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COMPUTER-MEDIATED COLLABORATION: A PCP APPROACH

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We have moved from an era of batch processing to one of highly interactive computing through timesharing and networked personal computing, but applications software is generally still targeted on supporting individual rather than group processes. Research on computer-mediated collaboration seeks to change this situation by developing systems to facilitate collaborative activities, the formation of mutual knowledge and the exchange of mental maps. Personal construct psychology provides theoretical and applied frameworks and tools to support computer-mediated collaboration on a principled basis. This paper gives a theoretical analysis of the knowledge structures of groups that encompasses that of individuals, and individuals as parts of groups. It uses this to develop a methodology for group knowledge elicitation and the analysis of consensus, conflict, correspondence and contrast in concepts and terminology. Finally, a group knowledge elicitation and modeling tool is presented that integrates existing knowledge elicitation methodologies with electronic mail. It is proposed that such tools are a logical extension of the use of electronic mail to coordinate group activities, and can be used to facilitate computer-mediated collaboration in a wide range of activities.

INTRODUCTION

Historically, interactive computer systems have been used primarily to support individual users either working at their "personal computers" or having "time-sharing" access to a central system. Even as personal workstations became "networked" the primary focus was to share resources, such as software, storage and printers, rather than to promote social "networking" between users. In the mid-1980s the growth of the Internet as a worldwide communication system supporting electronic mail and access to active shared resources began to change perceptions about the use of networks, and computer-mediated collaborative activities began to become of major interest. We had moved from an era of batch processing to one of highly interactive computing through timesharing and networked personal computing, but applications software was still targeted on supporting individual rather than group processes. Collaborative use of networks is now recognized as a major applications domain and research topic (Greif, 1988; Bannon, Robinson and Schmidt, 1991; CSCW, 1992).

Understanding and facilitating normal human collaboration involves many deep psychological, cultural and sociological issues. Personal construct psychology (PCP) emphasizes the personal nature of individual construction systems and sees communication and coordination between individuals as requiring modeling in terms of the relations between individual construction systems. PCP provides a basis for modeling cultural mechanisms that lead to correlations between individual construction systems through processes of socialization that lead to individuals playing *roles* in communities (Shaw, 1985). Repertory grid elicitation and analysis in group situations may be used to operationalize such models and facilitate collaborative activities by making overt unrecognized differences in the construct systems of the participants (Shaw and Gaines, 1989).

Developers of computer-mediated collaboration systems have come to recognize the need to understand, instrument and model the "mutual knowledge" (Krauss and Fussell, 1990) or "mental maps" (Day, 1994) of participants. Networked computer systems also provide an opportunity to deliver PCP tools that were developed for off-line analysis of group processes and relationships (Shaw, 1979; Shaw, 1980) in an interactive, partcipatory environment (Shaw and Gaines, 1993). The studies reported in this paper are part of an attempt to move computer-based techniques for supporting the analysis of group cognitive processes and decision-making from being specialist applications, typically used once in studying or supporting a group, to becoming a routine enterprise support tool.

Electronic mail has been taken as a starting point because: first, it is already widely used within organizations on a routine basis (Kerr and Hiltz, 1982; Quarterman, 1990)—a logical, and psychologically harmonious, extension to email is far more likely to be accepted and used routinely than a new application where a major decision has to be made about use; and second, human discourse is an essential process in the formation of functional groups within society that is supported at a very basic level by email. The objective of the research reported is to use PCP to extend the support of discourse through tools that make conceptual models more overt as an aid to mutual understanding—what Habermas (1981) has termed "communicative action."

This paper reports some preliminary experiments on the integration of knowledge acquisition with an electronic mail system to support functional groups within an enterprise, and the structured development and exchange of knowledge in such groups.

UNDERLYING COGNITIVE AND SOCIAL THEORY

With the power of current technology it is easy to create impressive systems that are not psychologically and socially functional because they do not mesh with human socio-cognitive processes. On the other hand, there is no widely agreed model of the underlying dynamics of such processes—cognitive and organizational psychology research is an area of explosive growth undergoing as rapid a change as computing technology (Gaines, 1991a), particularly as our understanding of the modern era is enhanced by post-modern perspectives (Heller, 1990). This section outlines the theoretical perspectives underlying the system development reported in this paper.

There are three basic premises underlying our work: that knowledge processes in society can be understood as the modeling procedures of a distributed anticipatory system; that

these modeling procedures can themselves be modeled in terms of the distinctions made; and that the cognitive processes of individuals and organizations can be understood within this framework (Gaines, 1989). Simmel made this inter-relation of wholes and parts the center piece of his sociology:

> "Society strives to be a whole, an organic unit of which the individuals must be mere members. Society asks of the individual that he employ all his strength in the service of the special functions which he has to exercise as a member of it; that he so modify himself as to become the most suitable vehicle for this function....man has the capacity to decompose himself into parts and to feel any one of these as his proper self." (Simmel, 1950, pp.58-59)

Simmel's insight that the group member is always a fragment of a person, a role created precisely to enable the person to enter the group has been developed extensively by Wolff with his notions of *surrender* and *catch*:

> "From the standpoint of the world of everyday life, the mathematician, as we often put it, lives in the 'world of mathematics', dealing with 'nonreal' elements, notably numbers, whose relation to 'real' things, to 'reality', is not part of his concern. Analogously for the logician. What makes our subject-object approach to this attitude misleading is the fact that the subject, the student of mathematics or logic—his or her individuality, including motives and attitudes—is irrelevant for our understanding; the only thing that counts is the pursuit, with its results and questions." (Wolff, 1976, pp.162-163)

He makes the key point that not only does the real world, the object, disappear to be replaced by the world of mathematics, but also that in entering into this world the person doing mathematics, the subject, also disappears to be replaced by a new entity, the mathematician.

Wolff was not alone in these insights and there are two further models which develop and complement his. In terms of his "subject" Pask's (1975) concept of "P-individuals" as coherent psychological processes capable of engaging in conversations is a useful representation of the results of Wolff's "surrender", particularly when we note that several P-individuals may execute within a single processor. Thus 'the mathematician' may engage in conversation with 'the physicist' or 'the statesman' all of whom happen to use the same brain for their processing. In terms of Wolff's "object", corresponding to our notions of "knowledge", Popper's (1968) concept of a "third world" of "statements in themselves" is a useful representation of that which we "catch", particularly when we note its distinct ontological status:

> "I regard the third world as being essentially the product of the human mind. It is we who create third-world objects. That these objects have their own inherent or autonomous laws which create unintended and unforeseeable consequences is only one instance (although a very interesting one) of a more general rule, the rule that all our actions have such consequences." (Popper, 1974, p.148)

Pask goes beyond Simmel in conceiving that a P-Individual is not just what we conventionally term a 'role' within a person (which he terms an M-Individual, or mechanically characterized individual) but may itself be composed of a number of roles coming together to form a unity that we conventionally term a group or organization:

> "a P-Individual...has many of the properties ascribed by anthropologists to a role, in society or industry, for example. A P-Individual is also a procedure and, as such, is run or executed in some M-Individual, qua processor. However, it is quite exceptional to discover the (usually assumed) one to one correspondence between M-Individuals and P-Individuals." (Pask, 1975, p.302)

Shaw (1985) has developed Pask's notions within the framework of personal construct psychology to show how Kelly's cognitive psychology may be used to account for the psychological processes not only of individual people but also for that of functional groups such as a nuclear family or a product executive. Figure 1 illustrates these ideas. Anne is shown as having three roles, wife, mathematician and technical vice president. John is also shown as having three roles, husband, golfer and sales vice president.

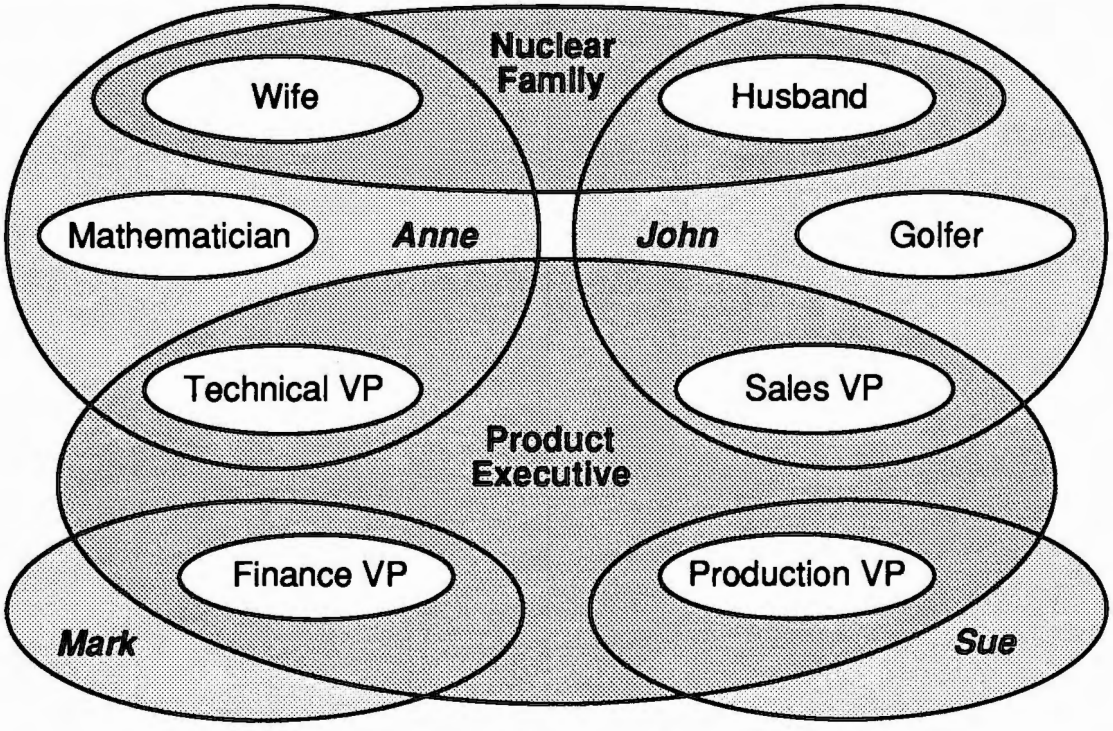

Fig. 1 Roles and groups as psychological individuals

The wife role in Anne together with the husband role in John together constitute a cognitive entity, a nuclear family. This has behavior, language, legal rights, and a model of the world, that are distinct from those of Anne and John in their other roles, and goes beyond those of the participating roles in Anne or John alone. Similarly, the technical VP role in Anne, the sales VP role in John, the finance VP role in Mark and the production VP role in Sue constitute another cognitive entity with behavior, language, rights and models that are distinct from those of its participants and of other cognitive entities in which they participate in other roles.

Switching from socio-cognitive theory to computer technology, we can see email as providing a communication channel for discourse between the individuals involved. However, it provides no structures other than linguistic communication for supporting the cognitive processes underlying that discourse. For example, how do the concepts and terms used by the technical VP in discussing the rationale for a new product relate to those of the sales VP? They may be using the same term for different concepts. They may use different terms for the same concept. They may have terms and concepts in their particular roles that are part of what that role peculiarly contributes to the group cognitive entity, and are not understood by the others involved. In an offline context, there are interactive computer-based tools specifically designed to elicit, analyze and present such conflicts,

correspondences and contrasts in a group decision support framework (Shaw and Gaines, 1989). However, as noted above, they are used for specific 'studies', not as a routine part of the discourse and decision process. It is interesting to investigate what will happen if such tools are integrated into routine enterprise communication.

The theoretical foundations for developing eliciting, analyzing and comparing the conceptual frameworks of the cognitive entities in Figure 1 is derived from the notion that concepts correspond to terms applied to *distinctions* made in modeling a world:

> "a universe comes into being when a space is severed or taken apart...By tracing the way we represent such a severance, we can begin to reconstruct, with an accuracy and coverage that appear almost uncanny, the basic forms underlying linguistic, mathematical, physical and biological science, and can begin to see how the familiar laws of our own experience follow inexorably from the original act of severance." (Brown, 1969)

Personal construct psychology notes that distinctions used by people often occur as a disjoint pair of concepts termed a *construct,* and that Brown's program of reconstruction is carried out using a technique termed the *repertory grid* to investigate the constructs used by an individual in a role (Shaw, 1980).

ELICITING AND COMPARING CONCEPTUAL MODELS

Repertory grid elicitation is an effective method for eliciting conceptual models in a domain (Gaines and Shaw, 1980; Shaw, 1980), and has been widely used in management, education, clinical psychology and the development of knowledge-based systems (Shaw and Gaines, 1983; Boose, 1984; Boose, 1986; Shaw and Gaines, 1987). It is an extensional approach in which individuals are asked to specify a set of entities in a domain, then make distinctions among them, naming the distinctions and classifying all the specified entities in terms of them.

The distinction determined in this way is an approximation to the underlying concept since critical entities may be missing. However, computer-based elicitation techniques attempt to prompt the individual for additional entities to discriminate between extensionally related distinctions (that is, making the same, or similar, classifications). Group comparisons, as discussed in this paper, have similar dynamics—an extensionally apparent correspondence may be accepted or rejected, and the rejection may be based on the specification of additional entities as counter-examples.

The set of distinctions made by a person in a role, and the relations between them, characterizes the conceptual models used by the person in that role. In comparing conceptual models between different roles and different people, there are two significant dimensions of comparison: one of the distinctions themselves, do they use equivalent distinctions; and one of terminology, how are the distinctions named?

Figure 2 shows how these dimensions combine to give four different relations between concepts: *consensus* arises if the conceptual systems assign the same term to the same distinction; *conflict* arises if the conceptual systems assign the same term to different distinctions; *correspondence* arises if the conceptual systems assign different terms to the same distinction; *contrast* arises if the conceptual systems assign different terms to different distinctions.

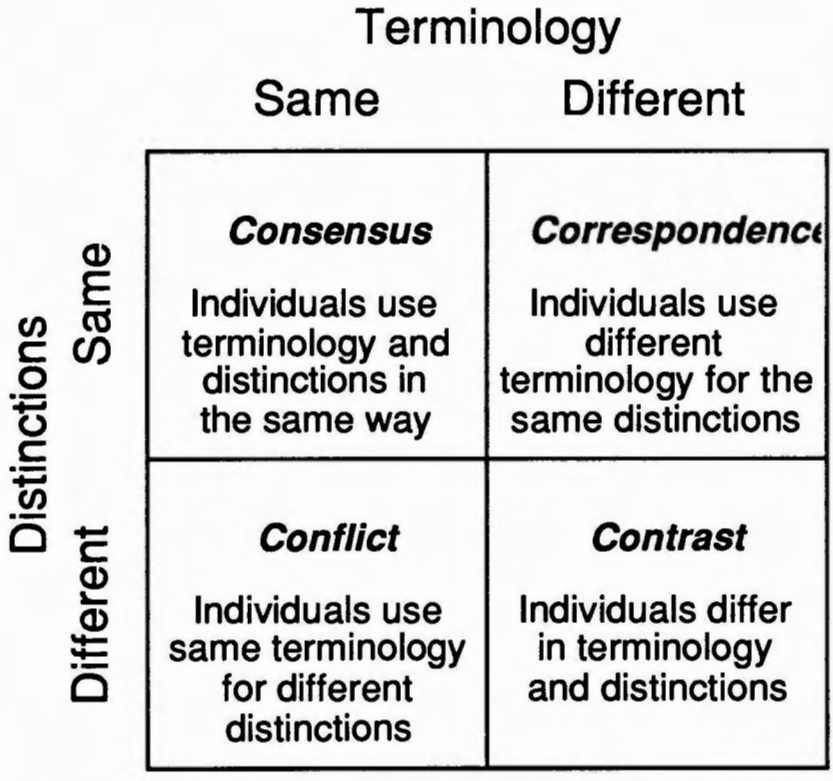

Fig. 2 Comparing terminology and distinctions

The recognition of consensual concepts is important because it establishes a basis for communication using shared concepts and terminologies. The recognition of conflicting concepts is important because it establishes a basis for avoiding confusion over the labeling of differing concepts with same term. The recognition of corresponding concepts is important because it establishes a basis for mutual understanding of differing terms through the availability of common concepts. The recognition of contrasting concepts is important because it establishes that there are aspects of the differing expertise about which communication and understanding may be very difficult, even though this should not lead to confusion. Such contrasts are more common than is generally realized. For example, one may derive the same theorem in mathematics either by using an algebraic perspective, or a geometric one. There is nothing in common in these approaches except the result. It may still be possible to discuss the same domain using consensual and corresponding concepts that were not fundamental to the problem solving activities.

We have previously developed computer-based interactive tools for the elicitation, analysis and comparison of conceptual structures using repertory grid techniques (Shaw, 1980; Gaines and Shaw, 1989; Shaw and Gaines, 1989). *RepGrid* is a knowledge support system providing an integrated set of tools for elicitation and analysis of elements and constructs in a given domain. It combines a number of different techniques, including element and construct elicitation and clustering, and is linked to an inductive rule generation program. It runs on the Apple Macintosh to provide a highly interactive and graphic knowledge acquisition environment. At the heart of RepGrid is an object-oriented knowledge base in which knowledge is formally represented as a multiple-inheritance digraph of classes, objects and properties (Shaw and Gaines, 1992).

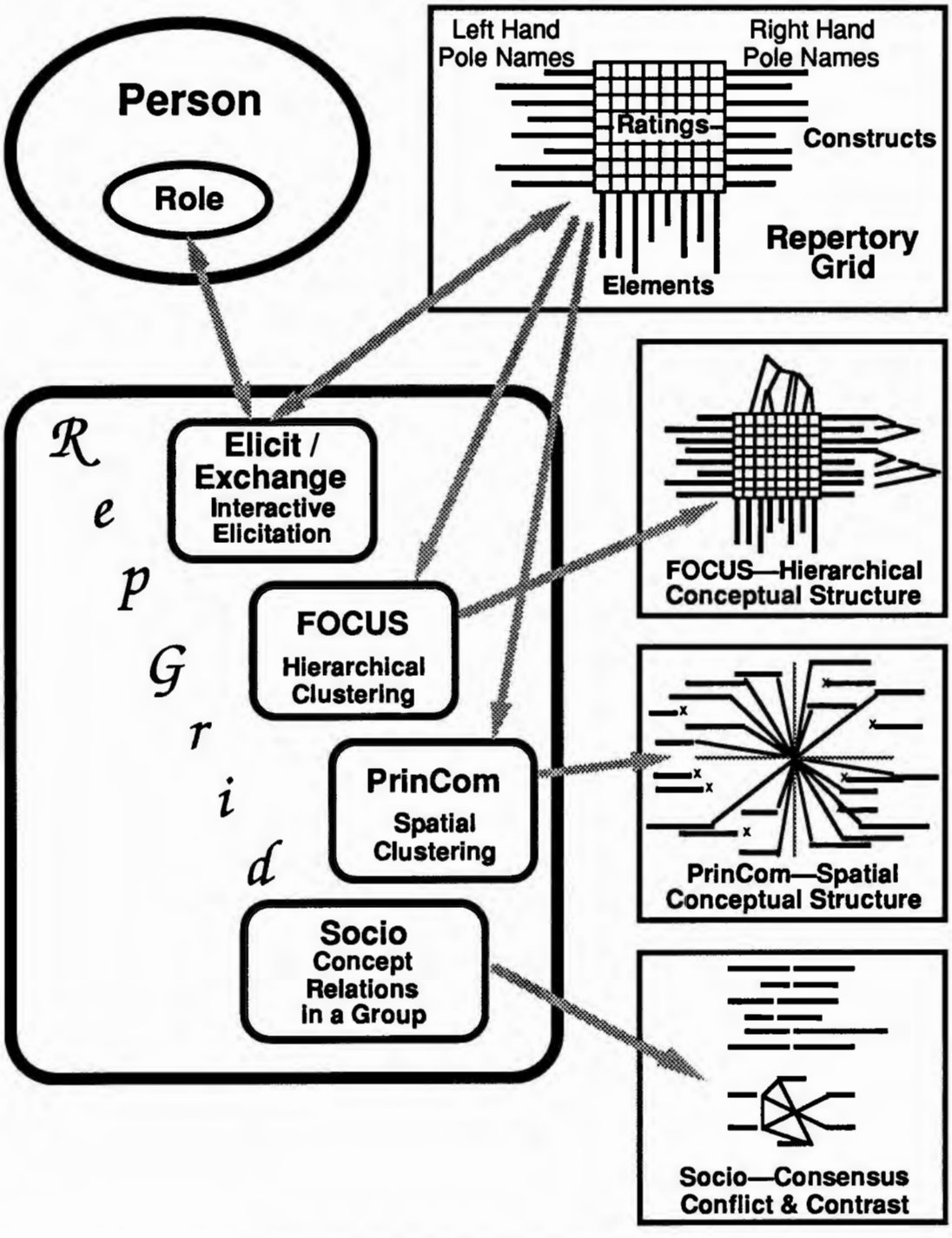

Figure 3 RepGrid Functionality

The main tools in RepGrid are shown in Figure 3:

- *Elicit* accepts specifications of elements within a domain and provides an interactive graphical elicitation environment within which a person can distinguish elements to derive his or her constructs within the domain. The resultant conceptual system is analyzed to provide feedback prompting the person to enter further elements and constructs.

- *Exchange* extends this to share elements and constructs between people and allows the terms in the conceptual system derived from one person to be used by another in order to determine whether the two conceptual systems are different in any way. It can also be used by the same person looking at changes in their own conceptual structures over time.
- *Process* gives access to clustering tools for the analysis and display of the conceptual systems elicited: FOCUS shows the system as a hierarchical structure; and PrinCom as a spatial map.
- *Socio* processes results from several people to reveal the similarities and differences in their conceptual systems, or the same person at different times, construing a domain defined through common elements or constructs. It can be used to focus discussion between people on those differences between them which require resolution, enabling them to classify them in terms of differing terminologies, levels of abstraction, disagreements, misunderstandings, and so on.

RepGrid is scriptable through the Macintosh System 7 inter-application protocol, and this has been used to integrate it with an email system to develop RepGrid-Net as described in the following section.

REPGRID-NET: A NETWORKING SUPPORT SYSTEM

RepGrid-Net is a computer-based message system that integrates conventional electronic mail and bulletin board facilities with the repertory grid elicitation and analysis facilities described above to provide both unstructured and structured communications supporting the formation and operation of special-interest networks. Users see a mail system in which special-interest groups are specifically supported.

The coordinator of a special-interest group provides a basic focus for it through statements of intent, topics and issues which are handled on a bulletin board basis. He or she also provides one or more kernel grids listing specific topics and the concepts which they apply to them. These kernel grids can be developed by others interested in the groups, using the stated topics and concepts, and adding to them.

General similarities between grids are analyzed to provide a socionet of people with common viewpoints, and this may be used to access the mail system to communicate with them. Detailed comparisons of similarities and differences between viewpoints may be made, and individual concept structures can be analyzed. The elicitation and analysis facilities are all highly graphical, designed to be easy and interesting to use.

Figure 4 shows the overall systems architecture. The message sub-system is written in HyperCard and is conventional in its operation. Users register with the system and may access lists of those with mailboxes registered on the system, lists of incoming mail and confirmations that outgoing mail has been accessed (see Figure 9). They may prepare and send mail, and receive and reply to mail. The special interest group sub-system is described in detail in the next section. It handles the group bulletin board and grid elicitation and analysis. The integration sub-system manages the interactions between the other two sub-systems, for example, that the graphic displays of networks of people with common interests may be used to send a message to one or more of them.

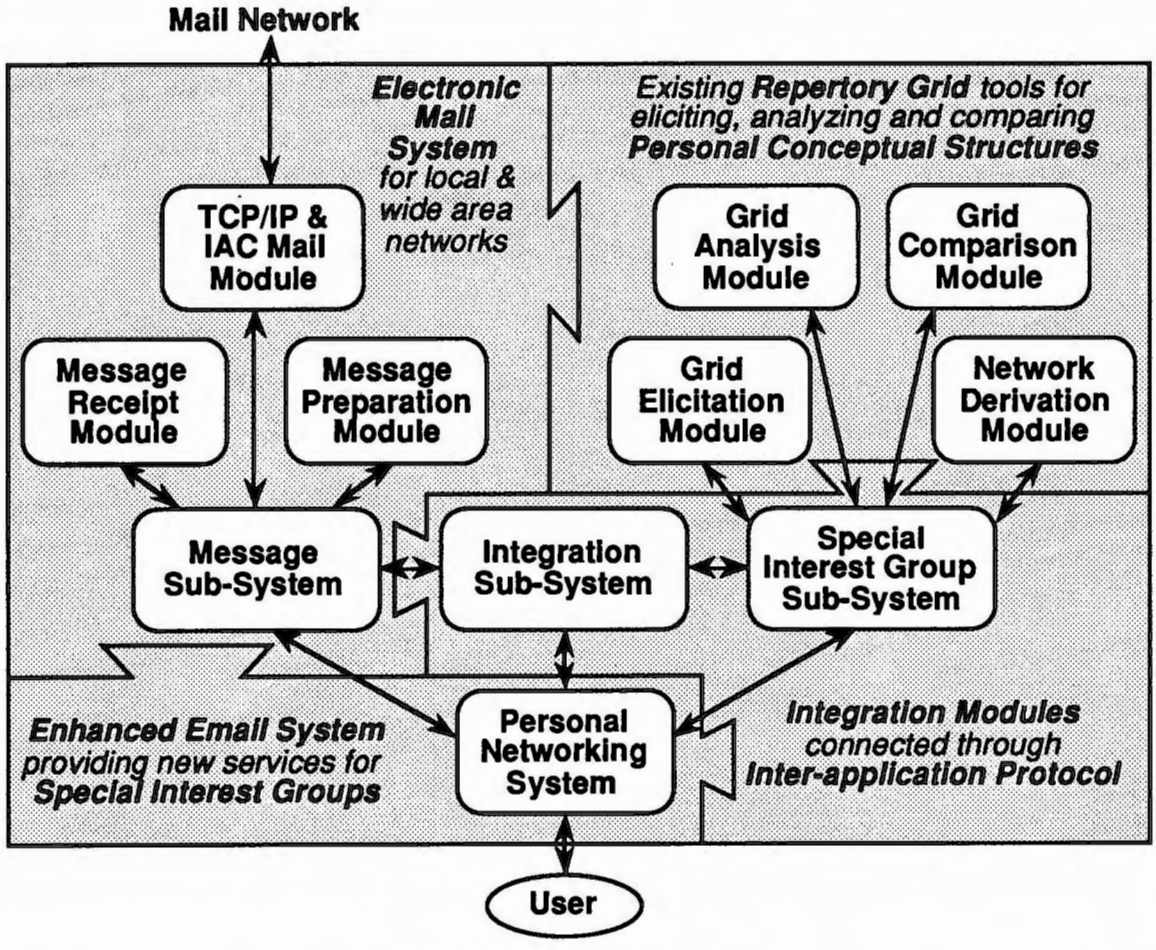

Fig.4 System architecture

RepGrid-Net is implemented on a network of Macintosh computers coordinated either through the internet using the Unix SMTP and POP3 mail protocols, or through AppleTalk access to a mail system on an AppleServe file server. Users see a conventional Macintosh program interface at all times and, even though two distinct programs are running, they communicate through inter-application protocols in such a way that there appears to be only a single application.

SYSTEM OPERATION

This section is based on a study of characteristics of a healthy relationship across people in a small group of therapists specializing in marital counselling. One of the counsellors has already entered a kernel grid on "the characteristics if a healthy relationship". The participants are Alan, Linda and Cynthia.

We will go through a sequence of Linda's interaction with the system. She sees the screen of Figure 5 at login.

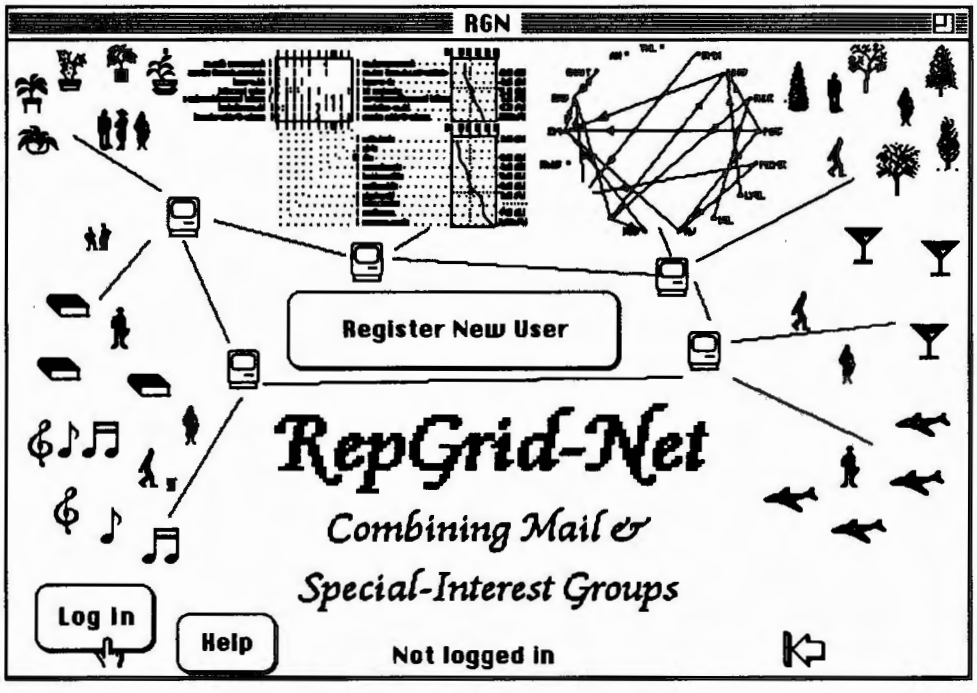

Fig.5 Initial login screen

Linda selects "Log In" and goes to the screen shown in Figure 6.

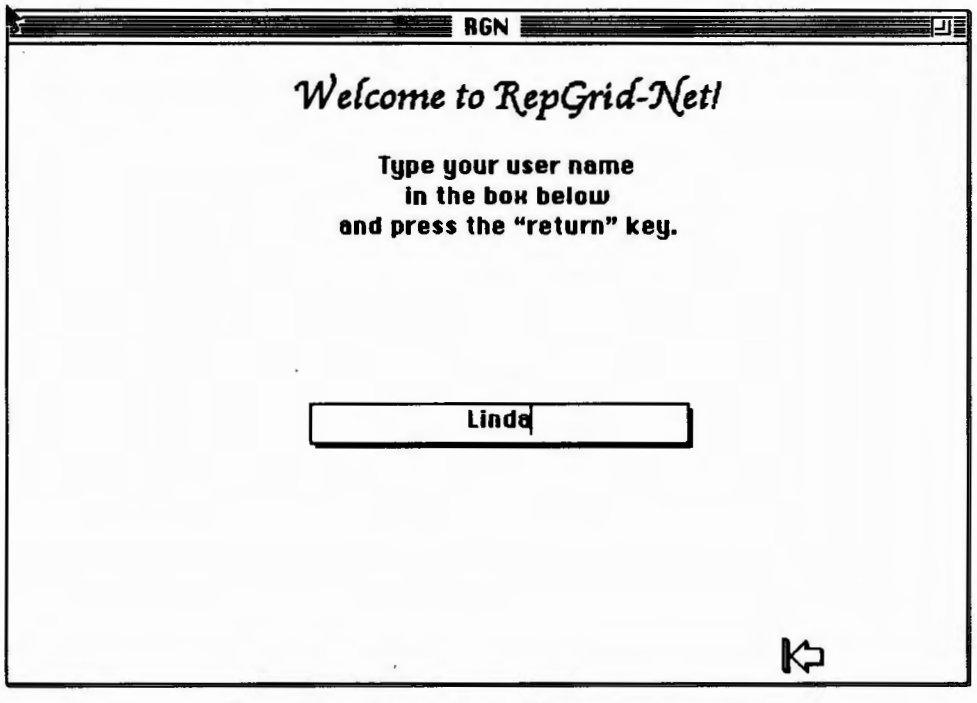

Fig.6 Log in and registration screen

She types in her name, logs in and goes to the screen shown in Figure 7.

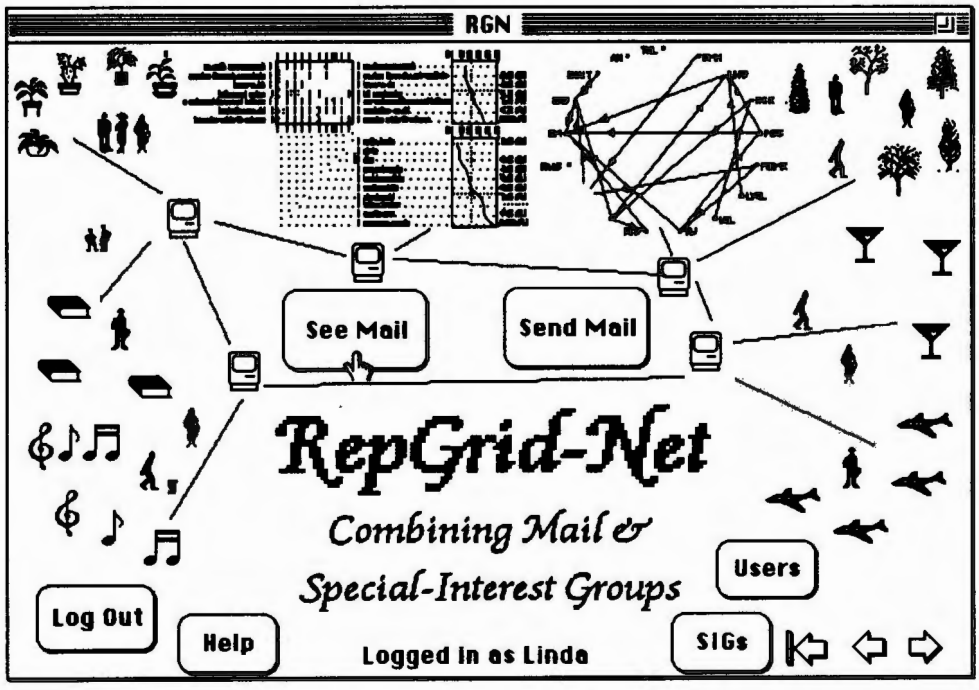

Fig.7 Main access to functionality screen

Linda selects "See Mail" and goes to the screen shown in Figure 8.

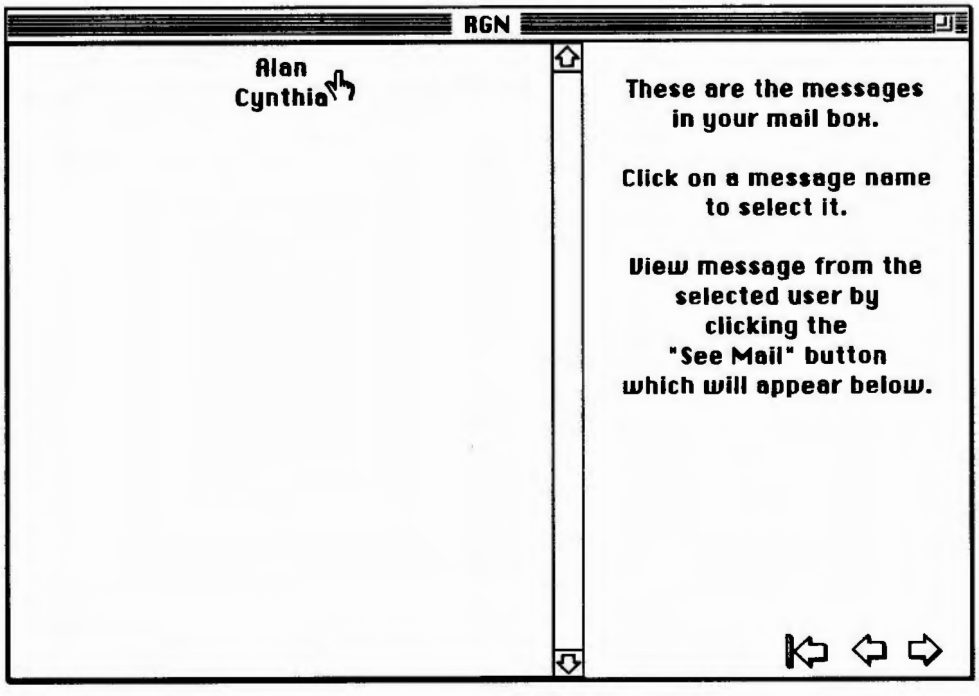

Fig.8 List of incoming mail screen

She clicks on "Alan" to access the mail and goes to the screen shown in Figure 9.

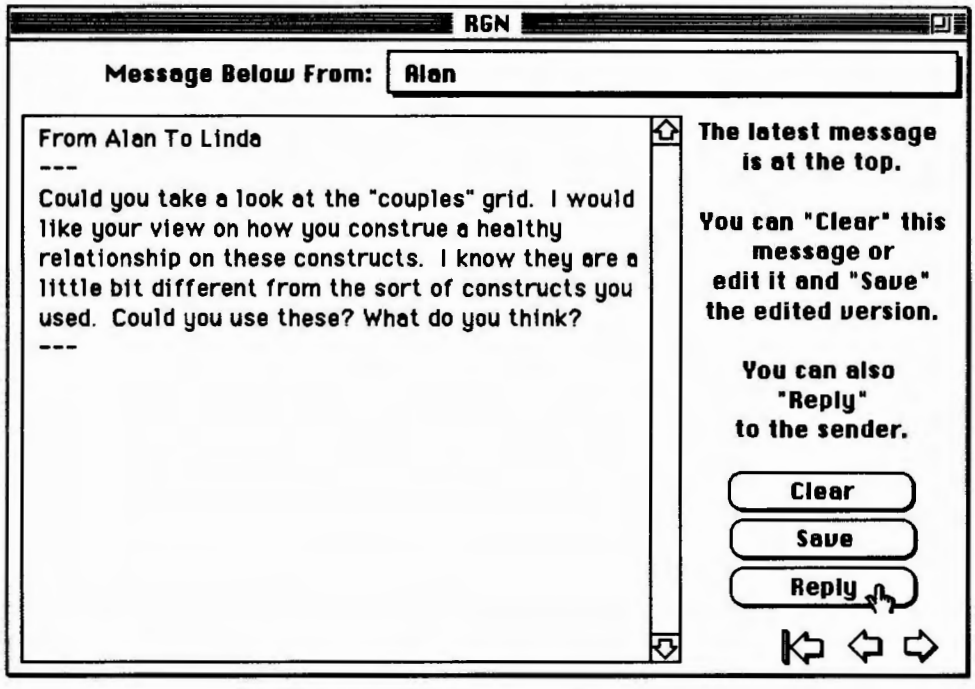

Fig.9 Incoming mail screen

Linda selects "Reply", goes to the screen shown in Figure 10, and types a reply.

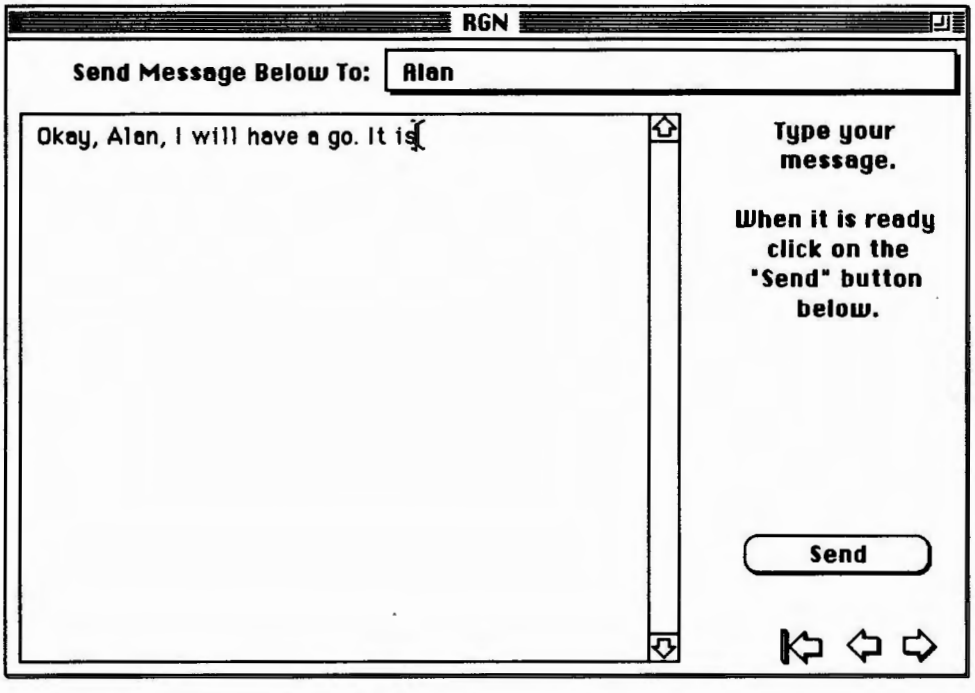

Fig.10 Outgoing mail screen

She selects "Send", returns to the screen shown in Figure 5, selects "SIGs", and goes to the screen shown in Figure 11.

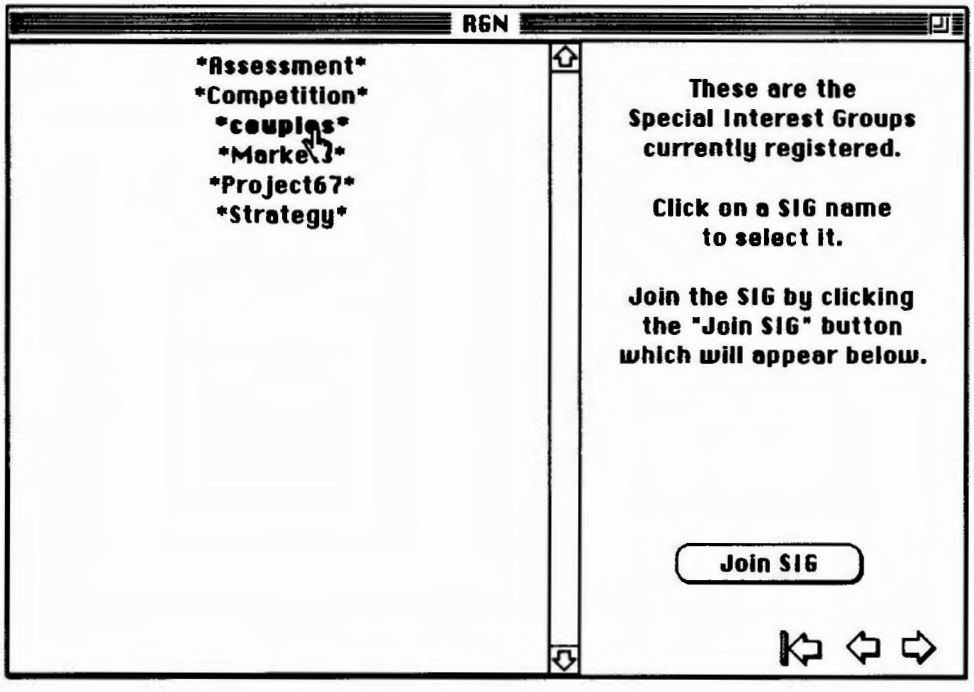

Fig.11 List of special interest groups screen

Linda clicks on "couples" to access the specialist group concerned with marital counselling and goes to the screen shown in Figure 12.

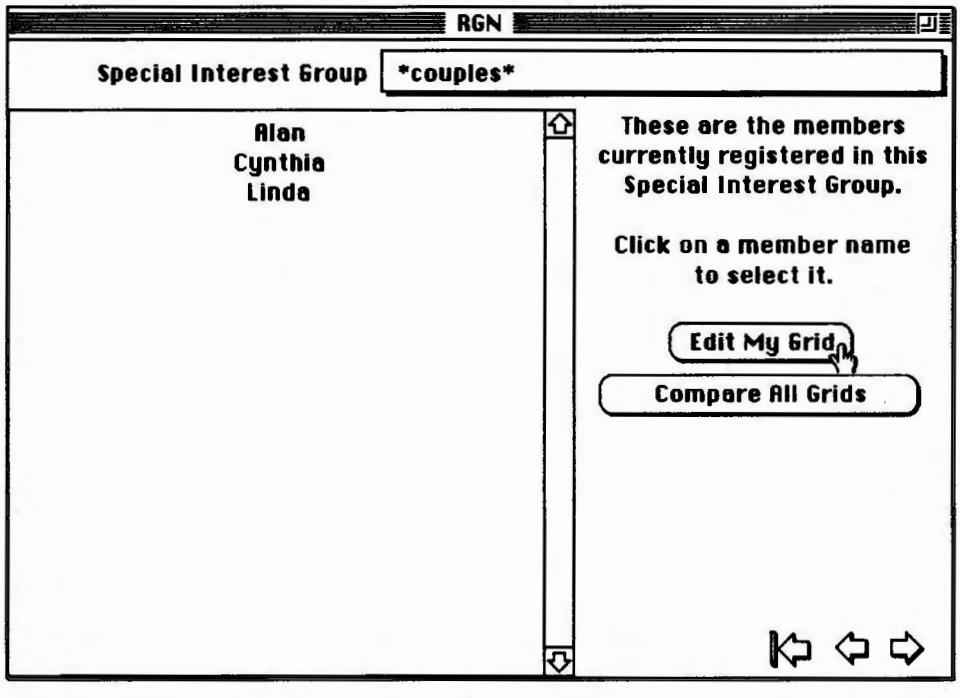

Fig.12 List of Project67 SIG members

She selects "Edit My Grid" and goes to the screen shown in Figure 13, accessing a grid she has already entered using the elements and constructs of Alan.

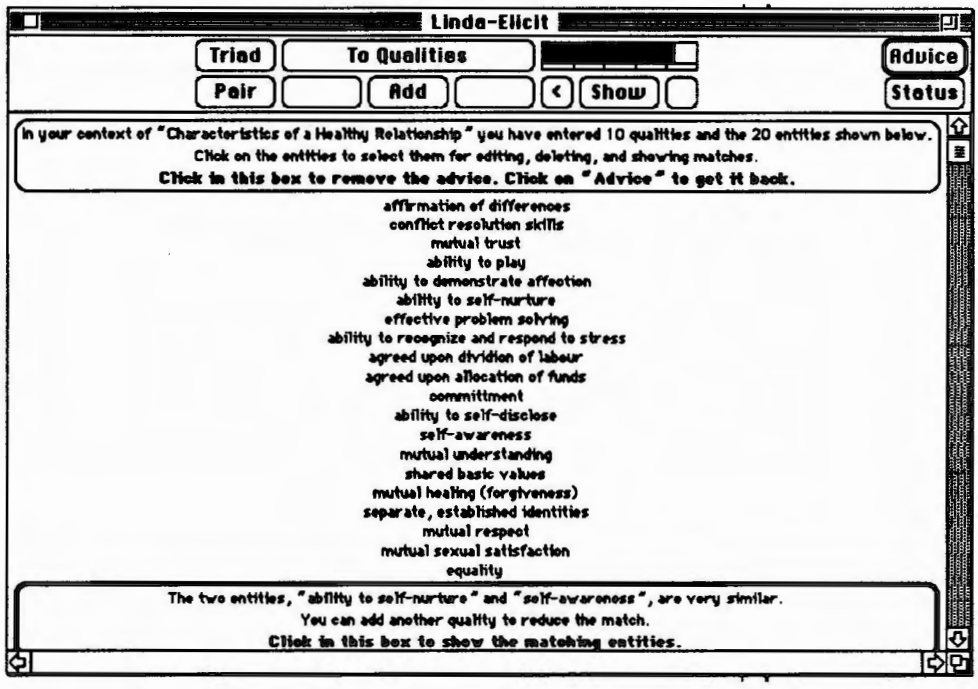

Fig.13 Repertory grid entities screen

Linda clicks the button at the bottom of the screen, and goes to the next one shown below.

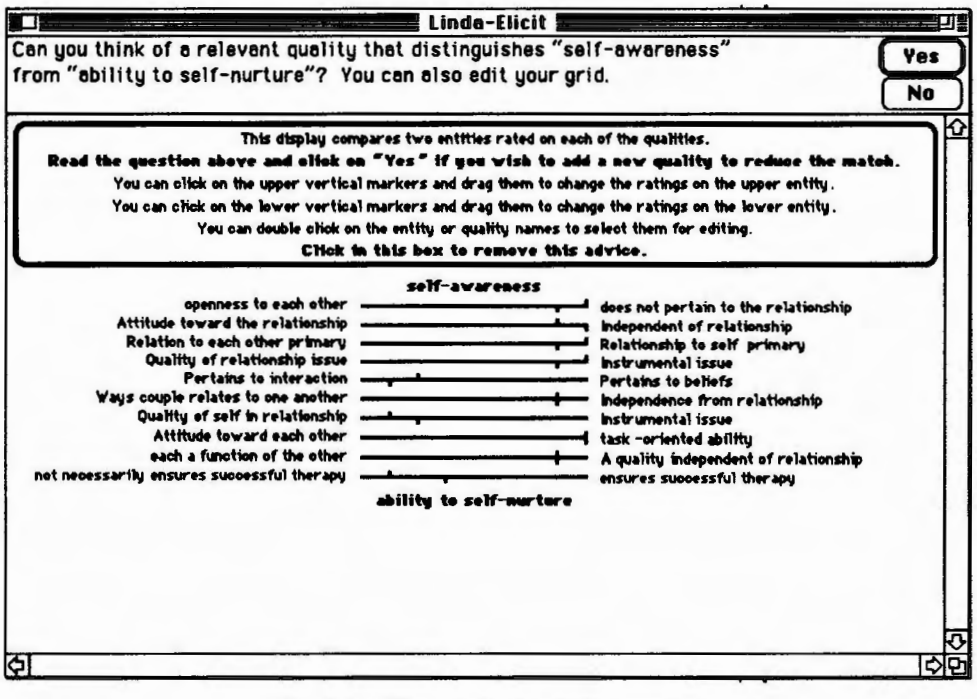

Fig.14 Element match screen

She selects "Yes" and goes to the screen shown in Figure 15.

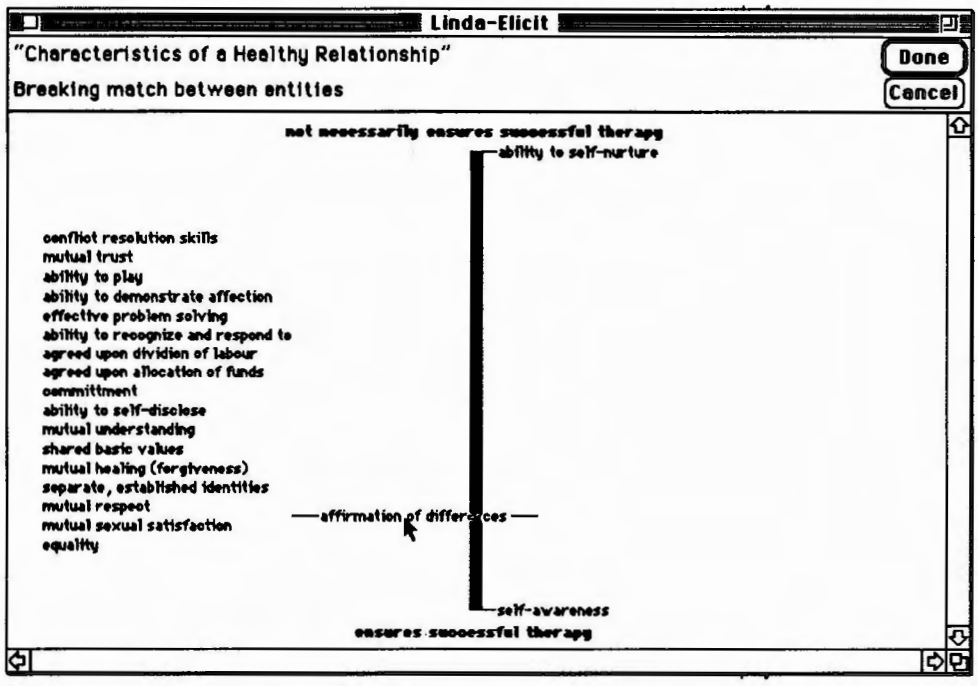

Fig.15 Element rating screen

When she has finished editing the grid, she returns to HyperCard as shown in Figure 16.

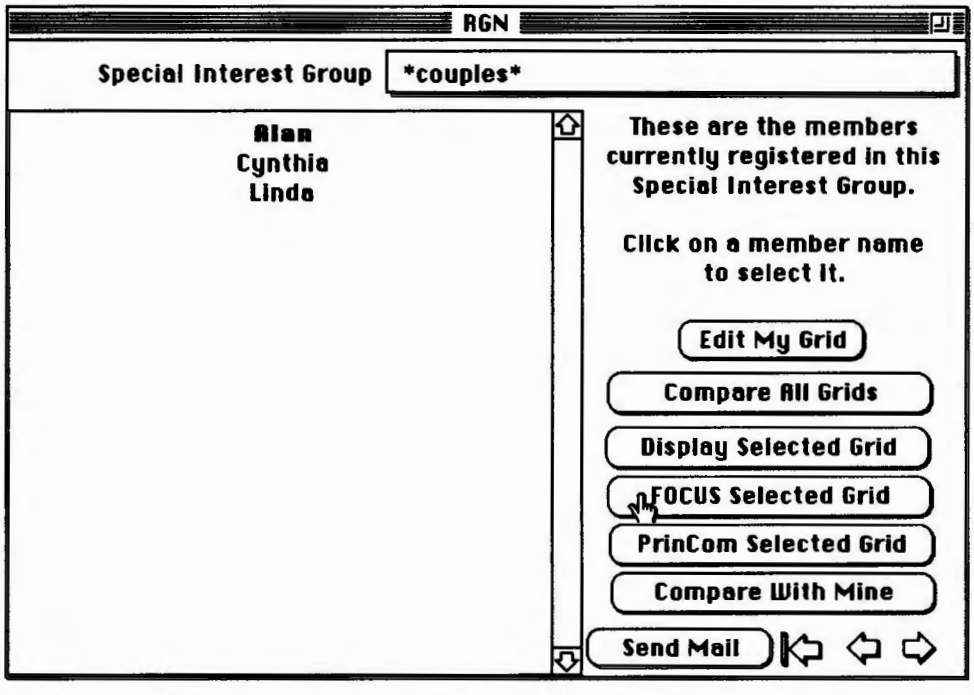

Fig.16 Grid analysis functionality screen

She clicks on "Alan", selects "FOCUS Selected Grid", and goes to the screen shown in Figure 17. This clusters Alan's grid and she can see that for him there are three major entity clusters.

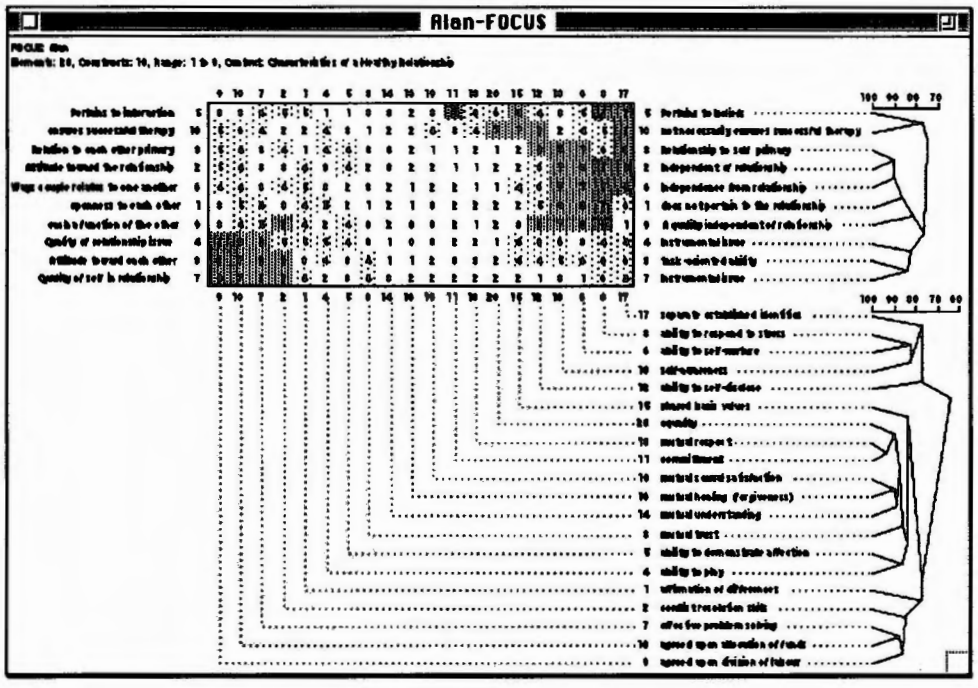

Fig.17 FOCUS cluster analysis screen

Linda returns to HyperCard, selects "Compare with Mine" and goes to the screen shown in Figure 18.

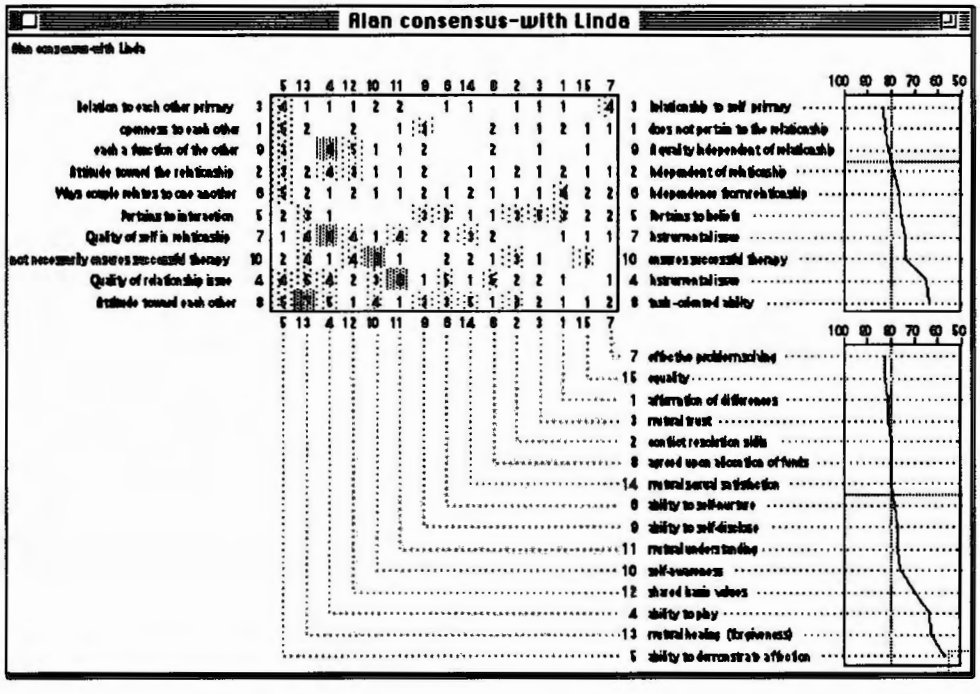

Fig.18 Grid comparison screen

From the comparison, it seems that she and Alan agree on the top three attributes, *relation to each other primary—relationship to self primary, openness to each other—does not pertain to the relationship,* and *each a function of the other—a quality independent of*

relationship, and on about half the list of entities which contribute to a healthy relationship. This comparison illustrates how the consensus-conflict axis in the left column of Figure 2 is determined and analyzed based on the participants' capabilities to use one another's terminology and distinctions in the same way.

She could also choose to "Compare All Grids" and see how each person in the group can understand the the constructs of the others. The capability to understand another person is assumed to depend on the availability of corresponding constructs that need not be consensual in that they may be termed differently. We have a basis for mutual understanding if we can make the same distinctions even if we have to determine a mapping between our terminologies to provide mutual translation. The system is highly non-modal and she can continue using the system as demonstrated, browse between cards, use the RepGrid tools to further develop grids, use the email to communicate, and so on.

CONCLUSIONS

We see the use of the internet to support group interaction at the knowledge level as the logical extension of current interaction at the information level through mail, news, gopher, WWW, IRC, WAIS, Archie, etc. RepGrid-Net is an example of a family of group support systems that we are developing through networking our existing knowledge acquisition, representation, dissemination and inference tools.

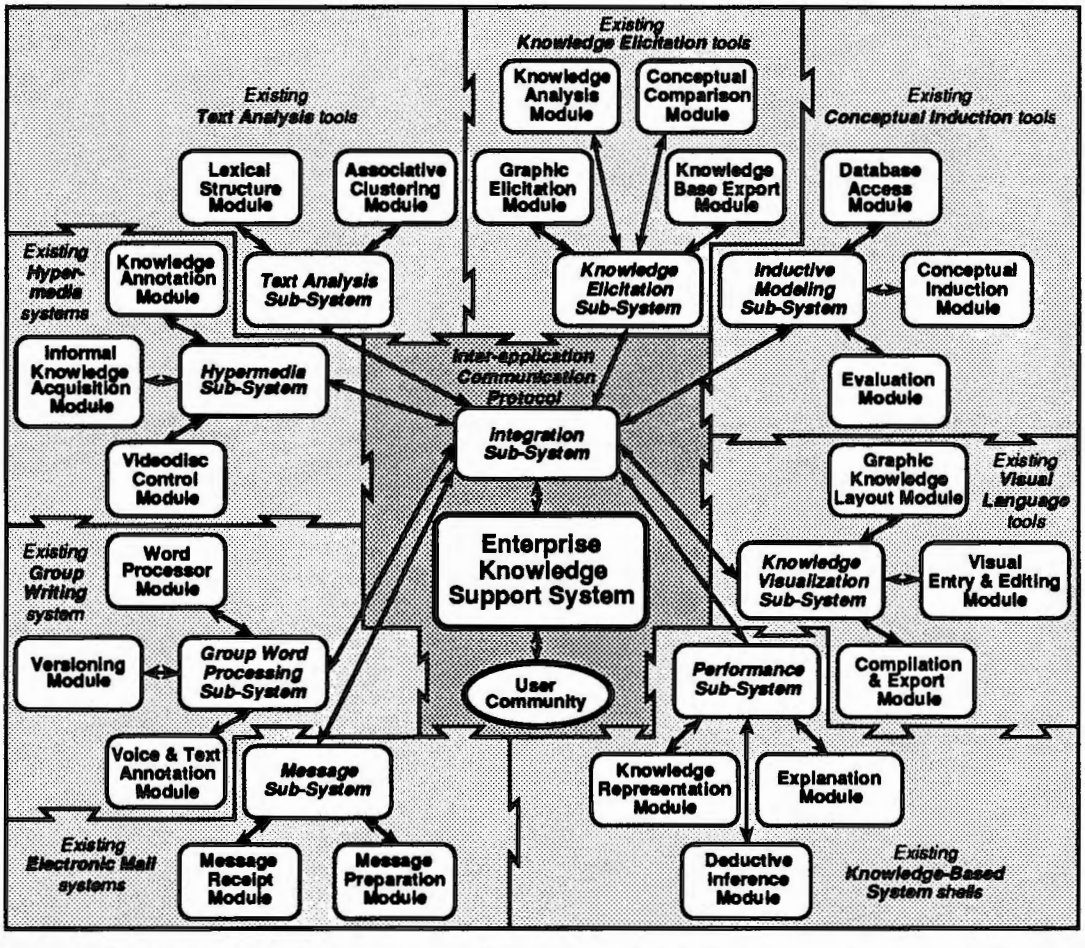

Fig.19 Networked enterprise support at the knowledge level

Figure 19 is a more complete jigsaw puzzle of which Figure 4 combines only two parts. The knowledge elicitation, empirical induction, and knowledge-based system shells and hypermedia tools have already been used to develop systems integrating knowledge acquisition and expert system performance (Gaines, Linster and Shaw, 1992; Gaines, Rappaport and Shaw, 1992), and to support graduate students in exploring and identifying their research areas (Shaw and Gaines, 1992a). The word processing modules have already been used to provide group writing tools (Gaines and Malcolm, 1993) for multimedia documents (Gaines and Shaw, 1993) incorporating knowledge bases represented as active diagrams in a visual language (Gaines, 1991b) such that the document is itself an expert system (Gaines and Shaw, 1992). Figure 19 is the basis for supporting group knowledge processes on the net.

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