COMPUTER SUPPORTED SOCIAL NETWORKING FOR AUGMENTING COOPERATION

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(Submitted June 15, 2007; Received ...; Accepted in final form ...)

Abstract. The exploration of social networks is essential to find capable cooperators who can help problem-solving and to augment cooperation between workers in an organization. This paper describes PeCo-Mediator-II to seek for capable cooperators throuth a chain of personal connections (PeCo) in a networked organization. Moreover, this system helps to gather, explore, and visualize social networks in an organization. The experimental results show that the system facilitates users' encounters with cooperators and develops new helpful connections with the cooperators.

Key words: Personal connections, on-line social networks, collaborative help networks, mediation, and software agents.

Abbreviations: PeCo – Personal Connection

1. Introduction

Recently, opportunities for communication and collaboration via computer networks have been increased immensely in networked organizations (Sproull and Kiesler, 1991). A fundamental problem is how to make contact with people who can help problem-solving. We are focusing on the problem of finding such people through social networks. Social networks are at least as important as the official organizational structures for tasks ranging from immediate, local problem-solving (e.g., fixing a piece of equipment), to primary work functions, such as creating collaborative groups (Kautz et al., 1997a).

In CSCW (Computer Supported Cooperative Work), researchers are interested in the role of social networks between organizational members. Clement stated that users developed informal collaborative networks to learn how to use a new software (Clement, 1990). Private networks are thus important for workers to solve problems by providing helpful information. A number of studies have shown that one of the most effective channels for gathering information and expertise within an organization is its informal network of collaborators, colleagues and friends. Such a network of helping relationships is called a *Help Network* (Eveland et al., 1994). However, the network is not collected and generally follows technical specialization rather than a work group alignment. Therefore, it is very important for network members to use interpersonal connections effectively in the course of their activities.

Our research focuses on "*Personal Connection*" (PeCo) which is a starting point for finding a capable cooperator. We propose PeCo-Mediator-II (Ogata et al., 1996a; Ogata et al., 1997) for gathering, seeking, and visualizing social networks in a networked organization. PeCo-Mediator-II is a distributed system with a personal database (PeCo-Collector) and a software agent (PeCo-Agent). Every user has both software on their respective site. PeCo-Collector incrementally gathers information on its user's acquaintances and connections by watching e-mail exchanges. PeCo-Agent moves to colleagues' sites and negotiates with other agents and users to find cooperators. Although the users of both NetNews and mail lists are often passive with regard to finding answers, our system can actively identify cooperators through the chain of personal connections linking the user and the cooperators.

2. Overview of PeCo-Mediator-II

When a computer network connects people or organizations, it is a social network. Just as a computer network is a set of machines connected by a set of cables, a social network is a set of people connected by a set of social connections, such as friendship, co-working, or information exchange (Garton et al., 1997). Computer Mediated Communication (CMC) systems also reduce the transaction costs of initiating and maintaining interpersonal ties (Pickering and King, 1992). Weak ties created by CMC expand the channels of information sources for the individual and have potential to become strong ties.

Social network analysis is focused on uncovering the patterning of people's interactions (Scott, 1992; Wasserman and Faust, 1994; Wellman and Berkowitz, 1997; Hiramatsu, 1990; Yasuda, 1997). Network analysis is based on the intuitive notion that these patterns are important features of the lives of the individuals who display them. Network analysts believe that how an individual lives depends in large part on how that individual is tied into the larger web of social connections. Many believe, moreover, that the success or failure of societies and organizations often depends on the patterning of their internal structures.

Typically, social networks can be obtained in two ways: socio-centric and ego-centric approaches. First, the socio-centric approach considers a whole network based on some specific criterion of population boundaries such as a formal organization. A whole network describes the ties that all members of a population maintain with all others in that group. Although this method is available for handling incomplete data sets, this requirement places limits on the size of networks that can be examined. Second, the ego-centric approach considers the relations reported by a local individual. This approach is particularly useful when the population is large.

Our initial system called PeCo-Mediator (Ogata et al., 1995) was based on the socio-centric approach. PeCo-Mediator was a groupware system that allowed sharing of PeCo in a group and searching for connections between the user and targets. The users needed to share PeCo with the common database of PeCo-Mediator. Although the system was very useful in some small groups, some users were reluctant to offer their private information like PeCo into the common database.

In this paper, our target is a large scale organization. Therefore, PeCo-Mediator-II gathers PeCo based on the ego-centric approach. PeCo-Mediator-II consists of the two systems, PeCo-Collector and PeCo-Agent (see Figure 1). Every organizational member

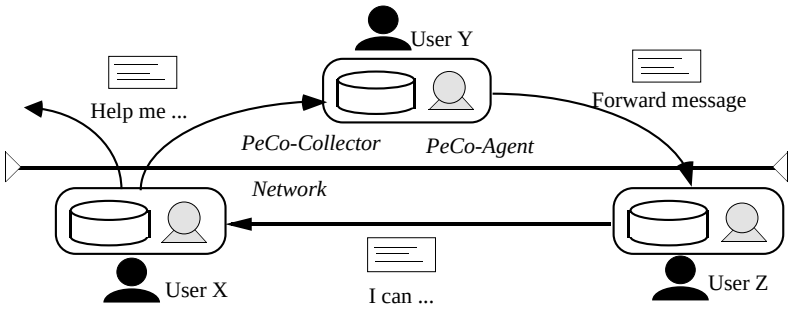

Figure 1. Overview of PeCo-Mediator-II.

has both software on their respective site. PeCo-Collector gathers information on its user's acquaintances and connections by watching e-mail exchanges. PeCo-Agent moves between members' sites to find a partner in the community. The user's PeCo is a starting point for the exploration. The user's acquaintance acts as a liaison between the user and the partner in this situation. In this figure, user X requests user Y to help with problem solving, and user Y introduces user Z. After that, user Z can help user X by request. Particularly in Japan, the introduction of mutual acquaintances is very effective for achieving successful negotiation of cooperation, because social connections have an influence on decision making (Matsushita, 1993).

The characteristics of this system are:

1. Accumulation of on-line and off-line social networks: Our system mainly deals with PeCo based on e-mail exchanges: PeCo-Mediator-II automatically stores connections based on e-mail tags. In addition, the user can provide on-line connections; e.g., based on the exchange of name-cards.

2. Measurement of PeCo strength: The strength of PeCo is estimated by the degree of frequency of e-mail exchange, which is very useful for identifying the receivers of a request.

3. Privacy protection: PeCo-Mediator-II manages individual ties with a distributed personal database at the user's own site. Personal data is safer in a personal database than in a common database. Therefore, it is easy for this system to protect a user's privacy and thus be accepted in a large scale organization.

4. Compatibility: The architecture of PeCo-Mediator-II is compatible with all existing e-mail systems, which thus reduces user overhead.

5. Scalability: Even if the number of users increases, this system can work robustly because of an agent-based distributed system architecture.

6. Parallel exploration assisted by agents: PeCo-Agent supports a user's search for a cooperator through social networks while negotiating with other users and PeCo-Agents. Moreover, the user can visually understand the current status of the exploration and easily control that process.

7. Mitigation of cooperators' overload: Most questions are likely concentrated on the part of users (experts). This system provides a common database of answers and

directs questions with strategies for educating secondary cooperators and spreading answers.

3. Social Networks Based on E-mail Exchange

This section presents how to gather individual ties through e-mail exchange and how to estimate the strength of PeCo.

3.1. Collection of Social Networks

We can classify PeCo as either explicit or implicit according to an e-mail header. Explicit PeCo is a human relation between a sender and a receiver who have directly exchanged e-mail. On the other hand, implicit PeCo is a relation between persons who have never exchanged an e-mail directly. Implicit ties are available for collecting friends linked through some connections. Table I shows the connections of user A when he/she has sent or received e-mail. Any connection has a direction from the sender to the receiver. The sender is written in the "From" field, receivers in the "To" and "Cc" fields. If user A sends an e-mail to users X, Y and Z, then the system stores the explicit connections from user A to users X, Y, and Z. Also, if user A receives e-mail from user B, the connection from user B to user A is collected explicitly. Moreover, if users S and T also receive the same e-mail, the system stores the connection from user A to users S and T. Since the system automatically gathers the user's connections, it greatly lightens the user's burden of data entry.

Table I. Connection derived from e-mail header.

The user A		*Sender*	*Receiver*
Header of email		From: A To: X Cc: Y, Z	From: B To: A, S Cc: T
PeCo	Explicit	A → X A → Y A → Z	B → A
	Implicit		A → S A → T

3.2. Strength of Social Networks

In social networking theory, PeCo (ties) have two types: strong and weak ties (Granovetter, 1973). To evaluate a connection, it is very useful to know its strength. We propose a scale derived from e-mail exchange. The connection is strong if the following conditions are satisfied:

1. Exchanging e-mail frequently;
2. Exchanging e-mail recently; and
3. Exchanging e-mail reciprocally.

Based on this consideration, we propose the following equation for representing the closeness between two persons, (P_i) and (P_j):

$$M_{i,j} = \frac{1}{2}\left\{\sum_{k=1}^{P} w_k \times \frac{n(s_k)}{N(s_k)} + \sum_{k=1}^{P} w_k \times \frac{n(r_k)}{N(r_k)}\right\} \tag{1}$$

where,

$$w_k = \frac{200(P-k+1)}{P(P+1)} \tag{2}$$

$$\sum_{k=1}^{P} w_k = 100. \tag{3}$$

The first and second expressions of this equation show how frequently the user has sent and received messages respectively during a certain defined period of time k, P. The number of delivered and received messages between the user and one of his/her acquaintances during the sub-period of the user-defined period is shown by $n(s_k)$ and $n(r_k)$, respectively. The total number of messages during the period is denoted by $N(s_k)$ and $N(r_k)$, respectively. The weight to the sub-period, W_k, is given by the user, and the sum of all weights is 100. The weights repesent the level of importance during the entire period. For instance, if the user has a very close connection with acquaintances who have exchanged e-mail recently, the user might give high weight to the period. The maximum of this scale is 100, and the minimum is 0. The closeness is used as a search criterion in exploring social networks. This system searches for connections using the criteria given by the user.

4. Exploration of Social Network

This section proposes a data diagram of PeCo exploration that is based on speech-act-theory (Winograd and Flores, 1987; Suchman, 1994). *Speech Acts* are utterances that contain information needed to assert and perform actions, or, according to (Austin, 1962), "things that people do with words." *Speech Act Verbs* are verbs used in speech acts' utterances, to perform actions. We describe users' actions in the exploration of social networks and how to support the exploration of social networks using a diagram.

4.1. PeCo Exploration Diagram

Figure 2 shows the data diagram of exploring social networks. User A is a sender of e-mail and user B is its receiver. Each node denotes the state of the exploration and moves to the next state if the user acts on the activity of the arc. The starting point is state 1, and the ending points are states 4 and 5. State 2' shows the exploration continues from state 2 after changing the receiver.

The sender has three options: request, cancel and remind. The receiver has five options: read, not-read, accept, forward, and reject. For example, user A sends a request to user B, who either reads it or does not read it. If user B does not read it, user A may remind user B to read it. If user B reads it, he/she either accepts the request, rejects it, or forwards it to his/her acquaintances. Exploration of the social network continues until someone accepts the request or user A cancels it.

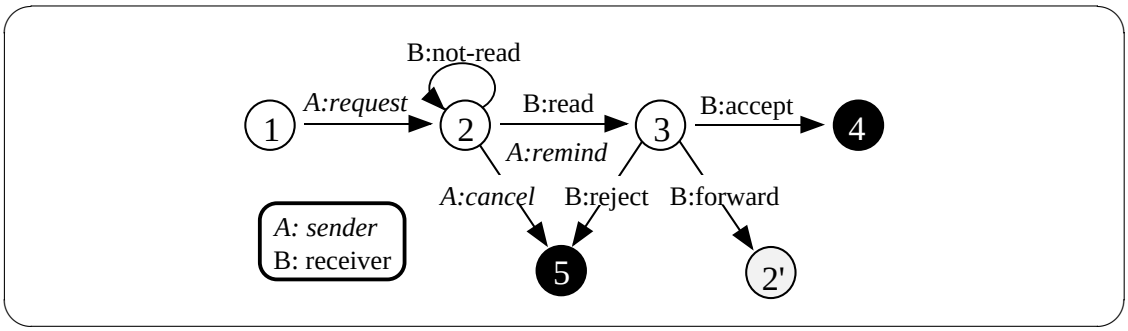

Figure 2. Data diagram of exploring social networks with e-mail.

4.2. Awareness in Social-Network Exploration

It is very meaningful for the system to provide awareness about the exploration process of social networks. According to the exploration diagram of social networks, the system provides users with up-to-the-minute infomation on the activities of receivers. This awareness enables the user to know where the request originated, who introduces whom, etc. Awareness is classified according to:

1. Awareness of a receiver's actions: This informs the user whether the receiver read the user's request, or the receiver rejected it, etc.

2. Awareness of social connections: This shows the connections between the user and the receiver(s).

The first awareness offers the user opportunities to communicate with the receiver. The second awareness facilitates communication between the user and the receiver through the chain of connections.

4.3. Control of Social-Network Exploration

It is necessary to place some restrictions on the exploration of social networks, such as not to continue to explore concurrently for a long time. Therefore, we propose the following methods to control the exploration:

1. Control by initial settings: Before the user starts a searching, the user sets a deadline, the minimum strength of connections, and the maximum hierarchical depth from the user to a receiver. If one branch of the exploration exceeds the settings, the request is automatically deleted, and that branch is terminated.

2. Control by remote commands: The user can control the request remotely according to awareness of a receiver's reaction. The system allows the user to cancel or remind the request based on the diagram. Canceling the request enables the user to prune the exploration tree. This command reduces the information overload of the receivers and prevents the request chaining. On the other hand, the remind command encourages the receiver to respond if the user wants a fast reply. If there is a message loop, the system automatically cancels the weaker of the two messages.

4.4. History of PeCo Exploration

To support the exploration of social networks, PeCo-Mediator stores the history of PeCo exploration when the user has sent or received messages. We represent the history with the following attributes:

1. Who: Who did the user send the request to or receive it from?
2. When: When did the user do it?
3. What: What did the user send or receive the request about?
4. Which: Which action did the user do?
5. How: How strong was the connection between the user and the requester?
6. Path: Which path was the message sent through?

Based on PeCo exploration diagrams, the attribute "Which" includes the following user actions: request, accept, reject, forward, receive-request, receive-forward, receive-accept, receive-reject. The topic of the request is represented with keywords that are derived from e-mail.

Table II. Taxonomy of users with an exploration history.

User type	Condition
Cooperator	$accept \geq \alpha$ and $accept > reject$ and $accept > forward$
Semi-cooperator	$receive\_accept \geq accept \geq \beta$
Mediator	$forward \geq \gamma$ and $forward > reject$
Non-cooperator	$reject \geq \delta$ and $accept = 0$
Unknown user	Except all the above conditions
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$*$ Italicized words mean the frequency of the action. α, β, γ and δ are constants provided by the user.

4.5. Taxonomy of Users

Based on the above history, we divide users into five types (see table II):

1. Cooperator: The cooperator is a user who usually accepts requests during the system use. The cooperator is often an expert in regards to the request.
2. Semi-cooperator: The semi-cooperator is a user who has the potential for cooperation in regards to the request. We assume that a semi-cooperator receives the answer from others rather than accepting requests.
3. Mediator: The mediator is a user who usually forwards the request to his/her friends.
4. Non-cooperator: The non-cooperator is a user who usually rejects the request.
5. Unknown user: If a user has never received or sent a request, the user is unknown to the system.

PeCo-Agent understands users' capability by watching the exchanges of questions and answers. We represent the capability of the user and his/her acquaintances with keywords in the e-mail. For example, a given friend is a cooperator regarding C programming language but the friend is a non-cooperator regarding Tcl/Tk.

4.6. Supporting PeCo Exploration with History

PeCo-Agent helps a user in the following situation:

1. Request support: When the user decides the receiver(s) of the request, this system shows the user the following information about each receiver:

   a) User's type (a cooperator, semi-cooperator, mediator, non-cooperator, or unknown user): If the receiver is a cooperator, the user may find the answer easily.

   b) Strength of connection: If the connection between the user and the receiver is strong, it is easy to ask for cooperation.

   c) The number of requests left unattended: If the receiver has many requests, his/her answer may be late.

   d) System usage: If the receiver uses this system at that time, the user can obtain the desired response as soon as possible.

2. Acceptance support: If the user accepts a request, the system provides the reply to the originator of the request. The user edits the previous stored answer result to answer the most recent request.

3. Forward support: PeCo-Agent shows the user possible acquaintances who can help with the results of the past exploration. If the user has a friend who is a cooperator, semi-cooperator or mediator, PeCo-Agent recommends them as the receiver.

4. Reject support: PeCo-Agent automatically rejects the request if the connection's strength between the user and the request sender is lower than the value given by the user.

4.7. Reducing the overload of cooperators

Cooperators are often burdened with requests from others. To mitigate this problem, we propose the following support in this system.

1. Educating semi-cooperators:

   If semi-cooperators are educated and reach the level of cooperators, the number of cooperators increases. Therefore, PeCo-Agent recommends a cooperator to send the request to semi-cooperators. The cooperator sends the answer to the requester after checking and correcting the answer from the semi-cooperators, thus reducing the overload of cooperators. The next time, PeCo-Agent recommends that the requester sends the request directly to the semi-cooperator. After that is done, the semi-cooperator becomes a new cooperator, and the requester becomes a new semi-cooperator. Moreover, the free-rider issue (Salomon, 1992), in which a user obtains information without giving any in exchange, might also be settled similarly.

2. Sharing answers with a database:

   Organizational memory has been proposed as a concept for sharing organizational members' knowledge (Conklin, 1992). We also adopt that concept into our situation. If both a cooperator and a requester permit sharing of an answer, the connection and the answer are entered into a shared database, depending on the connection and the answer. Because the requesters can refer to the answers in the database before sending their requests, cooperators need not write down the same answer repeatedly.

3. Spreading answers:

   When a cooperator permits propagation of the answer, the system sends the answer to the mediators between the cooperator and the requester as well as the requester. In this way, mediators too can know the answer.

5. Implementation

This section describes the development of PeCo-Mediator-II.

5.1. Data of PeCo

The data of PeCo consists of three classes: person, e-mail and connection.

1. Person object: PeCo-Collector automatically creates a new person object and enters his/her e-mail address by referring to the "From", "To", and "Cc" of an e-mail header. Then the user inputs some data such as an office address and interests during this system use. The user has to enter and update the personal data of her/his acquaintances by himself/herself, e.g., place of employment or URL. However, the e-mail exchange log is automatically updated for a certain period of time. The user supplies the deadline of the exchange log, e.g., one year.

2. E-mail object: PeCo-Collector manages e-mails that are hypertextuallly linked with keywords. The signatures are convenient for accessing people by WWW or e-mail. The e-mail object is automatically linked with the sender's and receiver's objects.

3. Connection object: PeCo-Collector also generates a new connections object at the delivered and received time of e-mail. A connection object has attributes of the social connections such as classmate status. Moreover, the connection object is automatically connected to the sender's and receiver's objects.

5.2. System Configuration

We developed a prototype system on a workstation with Tcl/Tk (Ousterhoult, 1994). The system consists of PeCo-Collector and PeCo-Agent. Every group user has both software on their respective site.

(1) PeCo-Collector
This system has two components: data management and e-mail handler. All data is managed by TRIAS (Yamamoto et al., 1989), and the e-mail tool is tkMH, based on MH

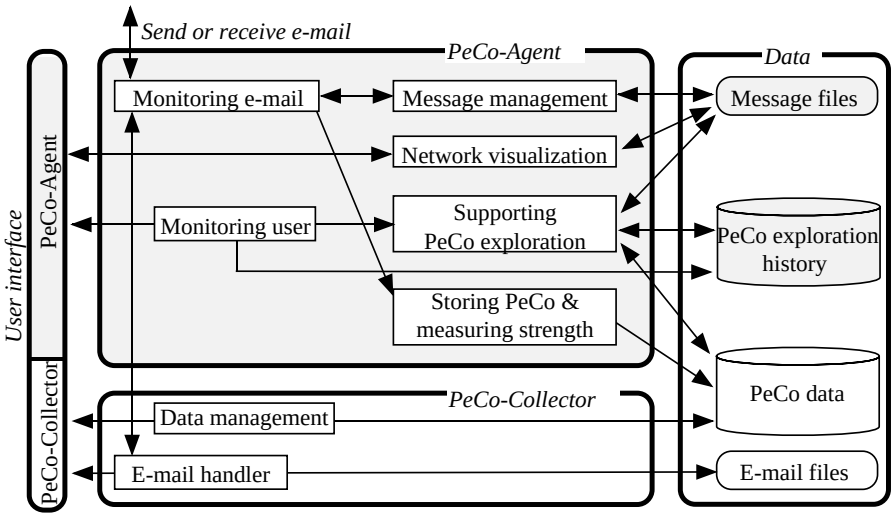

Figure 3. System configuration of PeCo-Mediator-II.

(Mail Handler) (Peek, 1994). PeCo-Collector links an e-mail object and its sender's or receiver's object automatically, and the user can make hypertextual links among e-mails.

(2) PeCo-Agent
The characteristics of PeCo-Agent are:

1. It represents a user's capability with keywords embedded in e-mails.
2. It obtains the capability of his/her acquaintances from the user and others' agents.
3. It can move around the Internet and communicate with other users and agents.
4. It finds cooperator candidates concurrently.

In PeCo-Mediator-II, a user communicates and negotiates with others through e-mail. In the same way, PeCo-Agent communicates through other agents with structured e-mail (Malone, 1986). In the exploration of a social network, the user sends and receives modified e-mail messages based on the data diagram. For example, when a user sends a request, PeCo-Mediator-II adds a special tag (X-action: request) to the e-mail header. By processing the special tags in an e-mail, the system classifies the messages.

Keywords provided freely by the user are used for seeking similar questions and answers. Only noun keywords are extracted from messages with Chasen (Matsumoto, 1997), a Japanese morphological analysis tool. PeCo-Agent calculates the similarity between the provided keywords and the stored questions by matching keywords elicited from the Chasen filter. In the Q&A matching process, we use a statistical similarity score. A Q&A pair is represented by a keyword vector that associates a significance value with each keyword in Q&A. We use TF/ITF (Salton and McGill, 1983) for weighting keywords. The TF (term frequency) component of this weight depends on the within-document frequency of the term, and the IDF (inverse document frequency) component varies inversely with the frequency of the term in the Q&A corpus.

PeCo-Agent consists of the following modules:

1. Monitoring e-mail: PeCo-Agent watches the e-mail exchange of users and distinguishes between normal e-mail and PeCo e-mail. If an e-mail is normal, it gathers

the user's connections into PeCo-Collector. Otherwise, PeCo-Agent interprets the tag fields of the messages and sends the results to the message management module.

2. Managing messages: This module stores PeCo e-mail into a message files database and manages the system's messages based on the PeCo exploration diagram in Figure 2.

3. Monitoring the user: PeCo-Agent monitors a user's actions in the exploration process and stores them into his/her PeCo exploration history database.

4. Network visualization: This component graphically shows the exploration process of a social network in real time.

5. Supporting PeCo exploration: Using the local databases, PeCo-Agent helps the user find suitable cooperators and connections.

6. Storing PeCo & measuring strength: This module stores the user's PeCo and the frequency of the e-mail exchanges into his/her PeCo database.

5.3. Interface

5.3.1. *PeCo-Collector*

Figure 4 shows a screenshot of PeCo-Collector for user Aiso. The user manages e-mail in window (A), e.g., moving a message into a folder. Window (B) shows the class hierarchy of the database. The user can search for the data of a person, connection or e-mail from this window. For example, personal data of user Gouji is shown in window (C). The user can easily update these data and add attributes. Window (D) is a list of e-mails in a folder. When the user sends the e-mail in window (E), PeCo-Collector stores PeCo data.

5.3.2. *Exploration of a social network*

Figure 5 shows the interaction after user Aiso requests his PeCo-Agent. In window (A), Aiso writes the request message. In window (B), the user sets the time out for seeking social networks, the minimum strength of PeCo and the maximum steps between Aiso and the receiver. PeCo-Agent finishes the exploration according to these settings. In window (C), PeCo-Agent assists Aiso in deciding who is the better receiver of his acquaintances, and the user agent provides information about the receiver candidates. Window (D) displays a list of the requests that the user has sent.

Window (E) shows the flow of the exploration from the user graphically. This tree is the result of following with the connections of Aiso. The icons, except for that of Aiso, denote the cooperator candidates. The shorter the distance between two icons, the stronger the connection. While the dotted line denotes the receiver has not read the message yet, the solid line shows the receiver has already read it. The black icon means the user has rejected the request. The node icon shows the user has forwarded the message to his/her friends. A leaf of the exploration tree and white icon means the user has accepted the cooperation. In this figure, Mendori has refused Aiso's request, while Ogata, Abe, and Kawasaki have agreed to his request. Akagi has not read the message yet. If the user reminds the reply to the request from this window, Akagi's PeCo-Agent of tells him to read the message. From this result, Aiso is most familiar to Gouji and can easily access the cooperator Ogata through the mediation of Gouji.

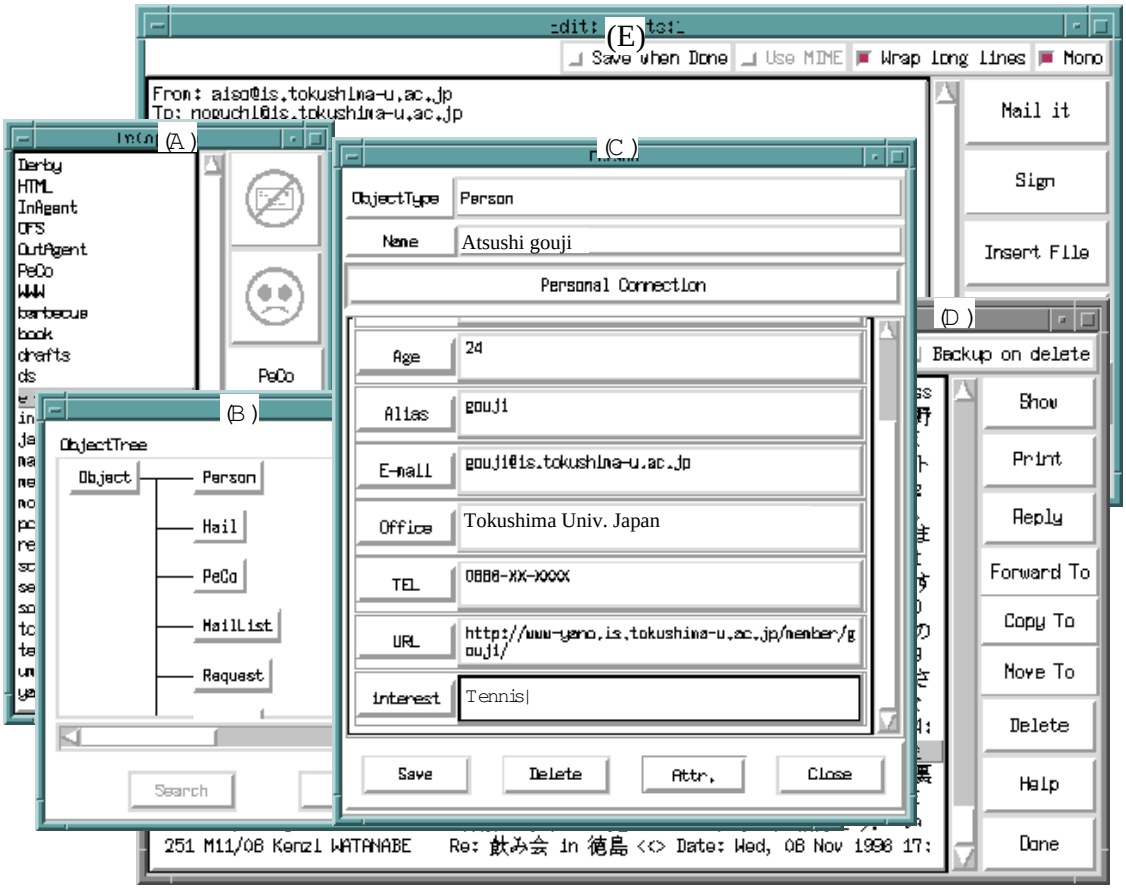

Figure 4. Screen shot of PeCo-Collector.

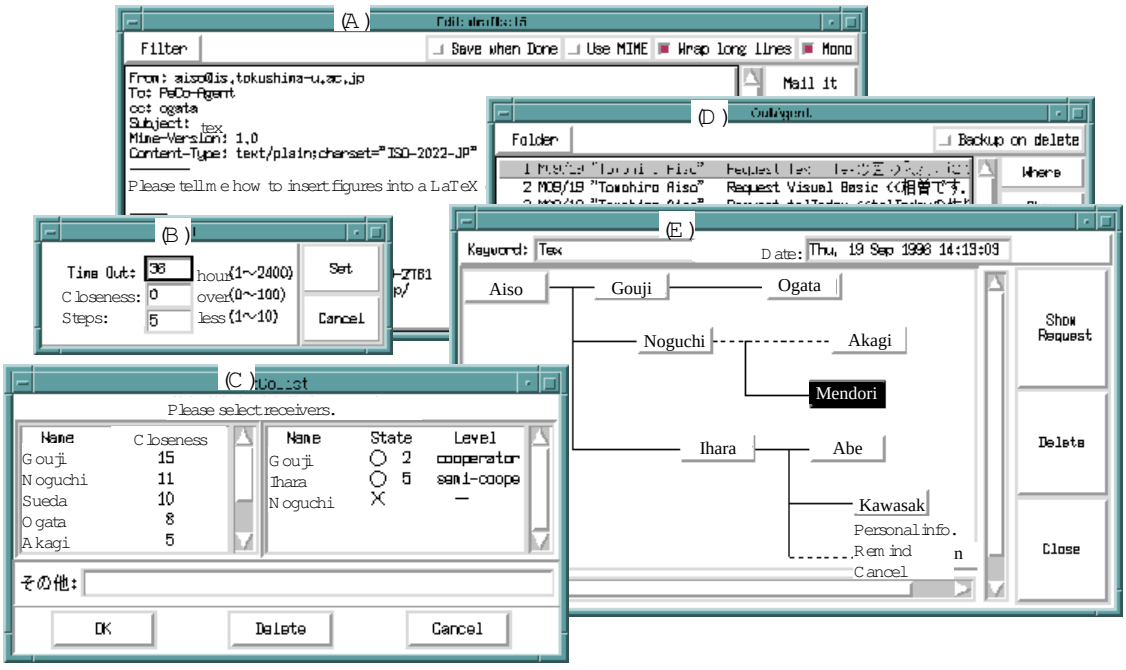

Figure 5. Screenshot of PeCo exploration with PeCo-Mediator-II.

6. Experimental Use

Because it is necessary to consider the points of both technology and a point of sociology, it is very difficult to validate the effectiveness of PeCo-Mediator-II in general. In this research, we experimentally tested and evaluated it in a special small community.

6.1. Users and Tasks

In this experiment, we arranged 13 master course students (group A) and 94 undergraduate students (group B) who had no connection with the members of group A in the first stage of the experiment. Only one person in group A, user VI, knows all the members of groups A and B. Both groups used the prototype system during nine weeks of a class in programming language C. Group B was given some homework every week. We divided the nine weeks into four terms. Because this experiment was short, α, β, γ and δ were set to one in table II.

1. Term 1: In the first three weeks, each group member communicated with his/her own group members without contacting any members of the other group. The system gathered the students' usual ties in this period.

2. Term 2: We allowed group A and B to communicate and collaborate with each other to solve problems. The users solved the given problems through this system without the system's support of PeCo exploration.

3. Term 3: In this period, we evaluated the function for supporting PeCo exploration using the history that was stored in term 2.

6.2. Experimental Results

6.2.1. *Social network analysis*

Figure 6 shows the social networks between the users after six weeks from the beginning of this experiment. While the users of group A are indicated by circles, the users of group B are shown by squares. The thick arrows denote the requested messages from the sender to the receiver. The thin arrows represent the forwarded messages over one period. This figure shows only the message flow across each group. The intra-group flow is not depicted in the figures. Of course, usual questions and answers occurred within each group. The weight of the arrow shows how many times e-mail was exchanged from the sender to the receiver. Group A's user VI was a central person and acted as a liaison between groups A and B. As shown in this figure, groups A and B learned to communicate with each other through the mediation of user VI, although the members of each group did not originally have connections beyond their respective groups. Moreover, most of the requests from group B concentrated on users VI and III, and the cooperators were almost fixed at six persons of group A. In this case, there was no cooperator in group B.

In the previous experiment (Ogata et al., 1998), we compared this system with e-mail, a mailing list and NetNews during four weeks. This experiment was conducted in the same class. Both the mailing list and NetNews were not often used for getting answers, because students hesitated to ask questions that could have been "heard" by everyone. On the other hand, both this system and e-mail were frequently used. In this case, the

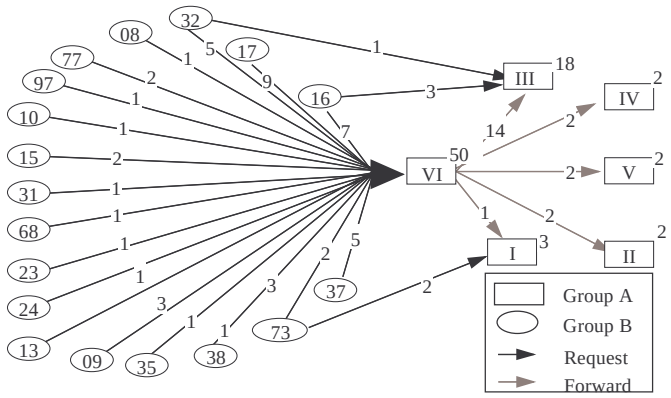

Figure 6. Network forming in term 2.

resulting expanded social network was stable because direct and explicit connections were used to get collaborative help. Likewise, (Yamakami, 1995) described how the interaction patterns of e-mail and bulletin boards were stable when observed over the long term.

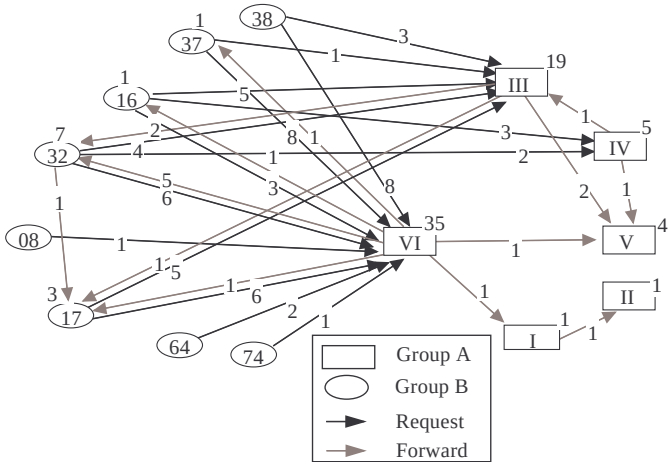

Figure 7. Network forming in term 3.

Figure 7 depicts the message flow in term 3. Some members of group B became cooperators because our system led the users to reduce the incipient cooperators' load. For example, the system recommended user VI to forward the request from user 32 to user 17 who was a semi-cooperator. After that, user 32 directly requested user 17 to cooperate in problem-solving.

Figure 8 shows the comparison of the cooperators in terms 2 and 3. In term 2, users VI and II accounted for 78% of all cooperators, and there was no cooperator in group B. In term 3, the cooperation rate of users VI and III decreased 69 % and some members of group B became cooperators. These experimental results seem to indicate that the system can prevent the cooperators from being fixed and facilitate mutual cooperation.

6.2.2. *Questionnaire*

We evaluated the functions of PeCo-Mediator-II with a questionnaire. Users had to answer each of 13 questions with a number between one and five. The obtained average was 4.2. Table III summarizes the results of the questionnaire.

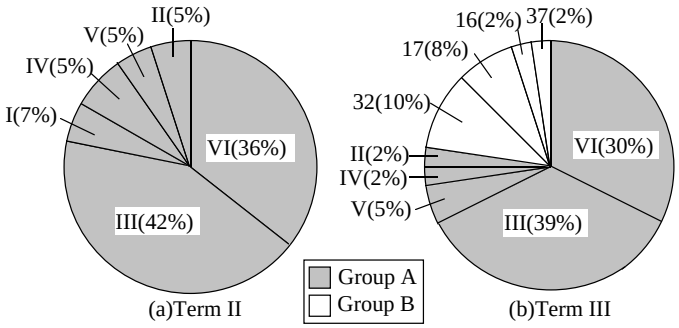

Figure 8. Rate of cooperators in term 3.

Table III. Results of questionnaire.

height 0.4mm *Question*	*Average*
(1) Could this system collect all the e-mail addresses of your friends?	4.1
(2) Could this system give appropriate social closeness to your friends?	4.0
(3) Was it effective in making the exploration process visible?	4.1
(4) Was it useful for controlling the exploration?	4.4
(5) Did this system facilitate finding new experts?	4.5
height 0.4mm	

Questions (1) and (2) were for evaluating the methods for storing PeCo and measuring their strength. According to question (1), most users were satisfied with the PeCo data gathered by this system although the experimentation term was very short. It was especially effective in storing implicit connections. Question (2) indicated the strength of connections formed through PeCo-Mediator-II was nearly the same as that of real ones. Therefore, our method to measure PeCo strength was adequate. However, some users commented that it was quite a job to enter and update the personal data of their own friends one by one, e.g., their interests or telephone numbers, though the social closeness is measured using the e-mail exchange log. In future work, we will investigate an effective way to extract automatically personal data automatically from the signature of an e-mail message.

Questions (3) and (4) are provided for testing the support of PeCo exploration. As shown in the result of question (3), the graphical representation of PeCo was very effective for the senders to understand the current exploration process and the receivers' actions. Moreover, most of the users commented that the remote control facility of exploration was very convenient in that it did not disturb the receivers. Finally, the result of question (5) showed the users could easily find cooperative and capable persons near themselves through PeCo-Mediator-II.

As for privacy, the user in PeCo-Mediator-II manages the personal database in his/her site, and the other users cannot access his/her database without his/her permission. Most users did not protest against both collecting individual ties and using them reciprocally. On the contrary, they were pleased to use this system for maintaining ties and establishing new connections with collaborators.

We evaluated this system in a very special and small social environment. In future work, we will continue to use, estimate and improve this system.

7. Related Works

There are many possible sources for determining direct connections. The initial version of our system imposed the entry of connection lists upon organizational members (Ogata et al., 1995). The provision of individual ties makes the burden heavy for the users. (Schwartz and Wood, 1993) proposed a way to establish connections by analyzing e-mail logs. However, the use of such information raises concerns of privacy and security that are hard to allay. ReferralWeb (Kautz et al., 1997a; Kautz et al., 1997b), and IKNOW(Inquiring Knowledge Networks On the Web)(Contractor et al, 1998) system, use the co-occurrence of names in close proximity in any documents publicly available on the web as evidence of a direct connection. Although these systems called communityware are readily available to discover public connections, it may be difficult to find real private networks. Our system focuses on current and personal connections based on the exchange of e-mail.

The concept of organizational memory is proposed as organizational knowledge with persistence (Conklin, 1992). Answer Garden(Ackerman, 1994; Ackerman and McDonald, 1996), FAQ Finder(Burke et al., 1997) FISH(Seki et al., 1994) and COMES(Ogata et al., 1996b) have been proposed to record and use organizational memory. In an organization, however, information seeking is not straight-forward information transfer. Colleagues choose not to go to the channel of the highest quality for information, but rather to go to the channel of the highest accessibility (Allen, 1977). Accessibility is concerned with the psychological costs in the potential lack of reciprocity between giving and obtaining information. PeCo makes it easy to agree to cooperation and to access information.

To increase communication opportunities, awareness is one of the most interesting topics. Awareness is an understanding of the activities of others, which provides a context for personal activity (Dourish and Bellotti, 1992). For example, CRUISER (Root, 1988) VideoWindow (Fish et al., 1990), Portholes (Dourish and Bly, 1992) and VENUS (Matsuura et al., 1995) were developed to support informal communication. However, through such awareness alone, it is hard to realize collaboration on a specific task with other users or accomplish tasks and common goals. Therefore, social aspects are very important considerations when attempting to obtain others' cooperation and valuable information.

(Foner, 1995) proposes Yenta, a matchmaker agent to bring people together. In this approach, a broker agent automatically introduces other agents and people. On the other hand, our work pays more attention to a human-centered approach for enhancing cooperation between organizational members. Therefore, the autonomy of PeCo-Agent is weak.

8. Conclusion

This paper proposed PeCo-Mediator-II as a support to find capable cooperators with the chain of personal connections (PeCo) in a networked organization. This system helps to gather, seek, and visualize the social networks of organizational members.

PeCo-Mediator-II is a distributed system to deal with e-mail based PeCo. This system consists of PeCo-Collector as a personal database and PeCo-Agent as a user's assistant. We proposed methods to gather PeCo by watching e-mail exchanges, to measure their strength, and to support exploration of social networks. PeCo-Mediator-II was experi-

mentally tested and evaluated in a C programming language course. The results showed the system could help the users to encounter cooperators and develop new connections with the cooperators. In our experiment in a classroom, we did not have any serious social problems. However, we might find a new problem in different social situations, e.g., in a company. In future work, our system will be used and evaluated in several different societies.

CSCW literature includes an expanding body of sociological studies on work and collaboration. However, technological support based on social aspects has received little attention in the CSCW research studies. As shown in this paper, it is very important to look at sociological and technology together when promoting cooperation between workers.

Acknowledgment

This research has been supported in part by the Grant-in-Aid for Encouragement of Young Scientists (A) No.09780291 and No.12558011 from the Ministry of Education, Science, Sports and Culture in Japan.

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