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ABSTRACT

This paper examines the main issues in hypermedia navigation, proposes research questions, and suggests a methodology for resolving those questions. The paper begins with an overview of navigation and a discussion of design issues in hypermedia databases, including being lost in hyperspace, the use of hypermaps, proper balance between links and nodes, level of learner control, and learning theories implemented in hypermedia applications research questions addressing the following design considerations for hypermedia databases are outlined: (1) screen layout; (2) use of color; (3) use of hypermaps or other locational devices; (4) degree of consistency to use in the design of navigation; (5) types of pathways for transit; (6) level of user control; (7) use of a help function; and (8) relationship between the learning styles of users and the navigational controls. A methodology for proposed research on hypermedia navigation is then presented; the proposed research will utilize the Perseus Project, a 10-year-old Harvard University interactive database on Greek Civilization, to examine whether hypermedia databases created in the past can be significantly improved by introducing navigational features that currently are advocated by hypermedia designers. Three figures depicting the Perseus system are included. (Contains 37 references.) (DLS)

Hypermedia Navigation: Where Do We Go from Here?

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As we begin the second decade of the development of hypermedia applications for personal computers, it seems appropriate to examine perhaps the most critical issue in the design of large hypermedia databases, namely navigation. Applications designed today look and feel quite different from those created over ten years ago. The difference is more than the addition of color. Today's applications employ different strategies or philosophies for navigation. As the navigation metaphor suggests, learners must move about in a database in order to access the information stored in it. With a small view screen, effective navigation is of paramount importance for complex and possibly vast hyperspaces. Clearly the method by which a user selects relevant information and instruction to appear on the screen in this computer environment will have a great deal to do with effectiveness of the resulting instruction.

Although theorists in such fields as educational technology, computer science, psychology, and education have written extensively about the components of good instructional design, the application of these theories to hypermedia has not always been satisfactory. Compounding the problem is the fact that many of the proposed theories conflict. Research into the effectiveness of various hypermedia designs is still in its youth. Consequently, there are currently no convenient foolproof rules to guide hypermedia designers. This paper will examine the main issues in hypermedia navigation, propose research questions, and suggest a methodology for resolving those questions.

What Is Navigation?

Navigation implies controlled movement from place to place. *The American Heritage Dictionary* (2nd ed., 1982) defines navigation to be "the theory and practice of navigating, especially the charting of a course for a ship or aircraft" (p. 833). Newer electronic publications do not significantly extend that older definition even though they themselves refer to "navigation" within their own hypermedia applications. For example, the *Grolier Multimedia Encyclopedia* (Version 8.0.3, 1996) defined navigation to be "the art and science of conducting a ship, airplane, or spacecraft safely and expeditiously to a specific destination. In the broadest sense anyone faced with the problem of 'finding the way' is a navigator, whether he or she travels on land, at sea, in the air, or in space" (Art. 21239).

As Conklin (1987) pointed out, the word "navigation," when applied to hypermedia applications, takes on a distinctly different meaning. In the world inside a computer, the traveler no longer need be on a ship or plane and to physically chart a course of travel in the sense of the dictionary definition. The concept of navigation in hypermedia refers to figurative movement within a potentially complex database of links and nodes, rather than physical movement.

The term navigation has become a metaphor for motion. Gygi (1990) stated that "navigation is a metaphor used to impart some sense of intentionality as well as spatiality" (p. 281). She pointed out that in hypermedia applications information is not brought to the user; rather the user must visit different places in the database to access the information. Sellen and Nicol (1990) reported that users make heavy use of spatial metaphors such as saying they are lost, they have reached a dead-end, they are going up and down to different levels, and they are moving forward and backward. Sellen and Nicol (1990) contended that users often construct spatial mental models to enable them to deal with "moving" from one context to another within a computer application. Such mental models are helpful for users to navigate even though the models do not in any way represent the actual physical location of information within the database itself.

Gygi (1990) and McAleese (1989) drew a distinction between browsing and navigation. They explained that browsing refers to users' discovering information by traversing the entire database in an unconstrained, even random, manner, whereas navigation refers to users' searching for information in a purposeful way in portions of the database where they can reasonably expect to find what they want to know. Canter, Rivers, and Storrs (1985) developed five categories for user navigation: *scanning* means covering a large area without much depth; *browsing* is following any path until an area of interest appears; *searching* means striving to find an explicit target; *exploring* is finding out the extent and nature of the database; and *wandering* signifies purposeless and erratic travel with recursion (revisiting nodes). McAleese (1989) and Horney (1993) attempted to characterize these different types of navigation by studying the navigational patterns of users. All five of these categories may be considered to be subsumed under the general heading of navigation.

Design Problems in Hypermedia Databases

Long before hypertext was a concept hatched in Vannevar Bush's fertile mind (Bush, 1945), the navigation of information loomed large as a consideration in learning environments. When such instructional materials are stored in a computer, designers no longer have the luxury of physical space afforded them in other teaching environments such as classrooms with extensive chalkboards, walls, or even tables to spread out materials. With computers, all exchanges between learners and instructional materials must be conducted through the myopic eye of a computer screen. Educators proficient in using wide-angle-lens techniques listed above to bring the world to their students must now constrain themselves to using a technology that views the world through a relatively restrained aperture.

In the emerging field of hypermedia instruction, becoming lost or disoriented is potentially the most difficult design problem to solve. The number of theories about the best way to navigate in hypermedia databases far surpass the amount of research that has been performed to justify those theories. Compounding the problem is the fact that many of the proposed theories conflict. The current cost of producing professional hypermedia applications for research purposes is so high that this trend is likely to continue for some time. From a user-centered point of view, it would appear that hypermedia applications should provide users with an entire arsenal of navigational tools, rather than force them to rely on just one strategy that may not necessarily suit them.

The implementation of non-linear access to many forms of information — text, sound, still images, video, animation, and the like — in one package driven by a computer is a recent development in education, not much more than ten years old. Although theorists in such fields as educational technology, computer science, psychology, and education have written extensively about the components of good instructional design, the application of these theories to hypermedia has not always been satisfactory. Research into the effectiveness of various hypermedia designs is still in its infancy. At present, there are no convenient rules to guide hypermedia designers. Consequently, the design of hypermedia applications is an *art* and likely will remain so for the foreseeable future.

Perhaps the foremost question in navigation is how to avoid becoming "lost in hyperspace." The questions considered below attempt to examine the potential causes of and cures for disorientation. A second idea for consideration is whether or not "hypermaps" should be provided. In a hypermedia application, not every piece of information needs to be explicitly linked to every other piece of information and, hence, a third area of interest is the balance between links and nodes. How many links are necessary and sufficient to do the job? Lastly, what level of learner control is advisable? Users choose where to go, but should they have the freedom to go anywhere?

The purpose of the questions raised is to attempt to systematize some of the choices developers must make when they design hypermedia databases. A second consideration is whether the hypermedia applications created ten years ago (when hypermedia environments were first became practical realities) can be significantly improved by introducing those features that are currently being advocated by hypermedia designers.

How Can Users Avoid Becoming Lost in Hyperspace?

Many authors have agreed that a major problem, if not the major problem, confronting users of hypermedia systems is becoming *lost in hyperspace* (Bernstein, 1991; Conklin, 1987; Jonassen & Grabinger, 1990; Locatis, Letourneau, & Banvard, 1989; Marchionini, 1988; Parunak, 1989; Shneiderman & Kearsley, 1989; Stanton, Taylor, & Tweedie, 1992). Stanton et al. (1992) pointed out there are inherent problems in navigating through a computer world that appears to be two-dimensional, although the underlying structure or metaphor may be three-dimensional. Picher, Berk, Devlin, and Pugh (1991) argued that getting lost in hyper*media* applications is more likely than getting lost in hyper*text* documents because the rules for navigating through nodes containing video, pictures, and sound are necessarily more complex than navigating text alone. In fact, Bernstein (1991) and Jonassen (1989) contended that users who fear they are overlooking crucial information because of navigation problems may abandon hypermedia in favor of regular materials.

Shneiderman and Kearsley (1989) posited that there are two aspects to being lost in hyperspace: not finding desired information and getting disoriented. They referred to this problem as the "dark side" (p. 10) of having the freedom to explore easily in hypertext. Edwards and Hardman (1989) listed three conditions wherein users are "lost": (a) not knowing where to go next; (b) knowing where to go next, but not how to get there; and (c) not knowing where they are in the overall structure of the document. Conklin (1987) also cited the last two conditions and called them a "disorientation problem" (p. 38). Bernstein (1991) pointed out yet another facet of disorientation. He maintained that an unexpected recursion (return to a previously-visited node) is intrinsically disorienting, especially when such recursions are rare. Users may perceive recursion as a signal that the database has been exhausted or that there has been a system error. He explained that some authors of hypermedia novels such as mysteries may want to intentionally disorient the reader by using recursion, but that in general unexpected recursion is to be avoided.

McAleese (1989) noted attempts for combating the lost-in-hyperspace syndrome in two well-known applications. In NoteCards, a Graphical History Tree records and displays the "neighborhood" of nodes that have been visited by the user. The nodes are marked so that users can see which links they have used. While a plain History Tree displays all accessed nodes in an hierarchical trail, a Summary Tree is a special case of a History Tree where annotations made by the users are also displayed. McAleese pointed out that HyperCard has a Summary Window, that users can activate by using the Recent command, which displays as many as the last 42 distinct cards/screens visited, but not the links used, and allows users to jump to any one of those cards/screens by clicking on its image. Fujihara, Snell, and Boyle (1992) applauded systems such as the Perseus Project (on ancient Greek culture at Harvard University) that have paths that can be saved for later use. Shneiderman and Kearsley (1989) contended that reversibility (being able to retrace steps and return to previous screens) is important to reduce disorientation.

Horton (1994) claimed that carefully chosen icons accompanied by short word labels outperform controls marked only by an icon or a word label, not both. Tolhurst (1993) recommended the use of a friendly guide that could be activated by clicking on an omnipresent icon for the guide. The guide could then make navigation suggestions to the user. Oren, Salomon, Kreitman, and Don (1990) showed a preference for what they called the "guides metaphor" over the "navigation metaphor" for helping users make navigational choices, even though they found that users sometimes confused the navigation advice given by guides with the content stories provided by other entities that also looked like navigational guides. Kappe, Maurer, and Sherbakov (1993) stated that since typical solutions that work well on small systems fail completely when applied to large systems, navigation must be extended by adding hierarchical organization of related material, guided tours through the information prepared by content experts, and advanced database query capabilities.

Should Hypermaps Be Provided?

Edwards and Hardman (1989) identified two principal advantages to having a survey-type cognitive map of any environment, be it a city or a database. First, there is the opportunity to visualize and then to utilize short cuts to reach desired locations. Second, for users who become distracted or lost *en route* to a specific goal, there is a far greater chance that they can regain their bearings and reach their intended destination if they have a spatial cognitive map of the environment. Kelly (1993) cautioned that navigational aids such as maps based on spatial analogies or metaphors may be appropriate for spatial navigation, but not for conceptual navigation.

Sellen and Nicol (1990) gave two other rationales for maps. They claimed that making mental navigational models explicit within hypermedia helps reduce the cognitive load for users, who would no longer have to rely on their memories to tell them where they are. In addition, a map can form the basis for a mental model of how to travel from one point to another in the database without having to keep in mind a set of procedures for navigation. Sellen and Nicol said that the type of map depends on the nature and structure of the application. In a file management database, for example, the map might display the hierarchical location of a file within a folder structure. However, maps could also take the appearance of you-are-here maps found in public buildings.

Tolhurst (1992) suggested that graphic environmental maps based on some concept (metaphor or mimesis) familiar to the user would be a useful navigational aid. For example, a learner studying human digestion could be presented with a diagram of a body with the various parts of the digestive system in view. By clicking with a mouse, users could choose body parts and reveal linked information about that part of the digestive system. At any point in the investigation of digestion, users could return to the body diagram (map) to reorient themselves if necessary.

Shneiderman and Kearsley (1989) pointed out that whereas the table of contents reveals a book's structure and content, it is not automatically apparent in hypermedia applications what information is available, how it is structured, and where the user is now. For hypermedia applications, they advised that a hierarchical view of structure and content be displayed by means of a dedicated area of the screen (which of course is only possible in a database with hierarchical structure). Locatis et al. (1989) as well as Shneiderman and Kearsley advocated having a "fish eye" view capability which allows users to see "nearby" nodes. Rada (1995) claimed that "hierarchical or fisheye views help users get a sense of the overall information landscape" (p.26).

A number of authors have recommended some type of overall structure maps for navigational purposes (Conklin, 1987; Gay & Mazur, 1991; Gygi, 1990; Litchfield, 1993; Locatis et al., 1989; Parunak, 1989; Tolhurst, 1992). Parunak (1989) claimed that useful maps could be defined even in large hypermedia systems as long as what he called the "topology," the system of links, was appropriate.

However, Landow (1990) declared that global maps do not work for any but the smallest of hypermedia databases. Landow drew this conclusion from his work with Intermedia (a hypermedia application generator originated at Brown University where Landow worked). Landow held that navigation is not a major problem in Intermedia since system features allow users to locate and travel to any information in the database by full text searches, folders, links, web views, and menus of link choices. He stated that in Intermedia users always know what documents "surround" the one being read through the use of a local tracking map (the web view) and that users can always travel to an overview document that helps reorient them.

Stanton et al. (1992) conducted a study with one hypothesis: "The presence of a spatial map will improve navigation and support cognitive map formation" (p. 433). The study was conducted using a relatively small hypertext environment with 42 screens. The study used local (fish eye) maps. Contrary to other studies, Stanton et al. found that the presence of maps resulted in poorer performance. In addition, participants using maps reported a perception that they had significantly less control over the information in the database than that reported by non-map participants. The non-map participants also performed significantly better than the map participants on their ability to classify the screens on a cognitive map task. Stanton et al. concluded that map aids may reduce the need for or interfere with learners' actively constructing their own cognitive maps — that it is wrong to assume that a map will always aid performance.

What Is the Proper Balance between Links and Nodes?

Glushko (1989) claimed that excessive linking causes serious problems of disorientation and cognitive overload for the user because it destroys most of the structural and contextual cues that users rely on for navigation. Although he stated that several researchers are working on creating new hypertext linking structures, he stated the opinion that limiting the links in the first place was a more practical solution. Langston and Graesser (1993) described one such system with a Point and Query interface where navigation is accomplished by combining a list of subjects with a list of questions. They claimed that users benefit from the "internodal coherence" (p. 357) that results from following such question trails.

McAleese (1989) described the "net" metaphor for hypertext linkages. He explained that in a "true network system" (p. 14) any given node is at most one link away from any other node, and that no node is more important than any other node. He termed network systems the ideal solution for understanding the linkages in hypertext. However, he stated that structuring, constraining the user's access to other nodes, was important if the system browser was to provide the user with scaffolding for purposeful navigation. Conklin (1987) envisioned users navigating databases via three modes: by using links, by searching for keywords (objects with certain attributes such as strings of characters or images), and by using a browser that displays the network graphically. Hence, Conklin's description of hypermedia supported both the network system approach and the structured or constrained approach to navigation.

What Level of Learner Control Is Advisable?

Litchfield (1993) defined learner control to be the amount of latitude a learner has over the direction and depth of investigation. She claimed that for some users too much learner control is counterproductive, and that many users choose to return to programs where the content is program controlled. On the other hand, Shuman (1998) asserted that hypermedia empowers users by giving them control — control that allows users to individualize their own instruction to address different learning styles and needs. Bernstein (1991) saw both sides of the issue. On the one hand, he said hypermedia authors could acknowledge learners' active participation by giving them a richer web of links to traverse. However, he said an author could reduce the apparent complexity of the content for learners by imposing a clear and limited organizational scheme on an otherwise complex system.

Shneiderman and Kearsley (1989) reported that some interface researchers hold the opinion that building sophisticated "intelligent agents" undermines the users' sense of control and their feelings of accomplishment. Instead of building intelligence into the machine, the designers seek to enhance learner control by providing navigation tools for browsing, searching, and employing filters. Laurel (1990) countered this argument by saying that a good agent "will do what I want, tell me all I want to know about what it's doing, and give me back the reins when I desire" (p. 357). She proposed that only users who wanted to use agents should have them, and those who do not should have other choices.

Jonassen and Grabinger (1990) maintained that learner control permits the user to direct the sequence of instruction in such a way that the user obtains the appropriate type and amount of support. Instead of the instruction directing learners, learners should be empowered to make judicious choices to adapt the instruction to their own needs and interests. For Jonassen and Grabinger, this notion is supported by the theory that learners know what is best for them and that learners in control of instruction will invest more mental effort in their learning. Nevertheless, Jonassen and Grabinger admitted that research does not support this sentiment, especially for average and below-average learners — that learners do not make the best decisions when given unrestricted control.

Learning Theories Implemented in Hypermedia Applications

Some authors have associated the type of navigation in various systems with particular learning theories. Horney (1993) said that the network system approach, where each node is linked to every other node, supports constructivist learning. By contrast, hypermedia applications that exhibit linear or severely constrained link structures could be construed to be behaviorist in philosophy. Traditional cognitive theories would then be associated with applications situated between the two extremes. Under this scheme, behaviorists would favor linear navigation with limited learner control and no maps. Constructivists would favor unrestricted navigation with high learner control and hypermaps that would allow users to jump easily from place to place in the database. Convinced that individuals are more than flesh-and-blood, stimulus-response machines and armed with the results of studies that show unrestricted travel between nodes to be disorienting for all but the most gifted of learners, traditional cognitivists would chart a central course with many opportunities for non-linear exploration. Cognitivists would choose to have learner control high but not so high that it creates disorientation and distraction. Cognitivists would also take advantage of cognitivist devices like maps and metaphors to supply navigation clues for users. Most hypermedia applications fall under the cognitivist rubric. Readers may find that the approaches used and conclusions drawn about hypermedia environments are best understood by considering the associated learning theories that the authors advocate.

Research Questions

The issues discussed above suggest the following research questions:

1. What is the appropriate screen layout for navigation in a hypermedia database?
    a. Should navigation controls reside in dedicated areas or be available only when requested by users?
    b. What are the most effective representations for navigation controls? For example, should navigation controls be marked by icons, by names, or both?
    c. Should navigation controls overlap other controls on the screen?
2. What is the appropriate use of color in a hypermedia database?
    a. Should special colors be used to allow users to differentiate between certain types of navigation controls ?
    b. Should special colors be used to allow users to differentiate between various locations in the database?
3. What is the appropriate use of hypermaps or other locational devices?
    a. Should users be provided with hypermaps or other devices so that they have a sense of where they are or have been?
    b. Should hypermaps or other location-indicating devices also allow users to jump from place to place in the hypermedia database?
    c. Should some device be provided to tell users how "deep" they are in the database?
4. What is the appropriate degree of consistency to use in the design of navigation?
    a. Should the functions of icons be consistent throughout the database?
    b. Should controls be consistent as to location on the screen, what they look like, and what happens when clicked?

5. What are the appropriate types of pathways for transit through a hypermedia database?
    a. To what extent should users be able to retrace their steps or save paths made through the database?
    b. How easy should it be for users to access, alter, or digress from previously stored paths through the database?
6. What is the appropriate level of user control in a hypermedia database?
    a. To what extent should expert users be able to move through the database quickly with fewer steps or key strokes than would be prudent for novice users?
    b. Is it better to have a few long pull-down menus or several shorter ones?
    c. Should designers eliminate controls that most users are not expected to use (that may be accessed in some alternate manner by those who need them)?
    d. To what extent should users be able to wander through the database to see what is available (the way that one might browse through a set of encyclopedias)?
    e. What mechanisms should designers provide so that users can determine with some certainty whether or not a particular piece of information is present?
7. What is the appropriate use of a help function in a hypermedia database?
    a. To what extent should the help function be sensitive to the context when help is sought by users?
    b. To what extent should the help function anticipate problems that users may have in using the database and suggest solutions?
    c. To what extent should the help function suggest strategies for using the database?
8. What is the appropriate relationship between the learning styles of users and the navigational controls available in a hypermedia database?

Methodology for Proposed Research on Hypermedia Navigation

As a strategy for resolving the research questions listed above, one does not necessarily need to create a brand new hypermedia database. One can examine whether the hypermedia databases created in the past, often at great expense, can be significantly improved by introducing those navigational features that are currently being advocated by hypermedia designers. One such database is the Perseus Project. Hypermedia applications were first developed for personal computers some ten years ago (Hall, Davis, & Hutchings, 1996). The first version of the Perseus hypermedia database embodied the design principles employed at that time. The second and most recent version of Perseus released in 1996 still retains the original navigational design structure proposed in 1988. Since Perseus is a hierarchical database, it is possible to alter the overall navigational superstructure in order to test various hypotheses about navigational design without changing the vast majority of the information stored in the database.

The Perseus Project

The Perseus Project is an ambitious undertaking begun in the Classics Department of Harvard University. It is devoted to the creation of a massive interactive hypermedia application, called "Perseus," on ancient Greek culture. According to Crane and Mylonas in their 1988 article: "The Perseus Project is developing interactive, computer-based materials on Greek Civilization. These are designed to support learners, instructors, and researchers as they explore this complex subject" (p. 25). The initial four-year funding proposal for Perseus to the Annenberg/CPB Project, Apple Computer, and Harvard University dated May 24, 1988, was for $3,390,541, with the final project cost between $4 and $5 million (Hughes, 1988). The literature about hypermedia applications includes frequent favorable references to Perseus. It has been praised in journal articles as a model for hypermedia development. Hughes called the Perseus Project "today's most ambitious, intriguing, and promising application of computer technology to academic instruction and research in the liberal arts" (1988, p. 1). In her article about evaluating Perseus, Neuman asserted: "The project is innovative in its development process, its technological sophistication, its range of potential applications, and its intended outcomes" (1991, p. 239). Since its carefully developed design epitomizes the navigational controls typical of hypermedia databases created over ten years ago (See Figures 1 and 2 for examples), it is a fit subject for the intended research.

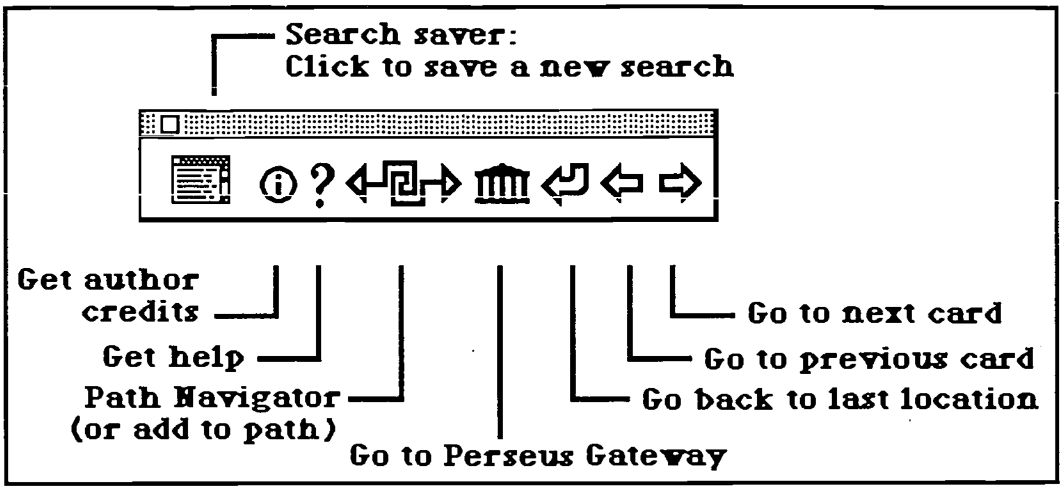

Figure 1. The Floating Perseus Navigator in Perseus 2.0

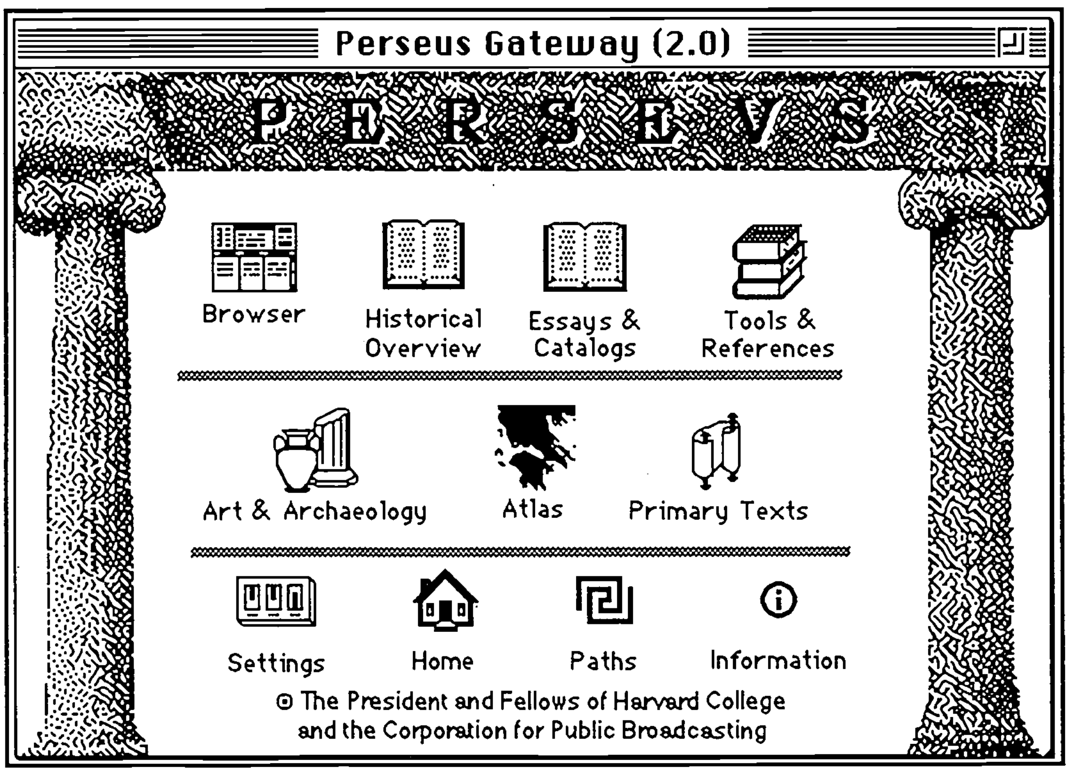

Figure 2. The Perseus Gateway

Previous Evaluation Results

Marchionini and Crane (1994) reported the results of a three-year evaluation of Perseus in a lengthy article in the *ACM Transactions on Information Systems.* The evaluation examined a number of instructional design issues. However, the evaluation was summative, not formative, in nature. Also, the evaluation was qualitative (naturalistic inquiry), not quantitative. Rather than suggest changes to the Perseus application, Marchionini and Crane suggested how users could be better prepared or trained to use Perseus more effectively.

The evaluation effort described here involves a complex system (Perseus) based upon a new technology (hypermedia) applied to abstract goals (finding relevant information, learning how to think critically). The overall evaluation effort aims to inform general hypermedia application design, develop human-computer interaction and information-seeking behavior theories, and add to our understanding of learning and teaching. (Marchionini and Crane, 1994, p. 6)

The Proposed Research Study

Testing the long list of research questions given above is a daunting task by anyone's standards. Even if only two alternative hypotheses are considered for each of the eight categories of research questions above, sixty-four test groups would be required to consider all possible interactions between the various treatments. Hence, the proposed study will concentrate on two treatments: decentralized dedicated areas for navigational controls vs. the centralized menu driven design of the original Perseus; and unique, named iconic representations of navigational controls vs. the representations in the original Perseus.

Hence, there will be four test groups in this two by two design: (a) the control group, which will use Perseus in its original form, (b) a group tested with Perseus modified to have dedicated areas for navigational controls, (c) a group using Perseus modified to have unique named iconic representations for navigational control, and (d) a group using Perseus modified to have both dedicated areas and unique named icons (See Figure 3). Participants for each group will be randomly selected from the target population, college-level students with some hypermedia experience.

Participants will be given a pretest and posttest to measure comprehension. They will be tested individually using the speak-aloud protocol while they are using the Perseus hypermedia database. Each session will be videotaped to preserve a record of each participant's performance (verbal and physical) using the version of Perseus appropriate to the designated group for that individual. The testing will produce two types of data: (1) measurements for comprehension by use of pencil and paper testing before and after each session, and (2) measurements of how long it takes to accomplish specified navigational tasks. The sessions themselves will be "scavenger hunts" through the Perseus database for the answers to a set of approximately ten questions. The sessions are called scavenger hunts because the questions may be answered in any order, thus, simulating a hypermedia learning environment where one might serendipitously stumble upon one answer while actually looking for another.

Future Directions

Assuming that the research study reveals a significant difference between the treatment groups and the control group in the proposed study, the authors intend to continue testing the various navigational research questions given above. The ultimate goal would be to develop a navigational system for Perseus that incorporates all the navigational features that produced significant improvement in comprehension and efficient usage (speed).

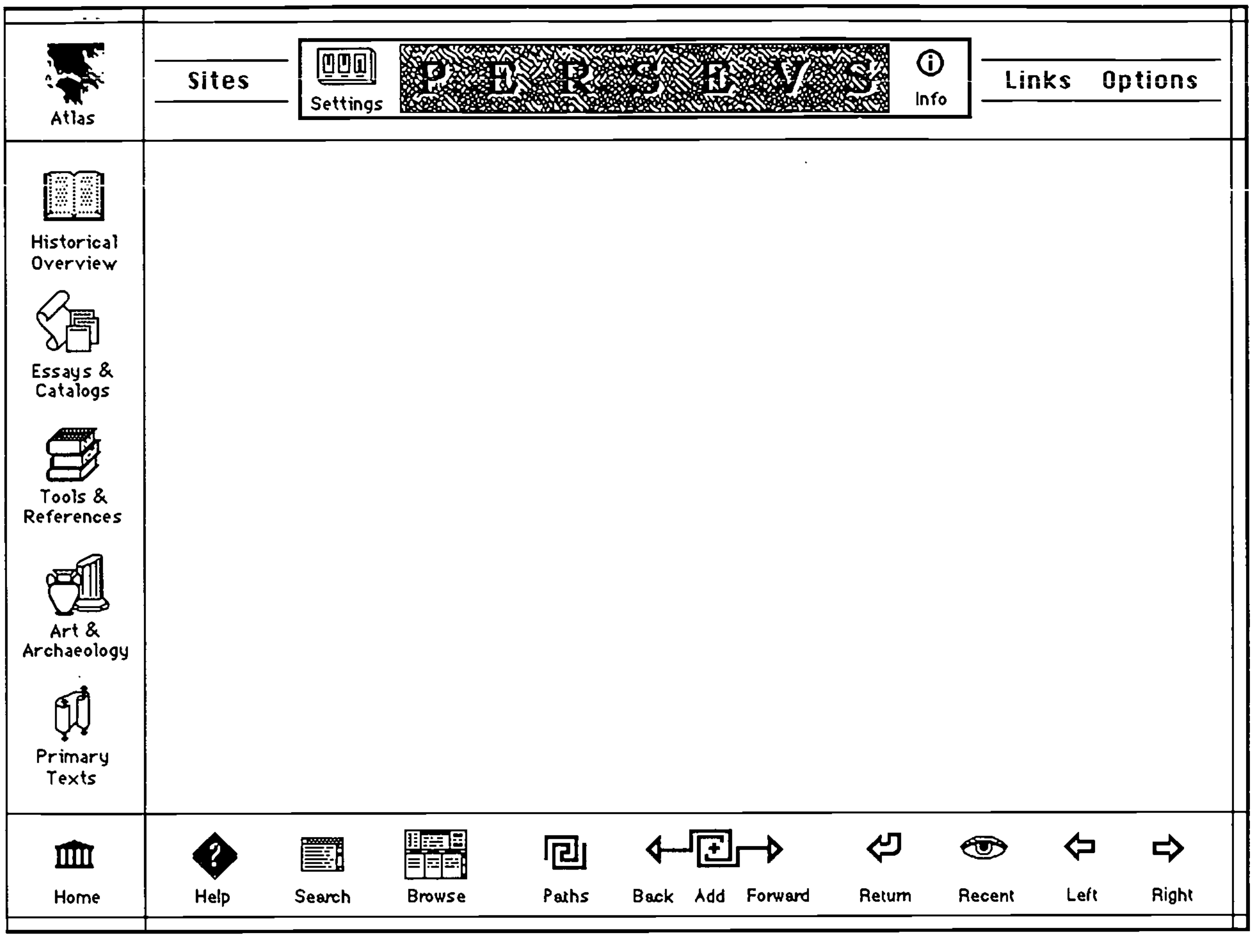

Figure 3. Suggested Decentralized Navigational Design to Replace the Perseus Gateway

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