

OntoStarFish: Visualization of Collaboration Networks using Starfields, Ontologies and Fisheye Views.

Alfredo Ramos, J. Alfredo Sánchez, Federico Hernández-Bolaños

Laboratory of Interactive and Cooperative Technologies

Universidad de las Américas Puebla, México

{alfred.exe, j.alfredo.sanchez, federicojhb}@gmail.com

ABSTRACT

We introduce OntoStarFish, a user interface designed for detecting, visualizing and exploring implicit collaboration networks. As its name suggests, OntoStarFish is based upon the use of multiple fisheye views on starfields for which the axis are determined by an ontological organization of attributes associated to potential collaborators. We describe this technique as applied to data on collaboration networks inferred from distributed collections of documents and report on results of a preliminary usability study of a working prototype.

Categories and Subject Descriptors

D.2.2 [Design Tools and Techniques]: User Interfaces; H.5.2 [User Interfaces]: Graphical User Interfaces (GUI); I.3.6 [Methodology and Techniques]: Interaction Techniques

General Terms

Human Factors

Keywords

Collaboration networks, information visualization, multiple fisheye views, ontological starfields.

1. INTRODUCTION

Repositories of scientific publications from all disciplines have been growing at extraordinary rates. Some relationships entailed by documents in such repositories are explicit, as the documents come from the same discipline or are produced by the same research groups. Other relationships, however, may not be evident, such as complementary areas in multi-disciplinary fields, or groups that have been working on related issues in different research centers or different countries.

We are interested in implicit collaboration networks, those that can be established among authors of documents by deriving relationships from their metadata. Such relationships may vary in strength, as they may result from direct, evident connections (such as co- authorship) or indirect ties determined, for example, by overlaps in the subjects of their documents in a collection. Finding collaboration networks is crucial for researchers in all areas for various reasons. First and foremost, researchers are interested in learning about the global community that is producing scientific advances in the area in which they are interested. Also, funding opportunities often require assembling multi-disciplinary, multi-institutional and multi-national groups, in which case researchers need to find potential partners with similar and complementary interests. Finally, funding agencies also may want to become familiar with existing or potential collaboration networks so as to make sure calls for proposals will find an audience as well as to validate proposed research groups.

We have been investigating several mechanisms for visualizing relationships, particularly among entities involved in repositories of scientific publications, from countries to institutions to authors. The node-link visualization method has been the most popular technique used for creating graphical representations of network structures such as ecological networks [37], criminal networks [35] and social networks [22]. However, adaptations of this method have yet to be generated specifically for collaboration networks. Although we have been working on such adaptations of the node-link method (as reported in [15]), we also decided to generate a novel visualization method that takes advantage of proven focus-plus-context techniques as well as semantic organizations of knowledge domains.

Our goal has been to produce a user interface that provides an overview of all relationships inferred from a number of distributed collections and assists users in filtering and focusing on those potential relationships that are relevant to a particular situation. Considering visualization guidelines such as those suggested in [25] and [29], *zoom, overview, context preservation, grouping techniques, and displaying relationship between entities* were deemed necessary characteristics of the proposed interface. Thus, our interface is based on the combination of two major visualization techniques: *starfields* [1] and multiple *fisheye views* [9]. Additionally, documents in the repositories are organized according to their main subjects by using clustering techniques and producing lightweight ontologies. Thus, the resulting method, which we termed OntoStarFish, presents the user with ontological starfields from which regions can be selected using resizable fisheye lenses. Collaboration networks can easily be detected by considering the intersections of authors in diverse institutions with research topics in the ontologies. This paper discusses the design

Copyright is held by the author(s), 2010.
MexIHC 2010, November 8, 9 & 10, 2010.
Published by Universidad Politécnica de San Luis Potosí

of OntoStarFish and reports on the initial user experiences with the interface.

The remainder of the paper is organized as follows: Section 2 offers an overview of related work. Section 3 presents an account of the design of OntoStarFish, including detailed use scenarios. Section 4 discusses the results from a usability study of a working prototype, whereas Section 5 focuses on our conclusions and ongoing work.

2. RELATED WORK

As noted earlier, various methods for visualizing network structures have been proposed in recent years [14], but node-link representations have been the most popular. Node-link visualizations have been used in many different contexts. Yoon and colleagues [37], for example, have used this technique for ecological networks. They created a 3D visualization tool called *Web On Webs* for analyzing the complexity of food webs on ecosystems. In their work, nodes represent species, whereas links represents whether a species can be eaten by another one. Similarly, visualization schemes are being used to study the structure of social networks. A social network is a collection of people, each of whom is acquainted with some subset of the others [20]. Research on this particular structure has been supported by graph-oriented techniques [36] and analysis tools [27]. However, a tool that combines exploration, statistics and visualization techniques has not been proposed. *SocialAction* [22] is a tool designed for finding relationships among people by using data sets, and for analyzing the structure of the resulting graph. Based on a similar approach, a system called *CrimeNet Explorer* [35] supports police agencies in the exploration of criminal networks and in understanding their complex structure by using a graph representation.

A user interface for visualizing collaboration networks must be able to represent entities, relationships, item groupings and their instances, collaboration groups and various properties of these groups. In order to create a visualization method adapted to these needs, we surveyed the area and characterized existing methods. Table 1 presents a summary of our findings related to 23 related projects. As it can be observed, all of the approaches make it possible for the user to obtain a general overview of a data set and to view relationships between items, at least within a close perimeter. Other popular functions include the ability to zoom in and out of selected areas, as well as to obtain details of required items. We found it interesting that 2D visualizations remain popular. Even though some 3D representations have been attempted, the simplicity of 2D, both for the user and the developer, have generally outperformed the complexity that 3D brings about. Only few methods allow users to filter items dynamically or to group them semantically. Even fewer offer functionality to maintain the context while exploring specific areas or to provide access to previously viewed scenarios (*history*).

Maintaining context is particularly important when visualizing collaboration networks, hence our decision to focus on features that make this possible. Also, grouping techniques, overview and zoom functionality, as well as context preservation and displaying relationships between entities were considered key features for a

model oriented to the discovery and exploration of collaboration networks. OntoStarFish, the method we propose, offers the advantages of these features in a single interface, as described in the following section.

3. OntoStarFish: A MODEL FOR DETECTING COLLABORATION NETWORKS

A collaboration network is a social structure consisting of a group of people that cooperate on a knowledge domain with a common goal. Whereas some participants may know each other, others may be working in the same area and may be interested in establishing collaboration ties. These implicit relationships may be inferred from the documents produced by researchers. Our group also has been working on inference mechanisms, but these are out of the scope of this paper, which focuses on one of the visualization components. The node-link approach provides an intuitive representation for small collaboration networks. Part of the structure of a collaboration network can be determined by the subject on which a researcher specializes [3], but the increasing number of new participants in the network also increases the complexity of this structure [34]. With an increasing number of participants and with different kinds of networks each one related to a particular subject, it becomes very difficult for the node-linked visualization to present a manageable graphical representation of all the relationships. We are working on variations of the node-link approach [15], but simultaneously we decided to explore other alternatives.

In order to create a new visualization model that will assist users in detecting collaboration networks, we selected two existing techniques that include most of the required features: *starfields* and *fish-eye views* [10]. A starfield is a grid-based information visualization method in which objects are represented by points scattered at the intersections of two axes, which represent the attributes of the objects being displayed. The axes show a relationship between the selected attributes and also display a general overview of the elements at any moment. This technique has been used successfully for visualizing large digital collections [26]. The fish-eye visualization method [9] is a focus-plus-context technique that allows users to explore in detail an area of interest while maintaining its context. It takes its name from the distortion effect it creates around non important elements and amplifying those that are important. *Starfish* [24] is a visualization method that combines the visual information seeking techniques of a starfield with the focus-plus-context technique of the fish-eye model [23]. This visualization method uses most of the features detected as necessary in our evaluation, but still lacks semantic grouping mechanisms, as items are ordered only chronologically or alphabetically on both axes.

In our work, we take advantage of the sets of relationships derived from document repositories, which are represented as ontologies. By combining the features of the *starfish* model with the use of ontologies, we provide a graphical representation of relationships at different levels. For example, users may visualize institutions that work on a given research subject, but also may drill down into each axis and see relationships between researchers and more specific topics. Since a starfield representing a large number of

relationships may become unmanageable, and regions of interest may not be contiguous in the grid, we introduced the option of multiple fisheye lenses that can be moved around to display details of the starfield. When two fisheye lenses are positioned in a way that they overlap vertically, potential collaboration networks of researchers (or countries or institutions) working on related topics correspond to coinciding columns in multiple fisheye views. When the lenses overlap horizontally, they show potential collaboration networks within the same country or institution. We called this adaptation **OntoStarFish** (or simply OSF) as it uses ontological axes and multiple fisheye views on starfields for detecting collaboration groups and networks. Figure 1 illustrates the main concepts involved in the design of OSF. We elaborate on this design next.

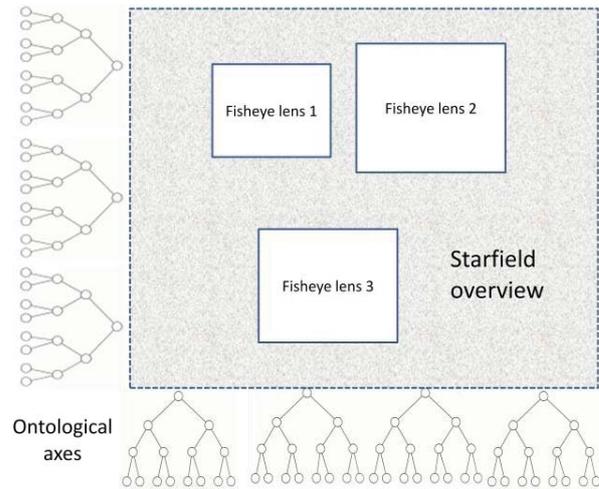


Figure 1. The OntoStarFish model interface and its graphical elements.

Table 1. Comparison of visualization mechanisms.

Project name	Overview	Zoom	Filtering	Details on demand	Viewing Relat'shps	History	Meta-data	2D	3D	Grouping	Context
Friendwheel [8]	X		X		X			X			X
Social Action [22]	X	X	X	X	X		X	X			
CrimeNet Explorer [35]	X	X	X	X	X			X			
Touchgraph [28]	X	X	X	X	X		X	X			
Nicheworks [32]	X				X			X			X
WebMap [31]	X	X			X		X	X		X	
Hyperbolic tree [19]	X				X			X		X	X
WebBrain [30]	X	X		X	X		X	X		X	
WebToc [21]	X	X		X	X		X	X		X	
GoSurfer [38]	X				X		X	X		X	
CropCircles [18]	X	X			X	X		X		X	
Grokker [11]	X	X		X	X	X	X	X		X	
Kart00 [17]	X	X		X	X		X	X		X	
Pad++[2]	X	X		X	X		X	X			
EVA2D [26]	X	X	X	X	X		X	X		X	
Starfish [24]	X	X	X	X	X		X	X		X	
Natto [16]	X				X				X		X
Web On Webs [37]	X		X		X		X		X		X
HyperSpace [33]	X	X			X				X	X	
Open Text Web Index [4]	X	X		X	X				X	X	
WWW3D [5]	X	X		X	X				X	X	
MAPA [6]	X	X			X		X		X	X	
Web Path [7]	X	X		X	X				X		

3.1. Ontological Axes

Attributes that are common to research documents include the author's name and institution, a country of origin and the main subject of each article. For the vertical axis in Figure 1 we used the fact that a scientist is affiliated to an institution or research center which in turn is based mainly in one country. For the horizontal axis, the ontology refers to subjects that can be specialized or generalized depending on the users' interests. With the introduction of ontological axes it becomes possible to explore countries, institutions or research centers and look at the relationships each of these elements has with a particular research subject.

3.2. Multiple Fisheye Views

The combination of starfields with fisheye visualizations makes it possible to focus on a single area [12] of a large data set. However, after observing users work with low fidelity prototypes we realized a single fisheye view may not be sufficient to detect collaboration networks. The new ontological structure of the starfield model we proposed suggests that various collaboration networks can be displayed simultaneously, but they may not be evident as they can be hidden by the large number of relationships. A single fisheye lens may bring forward relationships in a particular area but those that are not contiguous still would remain hidden. In order to detect as many collaboration networks as possible we introduce multiple fisheye views. The multiple fisheye views allows for the exploration of multiple areas of interest [13] over the ontological starfield, making it possible to detect not only collaboration networks in different countries or institutions, but also collaboration groups within the same country or the same institution. We explain how collaboration networks are detected in OSF next.

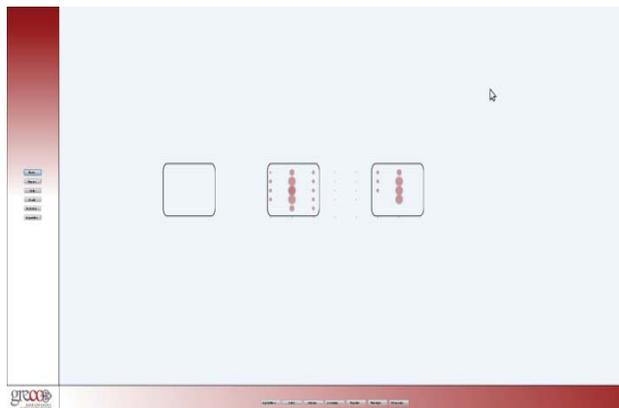


Figure 2. Starting an OntoStarFish session.

3.3. Finding Collaboration Networks

Figure 2 illustrates the initial configuration of the OSF interface, displaying three fisheye lenses and only the highest levels of the ontological axes. Finding a visualizing collaboration networks using OSF can be seen as a process performed at one of three levels, which can be viewed in sequence: Country level, institution

level, and author level. Initially, the starfield displays red dots indicating which countries are conducting research on the general topics listed on the horizontal axis. The fisheye lenses may be moved around the starfield to explore different areas. What is distinctive in OSF is that the user can select any of the items on the axes to obtain a more detailed view. So, for example, Figure 3 illustrates the case when the user has clicked on an element of the subject ontology, thus producing a view of the next level of detail of potential subjects for collaboration. Note that when one item is expanded, the others remain on the display to maintain context. Although the amount of information on the starfield increases, fisheye views help in exploring specific areas, whereas the ontological arrangement on both axes make sure that items displayed contiguously also are semantically close.

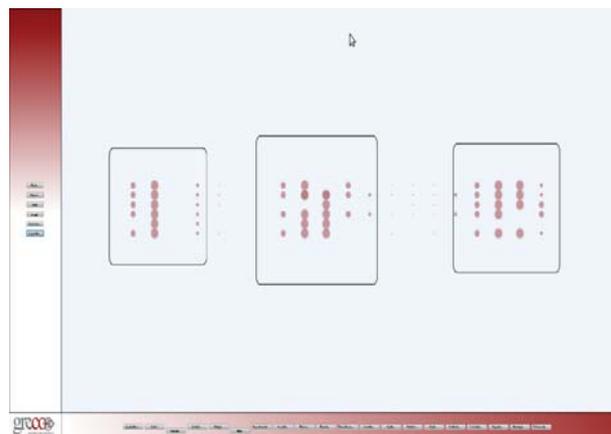


Figure 3. Expanding the subject ontology.

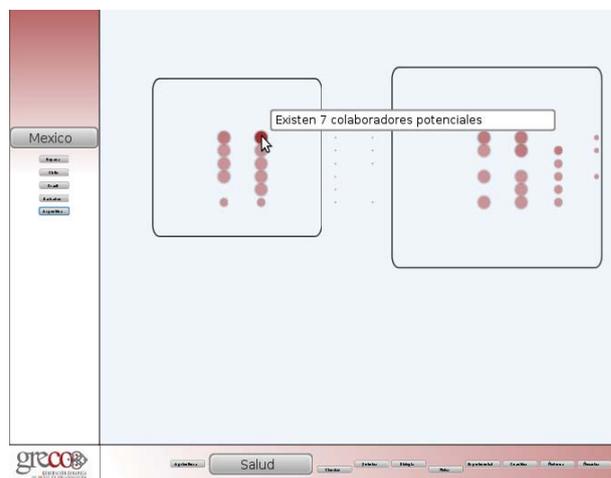


Figure 4. Selecting a country in the OSF.

At the second level of the vertical axis the user can explore institutions or research centers paired with potential subjects. As shown in Figure 4, by selecting a country on the vertical axis or a dot on the starfield, the user obtains a listing of all the institutions in that country that have publications in the repositories being considered. As result of this action, blue dots (or "stars") may appear on the screen. This implies that the selected institution has publications on the corresponding subject.

A group of five subjects with background in information technologies, industrial engineering and environmental engineering participated in this study. A first group of tasks was related to the capabilities for exploring collaboration networks. Users were asked to explore the existing collaboration networks on screen by using fisheye views, stars and also the elements contained on both axes in order to bring new relationships to the screen. The next group of tasks was designed to explore the quality of the networks obtained by OSF. On this part of the evaluation we asked the users to list all the members of the newly available networks on the screen. Finally a last group of tasks were related to the interface attractiveness.

At the end of the evaluation we requested formal feedback from users through questionnaires. A summary of their responses is illustrated in Figure 8. For numerical responses we used a scale from 1 (totally disagree) to 4 (totally agree), so a maximum total score of 20 was possible for each question.

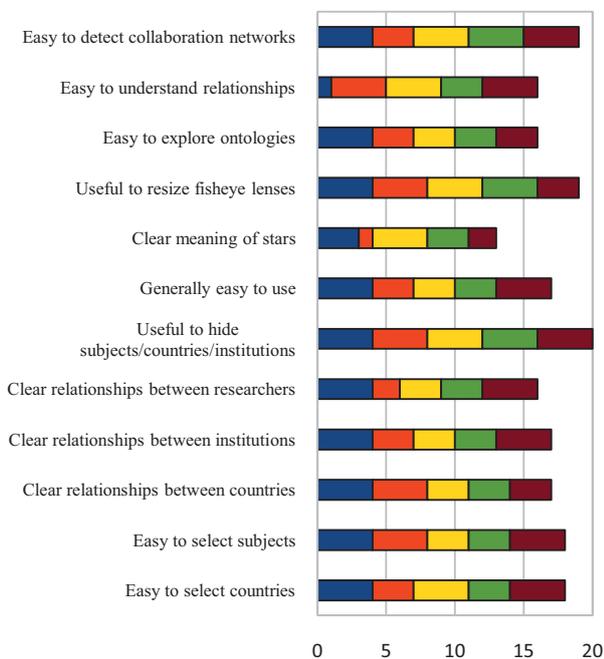


Figure 8. Summary of user feedback for OSF

As noted in the figure, most of the features were evaluated positively. In particular, subjects found it very useful to be able to display or hide at will the visual representations of the various ontological levels. Most importantly, they found OSF helpful to find an explore collaboration networks. The relatively low rating for the intuitiveness of stars seems to indicate that some initial training would be needed to take advantage of OSF.

We also obtained interesting feedback from post-test questionnaires. In general, users considered that the OSF model has a lot of positive aspects that make the discovery of collaboration networks fairly easy. The most important aspect noted by users was the use of multiple fisheyes over the starfield. Users liked the possibility of exploring different areas on the same starfield and having access to different collaboration groups through multiple fisheye lenses. Also, the resizing capability

feature of each fisheye was very useful for exploring larger (or smaller) areas of interest over the starfield.

Another positive aspect was related to the exploration of ontologies and finding relationships based on the “stars” in the interface. The use of colors (red for countries, blue for institutions and green for researchers) made it easy to determine not only the ontological level users are exploring but also to focus on the kinds of groups users wanted to explore. Another important feature commented as positive was the use of indentation on each axis which helped users in maintaining their focus on the elements they were exploring. Zooming into the various levels of the subject ontology as well also contributed to find potential collaboration networks.

Finally, users also commented positively on OSF’s functionality to detect different types of collaboration networks related to a specific subject, but they did consider that the rendering speed of the elements on this visualization method needs to be improved.

4.1. Discussion

One of the main issues when visualizing collaboration networks is to find an adequate technique to represent the existing relationships between researchers, their institutions or research centers and the countries in which they work. The information stored in digital collections does not exhibit any evident pattern that describes such relationships. Thus, by using this available data, we created a new ontological data collection which uses the Author-Institution-Country-Subject pattern proposed for the OSF technique. By relying on this pattern, OSF provides several advantages over the traditional node-link scheme, including the visualization of complex network structures, a detailed view of potential collaborative groups, and the visualization of multiple collaboration networks at the same time.

Let us consider a scenario that further illustrates how OSF can be helpful. Say a researcher at Universidad de las Americas Puebla (UDLAP) is looking for potential collaborations between institutions in “science.” Figure 9 shows how the node-link technique can be used to visualize all possible collaboration groups. Evidently, the number of available elements and the number of relationships among them make it difficult to visualize collaboration opportunities in a practical manner.

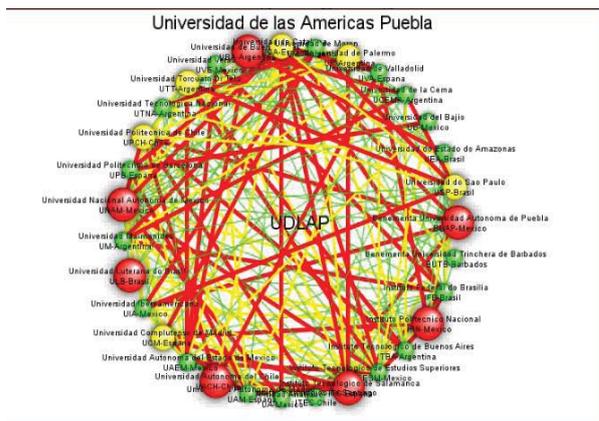


Figure 9. Visualizing relations between institutions and the science area using the node-link technique.

Figure 10 shows the same example using the OSF model. As we can see, all the network elements are visible on a single column, thus making it possible to visualize potential collaboration groups even if the network structure is complex. It is worth noticing that we also are exploring improvements of the node-link approach. This is reported in [15].

Consider now the case when someone is interested in finding possible collaboration groups between researchers and a given subject. As shown in Figure 11 the node-link visualization technique removes all existing relations to bring new ones to the screen. This makes it difficult for users to keep track of context. Using the OSF technique it is possible to visualize different networks without removing any element from the display (see Figure 12). Additionally, fisheye lenses assist users by emphasizing the degree of interest (DOI), as proposed when it was first introduced [9]. The scale of each star contained in a fisheye lens is increased but only the ones that are at its center display a “tooltip” showing the number of relationships available at the next ontological level. With this feature the researcher can detect where the largest group of researchers is and may explore that area further. (see Figure 13).



Figure 10. Visualizing relations between institutions and the science area using OSF.

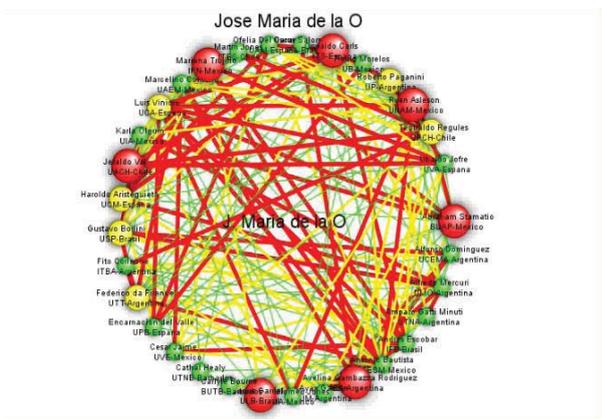


Figure 11. Visualizing relations between researchers and the science area using node-link.

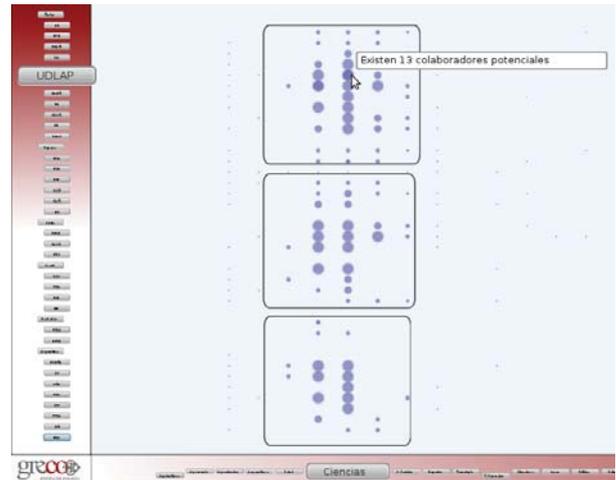


Figure 12. Visualizing details using the fish eye views on OSF.

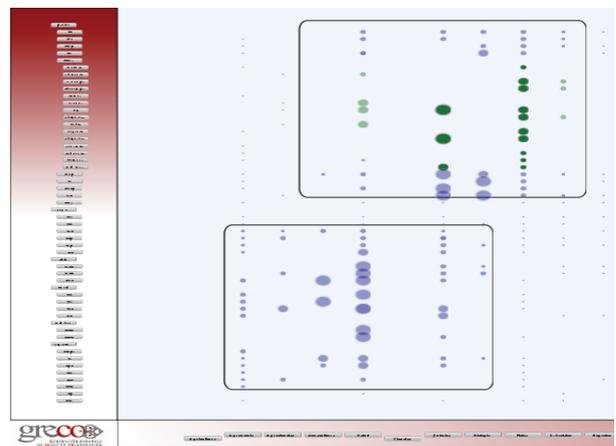


Figure 13. Visualizing relations between researchers and the science area using OSF.

5. ONGOING AND FUTURE WORK

OntoStarFish is an interface designed for detecting, visualizing and exploring collaboration networks. Although it takes advantage of a representation of the relationships among documents in a repository (inferred by a software component not discussed in this paper), visualizing documents associated with research subjects or institutions was not initially considered. However, when low-fidelity prototypes were presented to researchers in early stages of our project, they mentioned this functionality would be desirable. For future work we plan to include options for visualizing documents from which relationships were inferred, as researchers find it important to learn about the reasons why OSF suggests potential collaborations on a specific area. This implies adding new features to the interface, such as a document previewing at the last level of the subject ontology. Performance is also a very important feature of visualization methods. In order to support document visualization on this model, changes to our rendering algorithms may be needed, thus making this our priority before adding new features to the interface.

6. ACKNOWLEDGMENTS

This project has been partially supported by the Conacyt-CUDI Program for Advanced Applications for the Internet 2. We would like to gratefully acknowledge the participation in this project of Ofelia Cervantes and Efrén Hernández Cosco. We also thank Paulo Cesar Espitia, Eduardo Rodríguez, Ignacio Paredes, Rafael Cornelio and Mariana Espitia for participating in our initial prototype testing.

7. REFERENCES

- [1] Ahlberg, C. and Shneiderman, B. 1999. Visual information seeking: tight coupling of dynamic query filters with starfield displays. In *Readings in information Visualization: Using Vision To Think*, S. K. Card, J. D. Mackinlay, and B. Shneiderman, Eds. Morgan Kaufmann Publishers, San Francisco, CA, 244-250.
- [2] Bederson, B. B. and Hollan, J. D. 1995. Pad++: a zoomable graphical interface system. In *Conference Companion on Human Factors in Computing Systems* (Denver, Colorado, United States, May 07 - 11, 1995). I. Katz, R. Mack, and L. Marks, Eds. CHI '95. ACM, New York, NY, 23-24. DOI= <http://doi.acm.org/10.1145/223355.223394>
- [3] Brandes, U., Kenis, P., Lerner, J., and van Raaij, D. 2009. Network analysis of collaboration structure in Wikipedia. In *Proceedings of the 18th international Conference on World Wide Web* (Madrid, Spain, April 20 - 24, 2009). WWW '09. ACM, New York, NY, 731-740. DOI= <http://doi.acm.org/10.1145/1526709.1526808>
- [4] Bray, T. 1996. Measuring the Web. In *Proceedings of the Fifth international World Wide Web Conference on Computer Networks and ISDN Systems* (Paris, France). P. H. Enslow, Ed. Elsevier Science Publishers B. V., Amsterdam, The Netherlands, 993-1005.
- [5] David Snowdon, Steven D. Benford, Chris M. Greenhalgh, Rob Ingram, Chris C. Brown, Lennart Fahlén and Mårten Stenius. "A 3D Collaborative Virtual Environment for Web Browsing" *Virtual Reality Universe '97*, Santa Clara, California, USA, [11], April 1997.
- [6] Durand, D. and Kahn, P. 1998. MAPA: a system for inducing and visualizing hierarchy in Websites. In *Proceedings of the Ninth ACM Conference on Hypertext and Hypermedia : Links, Objects, Time and Space---Structure in Hypermedia Systems: Links, Objects, Time and Space---Structure in Hypermedia Systems* (Pittsburgh, Pennsylvania, United States, June 20 - 24, 1998). HYPERTEXT '98. ACM, New York, NY, 66-76. DOI= <http://doi.acm.org/10.1145/276627.276635>
- [7] Frécon, E. and Smith, G. 1998. WebPath - A Three-Dimensional Web History. In *Proceedings of the 1998 IEEE Symposium on information Visualization* (North Carolina, October 19 - 20, 1998). INFOVIS. IEEE Computer Society, Washington, DC, 3-10.
- [8] Friendwheel. 2007. Friendwheel Friend Network Visualization. <http://thomas-fletcher.com/friendwheel/> Last accessed on July 17,2010.
- [9] Furnas, G. W. 1986. Generalized fisheye views. *SIGCHI Bull.* 17, 4 (Apr. 1986), 16-23. DOI= <http://doi.acm.org/10.1145/22339.22342>
- [10] Furnas, G. W. 1999. The FISHEYE view: a new look at structured files. In *Readings in information Visualization: Using Vision To Think*, S. K. Card, J. D. Mackinlay, and B. Shneiderman, Eds. Morgan Kaufmann Publishers, San Francisco, CA, 312-330.
- [11] Grokker. 2001. Grokker Visual Search Engine. <http://www.groxis.com/> Last accessed on January 27,2009.
- [12] Gutwin, C. 2002. Improving focus targeting in interactive fisheye views. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Changing Our World, Changing Ourselves* (Minneapolis, Minnesota, USA, April 20 - 25, 2002). CHI '02. ACM, New York, NY, 267-274. DOI= <http://doi.acm.org/10.1145/503376.503424>
- [13] Gutwin, C. and Fedak, C. 2004. A comparison of fisheye lenses for interactive layout tasks. In *Proceedings of Graphics interface 2004* (London, Ontario, Canada, May 17 - 19, 2004). ACM International Conference Proceeding Series, vol. 62. Canadian Human-Computer Communications Society, School of Computer Science, University of Waterloo, Waterloo, Ontario, 213-220.
- [14] Herman, I., Melançon, G., and Marshall, M. S. 2000. Graph Visualization and Navigation in Information Visualization: A Survey. *IEEE Transactions on Visualization and Computer Graphics* 6, 1 (Jan. 2000), 24-43. DOI= <http://dx.doi.org/10.1109/2945.841119>
- [15] Hernández-Bolaños, F. 2010. UltraVCN: Uso de filtros y características gráficas para la visualización de redes de colaboración. B.Sc. Thesis. Department of Computing, Electronics and Mechatronics. Universidad de las Américas Puebla (August).
- [16] Hidekazu Shiozawa and Yutaka Matsushita. "WWW visualization giving meanings to interactive manipulations" *Advances in Human Factors/Ergonomics 21B* (HCI International p 97), San Francisco, CA, 791- 794, August 1997.
- [17] Kartoo. 2001. KartOO Visual Search Engine. <http://www.kart00.com>. Last accessed on July 17, 2010.
- [18] Katifori, A., Halatsis, C., Lepouras, G., Vassilakis, C., and Giannopoulou, E. 2007. Ontology visualization

- methods—a survey. *ACM Comput. Surv.* 39, 4 (Nov. 2007), 10. DOI=<http://doi.acm.org/10.1145/1287620.1287621>
- [19] Lamping, J. and Rao, R. 1996. Visualizing large trees using the hyperbolic browser. In *Conference Companion on Human Factors in Computing Systems: Common Ground* (Vancouver, British Columbia, Canada, April 13 - 18, 1996). M. J. Tauber, Ed. CHI '96. ACM, New York, NY, 388-389. DOI=<http://doi.acm.org/10.1145/257089.257389>
- [20] M. E. Newman. The structure of scientific collaboration networks. *Proc Natl Acad Sci U S A*, 98(2):404–409, January 2001.
- [21] Nation, D. A. 1998. WebTOC: a tool to visualize and quantify Web sites using a hierarchical table of contents browser. In *CHI 98 Conference Summary on Human Factors in Computing Systems* (Los Angeles, California, United States, April 18 - 23, 1998). CHI '98. ACM, New York, NY, 185-186. DOI=<http://doi.acm.org/10.1145/286498.286664>
- [22] Perer, A. and Shneiderman, B. 2008. Integrating statistics and visualization: case studies of gaining clarity during exploratory data analysis. In *Proceeding of the Twenty-Sixth Annual SIGCHI Conference on Human Factors in Computing Systems* (Florence, Italy, April 05 - 10, 2008). CHI '08. ACM, New York, NY, 265-274. DOI=<http://doi.acm.org/10.1145/1357054.1357101>
- [23] Pirolli, P., Card, S. K., and Van Der Wege, M. M. 2001. Visual information foraging in a focus + context visualization. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Seattle, Washington, United States). CHI '01. ACM, New York, NY, 506-513. DOI=<http://doi.acm.org/10.1145/365024.365337>
- [24] Sánchez, J. A., Quintana, M. G., Razo, A. 2007. Starfish: Starfields+fish visualization and its application to federated digital libraries. *Proceedings of the 3rd Latin American Conference on Human-Computer Interaction (CLIHC 2007)*. Rio de Janeiro, Brazil. Nov)
- [25] Shneiderman, B. 1996. The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. In *Proceedings of the 1996 IEEE Symposium on Visual Languages* (September 03 - 06, 1996). VL. IEEE Computer Society, Washington, DC, 336.
- [26] Silva, N. N., Sánchez, J. A., Proal, C., and Rebollar, C. 2003. Visual exploration of large collections in digital libraries. In *Proceedings of the Latin American Conference on Human-Computer interaction* (Rio de Janeiro, Brazil, August 17 - 20, 2003). CLIHC '03, vol. 46. ACM, New York, NY, 147-157. URL=<http://portal.acm.org/citation.cfm?id=944519.944535>
- [27] Smith, M. A., Shneiderman, B., Milic-Frayling, N., Mendes Rodrigues, E., Barash, V., Dunne, C., Capone, T., Perer, A., and Gleave, E. 2009. Analyzing (social media) networks with NodeXL. In *Proceedings of the Fourth international Conference on Communities and Technologies* (University Park, PA, USA, June 25 - 27, 2009). C&T '09. ACM, New York, NY, 255-264. DOI=<http://doi.acm.org/10.1145/1556460.1556497>
- [28] TouchGraph. 2007. TouchGraph Facebook Browser. <http://www.touchgraph.com/TGFacebookBrowser.html> Last accessed on July 17,2010.
- [29] Ware, C. 2004. *Information Visualization*. Morgan Kaufmann. San Francisco, Calif.
- [30] WebBrain.2009. WebBrain a non-linear interactive medium for sharing thinking. <http://webbrain.com/> Last accessed on July 17,2010.
- [31] Webmap. 2001. Webmap Plugin For Visualizing the Web.<http://www.webmap.com/> Last accessed on January 20,2009.
- [32] Wills, G. J. 1997. NicheWorks - Interactive Visualization of Very Large Graphs. In *Proceedings of the 5th international Symposium on Graph Drawing* (September 18 - 20, 1997). G. D. Battista, Ed. Lecture Notes In Computer Science, vol. 1353. Springer-Verlag, London, 403-414.
- [33] Wood, A, Beale, R, Drew, N & Hendley, R, "HyperSpace: A World-Wide Web Visualiser and its implications for Collaborative Browsing and Software Agents", *HCI'95*, UK.
- [34] Wu, B., Zhao, F., Yang, S., Suo, L., and Tian, H. 2009. Characterizing the evolution of collaboration network. In *Proceeding of the 2nd ACM Workshop on Social Web Search and Mining* (Hong Kong, China, November 02 - 02, 2009). SWSM '09. ACM, New York, NY, 33-40. DOI=<http://doi.acm.org/10.1145/1651437.1651444>
- [35] Xu, J. J. and Chen, H. 2005. CrimeNet explorer: a framework for criminal network knowledge discovery. *ACM Trans. Inf. Syst.* 23, 2 (Apr. 2005), 201-226. DOI=<http://doi.acm.org/10.1145/1059981.1059984>
- [36] Yang, X., Asur, S., Parthasarathy, S., and Mehta, S. 2008. A visual-analytic toolkit for dynamic interaction graphs. In *Proceedings of the 14th ACM SIGKDD international Conference on Knowledge Discovery and Data Mining* (Las Vegas, Nevada, USA, August 24 - 27, 2008). KDD '08. ACM, New York, NY, 1016-1024. DOI=<http://doi.acm.org/10.1145/1401890.1402011>
- [37] Yoon, I., Yoon, S., Martinez, N., Williams, R., and Dunne, J. 2005. Interactive 3D visualization of highly connected ecological networks on the WWW. In *Proceedings of the 2005 ACM Symposium on Applied Computing* (Santa Fe, New Mexico, March 13 - 17, 2005). L. M. Liebrock, Ed. SAC '05. ACM, New York, NY, 1207-1212. DOI=

<http://doi.acm.org/10.1145/1066677.1066950>

- [38] Zhong, S. and Xie, D. 2007. Gene Ontology analysis in multiple gene clusters under multiple hypothesis testing framework. *Artif. Intell. Med.* 41, 2 (Oct. 2007), 105-115. DOI=
<http://dx.doi.org/10.1016/j.artmed.2007.08.002>