Toward a More Structured Use of Information Technology in the Research Community[1]

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Abstract

Information technology has great potential for supporting the activities of research networks. However, some fundamental problems must first be addressed to determine whether the technological support is necessary at all. Once that need has been determined, merely installing a set of isolated, generic information tools is not sufficient to address the full spectrum of network information needs. Therefore, a comprehensive and customized network information system is required. We argue that a specification method can help to structure the development of such an information system.

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1. Introduction

Enormous progress has been made in information technology in the past few decades. If applied wisely, it considerably improves the efficiency and impact of professional work. The technology can assist professionals in creating, collecting, processing, and communicating relevant information much more efficiently. Many applications, such as spreadsheets and word processors, increase individual productivity. However, even more interesting from the perspective of improving work is distributed information technology, which helps to improve professional collaboration. Distributed information technology is defined here as those applications of information technology that have their data and software stored in more than one physical site, and that use a computer network to establish the connections between these sites. Examples of such technology are computerized conferencing systems (Black 1987; Swanson, 1993) and interoperable databases (Brodie 1992) have received considerable attention in the past few years. Drawing from these research efforts is the field of computer-supported cooperative work (CSCW) (Grudin 1994; Ellis and Wainer, 1994). Social psychology is also prominently involved in this branch of information science (Thorngate 1985; Borovits et al. 1990). CSCW researchers study collaborative group processes and develop software, called groupware, that can support these processes. In groupware, work processes are not seen as simple data input-output relations, but as communicative relations between requesters and providers of services (De Michelis and Grasso 1994). Thus, groupware uses communication structures rather than the data communicated as the basic software organizing approach.

One likely beneficiary of groupware is the research community. The scientific research process is rapidly transforming from a relatively solitary operation into a much more collaborative effort (Shade 1994). This can also be seen in the increasing number of research networks being established. Research networks are goal-oriented networks of professionals that focus on supporting certain stages of the research process. Most of the literature on scientific work processes analyzes relatively basic, but already hard to specify article-authoring tasks involving relatively few authors, such as outlined by (Kraut et al. 1987). The planning and conduct of research activities and the dissemination and implementation of the results by research networks are even more difficult to model (de Moor 1994). Groupware and related technologies can make an important contribution to the execution and coordination of such complex human interaction processes (Malone and Crowston 1994).

However, to truly justify the use of information technology to support research networks, two important categories of issues need to be addressed first. The most fundamental questions have to do with whether research networks need information technology at all. The second set of issues deals with how the technology can be most effectively and efficiently applied: how to find out what information needs the network has, and how best to use the available technological resources to address these needs. In the next section, we will discuss the first problem. We will argue that information technology, in many cases, indeed does have the potential to improve research network collaboration. Subsequently, we will describe some of the problems related to the way in which information technology is being applied in research networks once its potential has been established. Finally, we will claim that a specification method for research network information systems can help to structure the development process.

2. The Rationale For Using Information Technology In Research Networks

Some important characteristics of research networks are that they are international, interdisciplinary, and interactive (de Moor 1994). The networks often allow for the collaboration between geographically widely dispersed participants. Many networks also form virtual organizations across disciplines, which is especially important in a time of research spending cuts when obtaining funding for creating new disciplines is ever more difficult. Perhaps most importantly, research networks facilitate a much higher frequency of systematic scholarly interaction than possible in traditional scientific media such as journals. In all of these cases, distributed information technology can be of great help by reducing geographical barriers, permitting the relatively easy creation and modification of organizational support systems, and dramatically increasing the capacity for rapid, large-scale and structured interaction.

Information technology has often been oversold as a productivity increasing miracle cure for all organizational problems (Forester 1992). Admittedly, groupware and other information technology has been used to create some successful on-line communities of scholars organized around common research interests (Harrison and Stephen 1992). The expansion of the Internet allows for such `invisible colleges' to be supported by ever more sophisticated `research environments', consisting of many different kinds of tools and information resources (Foley and Pitkow 1994). Still, these technological opportunities do not have only positive effects: they also create a lot of problems of their own. For example, great care must be taken to prevent the creation of an artificial environment in which the human ability to cope with various situations is reduced to the problem solutions that a computer can arrive at (Krebsbach-Gnath et al. 1987). The interesting thing about groupware in this respect is that it is specifically intended to foster human creativity as much as possible, rather than inhibit it, although it is true that many applications still do not sufficiently realize this ideal. Two of the most salient problems considering the justification of information technology in research networks deserve some further elaboration: the issues of information overload and information control.

2.1 Information Overload

One of the most pressing problems caused by modern information technology is that of information overload. Owing to the rapidly increasing number and connectivity of large databases, computer conferencing systems, World-Wide Web sites, and so on, information chaos is arising. Computer network users, not in the least researchers, are increasingly complaining about not knowing where to even begin looking for what they need because of the overwhelming amount of available sources. Moreover, once potentially interesting information has been located, it is often difficult to interpret and assess its value to the purpose of the user, as it is often badly documented (Chen 1994). To address these information retrieval problems, several technological solutions are being developed, such as better information resource discovery and mediation techniques (Schwartz et al. 1992; Wiederhold 1992). However, these techniques are far from sufficient to reduce information overload, and they probably never will be. Machines will most likely never be able to provide the rich common sense knowledge and subtle associative capacities of human beings.

Fortunately, we can observe an - albeit slow - paradigm change taking place in the information science community. No longer is it trying to build the omniscient `superhuman' computer that the artificial intelligence adepts of the fifties dreamt of. Information science has made a hard landing and has become much more realistic, increasingly seeing the role of the computer as assisting human intellectual production and communication, rather than replacing it. Information technology-supported networks of knowledge workers can be of great importance in reducing information overload, by letting participants systematically evaluate raw information and guiding colleagues to important sources (Jarvenpaa and Ives 1994). Thus, the information technology serving these knowledge workers can be an important instrument to help reduce the quantity and increase the quality of retrieved information, provided that the most crucial evaluations are carried out by the users themselves.

2.2 Information Control

The second issue is that of control. Many fear that excessive power is coming into the hands of those who control the information networks, power which is all too often abused. As Roszak puts it: `If information technology is to be rescued for its most humane uses, one must at some point face the hard, unpleasant fact that the computer lends itself all too conveniently to the subversion of democratic values. This threatening liability arises precisely from what has always been advertised as the technology's greatest power: the ability to concentrate and control information' (Roszak 1986 , p. 179). The classic case where this concentration and control has indeed happened, is in the mass information media, as has been well documented by, for instance, Herman and Chomsky (1988). There are some ominous signs that the same mass media moguls are attempting to take over the computer networks as well (Young 1994). However, this does not necessarily mean that they will also be able to control all the applications that run on their networks. To put it even stronger: distributed information technology, such as mundane unmoderated mailing lists, can be seen as one of the strongest allies in the defence of freedom of expression. It makes it much easier for small groups of people to create their own, uncensored information and communication media which can be used for free but professional discourse (Sachs 1995).

This particular kind of technology is especially important for open research networks. Such networks concentrate on carrying out multiple-perspective, opinion-generating and comparing activities. This includes listing all possible alternative solutions to problems and the context in which these are valid. This is the opposite of closed, often heavily institutionalized research networks, which focus on furthering specific dogmas, and a priori exclude specific viewpoints and approaches that are relevant to the network problem domain. The information technology used by open research networks allows all original opinions to be recorded and commented upon, and permits fair procedural checks and balances to be built in. According to some, such public accountability is systematically undermined in our computerized society (Nissenbaum 1994). Making the use of information technology publicly accountable will of course only be possible if issues such as who has the creation, modification and access rights to information and tools are explicitly considered during the information system specification process. This process will become even more important as the networks move away from simple mailing lists to more sophisticated groupware applications, which are fuzzier and less transparent to their users. These and many related aspects of network strategy are often overlooked by technical information system developers, and provide interesting opportunities for future research by network theorists.

Still, knowing that information technology can be used to support a research network is not sufficient. One also needs to know how it must be applied in a successful way. This, however, is more easily said than done, as we will show in the next section.

3. Generic and Isolated Information Tools: Only the First Step

Currently, most research networks use only a few standard information tools, which do not meet the actual information needs of their users. Furthermore, these tools are not well connected, so that it is not clear how they can cooperate to provide the user with a seamless technological research environment. In this section, we will illustrate some of these problems.

Most research networks that are supported by distributed information technology currently use a simple mailing list as their medium of communication. Discussions are stored in the archives of the mailing list server. The archives can be searched by sending commands and keywords - also by e-mail- to the same server. Two problems arise with respect to the information and communication support provided by this mailing list tool . The first is that retrieving the information produced is a cumbersome procedure, often prohibiting effective access by list members. The second even more important concern is that there is no structured discussion support. Most discussions come and go, and come back. Although often very good ideas are presented by participants, few concrete results materialize from these public exchanges of ideas. It is clear that other technologies are needed to better address the information and communication needs of the network.

Some networks deal with the retrieval problem by installing an information server such as a Gopher or World Wide Web site. These servers provide network members with easily accessible information, such as discussion archives, documentation, and research reports. The information can have many different formats: text, graphics, and sound. Sometimes, even motion video is available, made possible by yet another high technology: multimedia. However, despite the sophisticated formats of this information, there is often no clear link between the information stored in the server and the specific research processes taking place in the network. Furthermore, many times procedures are lacking that determine which privileges and obligations network members have, leaving it unclear who can store, update, access, and annotate which documents. This raises difficult to answer questions like how to determine the quality of the information offered, and what information gaps still exist.

The second problem, how to focus and structure discussions, has been given little attention. True, some existing groupware applications tackle the problem with varying rates of success in the lab environment. One type of groupware-related application especially relevant to the discussion structuring problem is the Issue Based Information System (IBIS) (Kunz and Rittel 1970). The core conceptual categories of an IBIS are issues, positions that can be taken by potentially conflicting parties, and arguments that they use to support their positions or refute those of their opponents. Even though the different systems which we will describe are implemented in very different ways, their basic mode of operation is simple. Users of the system can start a discussion by creating a text file and labeling it as some type of issue to be discussed or as a position or argument that is linked to one or more files that were stored earlier. Other users can then query parts of this document and add their own comments. For example, users can request all supporting opinions on a certain issue, compare the available support for contrasting positions, and so on. This process can be repeated indefinitely. In this way, a structured hypertext document is created which helps the reader to identify questions, develop the scope of positions in response to them, and get involved in discussions (Kunz and Rittel 1970).

Several applications have been developed that incorporate the IBIS concepts in slightly different ways. gIBIS is a graphical hypertext system to be used with rather advanced computer configurations (Conklin and Begeman 1988). HyperIBIS is a simpler version of gIBIS aimed at the low-end PC market. Another characteristic is that it makes explicit distinctions between different types of issues, such as deontic issues (should something be?), factual issues (what is the case?), and instrumental issues (which alternative actions lead to the desired goal?) (Isenmann 1993). One advanced IBIS that was explicitly designed to be used for research purposes is the Scientific Collaboration System (Kim et al. 1993). This system is based on an issue-based collaborative exploration paradigm, and offers extensive techniques for modeling discussions. Another sophisticated system, much further removed from the original robust IBIS paradigm, is the collaborative knowledge construction system CLARE (Wan and Johnson 1994).

Most of the abovementioned systems have only been tested in very restricted environments. After examining the scarce experimental findings of these systems described in the IBIS articles referred to in the previous paragraph, one could conclude that, in the unruly reality of research, not many of them would operate satisfactorily. The reason is that insufficient insight exists into the variables and processes that should configure these applications. Discussion support, especially in the research domain, is a very complex process and hard to automate. In a real-life research network, if there is any discussion support at all, it often depends on human moderators to set agendas, keep discussions focused on a certain topic, make sure that all sides get to state their opinions, summarize results, and so on. Unfortunately, moderators usually cannot devote sufficient time to discussion maintenance. Furthermore, the work is often unrewarding, so ways must be found to delegate these leadership tasks (Thorngate 1985). Despite its shortcomings, information technology such as an IBIS, if properly applied, can be at least of some assistance here, but it is clear that other tools and procedures need to be part of the solution as well.

4. The Need for Comprehensive and Customized Network Information Systems

In the previous sections we have contended that the use of information technology can be justified, provided that its possible social and other implications are thoroughly studied well in advance. Moreover, we have seen that many easily adaptable applications are simultaneously required in order to address all the information needs of the network. Much more could have been said about the design and implementation of these tools, but their specifics are not relevant for the purpose of this paper. The important point is that offering a number of isolated tools that are not tailored to the requirements of the users will not be able to satisfy the many information needs of a research network.

Many groupware designers still tend to be fascinated with the creation of ever more advanced technological features, seemingly for features' sake only. Most groupware applications are still built from this technological perspective, while the real focus should be on the kind of cooperation being undertaken (Rodden 1991). Even when application developers manage to transcend this tool-focused level, much groupware is still either very limited in scope and only applicable in artificial and restricted work environments, or it is so general that users are not given enough guidance in determining how the potentially present functionality may suit their purposes. Furthermore, the groupware is frequently not well enough integrated with other types of applications, such as databases. Thus, implementing information technological support by means of a set of inflexible, independent tools and information resources is not sufficient to adequately deal with these problems of lack of functionality, customizability and integration.

To really be able to solve these problems we need to focus our attention on to the next stage in the information technology for research networks evolution. A research network needs a comprehensive, customized network information system which combines and configures various tools according to the ever changing network information needs. Here, we are not talking about the traditional, fixed kind of information system, consisting of rigid, predetermined collections of hard- and software, which can perform only a standard number of tasks. Instead, the information system should be regarded as a semi-formal system, which formalizes some, but not all, of the processes and information relevant to people acting in a given situation. In such a flexible system, not only the information objects, but also the processing rules must be visible to and modifiable by the users to a great extent (Lai et al. 1988). Thus, the network participants need to play many roles, not only using but also being responsible for at least part of the development and maintenance of the information system facilities. In other words, the information system can be regarded as a dynamic set of modular, actor-initiated information and communication processes, including those that modify other processes. These processes (and their accompanying data sets) can be implemented on various, interconnected information technology platforms. This leads us to the following definition of a network information system:

Network information system (NIS): a set of meaningfully combined and configured information and communication processes necessary to support and coordinate the activities of the network participants in their various roles.

5. Structuring the Information System Development Process

Good NIS do not emerge spontaneously. The early stages of complex information system development, namely requirement analysis, specification, and high-level design, are often dealt with in a very unstructured way. A formal method structuring these stages can help create considerably better information systems (Cohen 1989). Therefore, an effort must be made to develop such a specification method for research network information systems.

In the previous section we saw that for a network information system to be truly useful, its development, and thus its specification method, must be user-driven. Furthermore, using this approach as a foundation for the method is not only important for improving the efficiency of the development process, but also for dealing with the information control and overload problems discussed in section 2.

So far, many distributed information systems have been centrally owned by large bureaucracies. However, this leads to the legitimate concern that the one who exercises control over the information technologies does this as a precondition to exercising control through them (Clement 1994). This centralized approach cannot be used in open research networks if information control problems are to be prevented. Consequently, a basic principle that should underlie the specification method is that the network participants themselves should be able to use this method to develop and maintain their information system. Instead of being forced to accept incomprehensible systems or to depend on unsatisfactory mediation by information system professionals, such an approach will empower users by giving them a greater sense of mastery (Shneiderman 1990).

Not only does this user-control principle allow participants to more effectively deal with information control problems, it can also help them reduce the dreaded information overload. To accomplish this, computer-mediated communication systems must be structured by their users according to their needs and abilities, rather than through general software features (Hiltz and Turoff 1985). This means that the method needs to allow network participants to continuously update the specifications of their information needs, in their own terminology rather than in some arcane low-level computer language, and help them to match these needs with available information and technology resources. Of course, this principle does not always work well in practice, as the theory of user-driven specification methods is still in such a rudimentary stage. However, interesting developments are going on in evolutionary systems development and many related theoretical fields (Orman 1989; Arthur 1992), which should provide us with at least some of the building blocks necessary for the construction of a viable method.

Several important questions need to be answered before the required specification method can be constructed. They can be subdivided into two different groups. The first class of questions deals with the modeling of realistic research network problem domains and organizational structures. Important questions are: What are the characteristics of professional research cooperation? What are research networks and how can they be used? What are typical activities within the various types of research networks? How do research networks interact with their environment? Specifically, how do they cooperate and align their activities with other research networks? How do research networks set their goals, divide tasks, and generate and allocate resources? What human actor roles are involved in developing, maintaining, and using research networks? All of these questions are only beginning to be asked, let alone addressed. However, it is not information scientists, but rather sociologists of science, organizational scientists, and, last but not least, the network participants themselves who should work out these issues. The role of information scientists here concerns formalizing the models defined by research network specialists, not doing the actual modeling.

The second set of questions deals with the information system itself and the method used to create it. Once we have better models of research networks, their activities, and their organization, we can use that knowledge to determine the characteristics of the required information systems. What categories of information systems are useful for which types of research networks? What is the required functionality of the network information system? What are the components of such a system? Finally, knowing about the requirements of such a system, we need to look into the actual development method. How can the information and communication needs of a research network be more systematically analyzed? How can the results of this analysis be used to generate the specifications of the required network information system? How can these specifications be matched with abstract representations of existing information tools so that flexible, modular information systems can be created quickly?

Work on the development of RENISYS, a Research Network Information System Specification Method, has just started (de Moor and van der Rijst 1995; van der Rijst and de Moor forthcoming). Many of the questions posed here will be addressed in the near future.

6. Conclusions

Information technology has considerable potential for changing work practices in research networks for the better. To realize this potential, we must find ways to harness the raw power of current information tools and resources into streamlined, integrated information systems.

Current information tools often still force their users to adapt their information needs to the available information technology, rather than the other way around. We therefore strongly advocate the conceptual separation of network information system specification from tool development. To this end, a user-controlled research network information system specification method can prove to be of value. This allows users to control the development process, instead of being controlled by it.

We are aware that this paper has only superficially touched upon some of the many pitfalls that one encounters when trying to promote socially responsible information system development for research networks. We therefore challenge sociologists to help us by clearly defining the social dangers and opportunities of information technology. We will try to incorporate these recommendations in formal methodological requirements and constraints. This may help to make information system development methods more explicitly sensitive to the social consequences of their use.

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