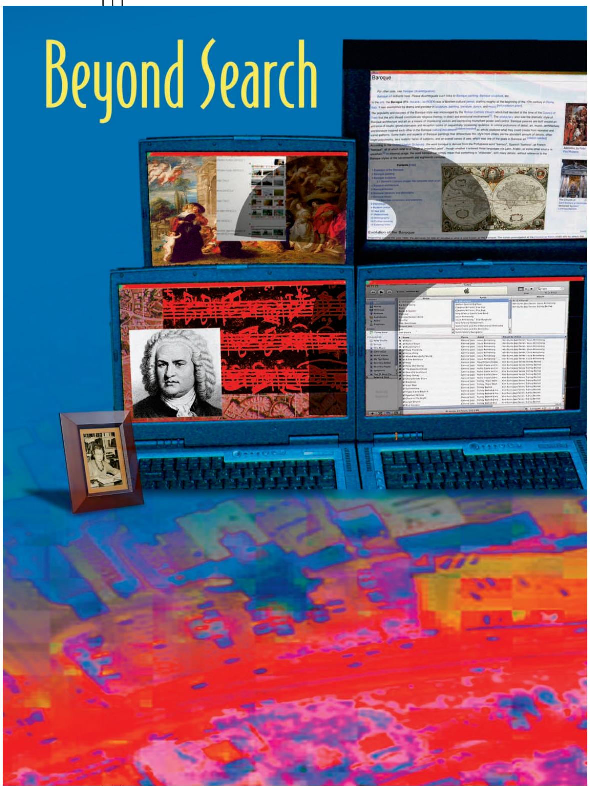

BUILDING KNOWLEDGE: WHAT'S BEYOND KEYWORD SEARCH?

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The success of the search engine may be our Newtonian paradigm for the Web. It enables us to do so much information discovery that it is difficult to imagine what we cannot do with it.

The Web's success as the main provider of information is indisputable. A key to this phenomenal success lies in our ability to find the information it contains.

Indeed, the main way we access the Web is via the white box that from a few words seems to read our mind and return a list of links to resources we want. This approach to finding information has become so successful that it is difficult to remember how we managed to find any information at all prior to Web-based keyword search or to envision needing or wanting any other tool for information discovery.

NEW(TONIAN) PARADIGMS

Successful paradigms can sometimes constrain our ability to imagine other ways to ask questions that might open up new and more powerful possibilities. The Newtonian model of the universe-as-clockworks, for instance, still explains a great deal of physical phenomena. Indeed, we could say that it was only some niggling phenomena that were not well described by that model that begged the question whether there might not be a better model, a different paradigm. Relativity and quantum mechanics, very different ways to imagine behaviors in the manifest world, opened up new ways to make sense of more of our universe.

The success of the search engine may be our Newtonian paradigm for the Web. It lets us do so much information discovery that it is difficult to imagine what we cannot do with it. But how does this paradigm quickly and effectively help a busy single mom find a better job that is a match for her passion and skills? And if that mom could use some extra training to support those skills and get that better job, how would the current paradigm bring in the relevant information that is outside the constraints of keyword search?

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In the information-retrieval and information-seeking literature, these kinds of complex information-discovery and knowledge-building tasks have been modeled in terms of search strategies and tactics.[1] In relatively recent work classed as exploratory search,[2] the emphasis has been on harmonizing human-computer-interaction (HCI) design with models of information seeking to develop new tools that will support alternative kinds of search and knowledge building.

Examples of such approaches include the following:

- *Knowledge building by association.* Creating new knowledge by building associations between one domain or concept and another rather than by seeing "an answer" in any one item.[3]
- *Domain exploration.* Without sufficient knowledge of the domain, someone who is not an expert might look for one piece of information without realizing that another component, not matched by a keyword search, is highly relevant.
- *Annotations and notes.* A well-known way of supporting knowledge building is to annotate information for a specific context. For example, "The socket described worked well for this project but was miserable for this other—despite what the authors claim here." Similarly, being able to create notes about something and add references easily from related sources is another powerful knowledge-building technique.
- C*ollections.* Pulling together information resources as they are discovered for future knowledge building, as part of information triage,[4] is another approach for developing knowledge.
- *History review.* This approach requires interrogating both previously looked-for information as well as working back through the paths taken to that information.
- *Collaborative knowledge building.* Brainstorming, shared search, and shared component development are examples of such knowledge building.

Each of these approaches to knowledge building involves information exploration that pulls together a wide array of information resources, but that has less to do with specific iterative searches for a particular preexisting answer than to providing support for the development of a new answer through the interrogation and association of these sources. In short, we need to develop the tools that will support these different kinds of approaches to exploration and knowledge-building goals. Some nascent efforts have been developed around these alternative search paradigms.

EXPLORATORY SEARCH TOOLS

The prehistory of exploratory search can be seen in the raison d'etre of hypertext: to support human-made associations through knowledge spaces. Theodor Nelson, who coined the term "hypertext" in 1965,[5] was inspired by Vannevar Bush's late World War II vision of the Memex.[6] Memex's goal was to support better knowledge management of a postwar science explosion by helping scientists build, maintain, and share their own paths through the document space. Bush called these paths *trails*. He postulated that these human-made trails of associations would be more meaningful for scientific discovery than having to track through library taxonomies of texts. Nelson took trails and envisioned what was to become the key component of the Web: the link, the ability to transclude—or connect by reference—into a new document both one's own thoughts and others' work to develop a perpetual exchange of ideas.

We need to develop the tools that will support different kinds of approaches to exploration and knowledge-building goals.

A key attribute of the hypertext link was to support nonlinear exploration of information for free-form association building. Fifteen years later, prior to the networked Web, the 1984 Notecards system put Douglas Engelbart's NLS (oN-Line System) on steroids via somewhat richer visualizations of the types of linking functions already described in NLS.[7] While most hypertext researchers point to the formalization of link types as a key contribution, from an HCI perspective, using the notecard as the metaphor for this system is significant. Researchers would later develop the card paradigm into spatial hypertext[4] to support not only a temporal model of seeing one card at a time (a limit of the 1984 display system), but also a cognitive model of presenting information via spatial layout and reorganization of cards in a physical world to build new knowledge through association of this information.

One take away from these pre-Web representations of knowledge building across automated resources is that keyword search was largely absent from these systems' primary vision. Perhaps it was simply assumed as a rudimentary tool/strategy akin to rooting through the various categorizations of a card catalog, but we should also recognize that such older strategies of recovering the path through a document space from start to finish (trails) were seen as critical for knowledge building. Likewise, visualizations that privileged nonlinear, nontemporally restricted representations of information—operations that can be carried out with notecards such as stacking,

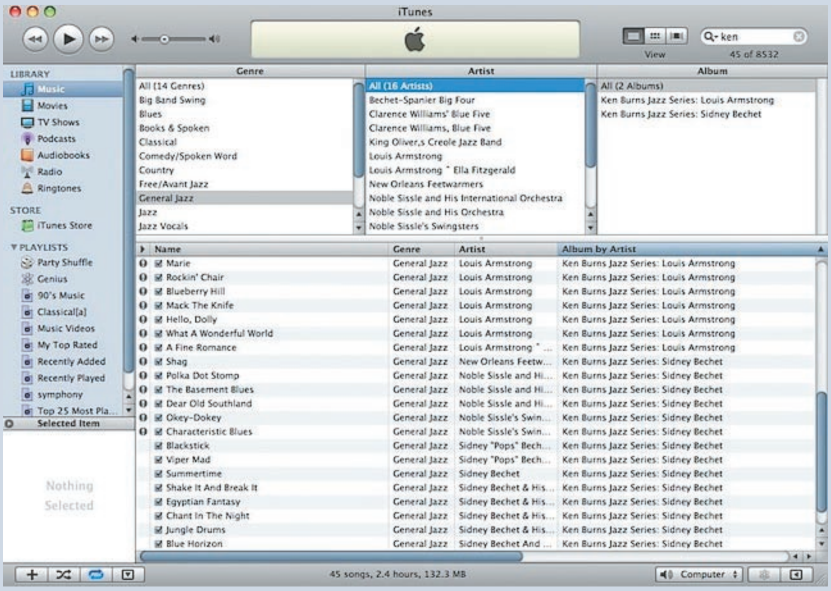

Figure 1. Apple iTunes browser.

sorting, selectively displaying, sharing, tagging—were also seen as key parts of information building and communication of that information.

And then the Web happened. This prehistory of current Web-based exploratory search is important because it motivates a kind of *recherche du temps perdu*. We have been here before, asking how to best enable knowledge discovery, not as fact retrieval alone, but in terms of how to support and enhance that retrieval for building new knowledge. With the Web's astounding success, however, we occasionally demonstrate a kind of amnesia about what we once sought to achieve as best practice. Part of this amnesia may be driven by a similar kind of Newtonian success model: We've gotten so much out of this approach so far, why not keep pushing its limits?

SERENDIPITY REDUX

One of the celebrated features in the early days of the Web was *surfing*—to come upon information serendipitously. The lack of a powerful search engine made this navigational hit-and-miss approach to information finding on the early Web a feature rather than a bug. It accelerated exponentially any kind of equivalent effort in the physical world of grabbing a book, checking references, finding those references physically, scanning them, and perhaps discovering something tangentially or serendipitously of interest along the way. What has happened to Web surfing? The Web's scale has grown so profoundly that surfing has been largely replaced by text search interspersed with reference to select sources of mediation, such as blogs, RSS feeds, and social networks: We leverage each other's serendipity.

We *serendip*, to coin a term, within a smaller set of known resources and search with intent for particular answers. We might be said to surf less broadly as a result. Part of this loss may be attributed to what happened to another exploration tactic of the early Web in the rise of text search: Category engines fell into disuse. While requiring human intervention to construct domain categories, their advantage is—like looking at library shelves—to give a person a sense of the scope of an information space. An opportunity for knowledge building in foregrounding such attributes of a space is the ability to foreground associations among these attributes. Over the past five years, exploratory search paradigms have largely focused on how to facilitate this kind of associative view. These models have become known as *facetted search*.

FACETTED SEARCH: THE METADATA IS THE MESSAGE

Whereas a keyword search brings together a list of ranked documents that match those search terms, facetted search's goal is to enable a person to explore a domain via its attributes.

iTunes

One of the most well-known examples of such a browser is Apple's iTunes application, shown in Figure 1, which is an interface to access and play back tracks or sets of tracks from a collection of music files.

The browser presents three columns, representing three facets of the music domain: genre, artist, and album. Attributes matching these facets are populated into the columns. A selection in any column acts as a filter on the column to its right. Once a selection is made, and the rightmost columns are filtered, a list of individual tracks is presented in the lower browser pane. Keyword search is integrated into iTunes such that the list of data matching the search terms populates the facets in the columns and also returns a list of individual track results. This layout means that even after the keyword search results are returned, the facets can be operated upon to further explore the collection. If returned results cover multiple genres, it's easy to highlight those instances that are associated with a given artist, genre, or album.

Exploration by facet lets the user make new connections about a domain or its attributes within a domain. The user might, for instance, discover that someone perceived to be a jazz artist has also recorded country music, which could lead to an exploration of the country music genre previously thought to be of no interest. This same ability to reconsider a domain via attributes also supports creating new knowledge about the domain. Whereas a person may not know that these attributes are a way of interpreting a domain, exposing these facets might implicitly help build domain knowledge.

Another attribute of note in most store examples is that quantity is also represented. The facets not only provide the categories of sweater possible, but how many of each there are. In a sense, this is reminiscent of seeing the number of books on a shelf for a particular topic: We immediately get a greater sense of the domain from this simple cue.

Relation Browser tool

The Relation Browser is a faceted tool that has made particular use of representing quantity. As the "Relation Browser Tool for Information Seeking" sidebar explains, the compelling attribute of the Relation Browser is the integration of multiple types of information against a single facet. Histograms reveal totals of single facets, but selections of other facets immediately show another histogram within the histogram to demonstrate how that query will affect the space. These lightweight information markers like numbers and spatial cues from histograms provide additional, easily scannable attributes about an information space that are not available from keyword search alone.

mSpace and backward highlighting

The mSpace browser (http://mspace.fm) uses a similar strategy to support multidirectional links across facets in what otherwise appears to be a directional browser like iTunes.[8]

In iTunes, a selection in the middle or left column only filters to the right; it does not populate back to the columns to the left of that selection. Picking the artist "Radiohead," in other words, does not show what genres that band is associated with.

Backward highlighting in mSpace shows both the filter to the right and the possible paths that could be associated with that selection from the left. In the example of a news film space shown in Figure 2—where the facets are Decade, Year, Theme, Subject, and Story Title—a person

RELATION BROWSER TOOL FOR INFORMATION SEEKING

Robert Capra, *University of North Carolina at Chapel Hill*

Developed by the Interaction Design Lab at the University of North Carolina at Chapel Hill, the Relation Browser is a tool for understanding relationships among items in a collection and for exploring an information space such as a set of documents or webpages. The RB provides facet lists and keyword searching to let users easily move between search and browse strategies.

As Figure A shows, the bars in the facet list indicate the number of results for the current query (purple) and the overall number of items in the collection that have this facet (white). Elements of the interface are coordinated and dynamic—as users brush the mouse over a facet, the elements update to show what the results would be after including the moused-over item in the search. This feature allows users to quickly and easily explore an information space.

Additional views are supported for both the results (display as a list or in a grid) and the facets (display in a list or as a "facet cloud" similar to a tag cloud). The current query is shown at the top of the display, and items in the current query are highlighted in red in other areas of the display.

For more examples and information about the RB, visit http://ils.unc.edu/relationbrowser.

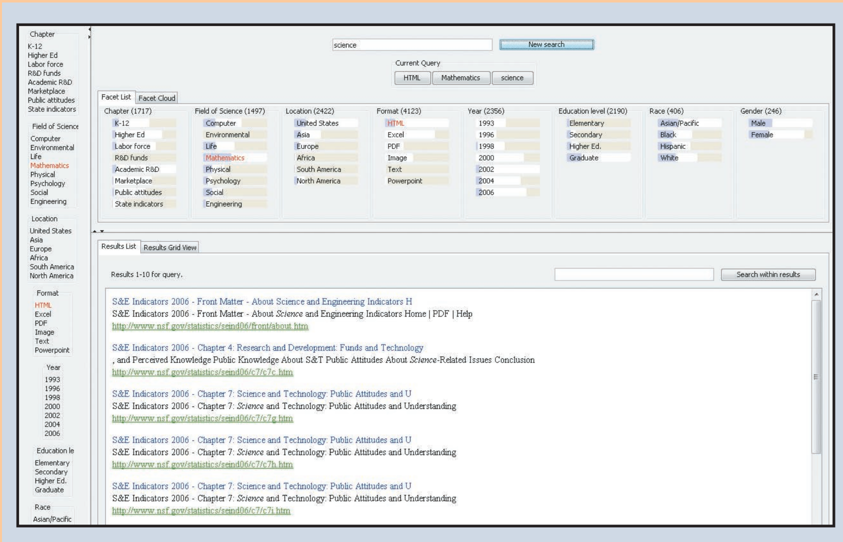

Figure A. Example of Relation Browser instance using data from the National Science Foundation's Science and Engineering Indicators publications from 1993 to 2006.

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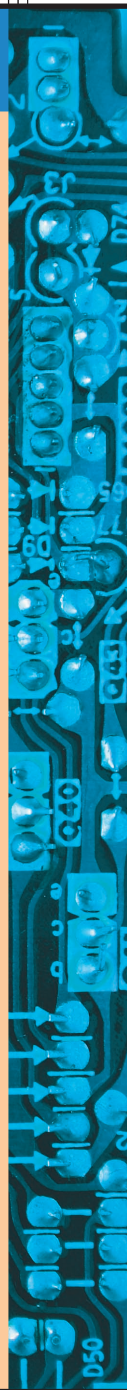

Figure 2. mSpace slice demonstrating backward highlighting.

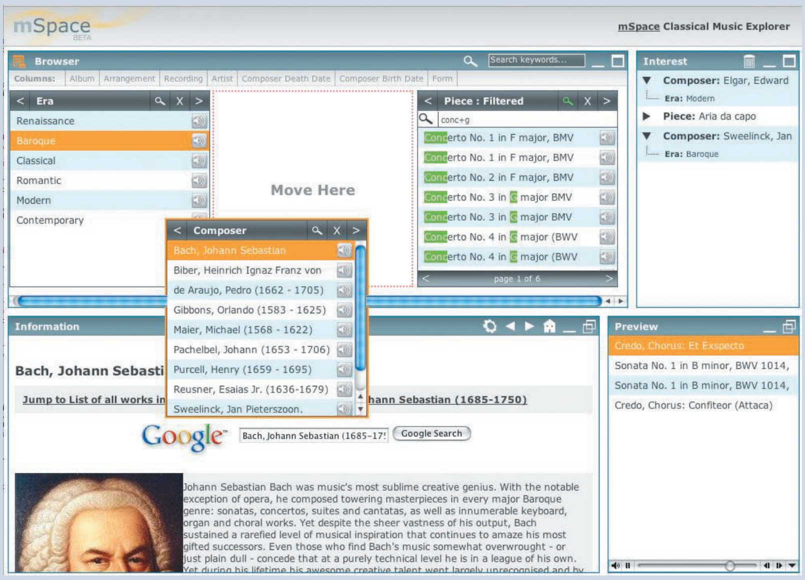

Figure 3. mSpace preview cues with in-context information about selected term.

has picked the 1940s in the leftmost column, and the columns to the right are all filtered by that choice. If that person then chooses a theme in the third column, the remaining columns to the right are filtered accordingly, and two items in the year column related to the chosen theme are highlighted. The intensity of the highlights also shows which attributes were deliberately selected (the bright highlight) and which were calculated (the duller highlight). These simple information guides have been shown to assist both recall and descriptions of information in a domain.

Preview cues are another sensemaking attribute in mSpace that can be associated with an individual item to help make sense of the facets themselves, as Figure 3 shows. Users might not know a sonata from a symphony, but associating appropriate music with each genre will at least offer an easy way to decide if it's of interest—do users like what they hear? Users can either step through those samples or decide to explore a particular domain based on a selected sample. They may also use those cues to help divine attributes that make the user sample part of that category rather than another.

In Figure 3, hovering over the speaker icon has triggered a preview cue for the Baroque composer Reusner. Four selections by the artist are also queued up in the preview queue. Where Baroque has been selected in Period, information about that facet is presented to help the user develop an understanding of the domain.

mSpace refers to the presentation of facets as a "slice" through a domain space. The user can reorder the facets as well as add or remove other facets to a slice. This capability to reorganize a slice according to a person's interests was motivated by the desire to enable exploring a domain by what is relevant or known, to offering more facility to make sense of a domain in ways that are meaningful to the person. In the news film world, for instance, it might make more sense to a user for a given question to organize a space around the work of a particular reporter than a particular topic.

KNOWLEDGE BUILDING THROUGH VISUALIZATION

While information facets enable rich exploration of a domain, mashups also have demonstrated the value of representing those attributes across a variety of visualizations. IBM's manyEyes (http://manyeyes.alphaworks.ibm.com/manyeyes) is an example of a tool that lets people upload their data, provides a display for it, and lets them select various attributes of interest. Tools like Exhibit and LifeLines take the interaction with the data further.

Exhibit

Exhibit is a tool that provides facetted data exploration while visualizing that data against maps and timelines.[9] The value of these representations is in the questions they foreground. For example, the main Exhibit demonstration of American Presidents makes it easy to see at a glance that most presidents were born on the eastern side of the US, Grover Cleveland was the last president to finish his term in the 19th century, and William McKinley bridges the 19th and 20th centuries, while simultaneously filtering the data to see only Catholic presidents.

LifeLinesII

As Figure 4 shows, projects like LifeLinesII mash up large datasets such as patients' health records and medical test results so that medical professionals can align, rank, and sort them according to the data's attributes.[10] This visualized and parameterized data readily facilitates seeing where there might be correlations across populations in response to a combination of condition and drug. For instance, a researcher can align all the data for heart attack patients to discover significant patterns that precede or follow such an incident.

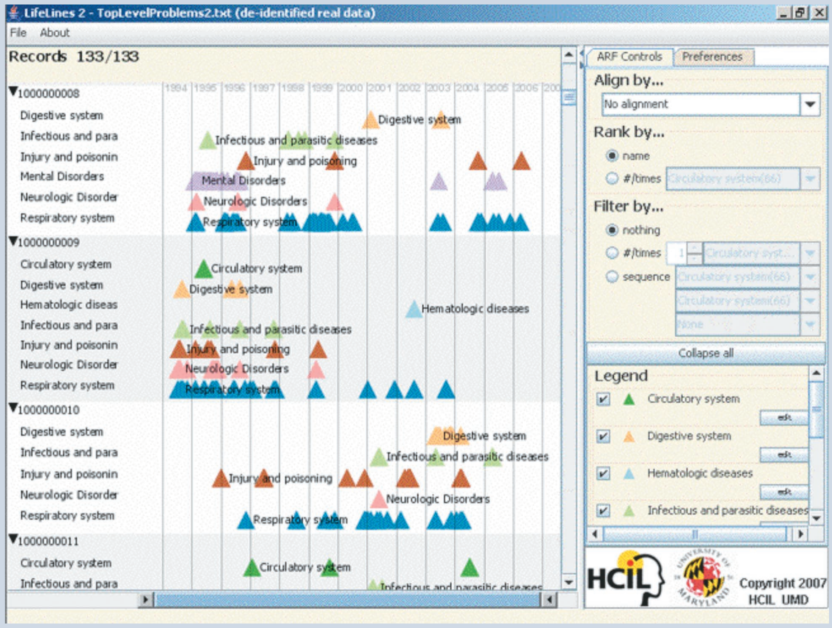

Figure 4. LifeLinesII interface, showing attributes to be aligned.

Facetted browsers and tunable visualizations make it possible to ask questions not easily expressed in a keyword search. They also facilitate rapid refinement of queries with real-time direct manipulation. Spatial layout of the data's attributes for manipulation allows relationships within the data to remain available for rapid comparison. All these types of interactions enhance information seeking and knowledge building.

FROM DATA MANIPULATION TO ELICITING NEW IDEAS

Using tags as annotation offers one strategy to enhance the personal or social value of found things: A tag helps gather that artifact into many potentially relevant contexts—the popularity of online photo tagging has shown that people will add metadata to their data. Indeed, the social sharing that tags enable has high value: It lets us say someone on the team found this thing relevant to our work; now all of us can get it quickly by hitting that tag. Projects like folksonomies are considering how more structured taxonomies might emerge from these flat spaces to add semantics to these annotations.

Collections

To reduce interruption while exploring and to make it possible to capture information quickly, Hunter Gatherer compiles webpage elements into collections.[11] Evolving this idea and adding modern graphics processing, Mira Dontcheva and Steven M. Drucker use the collection notion to lay out each captured component as an individual card.[12] LiveLabs' recent version of this project, Thumbtack (http://thumbtack.livelabs.com), adds machine-learning processes so that data such as addresses or authors extracted from a collection can be mapped automatically; books can be explored via extracted author or genre information; and cars can be compared by price, engine size, model, and so on. New techniques in machine learning are making such semantic extraction increasingly tractable across an increasing range of content.

HISTORY AND THE NOTEBOOK

At a recent National Science Foundation workshop on Information Seeking, two concepts that kept resurfacing as critical for exploratory search were history and note keeping. An expressed desire was for tools that would help surface things we should know about if and when we're looking at a given topic.

History

For history, currently we have our browser's history list. In mSpace, when someone shares an article with another person, they also share the facets' state—that is, the path to that artifact—so that a larger context of discovery is available. Going outside the context of a single application, the Jourknow project (http://projects.csail.mit.edu/jourknow) proposes using local computer context to associate and recover information across personal facets like location, date, and applications to support questions like "What page was I looking at when I was in the café last Sunday?" The philosophy behind Jourknow is that any process might inform other processes of interrogation and discovery, so how can we make the processes available to each other for exploration?

These questions lead us back to issues of how we capture and reflect upon the knowledge building we are doing.

Right now, the main paradigm for exploration is to go to the Web via a browser to trawl for information. Is this the optimal interaction?

Annotation and notetaking

It seems there are at least two challenges for knowledge building via information seeking while we are working on our own thoughts. One is taking notes. We might wish to take notes about something while we're reading it; unfortunately, being able to select and annotate Web documents, as Nelson imagined decades ago, is still uncommon.

SparTag.us. The authors of SparTag.us make the case that much of the Web's available content, ranging from news articles to blog posts, is frequently reprinted verbatim.[13] SparTag.us not only associates notes with a webpage so that users can share them, but these notes also can automatically show up anywhere the document is cloned online.

DataPress. In addition to annotating, we also write notes on our own thoughts. Blogging is a popular demonstration of how we can effortlessly add links to our notes, thoughts, and other people's writings. Indeed, with trackbacks we can inform those to whom we've linked that a conversation involving their work is under way. Comments on blogs set up metaconversations around the initial seed of a discussion. But blogging is still largely text-based. Sure, we can link in photos and YouTube videos, but there are many other kinds of data that we might want to reflect upon and share with others (including active code). DataPress (http://projects.csail.

CONTEXTMINER: EXPLORE GLOBALLY, AGGREGATE LOCALLY

Chirag Shah, *University of North Carolina at Chapel Hill*

ContextMiner is a framework originally designed to assist archivists in harvesting and analyzing video assets, associated metadata, and contextual information to supplement their collections. The framework is based on the idea that in addition to primary resources, contextual information such as annotations, popularity, and usage data is critical to preservation and future sensemaking.

As Figure A shows, ContextMiner helps an individual or group run automated crawls on various Web sources—in this case, YouTube—to collect data and contextual information. In addition, users can analyze and add value to collected data and context as well as monitor digital objects of interest over time.

The following is a typical ContextMiner flow:

1. Start a new campaign (project) based on a story, concept, or object.
2. Choose the sources to harvest—for example, Web, blogs, YouTube.
3. Define search parameters such as frequency of probes, categories of context—for example, comments, ratings, result list rankings—and data-flow paths (what to get and where to put it).
4. Initiate and monitor resultant streams. Figure B shows an example status display.
5. Manipulate and annotate individual items, context, and sets.

Several members of the National Digital Information Infrastructure Preservation Program (www.digitalpreservation.gov) use ContextMiner; teachers or researchers who wish to harvest content on specific topics also can use the framework.

Further development providing access to more sources and tools for information exploration is under way. ContextMiner is available as either open source code or a Web-based service (www.contextminer.org).

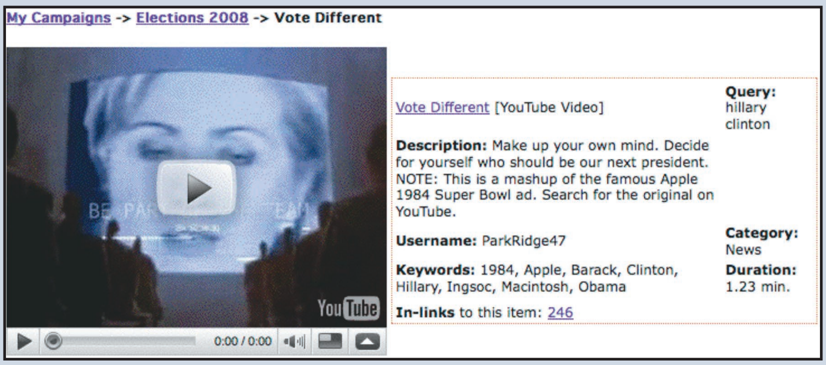

Figure A. Video captured from YouTube along with some contextual information.

Select: | Action: | Go

	Title	Date Created	Collection	Status	Last Export	Manipulate
☐	Elections 2008	2008-07-08	YouTube: 343, In-links: 106729 Blogs: 4999	Active	N/A	Description | Parameters | Queries
☐	civil rights	2008-07-08	YouTube: 0, In-links: 0 Blogs: 0	Active	N/A	Description | Parameters | Queries
☐	commercial fishing	2008-07-08	YouTube: 959, In-links: 8449 Blogs: 0	Active	N/A	Description | Parameters | Queries
☐	library of congress	2008-07-08	YouTube: 149, In-links: 4389 Blogs: 0	Active	N/A	Description | Parameters | Queries
☐	Wisconsin Dairy	2008-07-10	YouTube: 223, In-links: 7715 Blogs: 0	Active	N/A	Description | Parameters | Queries
☐	Sarah Palin	2008-08-30	YouTube: 775, In-links: 88745 Blogs: 9352	Active	N/A	Description | Parameters | Queries
☐	Stock market	2008-10-10	YouTube: 517, In-links: 32288 Blogs: 11111	Active	N/A	Description | Parameters | Queries
☐	collaborative search	2008-10-15	YouTube: 844, In-links: 19271 Blogs: 8418	Active	N/A	Description | Parameters | Queries
☐	President-elect Obama	2008-11-10	YouTube: 711, In-links: 37371 Blogs: 7489	Active	N/A	Description | Parameters | Queries

Figure B. Example status display.

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mit.edu/datapress) is an initial effort to let bloggers share and manipulate structured data like election stats within their blog posts.

Backstory. A scientist might want to gather up scientific data generated from an experiment, add some notes, tie in some data about the apparatus, and include several quotations about the informing theory—all of which to give as a blog to a colleague to ask, “Why aren’t my results what your theory predicted?” On a more casual note, someone has thoughtfully used Thumbtack to gather considerable data about various digital cameras. In the mix is the camera selected for purchase. How would that annotation be captured and shared? Likewise, as the data rapidly goes out of date, how might the person share the attributes of the choice to act as a template for a friend’s future choice?

Backstory is a search tool that has been developed to look at some of these issues within a software developer support group.[14] By gathering up Web-based sources with local resources and notes on use contexts, Backstory makes it possible to share local knowledge within a team across data object types.

If these kinds of data-gathering and data-sharing tasks for enhanced knowledge building were better supported, we could readily imagine that the process of discovery and innovation would accelerate. As we have seen with search engines, when a process accelerates—finding a phone number, document, or the answer to a “what is it” question—the activities supported by those processes change. If we can quickly accomplish what once took hours or days, we move rapidly from information seeking to knowledge building.

ENHANCING SEARCH WITH AWARENESS

A repeated demand made at the NSF workshop was, “Tell me what I don’t know that I need to know.” Such a challenge goes beyond recommendations like “people who read this also read that.”

How might we assess search patterns of “successful” persons in a domain and how they associate related content to a search on a particular topic—for example, nutrition—to help find a successful approach to eating better?

Some strategies involve collaborative search; others may be based on mining search patterns across the Web. The design challenges here are significant: How can we surface this kind of valuable associated knowledge that would not show up in a keyword search? How do we reflect back why this type of information was being surfaced? Are there ethical issues concerning how information is associated? For example, people who are interested in offshore suppliers of hydrogen peroxide might also be interested in explosives, but they may just be interested in cheap hair bleach and cleaning solutions.

Contemplating these kinds of challenges is exciting and demanding. They suggest that there are many more ways in which to find, manipulate, ponder, share, and reflect upon information—all with the facility of keyword search, but none of which keyword search addresses. All of which are part of the larger information-seeking space beyond the paradigm of simple search. C

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