LOCAL NAVIGATION CAN REVEAL IMPLICIT RELATIONS

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Abstract. This paper intends to analyze, compare, understand and explore the data relations among a collection, the collected items and user-created meaning appearing in different digital applications. Details of such relations are introduced and investigated with reference to several actual systems. In order to represent these three components in a way easy for users to interpret, navigate and interact, we introduce NEAR, a localized graph visualization tool to help people browse, understand and manipulate information in a digital architectural repository A•VI•RE.

1. Introduction

Through several distinctive use cases, we analyze the information seeking problems existing in different digital applications. In these systems, digital collections share a common form that includes the collection, the objects collected and the meaning of the collection. Relations between these three components are complicated. Some of the relations are obvious such as an object may be included by a collection. Others, such as *bibliographic coupling* and *co-citation* and are hidden under the surface. In this paper, we consider to use these relations as shortcuts for navigation design. After analyzing four use cases in actual systems, we review related theories and technology. In an architectural visual repository A•VI•RE, we present a visualization panel to prototype and evaluate our understanding of a more supportive navigation tool through visualizing and manipulating relations.

2. Several Use Cases

We start by considering four use cases selected from extant systems.

2.1. USE CASE 1: SEARCH FOR IMAGES IN THE IMAGE BANKS

A creative graphic designer requires large collection of raw images as antecedents and points of departure. Many public image banks such as DGL

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(digital graphic library of Microsoft), Flickr.com and Corbis.com provide image searching service. In these galleries, images are cataloged or tagged by keywords. Because of its multi-perspective nature, an image usually belongs to different catalogs or has multiple keywords. The rich cataloging system may help users to find as many related images as possible.

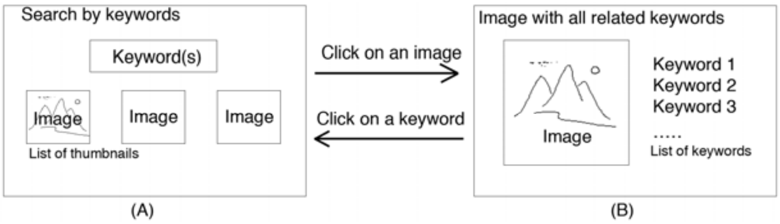

Figure 1. Scenarios of image searching in image banks

In many image gallery systems, users can search multiple keywords/tags at once to sort out the intersection of different collections (Figure A). Most of them also provide backlinks allowing users to read keywords related to the image (B). In the DGL and Corbis, when a user opens the window of one image, all related keywords would be listed (A→B). The user can click on any keyword to navigate to the whole collection of all the images tagged by this word (B→A). DGL only provides a clickable link from the keyword back to image list while Corbis allows users to select on multiple keywords at once. So in Corbis, the user can search for more similar works by selecting related keywords.

However, the searching task is still challenging since the user has to make several clicks and go through different webpages to get the result. Human's visual working memory is quite limited (with acquisition 3-4 chunks in 30 seconds). Also there is no easy way to find the difference or intersection of two sets of results, so it is hard to compare image features. The user usually has to open many windows and show all the potentially useful results on the desktop. Keyword and tagging system links related images together, but navigating through this net of words and looking for specific images is still an intricate task.

2.2. USE CASE 2: SEEKING ADVICE FOR NEW PRODUCTS

When a customer purchases a new product, he/she usually relies on expert reviews or others' experience to make the decision. Many websites provide a space for users to exchange opinions and post comments on products. Some websites also use such information for product recommendation.

Dpreview.com is a website providing digital camera reviews for photography fans. In the site, there are reviews from professional photographers and testing results in laboratories. Users can discuss different kinds of digital cameras and compare them in different forums as well. Generally these forums are grouped by brands and full of discussion threads. Famous brands (such as Nikon and Canon) of digital single-lens reflex (DSLR) camera introduce new products every year. Many new users come to this site to seek for advice from experts. Users usually have strong preferences for different brands. For example, in Canon forums, most discussions relate to Canon and in Nikon forums, most discussions relate to Nikon. To compare the cameras across models and brands, there are separate threads located in different forums. Some threads pay attention to technical data while others emphasize ergonomics and handling. Unavoidably, biases exist in many of the discussions. To gather a whole picture, the user has to shift across forums to find all the related threads. The user may use keyword search to help, but it is hard to gather all related discussion threads without bias.

While reading one discussion thread, the user may want to see the whole picture or focus the following topics: details of all the products discussed in the thread; any other threads also discussing products in the current thread; and any other forums on similar products. The current system does not provide such capability.

2.3. USE CASE 3: TRACE ACAEMIC RESEARCH PAPERS

In academia, researchers read and refer to others' publications frequently, building webs of citations. For a professional researcher, the following are important: citations in this paper, any paper citing this paper, and the originality of the idea. In citation index research the concepts of *bibliographic coupling* and *co-citation* are both essential in to finding similar papers or papers originating from the same idea but going in different directions.

In some online library systems such as Sage publication's digital library, a citation map is generated for every journal article. The map faithfully reflects all citation relations around this paper. The researcher can see connections between papers and read the idea flow. However, it is hard to get a clear overview as the number of cross links grows. It is also hard to recognize the strength of the relations among papers. Due to the incomplete collection of resources, the originality of a theory is a difficult task. The academic world still needs a more complete solution that can include and represent clearly relations of reference, citation, bibliographic coupling and co-citation.

2.4. USE CASE 4: EQUIP A CUSTOMIZED SYSTEM ONLINE

A functional system is usually a combination of several components. A digital SLR camera cannot work without lenses, memory card, battery reader and other supplements. To equip a HDTV, the customer also needs an AV receiver, speakers and cables. In e-commerce systems, although there are kit solutions provided, many users still want to make their own customized solutions. Novice users need, not only the technical data of equipments, but also accounts of other "experienced" users' solutions. In some e-commerce system, such as Amazon.com, collaborative filtering recommendation has been widely used. In forums or customer reviews, there are also many users discussing combinations of equipments, but there is still no simple and centralized channel through which the user can read others' customized combination as references.

3. Understand Local Browsing in the Use Cases

3.1. RELATIONS EXISTED IN THE USE CASES

Considering the above four use cases, there are three kinds of objects involved: collections, user's comments and products. Among these objects, the most basic relation is the *inclusion/reference* relation: images are cataloged under categories (or keywords/tags), discussion threads are grouped by forums, and products are referenced by discussion threads.

Being included is the reverse of inclusion. One object can be included into multiple collects. *Being included* also assigns multiple attributes to an object. In the digital world, *inclusion* (link) and *included-in* (back-link) form complex relations, which can be locally or globally transitive, symmetric reflexive, one-to-one, one-to-many, many-to-one and many-to-many. Some visualization technologies such as CZWEB (Collaud, Dill, Jones et al. 1995) have been developed to represent link and backlink relations between Internet nodes, treats the web as an information space and represents the complex link structure as a map.

Extending the relations of inclusion and included in, *co-citation* (Small 1973) and *bibliographic coupling* (Kessler 1963) relations can be found. If two papers refer to the same paper, they are bibliographically coupled. In contrast to bibliographic coupling, if two papers are cited together by the same paper, they are related by co-citation. Bibliographic coupling and co-citation pattern among research papers are importance in computing similarity of papers.

In digital space, bibliographic coupling and co-citation relations are very common. Two images could be co-cited by the same tag(s), and two products can be co-cited by the same discussion(s). On the other hand, similar to papers being bibliographically coupled by the same references, discussions can be coupled by talking about same product(s), and two customers' shopping carts can be coupled by having the same item(s).

3.2. SIMILARITY RANKING AND COLLABORATIVE FILTERING

Many applications require a measurement of similarity among objects. An obvious example is "find-similar-document" on the Web (Baeza-Yates and Ribeiro-Neto 1999). Co-citation and bibliographic coupling have been applied to cluster scientific papers according to topic or cluster web pages (Larson 1996). SimRank (Jeh and Widom 2002) developed mathematical equations to formalize the recursive notion of structural-context similarity and defined similarity scores in terms of these equations.

Collaborative filtering (CF) has been widely used in recommender systems including e-commerce systems such as Amazon.com (Linden, Smith and York 2003). In the process of decision making, people tend to make use of the advice of others who have made decisions earlier (Schotter and Sopher 2001). Based on building a database of preferences of users or an item-item matrix, CF is one of the most promising technologies for recommendation. In the use cases we studied above, CF algorithms could be applied to improve the system's usability and help people make decisions.

3.3. LOCAL BROWSING AND DIRECT MANIPULATION

Media present both themselves and the external events they depict to users. Users interact with a medium and so are indirectly interacting with the event. A good user interface should bring the user face-to-face with whatever is being manipulated and experienced. Principles of immediacy and direct manipulation (Shneiderman 1983) are essential. The intention of direct manipulation is to allow a user to directly manipulate objects presented to them, using actions that correspond at least loosely to the physical world. It involves continuous representation of objects of interest, rapid, reversible, incremental actions and feedback. With direct manipulation, users may learn more quickly, make fewer errors and operate more effectively.

Immediacy is the erasure of the gap between signifier and signified, such that a representation is perceived to be the thing itself. The desire for immediacy is the desire to get beyond the medium and get to the objects of representation themselves. An interactive system designer should attend to immediacy in at least three dimensions that are important for users experience: time, space and semantics (Ungar 1997). Temporal immediacy links cause and effect. Humans recognize causality without conscious effort only when the time between causally-related events (latency) is kept to a minimum. Spatial immediacy means that the physical distance between causally related events is kept to a minimum. Objects that are widely separated by space on the screen force the user to devote more conscious effort to link them. Semantic immediacy means the conceptual distance between semantically related pieces of information is kept to a minimum. In interactive interfaces, the conceptual distance between two pieces of information is represented by the number of operations such as mouse clicks.

With the address of direct manipulation and immediacy, a system with good usability should present all the related information in a simple, compact way.

3.4. EXAMPLES OF INFORMATION VISUALIZATION SYSTEMS

Information visualization is useful in visualizing objects and may help users understand them. We are interested in representing object relations and context as well as the objects themselves. Therefore, our focus is on representing the object and context, as well as reviewing the current theories, technologies and design projects.

3.4.1. Visualizing Large Image Database with Context

In most image database systems, image data are put into categories 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 (Ogle and Stonebraker 1995). For document browsing, the Document Lens (Robertson and Mackinlay 1993) uses a focus+context technique to display the document of interest in detail while compressing the rest of the document space. Apart from giving an overview of the entire document/image space, recent projects such as Concentric Rings (Torres, Silva, Medeiros et al. 2003) and MoiréGraphs (Jankun-Kelly and Ma 2003) highlight the relations among documents/images. However, in their detailed examples, images are overlapped and relation lines are entangled with each other.

3.4.2. Compact Visualization with Rich Information

"Useful field of view" (UFOV) is a concept developed to define the size of the region (one to 15 degree) from which we can rapidly take in information (Ware 2004). When we are reading fine print, we can read only the words within the foveal view, but we can see the overall shape of a larger pattern at a single glance. Thread-Arcs email visualization is a novel interactive visualization technique designed to help people make use of threads found in emails (Kerr 2003). Thread-Arcs combine the chronology of messages with the branching tree structure of a conversational thread in a stable and compact visualization panel. The threads are visualized in a node-link graph. Message nodes are linearly distributed from left to right connected by arcs.

Thread Arcs also have an interaction to allow users to highlight and inspect thread and message attributes dynamically. By quickly scanning and interacting with Thread Arcs, people can see various attributes of conversations and find relevant messages at a glance. Thread Arcs thus are a good example of compact visualization with rich information.

To implement our understanding of supporting local browsing, we designed and implemented visualization tool on an architectural visual repository.

4. Local Browsing in a Visual Repository A•VI•RE

4.1. DATA STRACTURE AND NAVIGATION ISSUES IN A•VI•RE

A•VI•RE (available at: http://www.avire.ca) is a generic repository for visual material related to cultural disciplines. A•VI•RE is designed to be an online space where different users (such as curators, exhibitors, critics and viewers) play together to create a large social entity. Users upload new resources, organize exhibitions, and annotate resources and exhibitions in the system. A•VI•RE began as an architecture visual repository hosting about 4000 architecture slides. There are three main types of objects in A•VI•RE, exhibition, annotation and resource. The information structure was designed according to following principles:

- A resource can be any type of digital work, such as an image, a multimedia file, a paper, or a webpage.
- An exhibition is a collection of exhibitions, annotations and resources.
- An annotation is a mixture of text and references to exhibitions, annotations and resources.
- One resource, annotation or exhibition can be referenced in multiple exhibitions.

Figure 2 demonstrates the data structure of A•VI•RE projects. In A•VI•RE, at the time of writing this paper (Jan 2007), on average each exhibition includes 30.8 resources and the standard deviation is 52. One exhibition has a maximum number of 179 resources. In contrast, on average each resource is included in 2.05 exhibitions, standard deviation 4.2, with a maximum number of one resource being included in 27 exhibitions.

Due to the rich content and flexible information structure, there exist some usability issues when users are browsing or searching in the system:

- It is hard to provide a contextual view of a resource from different perspectives.
- It is hard to see the sharing relations between exhibitions.

- It is possible to see a resource as referenced by multiple exhibitions and annotations and concepts across annotations, but hard to see the relations among annotations and exhibitions.
- It is hard to locate relevant resources, exhibitions and annotations. It is easy to search one resource or exhibition by key words, but searching for an unknown object with some related hints is still difficult due to the lack of information about the direct keywords or metadata.

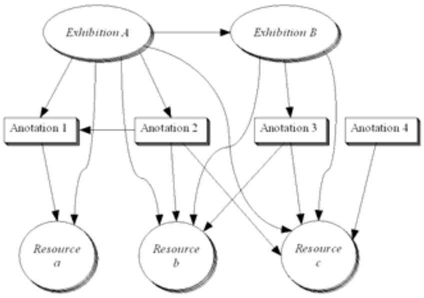

Figure 2. Data structure of objects in A•VI•RE (Chen 2007)

We believe a compact, small-scale, interactive visualization embedded into the interface of the A•VI•RE system can enhance the user's experience while browsing, navigating, understanding and using information in this generic multimedia repository.

4.2. KEY PROPERTIES AND QUALITIES FOR REPRESENTING A•VI•RE OBJECTS

As the first step to solve above issues, we propose a compact interactive visualization panel to help users visualize, analyze and navigate through A•VI•RE objects (Qian, Chen and Woodbury 2006). The panel's name is called "**N**avigating **E**xhibitions, **A**nnotations and **R**esources" (NEAR). There are several key properties of A•VI•RE objects addressed in the design: *relations* among resources, exhibitions or annotations**;** *popularity* of an object, the object's *visitation status***,** and *chronology* (evolution and creation sequence of idea).

The qualities of the visualization we considered most important were: compact, simple, preattentitive, responsive, recognizable and scalable to handle reasonable number of objects in a relatively small area. To achieve a successful solution, the development process for NEAR comprised three spiral cycles. Formative evaluation studies with small sets of users advised the next design cycle.

5. Design of NEAR Panel

There are three parts in the design: icons are used to represent the individual objects of exhibitions, annotations and resources. Graphs represent the relations among objects and the interaction helps users to explore and reveal deeper relations.

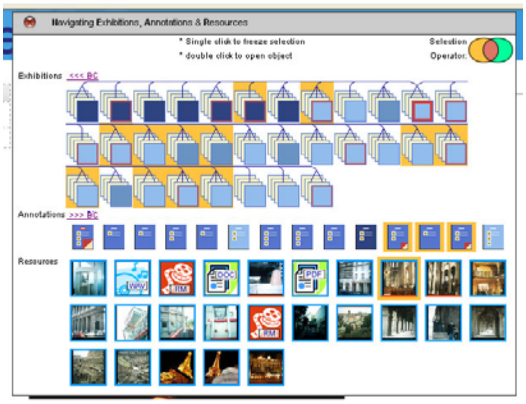

Figure 3. Screenshot of the NEAR panel in A•VI•RE

Figure 3 is an expanded exhibition-centered view showing: all resources referenced in the current exhibition, all exhibitions that are bibliographically coupled with the current exhibition, and all annotations that annotate any of the resources (the annotation does not necessarily belong to current exhibition). Individual objects of exhibitions, annotations and resources are represented by icons. Content-based thumbnails are used to represent resources to provide maximum preview where possible, otherwise type-based icons are used. The levels of bibliographic coupling with the current exhibition are indicated by the links on top of the exhibition icons.

5.1. ICONS FOR OBJECTS

Figure 4. Examples of icons – exhibition icons, annotation icons and visitation status for all objects (Qian, Chen and Woodbury 2006).

In NEAR, icons are designed to visually represent individual objects. Attributes of the object (visitation status, popularity, size and content arrangement etc.) are mapped to the features (or degrees of freedom) of the icons. Due to the limited capacity of human visual working memory, only three to four variations for each attribute are represented in the design.

5.2. LINKS OF HIDDEN RELATIONS

As demonstrated in Figure 2, co-citation and bibliographic coupling create crosslinks. To make the visualization planar, we use node-link graphs to represent the indirect relations, and hide the direct inclusion relations among exhibitions and resources. The direct relations only appear at the user's request by interaction. In NEAR, smooth continuous curves show the relations of co-citation and bibliographic coupling (*Figure 5*). Exhibitions, annotations and resources can be linked by such edges to represent bibliographic coupling and co-citation information when the user is focusing on different objects. The level of sharing is represented by the number of branches from the node. Since all the relations are counted toward the current object, it is important to show the "root" in the graph representing the current object. The exhibition icon with thick red borders indicates the current visit, and all edges from other icons bend toward the current icon to emphasize such root information again.

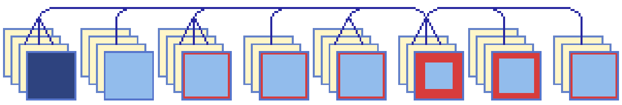

Figure 5. Bibliographic coupling relations between exhibitions
Branches on the top of icons show the levels of sharing resources

5.2.1. Interaction Design

The NEAR panel uses interactions to support local navigation in the hierarchy and citation graph of A•VI•RE. There are three kinds of interactions in NEAR: cursor over (brushing), click and double-click. Cursor over and click provides "filter" related objects by highlighting, and double-click leads users to view the details. Brushing by mouse over enables visual linking of components of heterogeneous complex objects dynamically and immediately. More importantly, brushing avoids link collision in the graph if large numbers of bibliographic coupling and co-citation relations exist within an exhibition.

Figure 6 shows an instance of how NEAR works. Moving the cursor over a resource will highlight all annotations and exhibitions that include the resource with red backgrounds, over an exhibition will highlight all the referenced resources and annotations, and over an annotation will highlight all quoted resources and related exhibitions. The user can freely move the mouse without changing the highlights. To avoid flicker, a click on the object will freeze the view. A click on an empty space re-activates the mouse-over effect. To support navigation, similar to desktop applications, double-clicking opens the document in the main window to display the full content of the object.

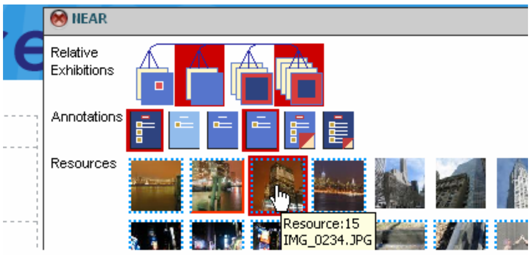

Figure 6. Screenshots of NEAR panel when the mouse cursor is over a resource.

5.2.2. Views

Relations among A•VI•RE objects construct a general graph. When we focus on one specific object, objects linked to it could be of interest. These objects can either be similar to the current object, or be supplemental information.

Just like the name "NEAR", when a user focuses on a specific object, we want the NEAR panel to bring the related objects of the current selection "near" to the user. The NEAR panel provides three different views to reveal relations around each type of object when user focuses. Each view has two states: the simple state shows the direct relations (inclusion and annotation), and the advanced state has multiple (2~3) complex views to show co-citation and bibliographic coupling information.

The NEAR panel switches to the annotation-centric view when the user is reading an annotation. This view focuses on the current annotation, listing all related exhibitions, annotations and resources around the annotation.

Figure 7. Annotation-centric views (left: simple view; middle: expand to show bibliographic coupled annotations; right: expand to show all)

The simple view of the annotation-centric view (*Figure 7*) provides the overview of the current annotation. The centre annotation icon shows the content arrangement of the annotation. The top exhibitions area shows all exhibitions that include the current annotation. All resources that have been annotated are listed on the bottom.

There are three views in the annotation panel's extended state due to an annotation's special position in the structure.

Since an annotation may include several resources and be included in several exhibitions, the following situations exist: exhibitions may bibliographically couple with the current annotation by resources; bibliographically coupled annotations may exist by including the same resources; and co-cited annotations may exist by being included the same exhibitions. Hence we provide three options for users to explore these relations: show all bibliographically coupled exhibitions with current annotations; show all annotations co-cited by the exhibitions; show all bibliographically coupled annotations with the current annotation. The three expanded views can be integrated with any combination. The user can choose to expand any two views or even three views together.

Exhibition centric view shows all related objects around the visiting exhibition, including annotations and resources referenced in the exhibition, and can be extended to show all bibliographically coupled exhibitions and annotations. The simple exhibition-centric view shows the most fundamental hierarchy structure of a current exhibition. Its annotations area lists all annotations and resources area lists all resources included. The expanded view shows all bibliographically coupled exhibitions. Also, annotations bibliographically coupled with current exhibitions can be expanded to be seen as well. Both in the simple view and expanded view, the resources area lists all resources under current exhibition.

The resource-centric view provides views from different aspects by showing all related exhibitions, annotations and similar resources. Resources can be co-cited by exhibitions and annotations. The strength of co-citation relations between two objects is determined by the number of parent objects citing these two objects together. The more objects co-cited by the two objects, the stronger the relation. Therefore we provide seven options to allow users to search for co-cited resources at different levels. A higher threshold of co-citing objects means the co-cited resources have stronger relationship (or similarity), but the user will see fewer of them.

5.2.3. Evaluation

Our design goal of NEAR is to have most of users understand the design (icons, graphs and interaction). We used evaluation to provide ideas for future improvement. We asked two groups of users to evaluate the current design. One group had three users who had participated in the design process to provide formative comments on the first two versions of NEAR. The other group has three novices who have never seen the interface before.

During the evaluation, we initially asked users to play with NEAR without any introduction and explanation and asked them to guess the meanings of each component: meanings of icon variations, the link graph, interaction and clickable links. After comparing the guessed meanings and our designed meanings, we found that experienced users grasp the semantic meanings faster than novices. We designed two rounds of experiments and assigned some small information seeking tasks for users to accomplish. In the first round, NEAR panel was disabled. Users were allowed to use NEAR in the second round. They found the panel gives them much useful information and shortened their navigation paths. Similar or relation objects are much easier to find. When focusing on one object the different views provide different levels of surrounding information based on their needs Generally, the feedback suggested that the NEAR approach maybe useful. We understand that it is only the starting point of an entire evaluation, acting as a short and nice pilot study. In the next stage of design, an extended evaluation would follow.

6. Conclusion

If we can apply the NEAR solution to the four use cases we discussed, maybe the distance between different pieces of information could be shortened, and their context objects could be better represented to users. In use case 1, a NEAR solution could allow the users to see connections among keywords, among images, and among keywords and images in one window. In use case 2, the user would be able to view all the discussion threads around one product, other products mention in these comments, and other discussion forums contain related discussions. Thus he/she could gain perspective and make a “smarter” choice. In case 3, the researcher can observe the idea flow though citations and references in a selected paper. In case 4, the customer may see how other people equip a whole system with the same product and their use review of the system before he/she makes the decision. The Internet has caused a flood of information, and what we most easily see is the information itself: the surface of the flood. Underneath and much more vast are the relations among the information elements. Our intention of NEAR is to reveal this underneath hidden information, bring this information close to user, and free the user from seeking information so that they can focus more on creative work. Although there is room for improvement, the user studies and our implementation show us our design approach has potential.

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