionalities of BiblioViz using the InfoVis 2004 Contest data.

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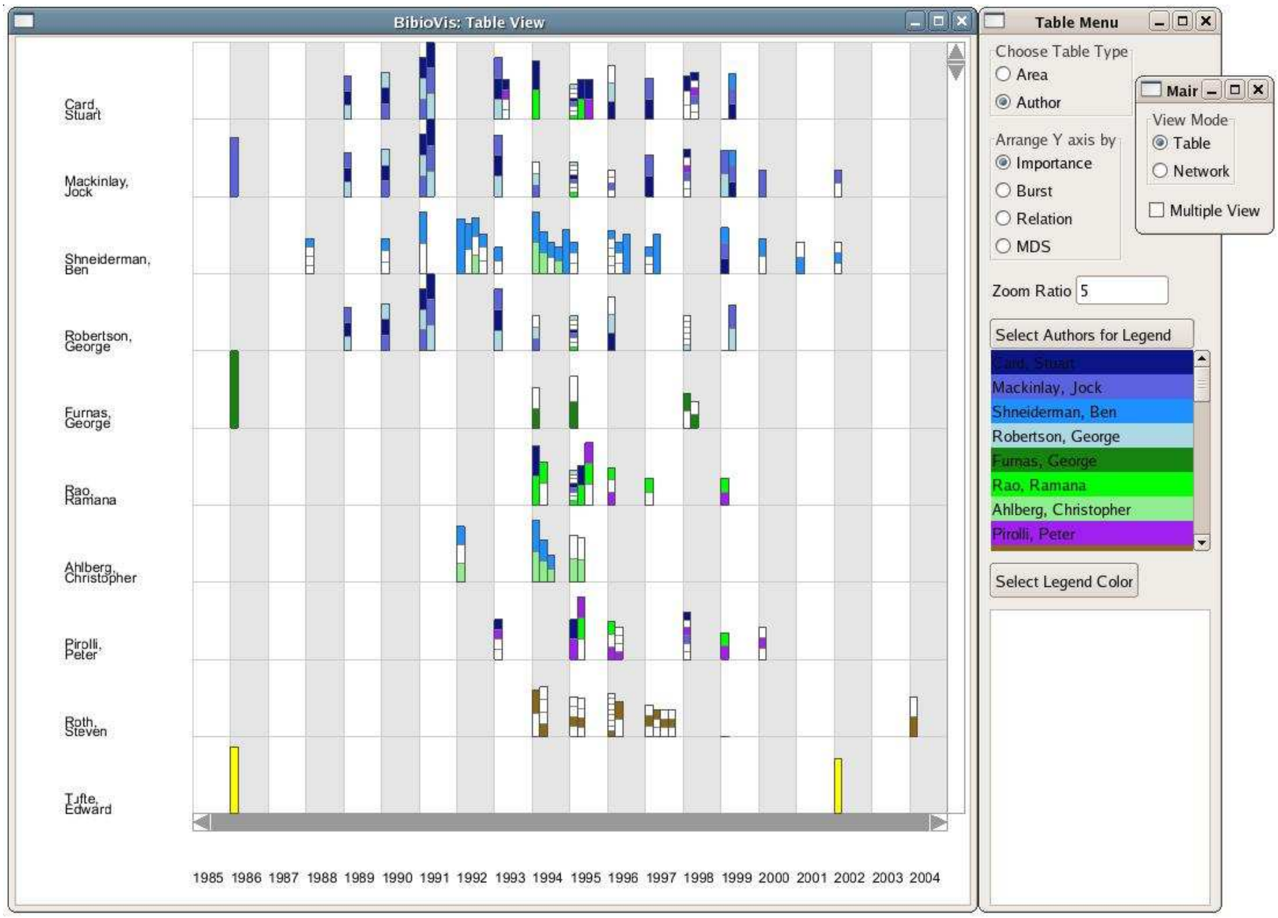

Figure 8: Table View of top 10 most widely cited authors in last 20 years. Stuart Card is deemed the most widely cited author in this period, followed by Jock Mackinlay and Ben Shneiderman.

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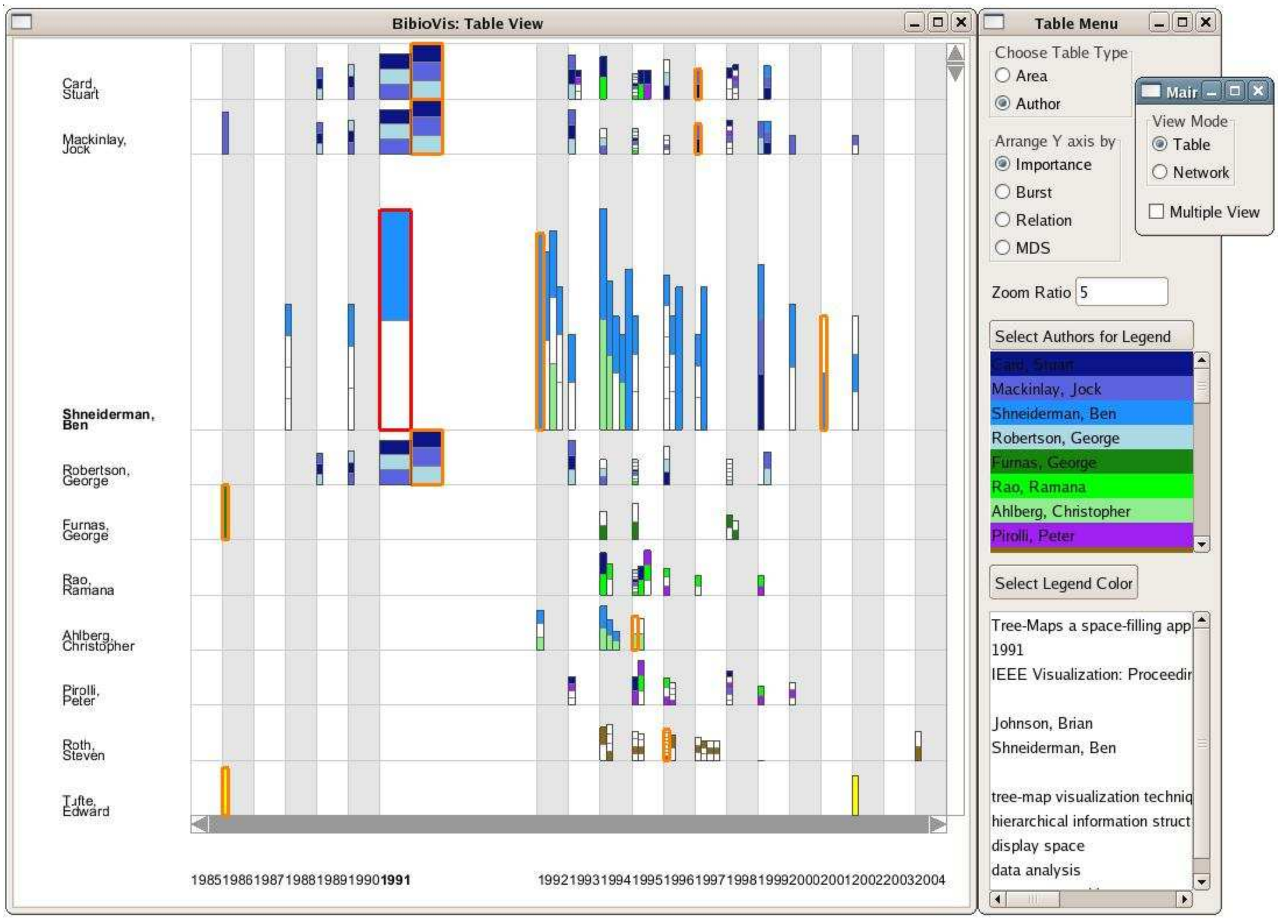

Figure 9: Table View of authors. One of Ben Shneiderman's papers: "Treemaps: A Space-Filling Approach to the Visualization of Hierarchical Information Structures." is highlighted.

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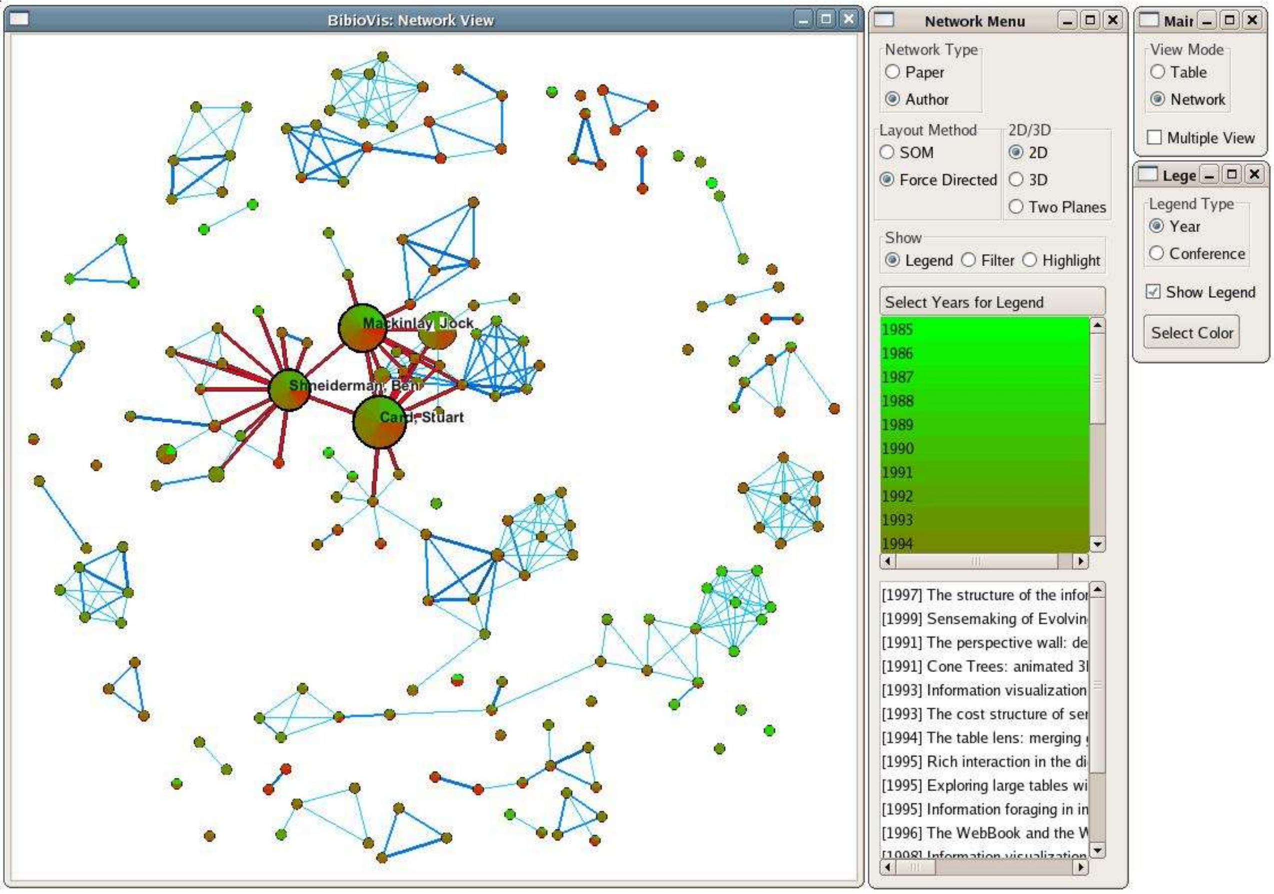

Figure 10: The Network View of authors shows that Card and Mackinlay are closely connected to Shneiderman.

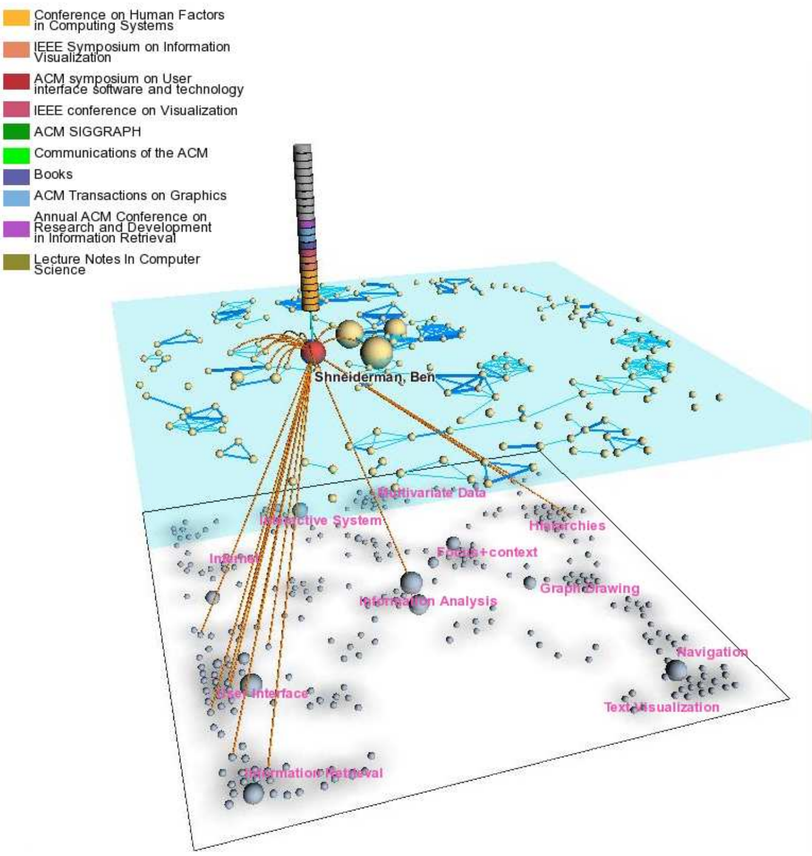

Figure 11: The dual-plane view shows Ben Shneiderman's main research area is "user interface."