Human Computer Interaction with Global Information Spaces – Beyond Data Mining

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ABSTRACT
This invited paper describes a vision and progress towards a fundamentally new approach for dealing with the massive information overload situation of the emerging global information age. Today we use techniques such as data mining, through a WIMP interface, for searching or for analysis. Yet, the human mind can deal and interact simultaneously with millions of information items, e.g. documents. The challenge is to find visual paradigms, interaction techniques, and physical devices that encourage a *new human information discourse between* the human and their massive global and corporate information resources. After the vision, the current progress towards some core technology development, we present the grand challenges to bring this vision to reality.

KEYWORDS: Information visualization, World Wide Web, data mining, digital libraries, visual paradigms, higher-order interaction, human-computer interaction

INTRODUCTION
Today's world is rapidly changing to become an information rich and analysis poor suite of societies. The rapid growth of the Internet, wireless communication, multimedia home and office servers, and the data interoperability among massive digital libraries will enable virtually everyone to have access to huge amounts of information on almost any topic. We also observe the business world rapidly changing from many smaller corporations focused on single or few products towards today's large international corporations providing a wide range of complementary services and products. These corporations and close partnerships are aimed at providing focused market socially acceptable solutions to customers while reducing the support structures, and single product competition.

Our technology suite for information analysis must advance to support these changes in the world around us. The vast majority of the technology mindshare has been directed toward providing collection of and access to this information. Now, we must re-direct at least a portion of our mindshares to providing technology for effective

1. searching that brings back relevant and to the extent possible complete information spaces,
2. visual paradigms that enable the human mind to process in parallel vast quantities of information,
3. interaction paradigms that allow a higher order interaction closer to the cognitive processes, and
4. physical devices which allow humans to take advantage of their many senses.

These emerging technologies will lead to a new human information communication - a discourse - that enables discovery, understanding and presentation/re-use of information. We no longer want to interact with the computer. We want to interact directly with the information resources.

As a technical community, we are not starting from scratch [1-11]. Great progress is being made in academia, government, and industrial laboratories. Several disciplines are offering parts of solutions, including information visualization, knowledge engineering and management, intelligent agents, human-computer interaction, information appliances, collaboration science, cognitive science, perceptional engineering, statistics, to name a few. Yet, we see mostly good but incremental technological inventions. What we need is a fundamentally new approach and suite of technologies that enable the human to interact with millions, if not billions, of information units in real time. We propose such a vision and some technology steps towards the goal of developing a New Human Information Discourse.

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THE VISION

Here are some thoughts on how such a discourse might proceed. As an individual, I can describe my situation, my knowledge and need for information. The available information resources relevant to my situation and time are then brought to me with supporting logic and help enable me to 1) discover enough information to seek further information, 2) understand and translate information into knowledge, insight, and actions, and 3) re-use and present this knowledge within my context and situation.

I must be able to ask questions and get knowledgeable information from experts. Human experts are yet another form of an information resource that must be included in the solution space either through intelligent agents, avatars, or direct communication. I must be able to determine the quality of what is there and most importantly what isn't there within the information resources. I must be able to find and interact with fine grain detailed information objects within a known context. This could also be stated, as working on the parts of an information space while understand the whole of the space. I must be able to understand and translate between the contexts of the information resources and the contexts of my knowledge and situation spaces. And, I must feel comfortable with my display and interaction devices that allow the presentation and real time interaction with these massive information resources.

This seems like a major leap in capability. Yet, if we look at the defining characteristics of this vision and some emerging technology examples, we can see that this new human information discourse is almost within reach. That is the outline for the remainder of the paper. We will first look at visual paradigms and what we have learned to date. Then we will present several examples of higher order interaction techniques. We proceed to a discussion of some interesting physical interaction tools. Then we conclude with some of the grand challenges we face in moving toward the new human information discourse.

VISUAL PARADIGMS

There is an increasing body of literature in the area of visual paradigms [12-38], with a dedicated workshop and even metrics proposed for evaluating visual paradigms [31]. Most focus on specific analysis and implementation of a single paradigm. When faced with a complex analysis problem in large information spaces, analysts will likely combine a number of information exploration methods and paradigms[xx]. For example, getting an overview of the information can mean many things, including

- getting a sense of the major themes in the information and how strongly they are present,
- understanding how the themes relate to one another,
- seeing how the information relates to another information collection or to a standard ontology, or
- getting a summary of the attributes of the information, such as source, date, type of document, etc.

In this section, we briefly describe two tools based on visual paradigms: SPIRE (Spatial Paradigm for Information Retrieval and Exploration) and WebTheme[10,17]. We present fundamental lessons learned from inventing, developing, delivering, and refining the technology in these tools.

The SPIRE system was explicitly designed to help enable information analysts to deal with masses of text documents. SPIRE automatically produces a suitable knowledge base of themes (key words) that can be used to distinguish groups within the document collection under analysis. The system then creates n-dimensional vectors characterizing each document with respect to those topics. The document vectors are clustered and projected from n-space into 2-space; the lower order projection is used to create the visual representations. In the ThemeView™ visualization, themes within the document spaces appear as a relief map of natural terrain, where taller peaks show dominant themes. It is particularly good for helping an analyst jump-start his or her understanding of the collection – it conveys the main themes in a collection and an overall sense of how they are related. Figure 1 illustrates a sample initial Galaxies display for a document space. Figure 2 illustrates a ThemeView™ for the thematic space.

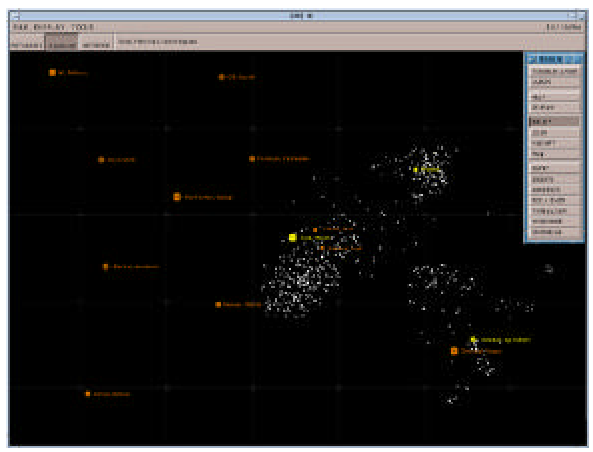


Figure 1. Galaxies visualization of documents and document clusters within a textual database.

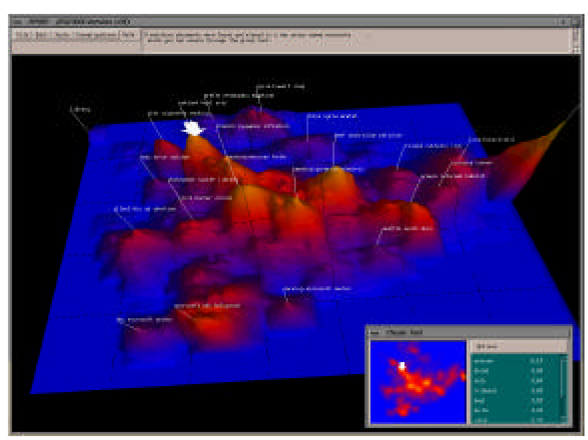


Figure 2. ThemeView™ of CNN news and a Probe tool for analysis

Within global information spaces we also must address digital libraries [39-41] and web information spaces [42-45]. WebTheme™ consists of a WWW harvesting and visualization server, which produces visual representations of the contents of WWW pages.

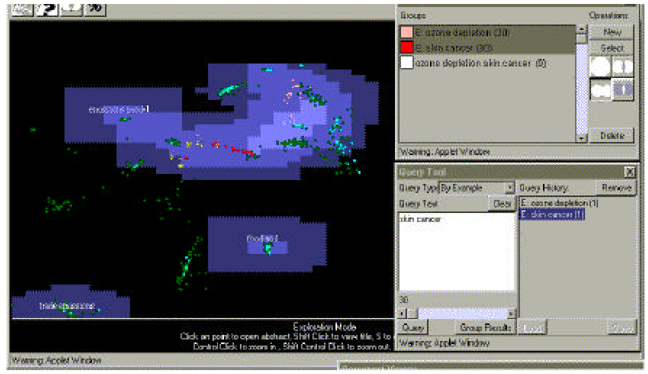
WebTheme, Figure 3, is designed to operate in conjunction with the SPIRE text engine and a Netscape WWW server. Although SPIRE and the WebTheme server run on a UNIX computer, WebTheme can be accessed by Netscape or Internet Explorer on a variety of computers.

Figure 3. WebTheme™, a web enabled version of SPIRE

This suite of technologies has been used for competitive analysis with patents combined science articles, masses of strategic organizational planning documents, resumes, science and medical research, national security applications, metadata management, and many others. Actual use has greatly exceeded our initial expectations and the technology continues to expand based on feedback from the users.

Some of the fundamental lessons learned are:

- People can deal with large amounts of visual information, given a good logical and physical paradigm. Within the Galaxies visualization space 20,000 - 100,000 document analyses are workable. Within the Themeview™ much larger information spaces can be understood.
- People think and interact beyond WIMP interface technologies. More often than not people must decompose their thinking processes to map into one word or one click interfaces now available within WIMP.
- Scaling to analyze large information spaces changes everything, from the visual paradigms, to the underlying mathematics, to the ways people keep track of their analysis and interactions. The influence of scale for analysis of global information spaces should not be underestimated.
- In large information spaces, finding what is missing is as important as finding what is there.
- People bring a lot of knowledge and situation-dependent information to most analysis tasks. This information must be considered as an integral part of the analysis processes and the information space.
- Insight and decision making from these large information spaces are not usually dependent on a single unit of information, but on the interrelationships of multiple information objects.



- A fundamental issue within large information spaces is quality and integrity of the information. The human mind can usually make some initial judgements with visual paradigms that allow analysis of the entire information space.
- The underlying mathematical signatures and associated metadata signatures within these information spaces are fundamental and must be developed in concert with the visual and interaction paradigms.
- The n-space internal information representations are a good foundation for information exploration and analysis.
- Time and Space are universal dimensions that must be exploited with most large information spaces.

Visual paradigms are one of the key components to the new human information discourse. Tightly coupled to visual paradigms are interaction techniques [46-65] that bring life to the analysis process for global information spaces. In many cases and references included it is impossible to separate the two.

HIGHER ORDER INTERACTION TECHNIQUES

For many years we have been using and developing effective interfaces using today's WIMP interfaces [3]. These have worked very well up to the point where both the largeness and complexity of our information spaces and tools to analyze them become a limiting factor. Today, on all our desktops, it is often very difficult to even find the files and information of importance for any current situation analysis. Experience shows that we each have 2,000 – 4,000 files on each desktop all nested in a complex hierarchy of windows, folders within folders, down to long lists of files.

Several of the application domains - specifically chemistry, and genetic engineering - have had to develop visual approaches that allow the human to interact with millions of information units. Doing so has required a different suite of interaction techniques which we call Higher Order Interaction Techniques (HOIT). One such discipline example is genetic engineering [51]. Figure 4 displays over 1M information items in an interactive environment allowing dynamic engineering for new biological forms [52]. Techniques such as "whole – part relationship", "Progressive disclosure", "relative positioning", all were absolutely required for large space analysis.

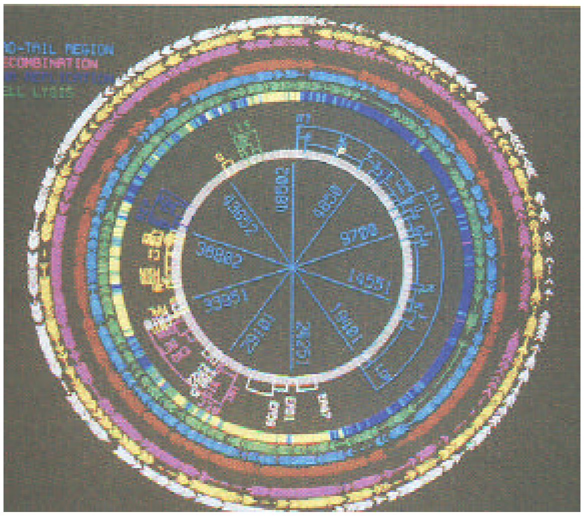


Figure 4. Cage/Gem Genetic Engineering System

The whole part relationship allows users to see the whole (context) while working on the parts. Progressive Disclosure allows users to see the maximum complexity possible for a specific view and have the system dynamically change visual paradigms to ensure visual completeness. Relative Positioning enables users to rely on visual information proximity as a key within their information spaces.

Another example of a higher order interaction technique comes from a private-energy-use situation analysis [58] where the goal was to illustrate the theory versus actual experiment results. In Figure 5, we see a transparent surface that illustrates the theory while the solid surface illustrates actual energy use over a three week period. The combination of both the theory and experimental values provided the required insight for decision making.

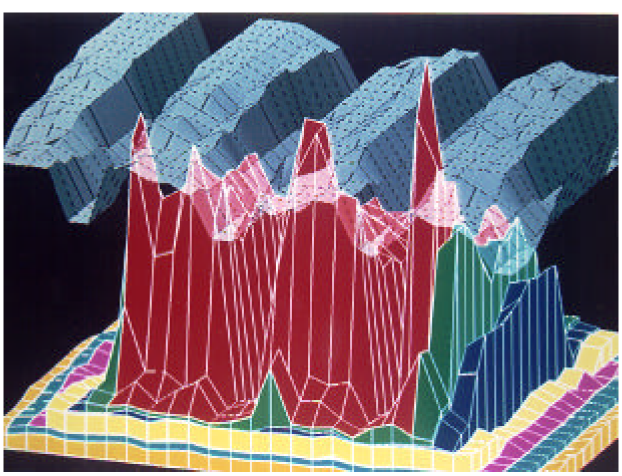


Figure 5. Theory/Experiment higher order interaction technique

Another such higher order interaction technique is relationship discovery. As shown in Figure 6 one can see potential relationships based on "rainbows" that connect information units. Initial white arcs are expanded into color segments based on the types of possible relationships. Evidence may also show the likelihood of strong dis-associations depicted as arcs below the information plane.

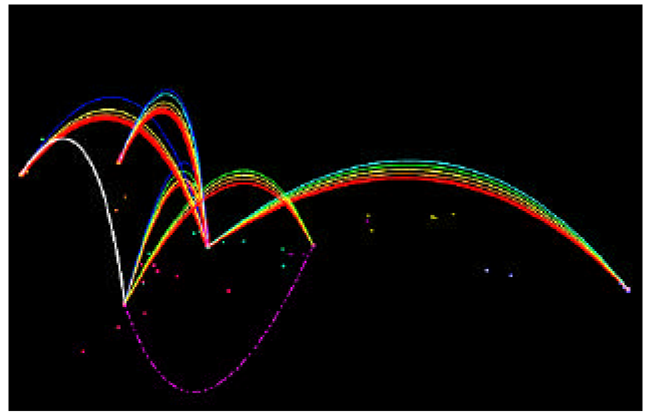


Figure 6. Relationship Discovery Rainbows Visualization

Another HOIT is that enabled by TOPIC-O-GRAPHY™ [32]. This technology allow users to tell the sequence of thematic flows within long documents. This is critical when one is attempting to illustrate plausible stories in and between large information spaces. Correlating information units that are part of other information units into stories will become a critical capability within large and complex information spaces.

In the following example, Figure 7, the beginning of the document is illustrated by the start of the signals and curves. Thematic changes are automatically recognized and depicted as changes within the curves, with the end being on the far right. Now that this technology can identify the location of specific themes, one can do automatic table of contents generation, automatic theme recognition, and automatic chunking for cluster analysis, enabling the user to see the thematically relevant structures.

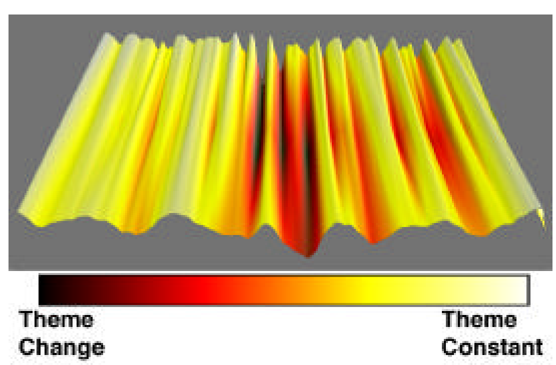


Figure 7. TOPIC-O-GRAPHY™ of a long text document

One of the fundamental interaction capabilities required is the ability to represent and interact with information flows (another HOIT) across multimedia information spaces independent of the media, and number of information units. The good example can be found in Tufte's book on Visual Explanations [8] illustrating the thematic flows of music and artists over time (pages 90 – 91).

Another example is ThemeRiver™, which illustrates the thematic flows of Castro's speeches over time as topics inside a river. Then potentially related external events are illustrated across the top by the dated events that may or may not have had an influence on the thematic changes.

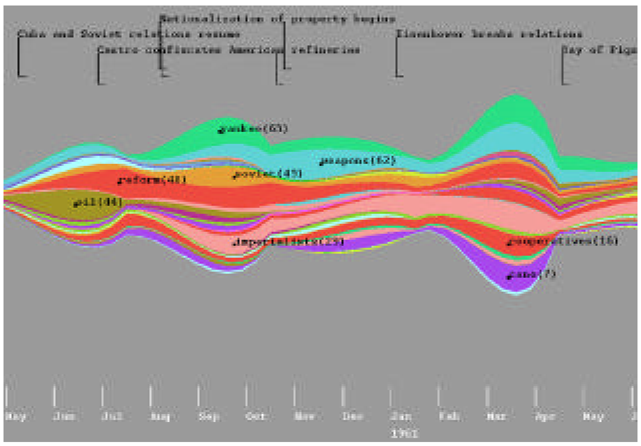


Figure 8. Information Flows – ThemeRiver™ Visualization

Another issue is the identification of the black holes in information spaces. This can be illustrated by looking at a Galaxies Visualization within Figure 1. Why are there no information units in some regions within this space? What would be the pertinent topics and themes if there were information units there? In large information spaces this is critical to establish confidence in understanding the interrelationships and to facilitate the discovery processes.

A final example of another HOIT is the information hypercube [31]. Within this example a fixed information topic space is defined and the information units are then mapped into space ordered by the most important to least important topics. This can be visualized as a large 3D cube, with the information units partially populating the cube. Here the empty or sparse regions have explicit meanings.

In summary, these higher order interaction techniques allow the user to address large information spaces through information flows, information relationships, fixed information spaces, comparing the theory and experimental evidence, relative proximity positioning, and progressive disclosure. These are only a start toward a sufficient suite of powerful interaction techniques.

PHYSICAL DEVICES

Within most of our offices today we have an implicit information organization. This often has the computer at the center of the workspace. In most cases the actual workspace is much larger and encompasses a large desk space. This information workspace can be organized in several manners. A common organization scheme is based on time. To the left of our workspace is the historical filing and stacks of reference materials. Then to the right is the phone, the schedules , and the near term action items. This workspace will include very different displays and interaction devices [66-76] .

One design for a new workspace that attempts to achieve many the goals as stated above is the HI-SPACE [68]. This is illustrated by Figure 10.

Figure 10. HI-SPACE (Human Information workSPACE)

Within this prototype implementation there are no devices that tether the users to their workspace. The users hands or any hand held object serves as the pointing device. There is a blending of physical objects (PHIcons) and logical objects (information units) through tangible interface constructs. By using gesture, tangible interfaces, and voice recognition a more robust interaction system can potentially be created. When combined with portable information appliances, this type of physical information workspace would allow interaction among people and large information spaces, in a mode that supports discovery, understanding, and information re-use.

GRAND CHALLENGES

While there has been indeed much progress towards the described vision there are still many grand challenges illustrated below:

1. New visual and interaction paradigms with appropriate combinations that enable billions of information objects to be analyzed.

2. New visual and higher order interaction paradigms

must become intelligent, such that the system can be adaptive and suggestive to help user selection of these techniques; a guided human information discourse is required.

3. Fundamentally new underlying mathematical and statistical approaches for multimedia information signature generation, information summarization, and information context understanding.

4. New physical interaction devices that require no special tethering, allow for large visual spaces, and easily blend with our logical massive information spaces.

5. New metrics that allow the developers to compare and measure the improvement of new visual, interaction, and physical techniques.

In summary, we have described a vision of some defining characteristics for management and analysis of large information spaces. Some emerging technologies for visual paradigms and examples of higher order interaction techniques give hope that there are effective visual and interaction paradigms for massive information spaces. Combined with a sample physical/logical human information workspace, this leads us to believe that it is within our future to go beyond current data mining into a fundamentally new human information discourse.

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