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ABSTRACT

This paper discusses issues related to the design of software tools that support learners in their participation in network-based learning activities. To guide the development and use of a new class of educationally-oriented network tools, this paper proposes a cognitively-based, distributed network learning framework (DNLF). This framework has three main aspects: (1) network mediators and the flow of information and knowledge; (2) networks and cognitive theories of learning; and (3) the human-network interface. As an example of an application of the DNLF, an ongoing research and development project is described that involves an electronic mail program called The Message Assistant is described. The Message Assistant is designed to promote higher order learning goals as a part of instructional activities conducted over distributed educational networks. In addition to the standard electronic mail features such as creating, sending, receiving, and reading messages, this program includes a user-defined incremental expert system and hypertextual linking functions to assist network users in their evaluation, organization, and distribution of network information and knowledge. Research using the DNLF can provide insights into important aspects of electronic educational networks and help guide the design of tools to better support learning in these rapidly evolving network environments. Six figures illustrate The Message Assistant screen displays. (Contains 14 references.) (Author/ALF)

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A RULE-BASED AND HYPERTEXTUAL ELECTRONIC MAIL SYSTEM FOR ELECTRONIC LEARNING ENVIRONMENTS: APPLYING THE *DISTRIBUTED NETWORK LEARNING FRAMEWORK*

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Abstract

There is an increasing interest in the use of electronic computer networks to enrich educational learning environments. This paper discusses issues related to the design of software tools that support learners in their participation in network-based learning activities. To guide the development and use of a new class of educationally-oriented network tools, this paper proposes a cognitively-based *distributed network learning framework* (DNLF). This framework has three main aspects. (a) *network mediators and the flow of information and knowledge*, (b) *networks and cognitive theories of learning*, and (c) the *human-network interface*. As an example of an application of the *distributed network learning framework*, an ongoing research and development project is described that involves an electronic mail program, *The Message Assistant*. In addition to the standard electronic mail features such as creating, sending, receiving, and reading messages, this program includes a user-defined incremental expert system and hypertextual linking functions to assist network users in their evaluation, organization, and distribution of network information and knowledge. Research using the *distributed network learning framework* can provide insights into important aspects of electronic educational networks and help guide the design of tools to better support learning in these rapidly evolving network environments.

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A RULE-BASED AND HYPERTEXTUAL ELECTRONIC MAIL SYSTEM FOR ELECTRONIC LEARNING ENVIRONMENTS: APPLYING THE *DISTRIBUTED NETWORK LEARNING FRAMEWORK*

The potential of electronic computer networks to extend and enrich the educational learning environment has been receiving considerable recent attention. There is an extensive amount of ongoing work related to developing network technologies for use by teachers and their students, providing access to educational networks, researching network-based instructional activities, and so on (e.g., Hunter, 1992). As such powerful technologies become more readily available to educators, there is an increasing need to design tools that go beyond providing mere *access* to network-based information and that instead support learners as they dynamically *acquire, organize, and apply* knowledge to a wide variety of learning and problem situations.

To help promote higher-level cognitive learning goals through the use of educational network resources, we have been involved with a research project to develop a new class of educationally-oriented network software that incorporates artificial intelligence and hypertext capabilities in addition to more traditional electronic mail and network access capabilities. However, the design of this program is guided not by specific technological functionalities, but rather by a more global vision of electronic learning environments that we refer to as the *distributed network learning framework* (DNLF). This cognitively-grounded framework is intended to describe important characteristics of information flow over educational networks and critical cognitive dimensions associated with the use of network structured learning environments. The rule-based and hypertextual telecommunications program we have been developing--which we call *The Message Assistant*--has a number of features that explicitly implement important aspects of the DNLF.

The first portion of this paper presents the main features of the DNLF, followed by a discussion of the major features of *The Message Assistant*. The paper concludes with a consideration of research issues for the evaluation of network-based learning activities that are suggested by the framework.

The Distributed Network Learning Framework

The *distributed network learning framework* (DNLF) will be described through three major aspects, each of which considers a different facet of the complex and dynamic network learning environments that are becoming available to students, teachers, and researchers. A central notion of the framework is that of *network mediators and the flow of information and knowledge*. As educational network activities are fundamentally concerned with learning, the second aspect of the framework is *networks and cognitive theories of learning*. The final aspect discusses the *human-network interface*, specifically with respect to the cognitive management of complexities associated with using the current generation of computer networks. Each of these aspects is briefly discussed in the sections below.

Network Mediators and Flow of Information and Knowledge

Network learning: Expected value of information. Fundamental to our view of electronic networks which support learning activities is that there are a variety of mediators--both human and computer-based--at nodes on the network that control the flow of information from an existing location towards a new location where it is currently needed. One general characteristic of electronic networks is that information can flow rapidly through the network. Another aspect of the movement of information on networks involves decisions which are made about the nature and value of the information at network nodes that result in much more gradual movements of stored knowledge. The DNLF is based on the following general principle: *At each node in the network, information appearing at that node is stored locally if the expected value of storing that information is positive.* The expected value of information storage is the expected benefit minus the expected cost. For human mediators, the evaluation of

expected value can be quite complex and situation specific, in contrast to computer mediators for which the expected value is typically crudely determined using relatively simple and well-structured criteria or rules.

The expected value depends on an estimate of the probability of needing the information again (i.e., a *prediction* problem). The simplest approach to prediction is to assume that the future will be like the past, and thus to predict that the likelihood of an event occurring in the future will be the same as the occurrence of the event in the past. So, if the computer-based mediator analyzed its log of past needs for a particular kind of information, it could, under this "the future will be like the past" assumption, predict that information needed frequently in the past will be needed again in the future. Mediators may also have other more sophisticated ways of predicting the future, but in the absence of such knowledge, the frequency rule can be used. The value of having stored the information locally is that the mediator does not have to go out on the network to get it when needed, which may entail a monetary cost or a time delay cost or both. Again, the mediator can infer the cost of future access (and the benefit from storing the information) by accessing its log or memory of past costs of accesses. The expected cost may also involve both the direct cost of storage and the increased cost of accessing already stored information. That is, each new piece of information can make the retrieval of previously stored information more difficult. One consequence of higher costs of accessing an increasing body of existing information is that the human mediator could be motivated to *restructure* the stored information to optimize access and reduce storage costs (see below).

As an example of network mediator interactions on an electronic network, consider a *person-to-person* interaction through electronic mail in which one person asks a question to another person on the network. Obviously, the person receiving the question must decide whether to respond, and if so, how much of a response is necessary. For the first individual who asked the question, the answer that is received must be evaluated and a decision made as to what to do with the information. Based on the framework presented above, the probability that the requestor would keep and use the received information would be higher if the expect value of the information was perceived to be high.

This notion of interacting network mediators can also be extended to include human and computer-based mediators. For example, there can be *person-to-computer* interactions over a network, such as when an individual uses a network to access an online database to obtain information on a topic. Perhaps a journal citation and abstract is found on the topic, but the person realizes the paper is old and therefore may contain out-of-date information. In this case, the probability that the human mediator would keep the information would be low. *Computer-based mediator-to-computer-based mediator* network interactions are also possible (although generally much cruder than human mediators), as when a software agent scans an online information source. The expect value of information would be high when a specific search criteria rule is matched, thus causing the software agent to obtain and store the information.

Network learning: Information optimization. There is another aspect of this probabilistic view of how the decision operations of human and computer-based mediators affect the flow of network information. One consequence of the DNLF general principle is that each node in the network attempts to optimize its functioning by storing things that are likely to be used again. Local storage of information thus occurs over time, essentially creating a local database of information. This local storage of information may also be internalized by the mediator, resulting in learning. There are several consequences of this. In a functional learning environment, there would be added value to information that is used repeatedly by a particular node. There would be a tendency to increase the judged probability of needing that information again, and thus the probability would be raised that the mediator at the node would attempt to store or learn the information. This rule also suggests that there would be a *graduate acquisition of expertise*, as over time the local storage of information would become increasingly richer and organized. The optimization that occurs at a node could be analogous to the learning processes of *accretion, tuning, and restructuring* (Rumelhart & Norman, 1978). Initially, there would be the mere accretion of information (either in terms of computer-based storage and the

human memory representations) which would evolve into more differentiated and organized knowledge structures over time. These knowledge structures (e.g., for the computer mediator: rules or hypertextual views; for the human mediator: schema or mental models) would then serve as the basis from which the mediator would evaluate new network-based information and would be *tuned* as new information is locally stored and used at the node. Finally, it may become necessary to *restructure* or develop new organization structures in order to accommodate the ever changing informational flow over the network and the ongoing educational activities of the learning environment.

Networks and Cognitive Learning Theory

Much of the discussion of the DNLF has so far been at a somewhat abstract level, dealing with general notions of information flow, probabilities of storage, and so forth. However, the *raison d'etre* of an educational network is determined by the context in which it operates, which is to support learning and knowledge dissemination. This second aspect of the DNLF, *networks and cognitive learning theory*, thus provides an important perspective to understanding and structuring productive educational experiences over electronic networks. Due to the scope of this paper, it is not possible to provide a detailed discussion of all the important cognitive theories of learning that are relevant to network instructional activities. This section is therefore a brief and selected overview of a very broad topic.

Given the explicit function of computer networks to link individuals and groups together, there is a natural affinity between the DNLF and general theories of learning that take into account the extended social contexts of learning. We regard the seminal theories of Vygotsky (1978) as being of central importance to understanding the dynamics of network mediated learning activities. One key Vygotskian concept is the *zone of proximal development* (ZPD) which proposes that there is a progressive internalization of knowledge by the learner that occurs through the interaction of the learner and other members of their social environment (e.g., teachers, parents, other students). From this perspective, computer networks can function to extend the ZPD that learners are exposed to by providing a wider and richer set of social contexts for learning activities.

Further insight into the complex context of learning is provided by recent cognitive instructional research that has documented a number of problems learners have with acquiring and transferring complex knowledge (e.g., Gick & Holyoak, 1987; Lave, 1988). As many network-based learning activities involve conceptually demanding content areas or the application of knowledge to real world situations and problems, it is important that cognitive factors associated with learning complex knowledge be considered. Certainly the theories of learning focussing on the social context of learning have much to contribute to this area (e.g., Brown, Collins, & Duguid, 1989; Vygotsky, 1978). Also, there are other contemporary cognitive theories of learning which are relevant to the use of technology-based systems in instruction, such as *generative learning environments* (Cognition and Technology Group at Vanderbilt, 1991) and *cognitive flexibility theory* (Spiro, Feltovich, Coulson, & Anderson, 1988; Spiro, Feltovich, Jacobson, & Coulson, 1991). These theories of learning focus on different aspects of the learning and instructional processes, such as anchoring instruction in meaningful problem-solving contexts and the structure of the knowledge representations given to the learner. Indeed, the application of multiple theories of learning that each address different facets of the overall learning context may function in a synergistic way that could help inform the design and use of network learning activities to foster better learning of complex subject content.

The Human-network Interface

Given the many technical complexities associated with the current generation of computer networks, it is not surprising that "ease-of-use" has been identified as a significant factor for the successful conduct of instructional activities over electronic networks (e.g., Riel & Levin, 1990). We view this factor broadly to encompass the *human-network interface*, which has two main aspects. First, network "ease-of-*access*" involves logistical problems such as lack of computers, phone lines, or building network

wiring pose serious obstacles to the educational use of computers. Ongoing efforts, such as the establishment of the National Research and Education Network (NREN), will provide critically needed support to help address this problem. Second, network "ease-of-use" must be considered, since even with access to the network infrastructure, there are still many human-computer interface factors that must be solved for educators and students using computer networks. There is thus a great need for software tools that are specifically designed to simplify and support the conduct of network-based learning activities.

The Message Assistant and the Distributed Network Learning Framework

Conceiving of activities conducted over network learning environments from the perspective of the *distributed network learning framework* suggests that the kinds of software tools which are developed for participants in these activities need to provide specific kinds of functionality that go beyond mere network access or menu driven interfaces. In this portion of the paper, we discuss features of a Hypercard-based interface to educational network resources called *The Message Assistant* (Figure 1; Levin & Jacobson, 1991) This program is intended to assist a network mediator in her or his access, organization, and distribution of network information. At a basic level, this program provides the standard types of electronic mail features, such as creating, sending, receiving, forwarding, and replying (Figure 2). In addition, *The Message Assistant* offers two important additional feature sets that are based on the DNLF: *message preprocessing* and *message organizing*.

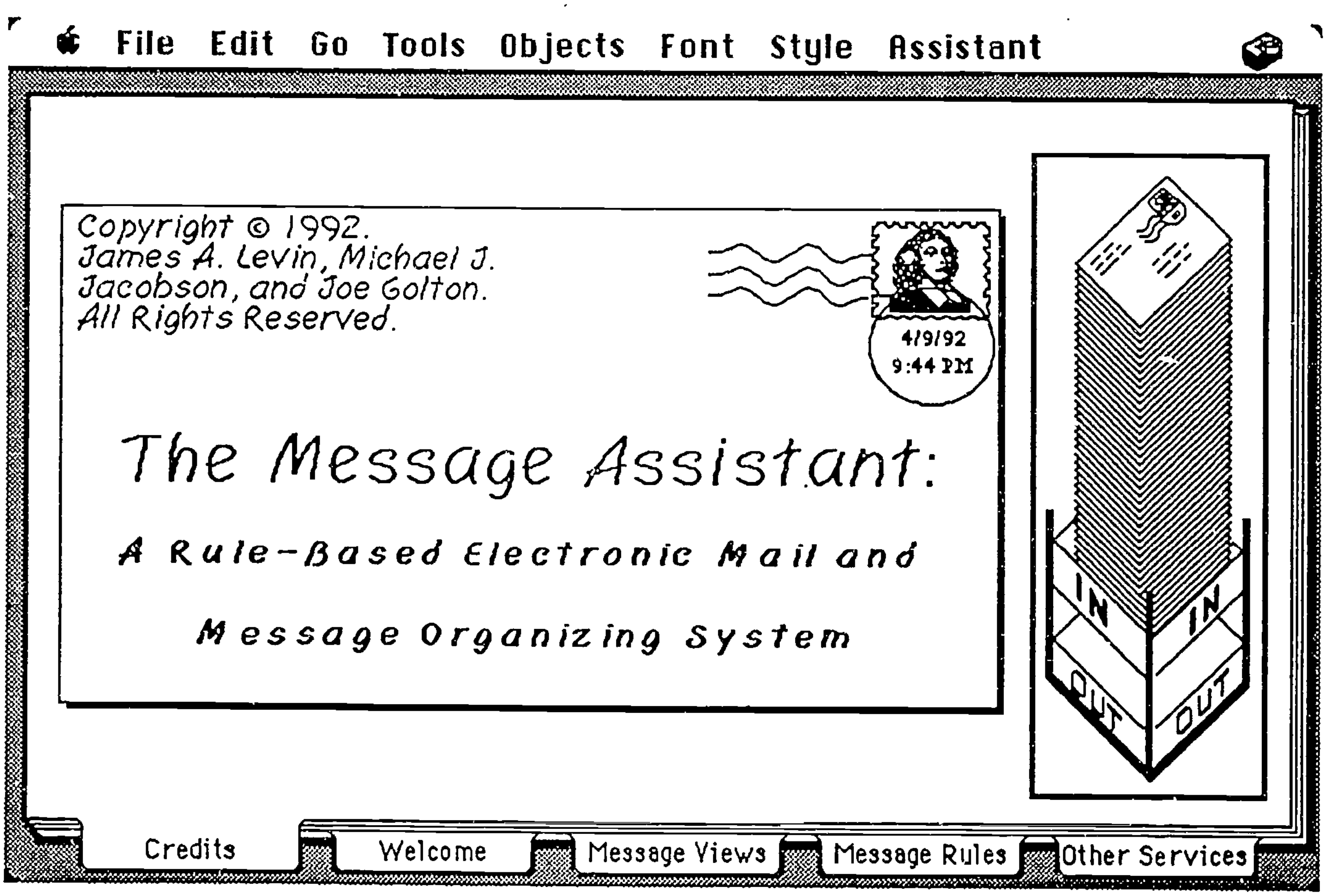

Figure 1. Opening screen of *The Message Assistant*.

We will illustrate different functions of *The Message Assistant* using selected messages (with all personal identification information from non-research participants removed) from an ongoing network-based learning activity, the *Zero-g World Design Project*. Students this past year from a number of schools around the country considered what life in a zero gravity environment such as a space station would be like. Teams of students at different schools focussed on a specific aspect of zero gravity life, such as eating and food, recreation, or school and education. They sent messages over the FrEdMail or Internet networks to other students, schools, teachers, researchers, and scientists to ask questions, share ideas, and discuss their designs. As *The Message Assistant* has been under development, the students did not actually use the program (although we plan to start wider usage of the program next year by teachers and students). However, we have begun to use several of the features of *The Message Assistant* as a research tool in our analysis of the many electronic messages generated by the Zero-g and other network research projects. Our discussion of the DNLF and *The Message Assistant* in this section will use Zero-g messages from the spring of 1992.

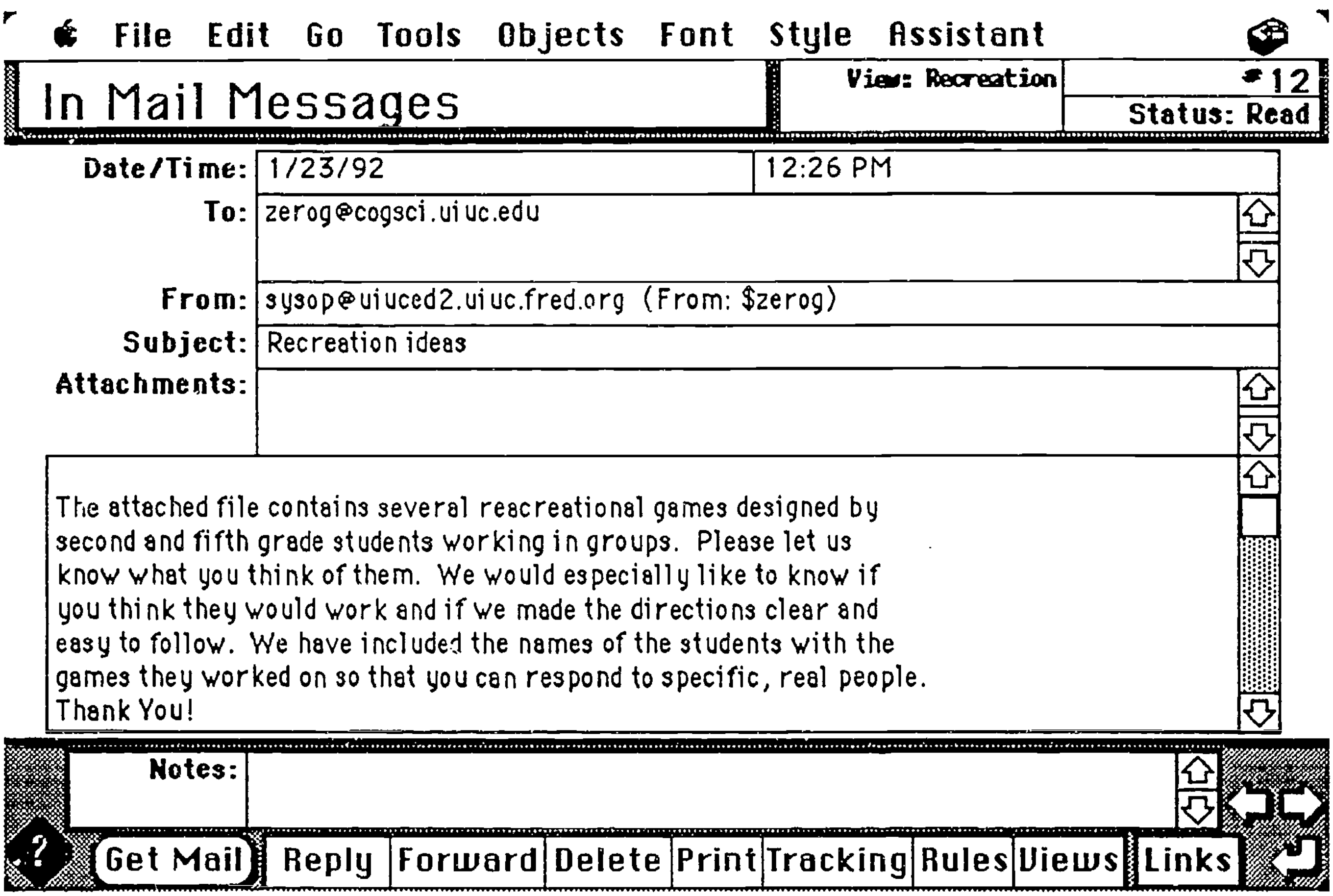

Figure 2. The Message Assistant's standard email functions and a sample Zero-g message.

Message Preprocessing

Users of national and international electronic networks can easily become inundated with large amounts of electronic messages and the need for electronic message filtering mechanisms has been noted (Malone, Grant, & Turbank, 1986). *The Message Assistant* permits the user to have messages preprocessed through a set of user-defined rules with conditions that trigger actions. Messages are initially presented in priority order, with the default priority being reverse chronological order (i.e., the program assigns recent messages a higher priority than older ones). The user can also create rules to

assign a specific priority ranking to messages. For example, a rule that checks for messages on Recreation is shown in Figure 3. These messages would automatically have their priority level raised moderately by .4 (on a scale of -1 to 1) and would also automatically be forwarded to a colleague who is interested this topic. A different rule could check for messages from a specific group one is only casually interested and lower their priority. The user can also easily ignore the message prioritizations since an overview listing of all messages is available and the user can select any of the messages to read. But we anticipate that when the user is confronted with a large number of new messages, the preprocessing and prioritization of messages based on the user's own customized set of rules will prove helpful to the user in deciding which messages to read immediately and which to read later.

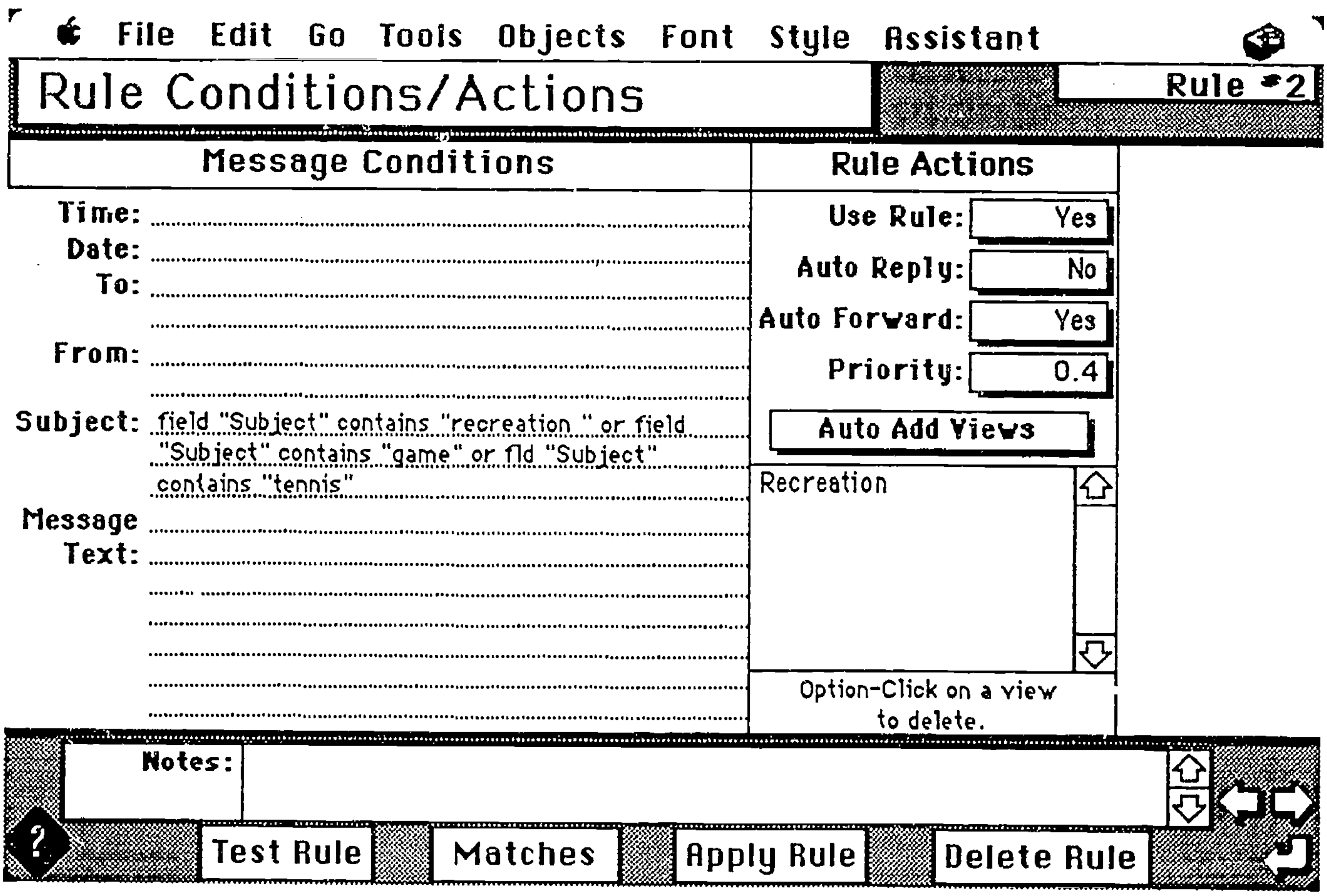

Figure 3. User-defined rule to adjust a message's priority, assign a message view, and automatically forward a message.

There are several ways in which these features instantiate aspects of the DNLF. The *network mediator and flow of information and knowledge* aspect holds that probabilistic evaluations of network information are made by a mediator at a particular node. The message rules function as a computer-based mediator that assists the human mediator in making an initial determination of the expected value of the information. The message rules form a user-defined expert system which is incrementally specified and tested over time and thus gradually increases its expertise with use. Such an expert system serves as a computer-mediator that takes over repetitive or low-level evaluations of the expected value of certain types of network information and then automatically initiate actions which filter, route, or store that information. Information that does not match any prespecified rules is passed on to the human mediator to be evaluated. If the new information is regarded as being of value, then the human mediator will operate on that information.

The use of rules in *The Message Assistant* also contributes to the *human-network interface* by reducing some of the technical and cognitive load on the human mediator. At a simple level (discussed previously), the prioritization of messages helps the mediator determine what to read first. Also, the rules function as an automatic filtering and routing agent, thus reducing the overall number of messages that the mediator has to explicitly deal with. At a more substantive level, the rules can assist the mediator in organizing the complex knowledge that is contained in a large corpus of messages by automatically creating hypertextual links between messages (see below).

Message Organizing: Hypertextual Links for Knowledge Structuring

As discussed in the first section of the paper, a central property of the *distributed network learning framework* is that network learning activities involve the flow of information from locations where the information is stored or available to different nodes on the network based on conditions of the learners' information needs. But it is obvious that the mere existence of a network infrastructure is a necessary but not a sufficient condition for significant *learning* to occur over educational networks. *The Message Assistant* is being designed to provide message organizing techniques that we hope will prove useful in helping users transform information into usable knowledge as a part of their learning activities conducted over the network. Message organizing is being implemented both through the user-defined expert system (i.e., message prioritization, see above) and through two types of hypertextual linking mechanisms: *fixed links and virtual hypertext links.*

Fixed links. Specific fixed links can be manually created between different messages by the user or automatically by the program when replying or forwarding a message. These "traditional" hypertext links allow the user to organize and access messages in a nonlinear manner. For example, Figure 4 shows a message screen which displays the list of three fixed hypertext links to other messages that were manually set. Clicking on any of these links takes you to the linked message. Return links are automatically created, so that you can easily return to this message.

Virtual conceptual hypertext links. A potentially more powerful feature for knowledge organization involves the ability of the program to create multiple sets of *virtual hypertext links* based on conceptual interrelationships between various messages. We refer to these virtual conceptual hypertext links as "views" of the locally stored messages. Two default views of the messages are "In View" and "Out View" that correspond to received and sent (or to be sent) messages (Figure 5). The user may then create new views of the messages that share a common topic, theme, issue, or other conceptual bond. Each view represents one possible set of hypertextual links between a subset of the messages; switching to a different view reconfigures the links between messages. *The Message Assistant* was used to organize multiple views of the Zero-g messages based on a number of issues and themes, such as Food-Eating or Recreation (see Figure 6). As many messages contained information that dealt with several issues, it was quite common to find such messages in several views. In addition, the program allows both the user-defined rules to automatically assign messages to a view and for the mediator to manually assign a message to a view. Overall, this ability to manually and automatically create views and then study the messages from these multiple conceptual perspectives is intended to help the mediator create organized information and lead to the generation of useful knowledge.

Message organizing and the DNLF. As with the preprocessing of messages, there are several ways in which the message organizing functionality of *The Message Assistant* has been guided by the DNLF. The user-defined incremental expert system is very specifically concerned with the *flow of information* into and out of the node. While these rules function to automate the initial decision process concerning the value, local storage, and flow of information in the preprocessing stage, the rules can also serve to automatically record and apply aspects of experience and expertise of the human mediator at a higher conceptual level through the hypertextual message view linkages.

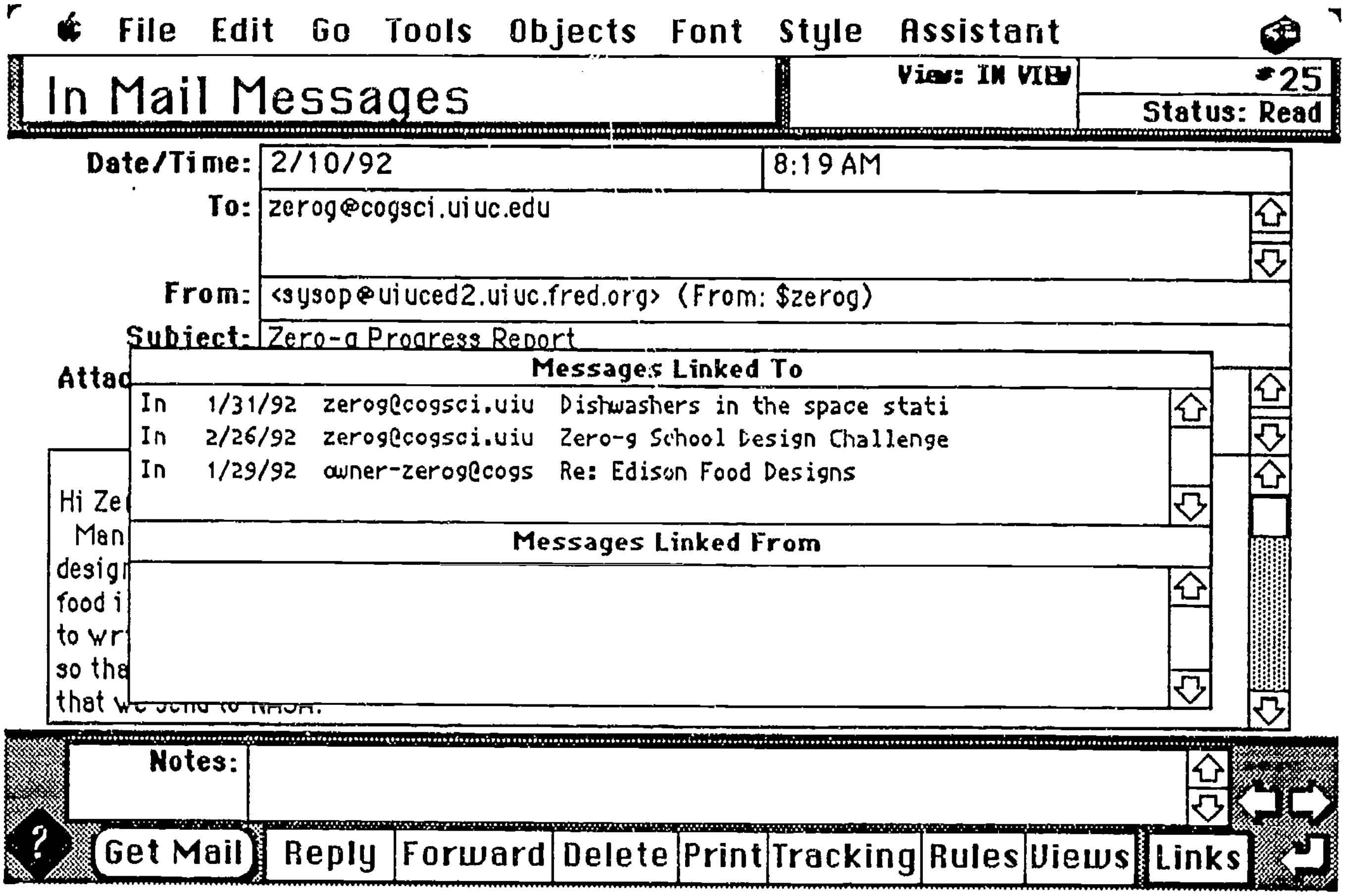

Figure 4. Fixed hypertext links to other electronic mail messages.

The virtual hypertext links feature also helps to instantiate the DNLF property of *optimization* (i.e., network nodes attempt to optimize their functioning by locally storing potentially useful information). The views function provides the mediator with a mechanism to create a personally meaningful knowledge-base that is also flexible in terms of organizing and accessing the information in the messages. We expect to see a *gradual acquisition of expertise* embedded in the computer-based mediator of *The Message Assistant* in terms of the user-created rules and views and in the human mediator in terms of acquired knowledge. With a functional learning environment, such as using the network for educational activities, there should be information that repeatedly comes to a particular node and thus becomes judged as having a higher expected value, leading to the local storage of the information and its incorporation in some capacity into the rule and view structures. Finally, over time the specification of message views and rules would be expected to progress from gradual accretion, to the tuning use of a body of accumulated views and rules, to the restructuring of views and rules as the human mediator works with the dynamic and changing learning environment.

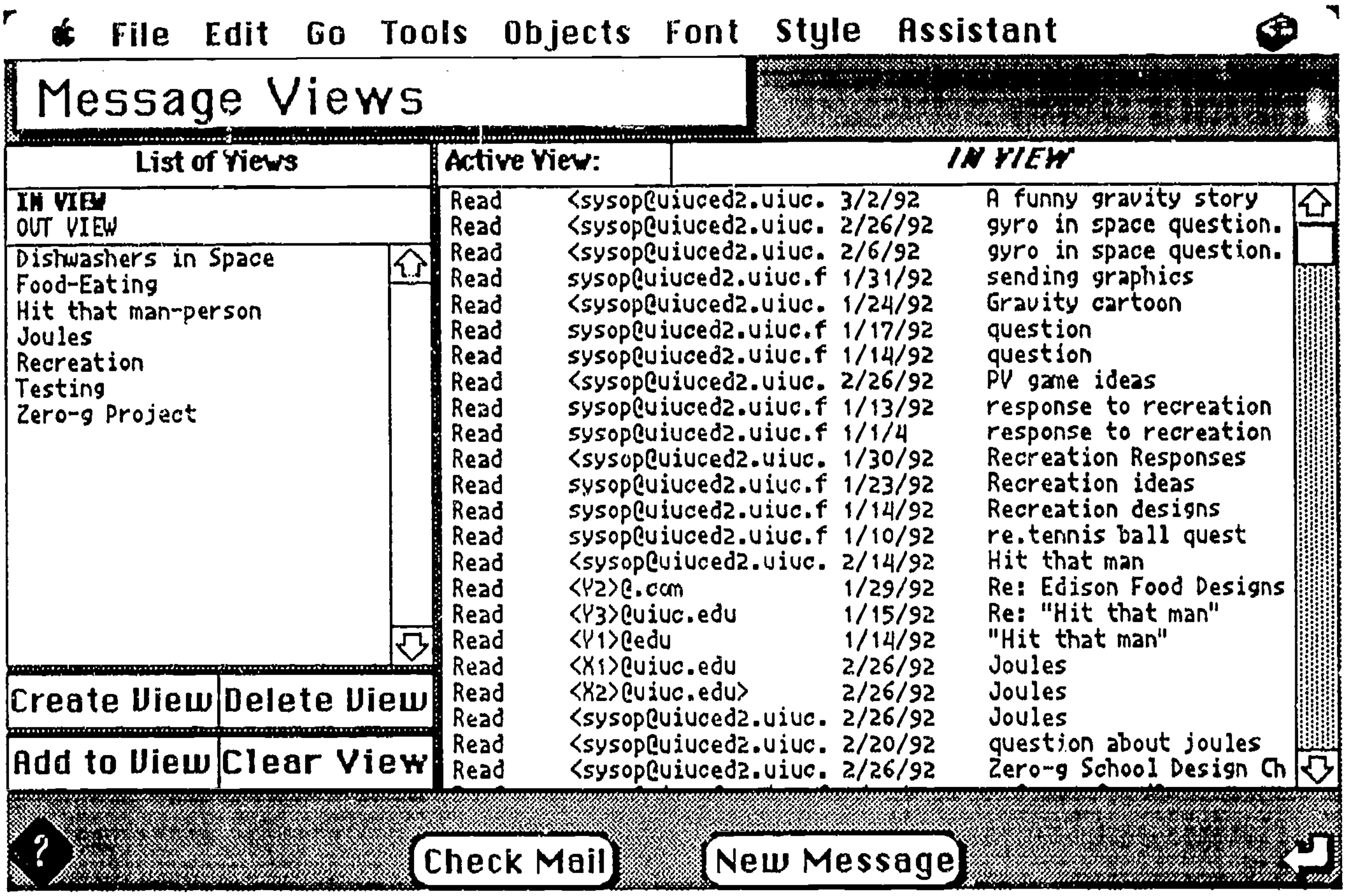

Figure 5. In View listing of Zero-g Design Project messages listed by priority.

There is another way in which the message organizing features of *The Message Assistant* relate to the DNLF. The second aspect of the DNLF, *networks and cognitive learning theory,* concerns "the bottom line" of a technological learning environment: that students be able to acquire usable information and knowledge as a result of their use of instructional activities. The cognitive demands associated with learning complex knowledge have been receiving increasing attention in terms of theoretical and research work in the cognitive sciences (e.g., Glaser, 1990; Spiro et al., 1988; Vygotsky, 1978). There are several aspects of *The Message Assistant* that attempt to implement various aspects of these current cognitive views of learning. As noted earlier, learning theories concerned with the social and situated contexts of learning are central to the DNLF. *The Message Assistant* is explicitly designed to function in a social context and to be a part of learning activities that involve students in real world problems and issues (e.g., Levin, Riel, Miyake, & Cohen, 1987). The preprocessing and message organizing functions of the program are intended to support both collaborative learning activities and a more recent notion of *teleapprenticeships* (Levin et al., 1987). Teleapprenticeships incorporate apprenticeship modes of learning into the network environments through using the network to allow novices and experts to interact in educationally significant ways by overcoming logistical and pragmatic constraints such as geographical location or work schedules. The message preprocessing and organizing features of *The Message Assistant* should prove valuable in supporting teleapprenticeship types of network learning activities and is one aspect of our current research.

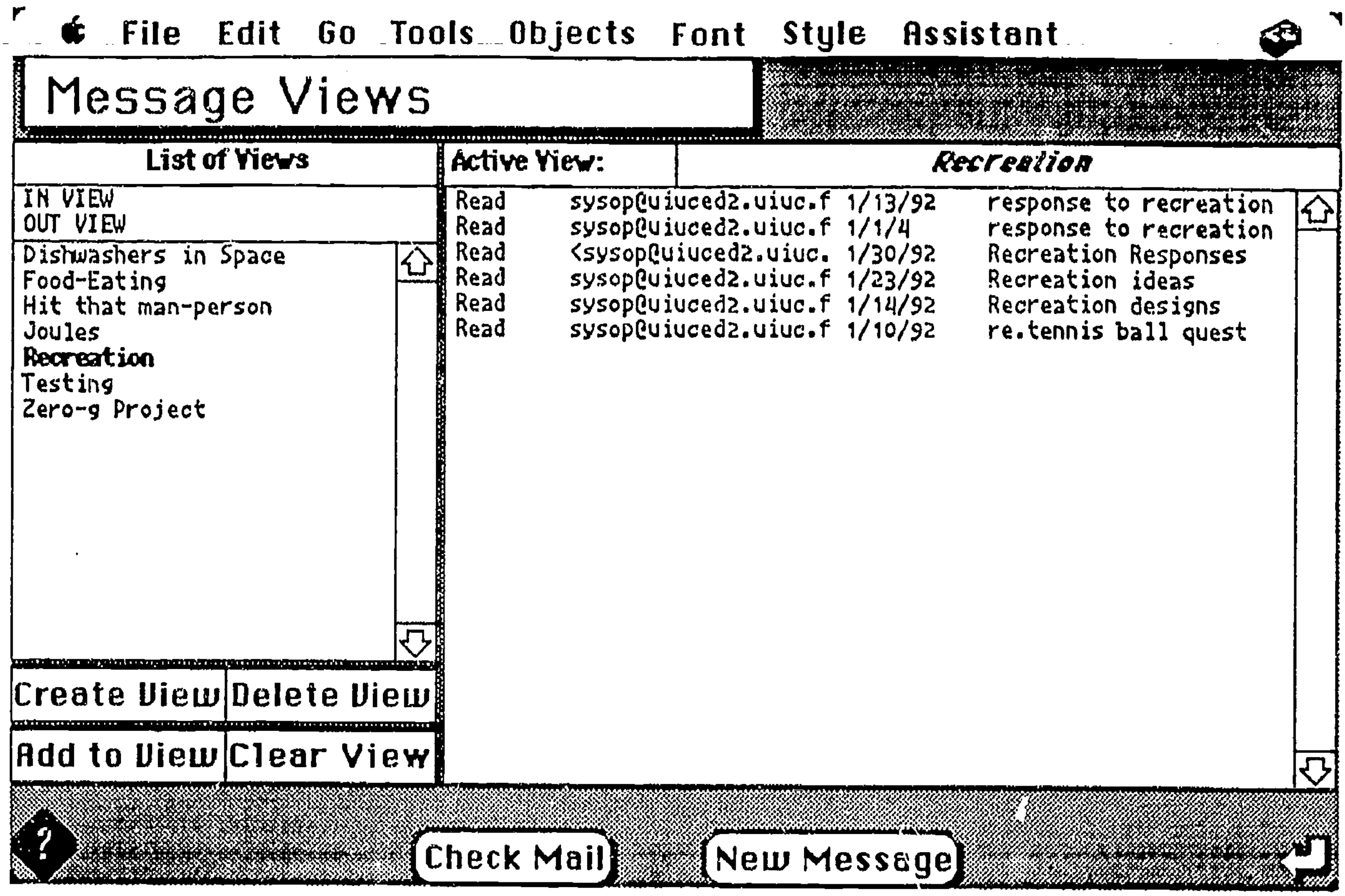

Figure 6. Electronic messages contained in the virtual hypertext links of the *Recreation View.*

Researching the Distributed Network Learning Framework

In the research to evaluate the DNLF, there are several primary questions we are interested in, such as: What sorts of predictions does the framework make concerning interactional patterns and the large scale flow of network-based information? How can software tools help support the transformation of fluid network information into structured and usable knowledge? What are the implications of the framework for guiding the optimal organization of distributed electronic networks for learning?

Because there are specific probability rules associated with the *flow of information and knowledge* aspects, we plan to construct models of information flow and then to compare those models to specific data on message interactions. *The Message Assistant* is currently being used by network mediators. Data collection routines in the program record a number of facets of the use of the program, particularly with respect to message flow patterns and the specification, evolution, and use of rules and views. Also, an important research agenda concerns factors associated with learning, particularly ascertaining the effectiveness of the learning activities being conducted over the network in terms of helping students acquire knowledge they can use in new ways and in new contexts.

Summary

This paper describes portions of a research project which is developing an electronic mail and knowledge organization program, *The Message Assistant*. This program is intended to promote higher-

order learning goals as a part of instructional activities conducted over distributed educational networks. The design of this software is based on a cognitively-oriented view of educational networks that we refer to as the *distributed network learning framework*. The DNLF consists of three main aspects: *network mediators and the flow of information and knowledge, networks and cognitive theories of learning,* and *human-network interface.* We regard the framework as a *flexible*--and *extendable*--set of perspectives from which to examine and to work with different aspects of this complex, multifaceted, and dynamically evolving learning technology. While we feel that there are numerous ways in which the *distributed network learning framework* may be applied to educational electronic network research, this paper discusses the framework in terms of the user-defined expert system and hypertextual features of *The Message Assistant* program. The research on models derived from this framework can contribute to the design and use of network-based learning environments that enhance the learning opportunities and outcomes of students.

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