

WEBCONTENT VISUALIZER: A VISUALIZATION SYSTEM FOR SEARCH ENGINES IN SEMATIC WEB

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Since the results from Semantic Web search engines are highly structured XML documents, they cannot be efficiently visualized with traditional explorers. Therefore, the Semantic Web calls for a new generation of search query visualizers that can rely on document metadata. This paper introduces such a visualization system called WebContent Visualizer that is used to display and browse search engine results. The visualization is organized into three levels: (1) Carousels contain documents with the same ranking, (2) carousels are piled into stacks, one for each date, and (3) these stacks are organized along a meta-carousel to display the results for several dates. Carousel stacks are piles of local carousels with increasing radii to visualize the ranks of classes. For document comparison, colored links connect documents between neighboring classes on the basis of shared entities. Based on these techniques, the interface is made of three collaborative components: an inspector window, a visualization panel, and a detailed dialog component. With this architecture, the system is intended to offer an efficient way to explore the results returned by Semantic Web search engines.

Keywords: Search engine visualization; Semantic Web; document metadata; carousel stack; Bezier surface link.

1. Introduction

Due to the vastness of the information on the web, the Semantic Web^{4,23,26} was proposed to help people better understand it through tagged information. Search engines that can take XML tags into consideration can assist users in quickly locating documents of interest in the Semantic Web. Search results returned by these engines are highly structured XML documents in which metadata provide useful information (or semantic information^{7,19}) as compared with web pages returned by the traditional search engines such as Google search. Traditional web browser such as Microsoft Internet Explorer cannot cope with the internal structure of Semantic

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Web documents and thus cannot render them properly. The purpose of this paper is to propose WebContent Visualizer (WebViser), a new generation of Semantic Web search result visualization that handles internal document tags and inter-document relationships. This work is also a part of the WebContent research project⁵ which aims to produce an open platform for content management integrating Semantic Web technologies.

XML documents in the WebContent project¹ are searched by date and clustered into ten classes. As such, documents, document classes, and search dates are the three basic components involved in WebViser. XML documents are tagged with metadata, such as Web address, time, date, location, etc. They are used to compute similarities between returned documents.

The visualization offered by WebViser is a 3D browsing interface²¹ based on four dimensions: search date, class, document, and entity comparison. Although there are some discussions on pros and cons of 2D or 3D design for information visualization (see Refs. 8 and 9), considering the high dimensionality of the data and the opportunity of using several views on the same data set, a 3D solution is pursued. The evaluation results presented in this paper show that users have a positive feedback on the 3D design.

Several visualization techniques are proposed in WebViser to better visualize documents along these four dimensions. A new model of carousel inspired by Wang *et al.*²⁵ is introduced to show the documents and search dates that share the same rank. Objects (documents) within a carousel are placed at regular intervals along the perimeter of the disk. With this model, each class of documents is represented as a local carousel and all the classes inside the results of a date query are visualized as a carousel stack. Each stack as a whole is then placed into a meta-carousel to show several search dates. Each carousel stack consists of local carousels with increasing radii from top to bottom according to their class ranks. Inter-document comparison is materialized by color links. Each link is a Bezier surface that is positioned to avoid cluttering the view with overlapping links and thus makes the comparison much easier.

The WebViser interface consists of three main components: an inspector window, a 3D view, and a detailed dialog. Inspector window sends commands to interactively visualize the search result in the 3D view, or display the details of each search or comparison in the detailed dialog. The 3D view and detailed dialog can communicate with each other. Selected document displayed in the 3D view can have their properties displayed in the detailed dialog. Reciprocally selected document or link in the detailed dialog can be highlighted in the 3D view.

In the next section, related work will be discussed. The visualization algorithm including the new carousel model, the carousel stack, and the colored link is presented in Sec. 3. The WebViser system including inspector window, 3D view, and detailed dialog is presented in Sec. 4. Evaluation is introduced in Sec. 5 and the whole paper is summarized in Sec. 6.

2. Related Work

The work focuses on the visualization of the XML documents from the Semantic Web search engine. Readers may refer to the related work^{13,14,29,30} for more general researches on data mining and knowledge discovery .

The documents returned for a search date are not ranked by the Semantic Web search engine, therefore it makes a circular model^{10,11,15,25} very attractive. In such a circular layout each object is placed along the perimeter and thus equally emphasized. However, existing circular models do not fit well with the requirements of WebViser. Nearest Neighbor Circle¹⁰ and 3D carousel²⁵ place all objects along the perimeter with different densities. This layout is not suitable for WebViser since: (1) each class contains at most 20 documents; and (2) an uneven distribution along the perimeter would lead to the false interpretation that some documents are closer than others. The 3D carousels such as Nearest Neighbor Circle and Rondell^{11,15} do not contain a termination mark that is necessary in the case to avoid users getting lost during navigation. Rondell, in addition, associates each object with its own widget. Such a solution has been rejected because it would hurt performance due to the important number of retrieved documents. Some other proposed models, such as the spiral model or the sphere model¹⁰ offer additional control values associated with document ranking (elevation for the former and longitude and latitude for the latter) that are irrelevant for the purpose.

Since 3D carousel uses a virtual carousel widget to hold objects, it offers a better integrated view of clustered objects than Nearest Neighbor Circle and Rondell. For this reason, a carousel layout for nonranked documents is preferably adopted into WebViser. In order to remove the limits of existing circular models mentioned above, a new carousel model with equally spaced and textured objects along the perimeter is proposed. Thus all documents have the same rank and computing is more efficient than in Rondell's model. While 3D carousel uses a termination mark, WebViser carousel model uses a start marker so that the user can find the initial position easily.

For class visualization, the fact that document classes are ordered must be taken into consideration. Although some studies, such as Data Mountain,¹⁶ Task Gallery¹⁷ and BumpTop,² may be used to visualize classified documents through separated piles, their design is not adapted to ordinal data. Trotts *et al.*²² used an image stack to show an image in a multiresolution model for the purpose of a smooth navigation at different level of details. Similarly WebViser proposes a carousel stack to visualize search results. Each document carousel represents the retrieved documents that belong to a specific class. The radius of the carousels increases progressively from bottom to top to represent the class ranks.

For document comparison visualization, color is often used to show similarity relationships.^{6,20,27} In the case of a dense layout, care should be taken for displaying such links to make their visualization readable. While links are used frequently to connect objects,^{3,12,28} Salton *et al.*¹⁸ proposed links to related text chunks. The

design of Salton *et al.* can also be adopted by WebViser to highlight the comparison of XML documents based on their semantic content. As opposed to the linear links of Salton *et al.*, a more flexible type of colored 3D link is proposed in WebViser to connect related documents. Made of Bezier surfaces, WebViser links have a higher curvature at their extremities that allows for a better control on their layout. The link colors represent the type of the XML entity on which the comparison is based. All these considerations make the comparison easier to track than existing methods.

3. The Visualization Techniques

Now more details on the design of the various components of the interface (carousels and links) are provided.

3.1. The new carousel model and the search visualization

In the WebViser carousel model, all objects are placed along the inner side of the carousel perimeter with a constant distance and there is a start marker representing their start position. Figure 1(a) shows the carousel model with four sample

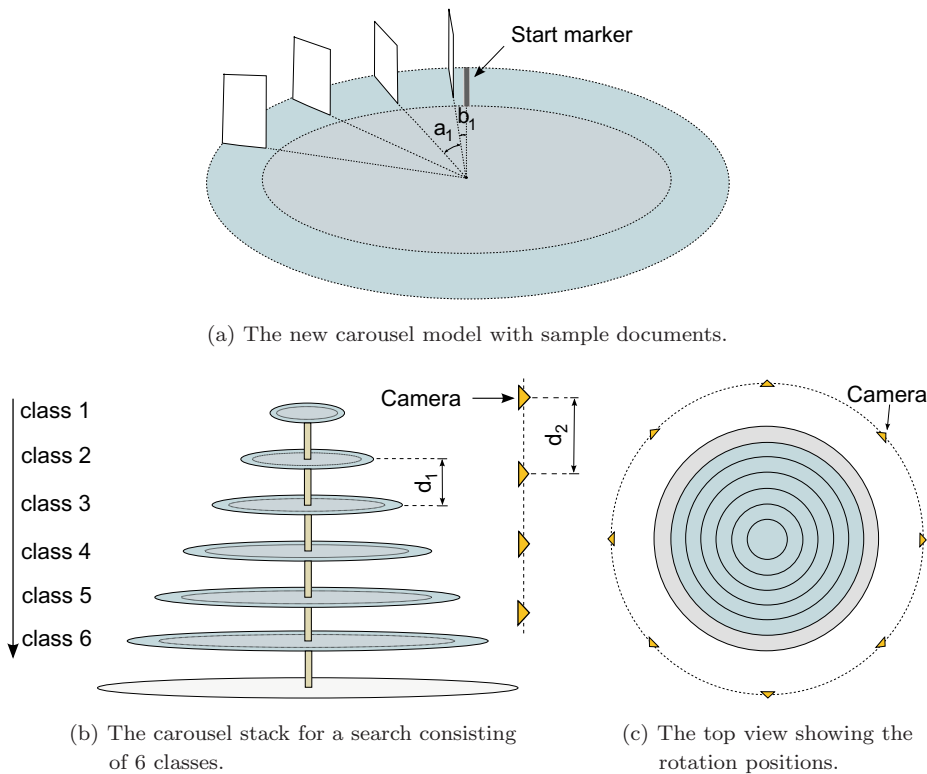


Fig. 1. Spatial layout and corresponding paths for navigation.

documents visualized as four rectangles. The objects are placed along the perimeter and separated by an angular distance a_1 and the first object is placed at an angle b_1 from the start marker.

A carousel stack is used to visualize all classes inside each search result. Each document class is displayed as a local carousel. Each document is materialized by a textured rectangle. The radii of local carousels in the stack increase progressively from bottom to top according to their rank. Figure 1(b) shows the design of the stack with an example search consisting of six classes. For simplicity, the documents in all these classes are omitted. The separation distance between neighboring carousels is d_1 , and a cylinder in the middle of the carousel stack is used to enhance the solidarity between the carousel components of the stack.

A meta-carousel is used as a container for different search results. Each stack is located regularly on its edge (see Fig. 6(b) left). The start marker on this carousel is on the center of the first stack.

To interactively view documents inside a stack, predefined vertical hopping and rotation angle of the camera allow the user to easily control the navigation as shown in Figs. 1(b) and 1(c). Figure 1(b) illustrates four vertical hopping positions separated by d_2 , and Fig. 1(c) displays a top view of eight rotation positions around each stack. For the meta-carousel, a fixed top view camera is defined together with predefined rotation angles.

3.2. Comparison with colored link

Two documents that satisfy the same search constraint based on values of specific entities will be connected with a link as explained in Fig. 2(a). The link is created as a Bezier surface, and the start and end positions are set to be the two related documents M and N . The two intermediate positions p and q are computed from the two vectors that join the center of M and N and a point located above at a

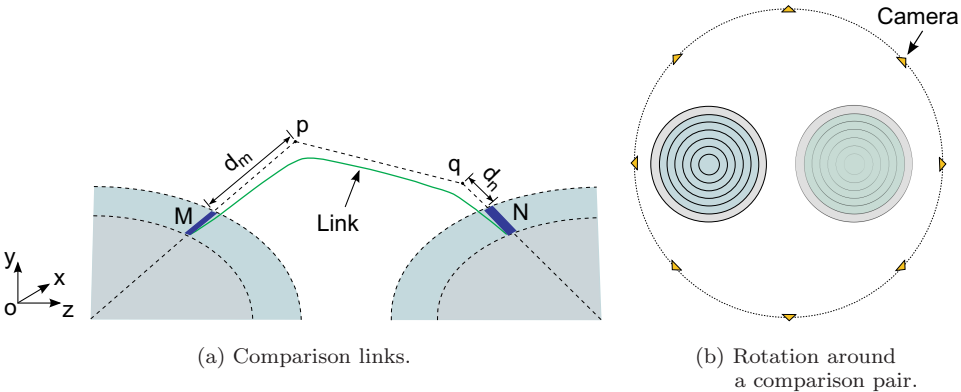


Fig. 2. Comparison through links.

distance of d_m and d_n , respectively. In addition, the intermediate point corresponding to the source document M will have a bigger separation distance than the point corresponding to the target document N to help distinguish them. If several entity comparisons are made simultaneously, the links associated with each comparison are shown in different colors.

There are four types of comparisons: comparison of all documents in one stack (internal comparison), comparison of all documents in one stack with its two neighboring stacks in the meta-carousel (neighboring comparison), comparison of any two search results (two date comparison), and comparison of one document from one stack with all documents from all other stacks (one document comparison). In the case of two date comparison, links shown in the meta-carousel could directly cross many intermediate stacks and thus make stacks and links collide. To avoid this, a new scene graph with these two selected stacks is generated. The links shown in this new scene graph can be more clearly captured than if they were provided at the meta-carousel level of representation. For one document comparison, to have a clear view of the select document with one particular stack, a new scene graph holding the stack to which this document belongs and the stack that contains the comparison target is generated. The links are displayed in the same way as those of two date comparison.

To interactively view the comparison result, such as Fig. 1, predefined camera positions are also used in vertical and circular directions for the compared stacks. While hopping is the same to all types of comparison (Fig. 1(c)), rotation depends slightly on the type of comparison. For internal comparison, rotation is centered on the selected stack (Fig. 1(c)). For the three other types of comparison, rotation is centered at the middle of the two search result stacks and surrounds them both as shown in Fig. 2(b).

4. The System

Based on the visualization method discussed above, WebViser is proposed as a visual explorer to view retrieved XML documents. The system is implemented with Java and Virtual Choreographer (VirChor).²⁴ VirChor is an open source real-time 3D engine with XML-defined 3D scenes. Java is very convenient for interface design, while VirChor is appropriate for 3D scenes rendered in OpenGL. UDP sockets are used for the communication between Java and VirChor.

4.1. The architecture

Figure 3 shows the architecture of the system. There are three components, inspector window, 3D view, and detailed dialog. Inspector window controls the whole program and sends commands to the 3D view and the detailed dialog. The visualization window and detailed dialog communicate with each other for the interactive display of the search and comparison results.

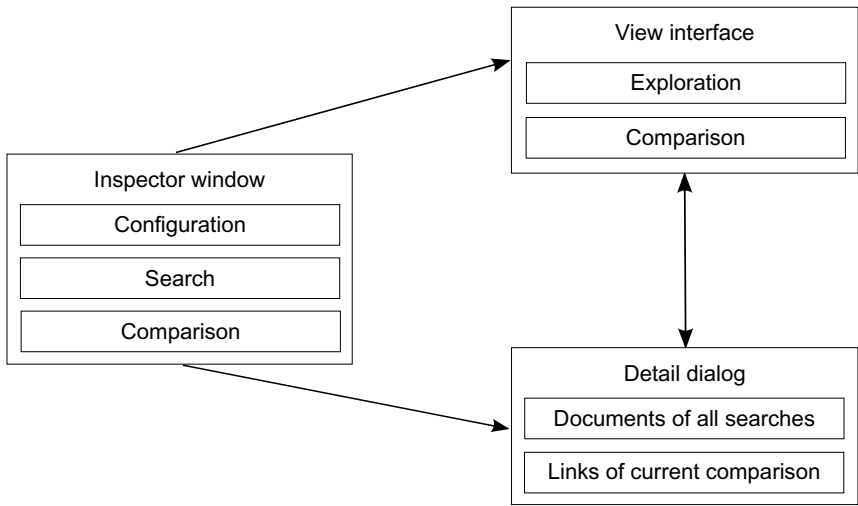


Fig. 3. The system architecture.

4.2. Inspector window

There are three main components in the inspector window, as shown in Fig. 3: configuration, search, and comparison.

Configuration is used to define the search range and to choose the comparison entity and related link properties as discussed in Sec. 3. Search is made of the following steps. First, the user selects a search date and the search engine is launched. Then, the search result is parsed and transformed into a 3D scene made of a carousel stack. Last the result is displayed in the 3D view, or some of its details are shown in the detailed dialog. Comparison setup requires the user to choose one comparison type and to select the source and target search date of the source document. Two comparison methods are provided: comparing neighboring classes only and comparing all classes below current class. Apparently, the latter generates more redundancy than the former, so the former is set to be the default comparison method.

Figure 4 shows the interface of the inspector window. It is divided into two parts: the left part is made up of action (configuration, search, or comparison) buttons, and the right part contains further settings for these actions.

4.3. 3D view

The 3D view interactively visualizes the search results returned by the commands from the inspector window, and highlights the selected documents and links defined in the detailed dialog.

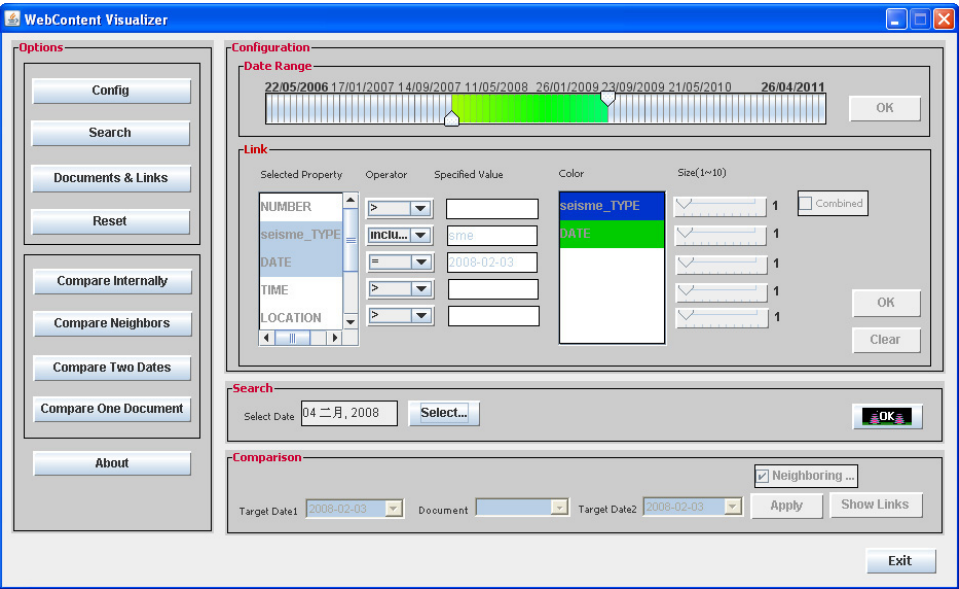


Fig. 4. Inspector window.

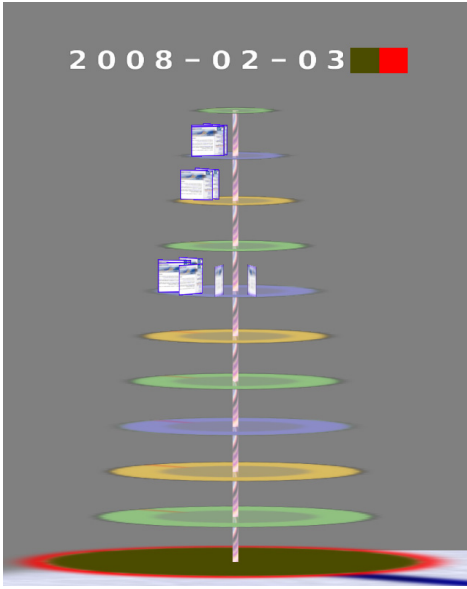
4.3.1. Basic design considerations

Now the design of search result visualization and comparison, and the configuration of the window for interactively visualizing each search and comparison is presented.

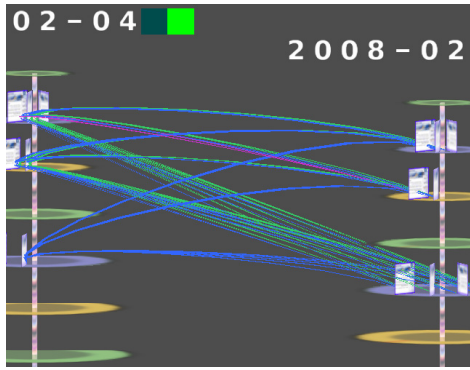
For better distinguishing search stacks and their inside carousels in each search result, three improvements to the carousel stack shown in Fig. 1(b) are proposed: (1) A date label with a two-color band is added on the top of the stack to help locating the search; (2) the stack base can be displayed as two concentric plates with their colors corresponding to the date label colors; (3) three alternating textures are mapped to the carousels to distinguish differently ranked classes.

Figure 5(a) shows a sample stack implemented in the system. In this figure, a carousel stack of 10 classes for the search of February 3, 2008 is displayed. The documents are rectangles textured with a single web page snapshot. The date label is “2008-02-03” and its two-color band is made of army green and red stripes. The same colors are used for the two concentric plates of the stack base to help the user recognize this stack in other views such as a top view where the date is not visible. Three alternating textures are used in different classes to help users locating each class and identifying the same class across different stacks. There is also a red start marker for each carousel in the stack.

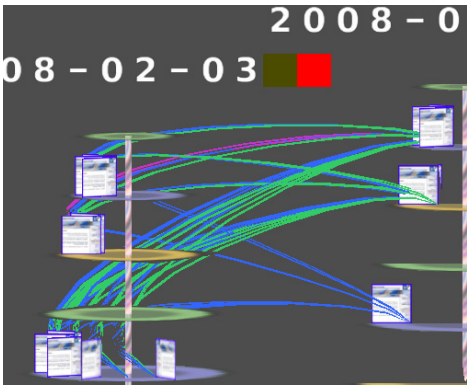
To better distinguish links and avoid link crossing, all the links that point to the same document are separated by a small distance due to the different positions of their p and q points (Fig. 2(a)) for different links. The y value (height) of p or q shown in Fig. 2(a) is larger than x and z so as to better separate neighboring links.



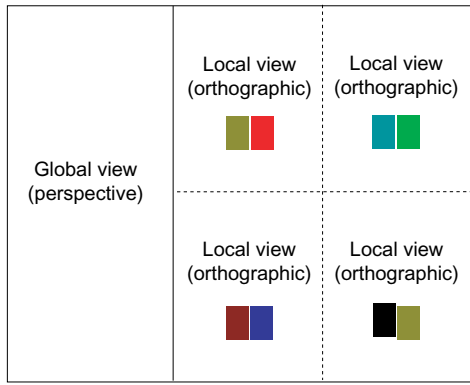
(a) Carousel stack implementation.



(b) Link implementation.



(c) Another view of Fig. 5(b).



(d) The general layout of the 3D view.

Fig. 5. (Color online) The basic design of the 3D view.

Figure 5(b) shows an example of comparison links associated with the dates, February 3, 2008 and February 4, 2008 (two date comparison). The links are visualized in green, blue, and dark pink for three conditions respectively, i.e. date equals to “2008-02-03,” type includes “sme”, and location equals to “Paris.” The two carousel stacks that correspond to February 3, 2008 and February 4, 2008 are put into a new scene graph with 103 associated links. There are 50 green links for date, 50 blue links for title, and 3 dark pink links for location. All these links can be clearly distinguished by a closer view. Figure 5(c) gives another viewpoint of Fig. 5(b).

Since February 3, 2008 and February 4, 2008 are set to be the start stack and the end stack, respectively, for each link, the start part from each document in February 3, 2008 is steeper than the end part to each document in February 4, 2008 as explained in Sec. 3.2.

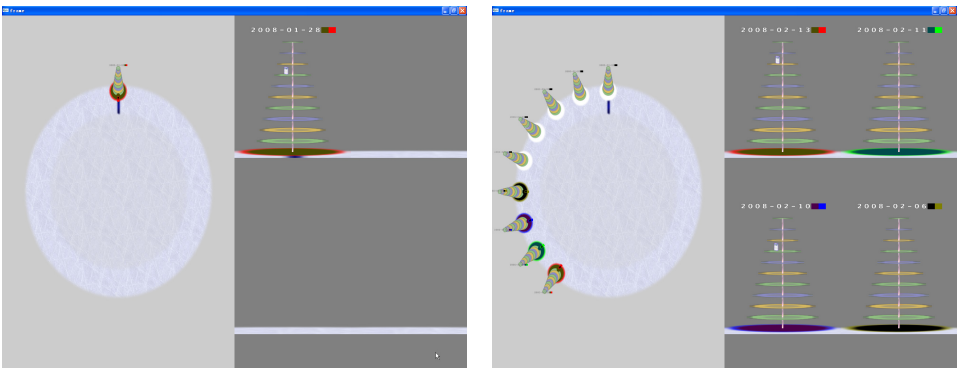
For a more efficient presentation of the carousel stacks and comparison links, the 3D view is split into five windows, as depicted in Fig. 5(d). The global view is a top view of the meta-carousel with a blue start marker. This bird's eye view provides users with a global presentation of all search results and links. The local view is an orthographic view that explores carousel stacks and also displays comparison results without distortion. The global view has one global camera and each local view is associated with its own local camera. The two colored rectangles shown in each local view correspond to the two colors used for date representation and stack base coloring as explained above. Each local camera is displayed in the view of the meta-carousel with the same two main colors so that it can be easily associated with its corresponding local view. While the camera in global view is fixed, the positions of local cameras is controlled by the commands entered in the inspector window.

Now the description of the two local view models (exploration and comparison) that differ on their spatial layout and interaction modes are discussed below.

4.3.2. Exploration model

Exploration begins when a new search is entered. In the exploration mode, four local views will display the four latest stacks with their four local cameras looking at their axes. As explained above, two local view main colors are used to identify their local cameras, their bi-color stack base, and the date label.

Figure 6(a) shows the interface after the first search query has been entered. In its left part, the meta-carousel is displayed with the virtual camera. In its right



(a) The first search visualized.

(b) Nine searches visualized.

Fig. 6. The exploration model of the 3D view. The nine searches of year 2008 are added one by one counterclockwise into the meta-carousel: January 28–30, February 3, 4, 6, 10, 11, and 13.

part, the first stack is shown in the top left local view. You can notice the bi-color correspondences between date, stack base, and virtual camera.

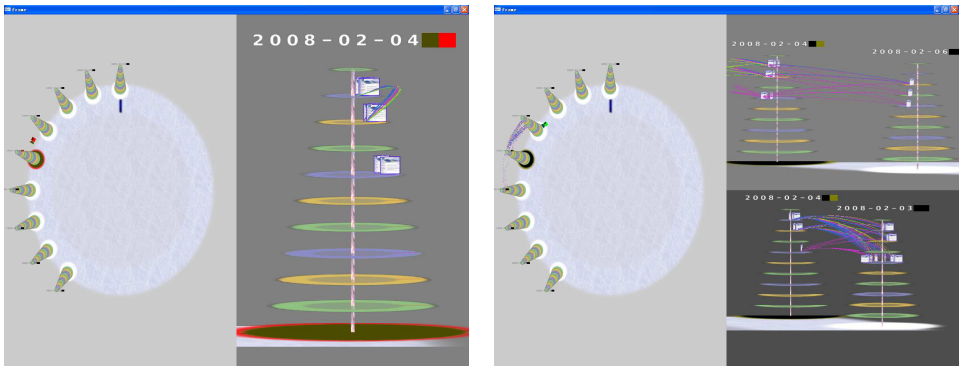
Each time a new search is entered, the result is displayed in the top left local view with the four latest search results in top left, top right, bottom left, and bottom right windows, in that order. In each local view, the stack is viewed in the same way as shown in Fig. 6(a) with its unique bi-color identity. Search results prior to the four latest ones are all displayed with the same black color for the date label and white color for the stack base. Figure 6(b) shows a view of the interface after nine queries have been entered. Its four local views are filled with the four latest search results.

4.3.3. Comparison model

Depending on the types of comparison, the four local views can be merged into one or two big views to display the comparison results. In this model, the two colors used for the date label, stack base, and virtual camera are not displayed in the same way as in the exploration mode.

For internal comparison, all four local views are merged into one view to show a large stack with its internal links. The bi-color identity is the one associated with the top left view. Figure 7(a) shows the internal comparison result of the February 4, 2008 query with 13 links obtained by comparing four metadata.

For neighboring comparison, the two top and two bottom local views are merged to show respectively the comparison with the left neighbor and the right neighbor. The date label and base of the middle (source) stack are shown with bi-color identity of the bottom right local view while the two other targets (left and right stacks) are shown with white base and black label. Two virtual cameras signal the position



(a) Internal comparison. Four metadata and 13 links.

(b) Neighboring comparison. Four metadata and 163 links.

Fig. 7. Comparison visualization. The nine search results shown here are the same as in Fig. 6 with the same query order. February 4, 2008 is set to be the source in all the comparisons. Different metadata are used for different comparisons and generate different number of links.

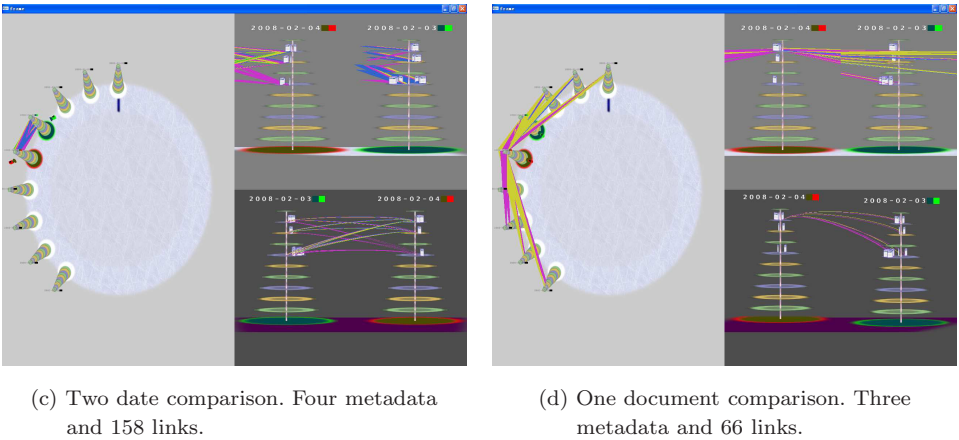


Fig. 7. (Continued)

of viewpoint in the top left and right views. Figure 7(b) presents the result of neighboring comparison with 163 links obtained by comparing four metadata.

For two date comparison and one document comparison, the two bottom local views are merged into one single view to show the new scene graph. The top left and right views show the original two stacks with their bi-color signatures. The two stacks shown in the two bottom views have the same colors as those in the two top views. The links associated with the comparison are also displayed in the bird's eye view of the meta-carousel to help the user understand the whole picture. Figure 7(c) shows the comparison between two selected dates (February 4, 2008 and February 3, 2008) and Fig. 7(d) shows the comparison between one document that belongs to the middle search result and all the remaining search results.

Through the inspector window and 3D view, all search results can be shown and compared interactively, but there is a need for an additional component, called detailed dialog, to inspect and get a detailed view of documents or links of interest found in these results.

4.4. Detailed dialog

This dialog has two parts that are used to provide users with details on documents and comparison links. The details of a XML document include date, class, title, and other entities. The details of a link include the date, class, and titles of the start and end documents. The link part also shows related entities and their associated values in the start and end document so that the details of their metadata comparison result can be obtained. Figure 8(a) shows such a dialog.

When the user selects one document or link to display, it will be highlighted in red in the 3D view. Figure 8(b) shows an example in which a document and a link are selected. The detailed dialog also appears when a document in the 3D view is selected.

Documents and Links

Documents

Date: 2008-02-03 Class: 1 Documents: La police portugaise fait son mea culpa dans l'af...

Properties

entity-info: 20080203/1750_19.html.txt.seisme-DB.xml text-file: 20080203/1750_19.html.txt

title: La police portugaise fait son mea culpa dans l'... agency: EuroNews publish_date: 2008-02-03 class: 1

Entities

NUMBER: DATE: 2008-02-03 LOCATION: Portugal GEO_COORDINATES: seisme_TYPE: tremblem... TIME: MAGNITUDE: DAMAGES: cinq morts

Links

Start document: 1: La rébellion tchadienne ... End document: 1: Mariage Sarkozy :"la situ... Related entity: 1: seisme_TYPE

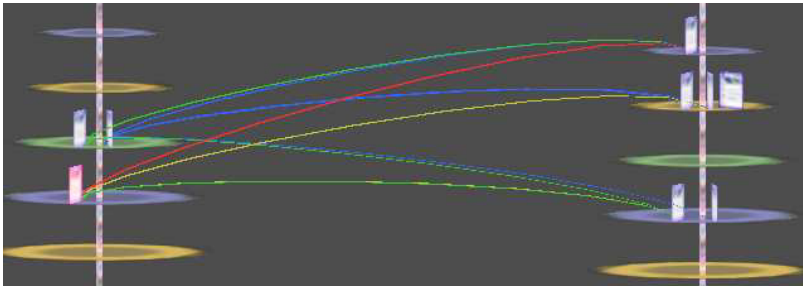
Start document

Date: 2008-02-03 Class: 1 Entity: 1: séisme Title: La rébellion tchadienne poursuit ses attaques

End document

Date: 2008-02-03 Class: 2 Entity: 1: Séisme Title: Mariage Sarkozy :"la situation se trouve clarifiée...

(a) The detailed dialog.



(b) The selected document and link shown in 3D view.

Fig. 8. (Color online) The detailed dialog and the corresponding visualization in the 3D view.

5. Evaluation

Now an evaluation focusing on two aspects of WebViser is reported: the visualization techniques and the interface. Twenty four people having no prior experience of the system were evenly divided into two groups for the evaluation. For the first group, six general tests were given to them for trying some of the functions of WebViser. These tests included two date queries and result comparisons under various setups. Six questions were then asked to the users about the ease of use of the carousel and its stack, and about his/her opinions on the system. For the second group, six tests belonging to two date comparison but with different numbers and types of

conditions were taken. The time spent for explaining the experiment and assisting users, as well as the total interaction time were recorded to evaluate the learning time and analyze the applicability of the whole system.

5.1. *Evaluation result of the first group*

5.1.1. *The visualization techniques*

The evaluation shows that all users appreciate the carousel and stack layouts and that they all believe that the documents inside one carousel have the same rank and that different carousels are associated with different ranks. They also consider that links give a good idea on how similar are carousels and documents. These results confirm that the design goal of the visualization has been reached.

Three users have expressed that they were not satisfied with the methods offered for navigation and think that fixed positions restrict their exploration of the data. One user said that he would like to check the differences between documents but the visualization algorithm does not provide such a function. Four users would have liked to remove the links that are not associated with the currently selected document.

5.1.2. *The system interface*

All users are satisfied with the functions provided by the interface and like the idea of splitting the 3D view into local views and its control by the inspector window. The details on links and documents reported in the detailed dialog help them quickly locate the data they are looking for.

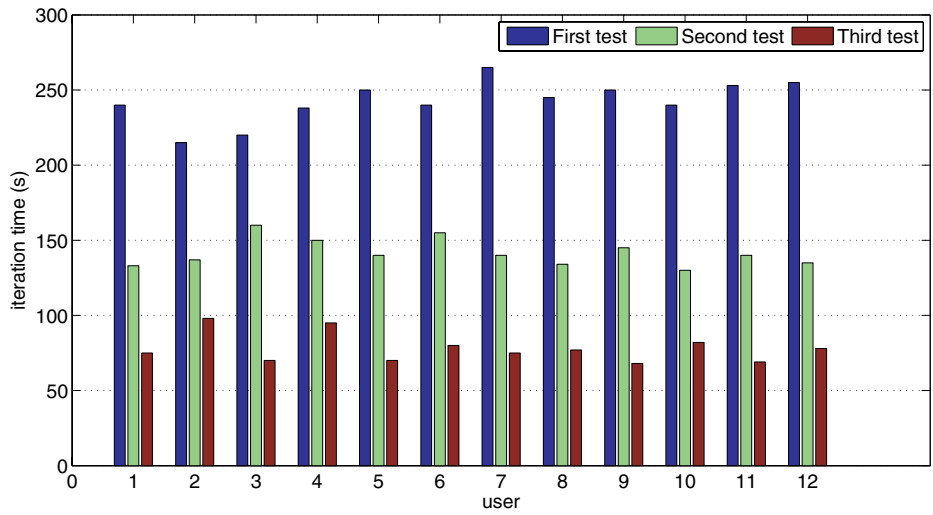
As for the negative feedback of the interface, eight users complained about information overload in the inspector window. Five users found it difficult to spot useful information on comparisons through the detailed dialog. However, after some additional explanations, they finally could use this dialog correctly to compare documents and links (more details on the learning and applicability of the system are discussed in the following subsection).

5.2. *Evaluation result of the second group*

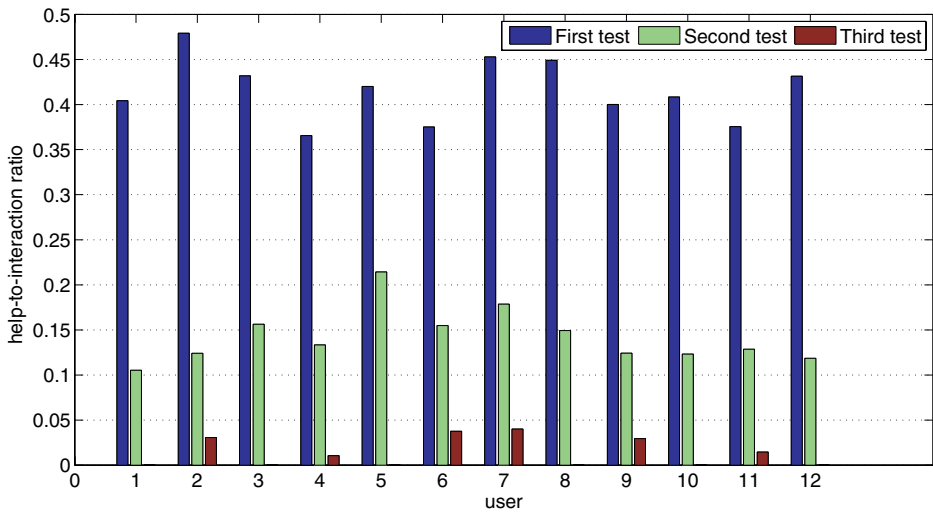
All users did slow in the first two tests. In this case, helps were always needed, such as where to search the date, how to set the comparison conditions, and view the content of the document. But no help was asked for from the fourth test, which means the users were used to the techniques and the system pretty well after the first three experiments.

Figure 9(a) shows the user interaction times. All users have very high interaction times in the first test, but perform faster and faster for the remaining tests. Figure 9(b) shows the proportion of the help time to the total interaction time (help-to-interaction ratio) during each test for each user. There is also a high ratio

in the first test for all users, but lower and lower ratios in the remaining tests. It can also noticed that half of the users (users 1, 3, 5, 8, 10, and 12) did not ask for any help in the third tests. Figure 9(c) gives the average interaction and help times in each test among all users. Statistically, almost 1/3 time of the first test with



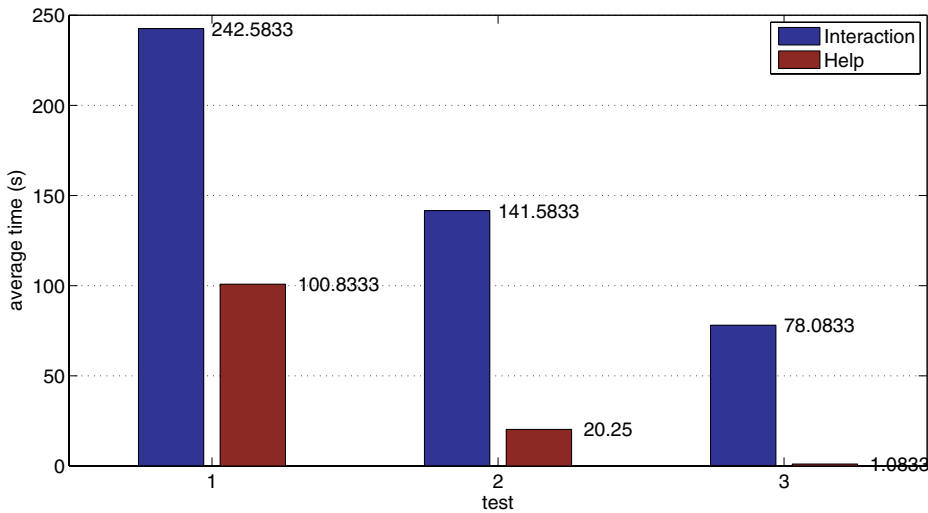
(a) The interaction times of different users in different tests.



(b) The help-to-interaction ratios of different users in different tests.

Fig. 9. The interaction times and help times used in the first three tests of the second group's evaluation.

Note: Twelve users have taken part in this evaluation and the time is counted in seconds.



(c) The average interaction and help times of each test among all users. Numbers shown beside each bin depict the height of the bin, which means the average help or interaction time of the corresponding test.

Fig. 9. (Continued)

almost no help at all (1.0833s in average) was required when users became familiar with the interface in the third test.

This evaluation shows that the user may require some time to understand the system at first. However, they can learn it quickly with a few trials and then use the system independently, which proves the system is easy to use and applicable.

6. Conclusion

This paper has presented WebViser, a visualizer of the results returned by queries on metadata structure of Semantic Web documents. The system focuses on four aspects of the visualization: document, class, search data, and entity comparison. The visualization techniques are proposed to overcome the limits of current visualizations for Semantic Web information access, which do not cope well with non-ranked documents and XML-entity comparison. WebViser offers a new carousel model to view objects without ranks, a carousel stack to show classes of documents inside a search result, and curved links to visualize metadata comparison between documents. Evaluation results showed that this system efficiently displays XML documents retrieved by a Semantic Web search engine and its associated document comparison algorithms. Thus WebViser proves to be an effective complementary to traditional explorers.

The evaluation results also suggest some further improvements. As for the visualization techniques, a filter function would be desirable to display only those links

or documents that are selected by the user. A new visualization that would highlight the difference between structured XML documents would also be nice. In addition, the interface could be made easier to manage by having, for example, two tabs, one for exploration and the other for visualization. Such a design would lead to a better integration of the different views and simpler dialogs.

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