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NEAR: Visualizing Information Relations in Multimedia Repository A•VI•RE

Qian, C. Z., Chen, V. Y., and R. F. Woodbury

***Abstract*—** This paper describes the NEAR (Navigating Exhibitions, Annotations and Resources) panel, a novel interactive visualization technique designed to help people navigate and interpret groups of resources, exhibitions and annotations by revealing hidden relations such as similarities and references. NEAR is implemented on A•VI•RE, an extended online information repository. A•VI•RE supports a semi-structured collection of exhibitions containing various resources and annotations. Users are encouraged to contribute, share, annotate and interpret resources in the system by building their own exhibitions and annotations. However, it is hard to navigate smoothly and efficiently in A•VI•RE because of its high capacity and complexity. We present a visual panel that implements new navigation and communication approaches that support discovery of implied relations. By quickly scanning and interacting with NEAR, users can see not only implied relations but also potential connections among different data elements. NEAR was tested by several users in the A•VI•RE system and shown to be a supportive navigation tool. In the paper, we further analyze the design, report the evaluation and consider its usage in other applications.

***Keywords*—** measure similarity, trace reference, inherent relation, information visualization, online multimedia repository

I. Introduction

BEING an extended online information repository system, A•VI•RE contains great amounts of semi-structured data such as resources, annotations and exhibitions. By using graphic nodes and links, we developed a visualization panel "NEAR" (Navigating Exhibitions, Annotations and Resources) as a small but supportive tool for users to navigate through A•VI•RE smoothly, reveal information and relations among different data elements and interpret data elements from different perspectives.

Graph visualization has many areas of application such as file hierarchy, website maps, object-oriented systems, semantic networks and logic programming [1]. The research on graph visualization has been widely used in visualizing structured data elements. NEAR explores the visualization of unstructured relations such as similarities and references graphically among structured data elements in A•VI•RE.

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Ms. C. Z. Qian is with the School of Interactive Arts & Technology, Simon Fraser University, Vancouver, BC, Canada. (phone: 604-268-7500; fax: 604-268-7488; e-mail: cherylq@ sfu.ca).

Mr. V. Y. Chen is with the School of Interactive Arts & Technology, Simon Fraser University, Vancouver, BC, Canada. (e-mail: yvchen@sfu.ca).

Dr. R. F. Woodbury is with the School of Interactive Arts & Technology, Simon Fraser University, BC, Canada (e-mail: rob_woodbury@sfu.ca).

A. *Information Structure in A•VI•RE.*

A•VI•RE (a Visual Rete, available: http://www.avire.ca), a generic repository for visual material related to cultural disciplines, is designed as an interactive online space where users in different roles (such as curators, exhibitors, critics and viewers) play together to create a larger social entity. Users can upload new resources, organize exhibitions, annotate on resources and communicate their understanding through the Wiki technology. Being such an extended online visual gallery system, A•VI•RE has a huge collection of exhibitions which contain resources and annotations. In A•VI•RE, each exhibition and resource has metadata as its attributes.

Having three kinds of data elements (resource, exhibition and annotation), the information structure in the system is designed based on following principles:

- A resource can be an image, a multimedia file of any type, an annotation or an exhibition. An exhibition is a collection of annotations and resources. An annotation is a mixture of text and reference to exhibitions and resources.
- One resource can be quoted from the metadata and used in multiple exhibitions.
- Every exhibition or resource may have one or more annotations. Annotations may also be annotated.
- Annotations can share information through Wiki pages.

In the system, one user sets up an exhibition and writes annotations. Another exhibitor might collect some same resources but interpret from a different perspective. Therefore, A•VI•RE provides a platform where a panorama view of a resource from different perspectives (different interpretation relate to the same resource) can be presented to the users.

B. *Problems of Visualizing Relations in A•VI•RE*

The original version of A•VI•RE is strictly limited by its TikiWiki template and appears as a rich repository environment but hard to navigate and interpret. Significant visualization problems of the system (and other similar systems) include:

It is hard to provide multiple viewpoints of a resource. A resource can be collected in multiple exhibitions and quoted in multiple annotations, so it naturally bridge different interpretations and connect interesting ideas. The system should provide a panorama view of a resource from different perspectives, but its design hasn't met the goal.

It is also hard to see the relations among exhibitions. An exhibition might share resources with other exhibitions or belong to another exhibition as a resource. Although references information among exhibitions is valuable, it could not be visualized in the original interface design.

It is easy to find one resource or exhibition by key word searching, but difficult to find specific relevant data elements. To search for a specific image among over 3000 images, the user is required to remember too much relation information around the image before he starts to locate it. During the process, too much working memory has to be consumed [2], but the exhibitor has not learned something useful.

C. Why to Apply Graph Visualization to A•VI•RE

In the A•VI•RE system, original resource elements have been structured according to a pre-determined metadata schema. There are a few hierarchy structures among exhibitions and no structure for Wiki annotation pages. However, when we start to consider exhibitions and annotations as resources, some original structures break down and new relations rise up. These new relations are very important. A useful feature in Amazon.com inspires us. Amazon.com uses previous customers' shopping experience as a kind of suggestion to new customers. The system cleverly captures an aspect of a group's intentions without making too much interruption on the online shopping process. In A•VI•RE, interpretation connections between resources and exhibitions linked by annotations are the most valuable information because they provide later users interesting knowledge and suggestion generated by pervious experience. It is essential to visualize these connections. In NEAR, our design aims to not only represent the inherent relations but also to discover the potential connections for the users.

II. Key Qualities

Outlined here are ten qualities we consider to be essential in effectively visualizing resources, exhibition and annotations, along with a brief discussion of their value.

- **Relations** - One should make the relations among resources, exhibitions or annotations visible at a glance. These relations give important context for later users' interpretation.
- **Interpretation** - The process of collecting resources as exhibitions and writing explanations and annotations is the process of interpretation. One should be able to trace the interpretation history of a resource and understand different perspectives around it.
- **Popularity -** One should be able to see how "popular" a data element is. If one exhibition contains more resources and attracts lots of attention, or one resource has been annotated many times, they could be more interesting or useful.
- **Compactness -** For a viewer, although both eyes together provide a visual field of a bit more than 180 degrees, the viewer can only resolve about one-ten the detail at 10 degrees from the fovea [3]. For this reason, the graph's central area should be preattentive and information highly concentrated so that the user can see the relations at a glance.
- **Simplicity & Consistency -** It is essential to keep the layout consistent and easy to be navigated.
- **Recognizability -** Most of the current resources are image-based. Since the size of image significantly affects the object recognition of this image significantly [3], the scale of visualization graph nodes should be small but recognizable.
- **Responsive & Communicative** - One must be able to see the relations from highlighting specific item. The purpose of highlighting is to make some information stand out from other information so that to draw viewers' attention [3].
- **History & Visit Status -** One should be able to see the hints of his own navigation history such as current, visited and unvisited items. The capacity of visual working memory is limited to a small number of simple visual objects and patterns (3 ~5 simple objects) [3].
- **Orthogonality -** One should be able to recognize the different relations and attributes of data demonstrated in the visualization panel at a glance. The visual method used to visualize each attribute (size, popularity, etc.) of the data elements should be unique.
- **Chronology -** One should be able to see the evolution of an interpretation, so exhibitions and annotations should be represented in the generating time sequence.

III. Existing Related Projects & Researches

This paper aims to visualize data relations such as similarities and references in an image database. We review literatures from three perfectives: measuring similarity, tracing reference and visualizing information.

A. Measuring Similarity

Many applications require a measure of "similarity" between objects. One obvious example is the "find-similar-document" query, on traditional text corpora or the World-wide Web [4]. More generally, a similarity measure can be used to cluster objects, such as for *collaborative filtering* in a recommender system [5, 6, 7], in which "similar" users and items are grouped based on the users' preferences. Various aspects of objects can be used to determine similarity, usually depending on the domain and the appropriate definition of similarity for that domain [8]. *Bibliometrics* studies the citation patterns of scientific papers (or other publications), and relationships between papers are interred from their cross-citations. Most noteworthy from this field are the methods of *co-citation* [9] and *bibliographic coupling* [10]. These methods have been applied to cluster scientific papers according to topic [11]. More recently, the co-citation methods have been used to cluster web pages [12]. However, few of these projects intend to present their final outcomes recognizably or efficiently. For example, in SimRank [8], the similarity outcomes are demonstrated through many simple node-link graphs, but it is hard for application users to understand at a glance.

B. Tracing References

A•VI•RE is an information and reference archiving system. It archives the information of how resources are contributed, shared, interpreted and annotated as exhibitions or annotations, and also archives this reference information as new resources. Techniques used in email archiving system such as node-link graph are inspiring. Node-link graph, a graph consisting of nodes and edges, is good to represent references and demonstrate overviews of links [3]. The email conversation could be visualized through a mixed model of sequential model and a tree model [13], a circular graphical model [14] or Thread Arcs [15]. Compared with other node-link forms, Thread Arcs is elegant because it demonstrates how a simple node-link diagram can represent complex email relations clearly and smoothly. The fundamental goal of visualizing emails is to keep tracking information of simultaneous email conversations. Thread Arcs provide a useful way for users to see the whole structure and background information at a glance.

C. *Visualizing Information in a Image Database*

In most of image database systems, image data are put under category which related to metadata and keywords. The result of a query in the image database systems is usually a set of images, displayed in an Image Browser or shown in a two-dimensional grid of thumbnails [16]. Most document or image visualization systems either do not display a graph of the space, or do not display the documents/images when they use a graph. For document browsing, the Document Lens [17] uses a focus+context technique to display the document of interest in detail while compressing the rest of the document space. Image browsing systems also display the entire space of images either without hierarchies (the default for most file mangers) or with some structural information provided by annotations [18]. Apart from giving an overview of the entire document/image space, recent projects such as Concentric Rings [19] and MoireGraphs [20] could highlight the relations among documents/images. But in their detailed examples, lots of images are overlapped and relations lines are entangled with each other. It seems that this design issue of visualizing big amounts of resources has not been satisfyingly solved.

IV. Visualization

To design a panel that demonstrate the relations among data elements in A•VI•RE, we think that there are essentially two parts: nodes (resources, exhibitions and annotations) and their links. The design is based on the ten key qualities we have determined and refer to related projects we have reviewed. In Figure 1, the NEAR panel shows: a list of all resources belong to the current exhibition, all annotations which have annotated any resources in the list and all related exhibitions which share any resources in the list. It is important to make the abstract image meaningful and capable of incorporation into a cognitive framework for the visual advantage to be realized [2]. So, in NEAR, exhibitions, annotations and resources are represented by graphic icons and thumbnails to better present logic structures and details. Hence we designed a serial of graphic icons to represent exhibitions and annotations. Also, due to the limited capacity of human's visual working memory [3], we only provide 3~4 variations for each attribute in the node design.

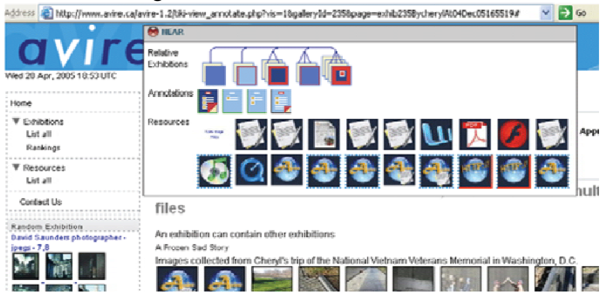

Fig. 1 Screenshot of the NEAR panel in A•VI•RE.

A. *Color Selection and Attribute Distinguishing*

Selecting color is an important issue when we design the graphic nodes. Color theories are used for choosing color. Since gray-scale colors are not a particularly good method for coding data [3], blues of different saturations have been chosen to indicate popularity. It is important to make current exhibition preattentive. When mouse is over one data element, connections between this item and other data elements need to be obvious too. Red color is used to represent these important elements – current exhibition and implied relations.

Orthogonality is important for user to distinguish different attributes. Since each kind of data elements has large amounts of varieties (exhibition nodes and annotation nodes have 432 varieties, and resource nodes has 9 varieties to represent visit status and popularity), color, shapes and number of shapes should be carefully chosen for readability and understandability.

B. *Nodes*

1) *Nodes of Resources*

Fig. 2 Icons of Multimedia Document Nodes

Resources in A•VI•RE can be an image, a multimedia file, a website or any type of document. Their visual nodes are represented by pictures (image) or graphic icons (other type except for images) (Figure 2). Thumbnail is naturally a good form to represent images.

Fig. 3 Examples of Resource Nodes
(the thumbnail frame of one resource node is determined by the frequency of this resource being shared by other exhibitions)

To meet the key qualities of compactness and recognizability, the scale of thumbnail nodes should be small but easy to be recognized. The size of resource nodes in current design is limited as 40px X 40px. Examples of such nodes are shown in Figure 3.

2) Nodes of Exhibitions

Fig. 4 Examples of Exhibition Nodes
Upper: Nodes of different size (determined by number of resources)
Lower: Nodes of different popularity (determined by the user visits)

An exhibition is a collection of exhibitions and resources. Since exhibitions are actually document/image containers in the system, we designed the icon as shown in Figure 4.

From the exhibition nodes, following information can be represented:

- ***Size of the exhibition***: the number of pages in the node (2~4) shows how many resources have been collected in the exhibition (3 possibilities).
- ***Popularity***: different colour covers show the amount of times being visited by all the users (3 possibilities).
- ***Chronology:*** Exhibitions are lined horizontally in the order of - be convenient for a user to recognize interpretation history.
- ***Reference***: how many resources have been shared with the current exhibition (figure 6)
- ***Currency relation***: if exhibition contains the opened resource or annotation (figure 7) & ***Visit status*** (figure 9)

To set a proper number to distinguish all the possibilities, we analyzed all exhibitions to get an average number, and set a number to make each possibility even.

3) Nodes of Annotations

Being the mixture of text and reference to exhibitions and resources, annotation is a method of weaving resources and text together to create a piece of artifact. A research paper is a good example of such artifact. So we use paper icons to represent the nodes of annotations (Figure 5).

Fig. 5 Examples of Annotation Nodes
1st line: Nodes of different organization (determined by number of resources)
2nd line: Nodes of different popularity (determined by the user visits)
3rd line: Nodes of different importance (if the annotation is the default view)

Although the annotation nodes appear similar, they represent about 6 types of information and include a lot of possibilities:

- ***Content organization***: indicate how many resources have been annotated in the annotation and how long the content (text) is (12 possibilities).
- ***Popularity***: the background in different colours show the amount of times being visited by all the users (3 possibilities).
- ***Being default***: the boundary colour of the small horizontal title line on the top of every node shows whether or not this annotation is the default view of its exhibition (2 possibilities).
- ***Chronology:*** Annotations are also listed according to the order of their creation time.
- ***Currency relation***: if annotation contains the opened resource (figure 7) & ***Visit status*** (figure 9).

C. Links and Relations

In NEAR, links are used to show the similarities and references among exhibitions, annotations or resources. To make user read these connections easily, smooth continuous contours are used to connect nodes [3]. Any exhibition share the same resource/resources would be linked, the amount of sharing is represented by the number of branches from one node (Figure 6). Inspired by Thread Arcs [15], icons are lined up in the order of creation time to satisfy the quality of compactness, simplicity and consistency.

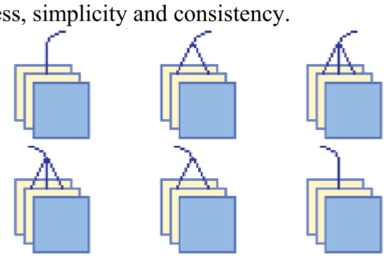

Fig. 6 Examples of Exhibitions Using Branched-Links to Share Different Amounts of Resources

Nodes can also be responsive when a related annotation or a shared resource is opened in the background browser window. Figure 7 shows the examples of an exhibition node and an annotation node which includes the currently opening resource.

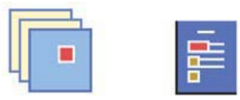

Fig. 7 Examples of Exhibition Node and Annotations Node with Currency Relations

V. Interaction and History

Interaction is essential in NEAR. A good visualization is not just a static scene that we walk through and inspect like a museum full of statues. Interaction is something that allows us to drill down and find more data about anything that seems important [3]. Ben Shneiderman also has called a “mantra” to guide visual information-seeking behavior and the interfaces that support it: “Overview first, zoom and filter, then details on demand [21]”. NEAR in the context of an online information repository also have interactive components that allow one to highlight and inspect elements dynamically. The data that users obtain through their interactivities are very important: relations across data elements. There are three kinds of interactions in NEAR: cursor over, clicking and double-clicking.

Since the relation among data elements are very complex, "Brushing" [22] is adopted in NEAR interaction to enable visual linking of components of heterogeneous complex objects. When the mouse cursor brushes over a data element, the user can find more relations between data elements and read the description of the element. Sometime people like to move mouse when they read. To avoid flicking, the users can click on an element to freeze the relation view and read the relationships between elements. A mouse click on empty space will clear the frozen view and re-active the mouse-over effect. Similar to any desktop applications, double clicking will forward the background page to display the full content of the element, and the panel will refresh and show the relations in the new situation.

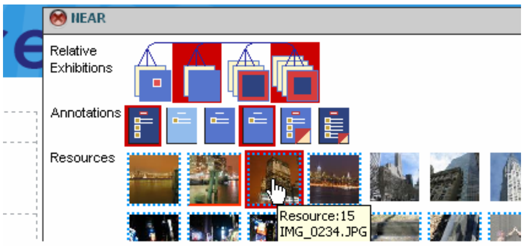

Fig. 8 Screenshot of NEAR panel (when the cursor is on a resource).

Figure 8 shows an instance of how NEAR is working in A•VI•RE. In the figure, when the cursor is over a resource, two exhibitions and two annotations are highlighted with red borders. The screenshot shows us a lot of useful information: which exhibition(s) sharing this resource (two in the screenshot, one is the current exhibition, and the other is a small and never-visited exhibition) and which annotations have quoted this resource (one default annotation with a lot of resources quoted and one un-default annotation with a few resources and text). Cursor-over also shows some property information of this resource such as resource ID, name, contributor and comments. Similar things happen when the cursor is over an exhibition or an annotation. When the cursor is over an exhibition, all the resources it shares and annotations under it would be highlighted. When the cursor is over an annotation, all resources it quote and exhibitions it belongs to would be highlighted.

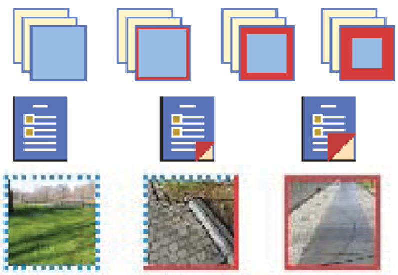

Fig. 9 Examples of Nodes with Different Visit Statuses.
1st line: Exhibition Nodes: unvisited, visited, just visited and current.
2nd line: Annotation Nodes: unvisited, visited and current.
3rd line: Resource Nodes: unvisited, visited and current.

Furthermore, to make user's navigation easier and increase the recognizability of nodes, NEAR changes some quality of the node to display the visited status (Figure 9). For an exhibition node, there are 4 statuses: unvisited, visited, just visited and current view. An annotation node and a resource node have 3 statuses: unvisited, visited and current view. Since the exhibition is at the top of the hierarchy structure: when an exhibition is changed, its related annotations and content resources will be changed correspondingly. The exhibition status of "just visited" makes it easier for the user to trace the relation between the current one and the previous one. "Visited' statuses also help to avoid unnecessary revisits.

VI. Evaluation & Discussion

We want to learn two things from the process of user evaluation: firstly, since every graphic node implies a lot of meaning and different relations, we want to optimize its design to maximally match user's common senses. Secondly, we want to learn about the usefulness and effectiveness of NEAR on solving problems in a user's navigation and interpretation.

Five people were invited to test the NEAR panel in different circumstances. They all had some experience with A•VI•RE before and found the original navigation paths frustrating. We showed three participants the list of nodes examples and taught them the meaning of linkages before their navigation. The other two participants start to navigate without taking any tutorial. The result showed that the tutorial was essential because it took those two participants quite a while to understand the meanings of the graphic nodes. Till the end of the test, they still haven't figured out all the relations in the panel.

All of the participants gave positive evaluations to the design. Some of them found it inspiring for their understanding around certain resources and most of them think it very useful in term of supporting navigation. However, they also provided a lot of critiques to the panel design. Some important comments are as below:

- To the participants, the NEAR panel is more like a tool box instead of a visualization window. So, participants want the panel can be movable and adjustable so that they can always have it somewhere in window without hiding other important content.
- One participant thinks that the high degree of detail in each icon precludes quick glances across the set to ascertain their meanings. Further, the high degree of detail also requires knowledge on the part of the viewer to ascertain the differences between the icons.
- Two participants (without tutorial) have different opinions on the design of annotation nodes' visit status.

People from different culture backgrounds do interpret icons differently and use different graphic languages to describe the same object. We accept the diversity of interpreting nodes and made some changes on our original designs. There are still a lot to be improved such as the flexibility of the panel and the layout of node elements. The evaluation results show us clearly that the panel is useful and supportive but not very self-expressive.

VII. Future Applications

NEAR was developed to address the need for visualizing implied relations such as similarities and references among different data elements. Although A•VI•RE is an independent system, the techniques of NEAR can also be applied to other applications.

Amazon.com has the applausive functions of suggesting new customers with previous customer's shopping experience. However, these functions are in lines of text and could be easily ignored by users. How to use visualization techniques to represent this set of functions is an interesting challenge.

We also believe that NEAR can improve the applications of academic citation index to support users' navigation and interpretation. The ISI Web of Knowledge provides seamless access to current and retrospective multidisciplinary information from approximately 8,700 of the most prestigious, high impact research journals in the world [23]. Web of Knowledge also provides a unique search method: *cited reference searching*. With it, users can navigate forward, backward, and through the literature, searching all disciplines and time spans to uncover all the information relevant to their research. However, the search results are isolated from each other and the navigation is not smooth. We believe our design of NEAR can help to represent those implied relations by graph visualization and enhance the navigation efficiency of cited reference searching and literature similarity comparing.

VIII. Conclusion

This paper describes the NEAR panel, a visualization technique that can display relationship and popularity properties simultaneously and reveal hidden relations such as similarity and inter-reference. Graph visualization research has been widely used in visualizing structured data elements. NEAR explores the possibility of visualizing unstructured relations among structured data elements graphically in a visual material repository A•VI•RE. The components of NEAR were designed based on ten key qualities we set according to the principles of visualization science and literature reviews. We present this visual panel to explore new navigation and communication approaches. By quickly scanning and interacting with NEAR, users can see not only implied relations but also potential connections among different data elements. From the user study, we gathered some useful suggestion to improve this design, and we also meet some unsolvable problems such as culture differences in icon interpretation. Generally, our evaluation shows NEAR is a supportive navigation tool. We plan to further develop this tool and implement this visualization design ideas in other kinds of information archiving systems. We believe the idea of NEAR can bring users near to the implied relations of information regardless of whether the information has already been well-determined.

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