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Formal Model of Network Collaboration

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Abstract：
A formal model of collaboration is proposed. Model has four elements: information flows with attributes, a set of participants, a function from one information flow to the subset of participants, and a function from one participant to the subset of information flows. We show that this model can represent collaboration systems and tools by providing appropriate values to attributes of an information flow. Furthermore, this model includes other systems such as DBMS and Information Retrieval Systems. We show that new combinations of values derive new collaboration styles; five typical examples of new collaboration types are described in this article.

Keywords： Network, Collaboration, Formal model, CSCW

JEL codes： L86, C88

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Formal Model of Network Collaboration

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1. Introduction

Collaboration plays an important roll in research and development. Recent widespread use and progress of computers and networks enable us to use them as tools for collaboration[1]. Video conferencing[2], collaborative learning[3][4], and Computer Supported Collaborative Work (CSCW)[5] systems are typical examples of collaboration. Therefore, research and development of collaboration systems are one of the most attractive and important research themes. There is a very wide diversity of the style of collaboration. In order to support collaboration, several tools are available now. Electronic mail (e-mail), electronic bulletin board system (BBS), and some groupware tools such as Lotus Notes are examples of tools. Furthermore database can be considered as a collaboration tool. In database, one user (person or software) will store data, and another user (person or software) will retrieve and extract stored data. This operation can be seen as collaboration with time difference. In order to develop appropriate collaboration systems, we should establish a unified formal model of collaboration. Without formal model, the development of tools tends to be ad hoc, and applying one tool to other sectors is not so easy. Therefore, we should establish the generic model of collaboration.

There are many research and development studies concerning tools and systems of collaboration, but there are few about the unified formal model which covers wide varieties of collaboration tools. Ellis proposed a conceptual model of groupware[7], but this work concerns synchronous collaboration. Conklin and Begenman proposed Issue Based Information System (IBIS) model and developed a collaboration tool based on this model[8], but this model cannot represent e-mail or bulletin board system (BBS), all of which are widely used nowadays.

In this report, a unified formal model of asynchronous collaboration is proposed. This model, called the Information flow-Participant (**IfP)** model, includes current typical collaboration tools as specific cases of the **IfP** model. The **IfP** model is composed of four elements: a set of information flows, a set of participants, a function from one information flow to a set of participants (participant function), and a function from one participant to a set of information flows (commitment function). Using the **IfP** model, we can explain various kinds of collaboration systems as specific cases of the **IfP** model. Furthermore, the **IfP** model can also be used for the models of Database Management Systems (DBMSs) or information retrieval systems, which are considered to be unrelated to collaboration, as specific cases of collaboration. In Section 2, the model is proposed through stepwise improvement from the model of one person's activity process. In Section 3, conventional systems are described by using **IfP** model. New types of collaboration are presented in Section 4.

2. Models of Collaboration

We first consider a model of one person's activity; then extend this model to a multiple participants, multiple topics model.

2.1 Model of One Person's Activity

Firstly we consider about one person's activity. It may not be thought that one person's activity is collaboration. But one person's activity is collaboration with him/her self. Therefore, one person's activity can be considered as collaboration.

Many kind of human activities are performed by the *system of knowledge* embedded in a human being. The system of knowledge is constructed from a previous activity such as survey processing or studying. Therefore, the activity is considered to be the generation of (new) information I^{new} by using both (old) information I^{old} and the system of knowledge KS. Therefore, we can represent the activity process as follows.

$$I^{new} = generation(I^{old}, KS) \text{ --------- } (1)$$

Furthermore, the system of knowledge KS is itself modified or updated through the process of receiving (old) information and creating (new) information. This process is considered to be the *learning* or *evolution* of the system of knowledge.

$$KS^{new} = modified(I, KS^{old}) \text{ --------- } (2)$$

This process is infinitely repeated. Therefore, we can say that the activity process is a dynamic recursive process that creates (new) information and modifies of the system of knowledge. We can represent this process by the following recursive formula.

$$[I, KS] = creation([I, KS]) \text{ --------- } (3)$$

Figure 1 schematically represents the model of one person's activity process M_1.

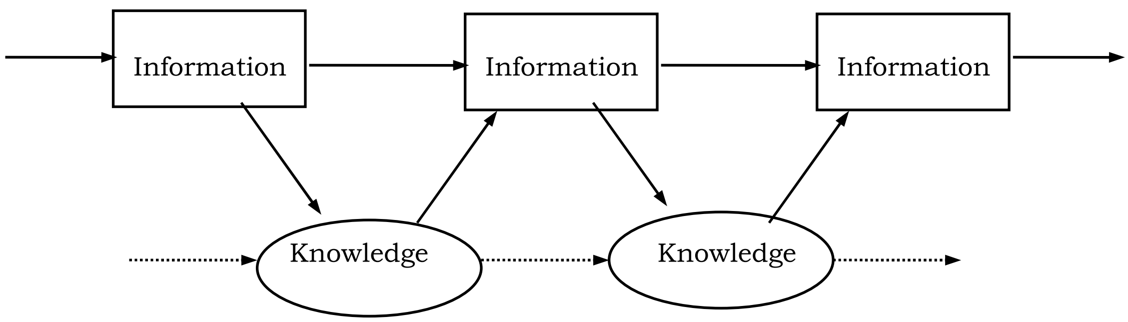

Figure 1 Schematic Representation of Model M_1

2.2 The Model of Collaboration Process with Multiple Participants

We expand M_1 to the multiple participants model M_2. In M_1, we do not consider input of information from the outer world. In other words, M_1 shows the process of *self-dialogue* or *collaboration with oneself*. However, communicating with other persons (systems of knowledge) is very important for better activity. When one person communicates with others, typical collaboration occurs. Therefore, we extend M_1 to the multiple participants model. We first consider the two participants model M_2; then extend M_2 to the multiple (more than three) participants model M_3.

2.2.1 Model of Two Participants Collaboration Process

In a collaboration process with two participants, the following steps are repeated.

step 1: One participant P_A creates new information using old information and the system of knowledge KS_A.

step 2: The system of knowledge KS_A is modified by receiving old information and creating new information.

step 3: Another participant P_b receives the information created by P_A.

step 4: P_b creates new information by using received information and the system of knowledge of P_b.

step 5: The system of knowledge KS_b is modified.

The two participants collaboration process is considered to be a repetition of the above steps. We represent this process by the following recursive formula.

$$[I, KS_A, KS_b] = creation([I, KS_A, KS_b]) \text{ --------- } (4)$$

Figure 2 shows the schematic representation of these steps, formula (4). We call this model M_2.

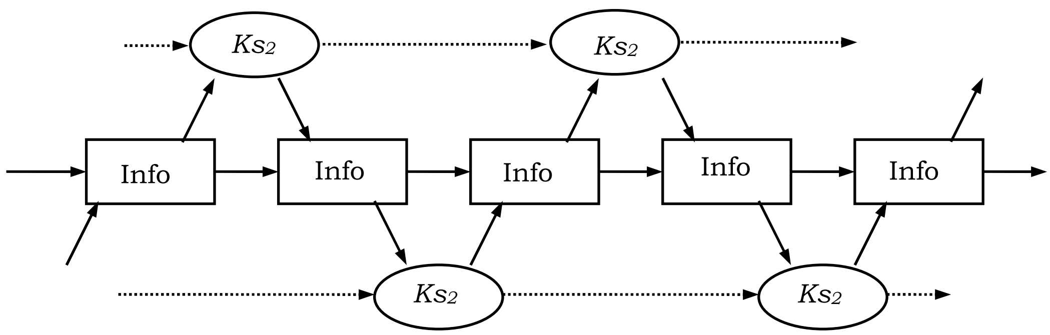

Figure 2 Schematic Representation of Model M_2

2.2.2 Model of Multiple (more than three) Participants Collaboration Process

We extend M_2 to a multiple (more than three) participants collaboration process. In M_2 , there is one information flow and two systems of knowledge surrounding this information flow. Figure 3 shows the extended collaboration model with multiple participants. In the model M_3, there is one information flow and multiple participants (systems of knowledge) surrounding this information flow. M_3 is a natural expansion of M_2. In M_3, one of the participants P_i creates new information by using old information created by other participants. Then his/her system of knowledge KS_i and P_i "submits" the new information to the information flow. Other participants P_j receive this information, create new information using their systems of knowledge KS_j and submit it to the information flow. The collaboration process of multiple participants is considered to be a repetition of this process.

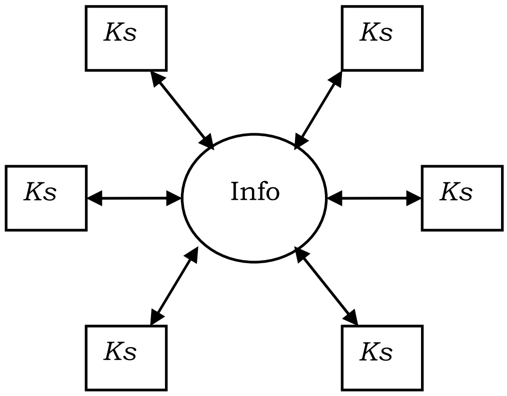

Figure 3 Schematic Representation of Model M_3

2.3 Multiple Topics Collaboration

Each information flow of model M_1, M_2, and M_3 is considered to be a *topic* of the collaboration. Therefore, models M_1, M_2, and M_3 deal with only one topic. However, in the real world, this is rare. Many people concurrently engage in many topics. For example, the author is presently researching the collaboration model, a digital library, and logic programming. In an enterprise, many employees often simultaneously engage in some different projects. Therefore, we must expand model M_3 to a model of multiple topics. We will expand M_3 in the following manner.

- There are plural information flows, and each one corresponds to a topic or project.
- Members (participants) of each information flow are usually different.

We propose the multiple topics collaboration model M_4 shown in Fig. 4; there are plural information flows I_1,...,I_n, and multiple participants p_1,...,p_m. Members of each information flow are different. For example, participants of I_1 are p_1 and p_2, participants of I_2 are p_1, p_3 and p_4 and so on. Mapping between information flows and participants is usually m :n. Furthermore, we can assume that there is no direct interaction between two or more information flows and that there is no direct interaction between two or more participants. This is a requirement derived from the viewpoint of security. We finally derive the multiple participants / multiple topics collaboration model M_4. This is our general model of collaboration. We call this model the **IfP** model." Figure 4 shows the illustration of model M_4.

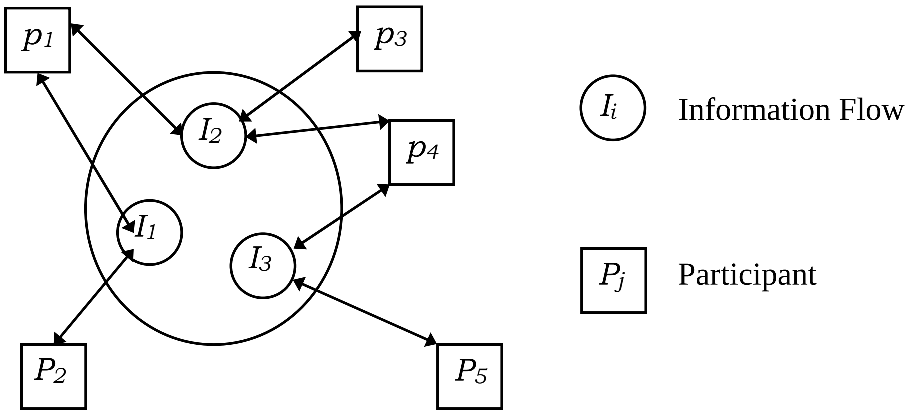

Figure 4 Schematic Representation of Model M_4

2.4 Formal Description of Collaboration Model M_4

From the model M_4, we obtain a description of collaboration as follows.

- a set of information flows ***F***
- a set of participants ***P***
- a function *part* from one information flow to a subset of ***P*** This function represents the members of one information flow.
- a function *commit* from one participant to a subset of ***F*** This function represents the commitment of each person to the collaborations.

Therefore, the collaboration C can be represented as

C={***F***, ***P***, *part*, *commit* }.-----------(5)

Note that all elements of the collaboration model are time-dependent. An information flow corresponds to one topic or project. When a new topic or project is created, a new member of ***F*** is added. One project is finished, one member of ***F*** corresponding to this project is eliminated from ***F***. New attendance and withdrawal of projects corresponds to an update of participant set ***P***. The modification of ***F*** and ***P*** reflects the functions *part* and *commit*. We can represent the dynamics of the collaboration by considering each element of the collaborate model as time-dependent.

3. Description of Conventional Technologies by IfP Model

In this section, we show that the **IfP** model includes conventional systems for collaboration as special cases, and we show that the usage of databases[11)] and information retrieval systems[12)] are also described by the **IfP** model. We first consider some attributes of information flows, and then show that the systems mentioned above have specific values for each attribute. We propose new combinations for the values of attributes, and use these to describe a new type of collaboration support system.

3.1 Properties of Information Flows

Basic operations of information flows are to create/delete, attend/withdraw, read/write, and store/reuse elements of information flows. Therefore, we propose the attributes of information flows described in table 1. Possible values of each attribute are as follows.

- **A**: All participants can perform this operation.
- **S**: Some specified participants such as the sender and receiver of e-mail can perform this operation
- **N**: Only system managers can perform this operation (super-users)

Table 1 Properties of Information Flows

	Property	Meaning
Creation		Who can create an information flow?
Deletion		Who can delete an information flow?
	Name	Who can read the name of an information flow?
Read	Title	Who can read the title of the elements of an information flow?
	Content	Who can read the contents of the elements of an information flow?
Write(submit)		Who can write (submit) the the elements of an information flow?
Attend		Who can attend the information flow?
Decline		Who can decline an information flow?
Store		Who can store the elements of an information flow?

3.2 Results of Describing Conventional Systems by Using the IfP Model

We state that the **IfP** model includes e-mail, and BBS (Electronic news systems) as special cases of the **IfP** model. Table 2 shows the definitions of an information flow and participants of each system. Table 3 shows the results of describing conventional systems. Values of each cell are described in 3.1.

Table 3 shows that typical conventional collaboration tools can be described by using the **IfP** model.

Table 2 Definition of Information Flow and Participants of Each System

	Communication Channel	Participant
E-mail	Exhange of mails	Peoples who have e-mail address.
BBS	Newsgroup	Peoples who can read news.

Table 3 Results of Descriptions

Operation		E-mail	BBS
Creation		A	S
Deletion		A	S
	Name	S	A
Read	Title	S	A
	Content	S	A
Write(submit)		S	A
Attend		A	A
Decline		A	A
Store		A	A

We will describe some features of each system.

(1) **E-mail system[9]:** A remarkable feature of e-mail system is that all participants can freely communicate with each other. In an e-mail system, exchange of mail corresponds to an information flow. Therefore, before the start of an exchange of mail, an information flow does not exist in the system. However, when two or more participants begin to exchange mails, others cannot notice the existence of the information flow. Therefore, no one except sender and receiver can read elements of that information flow. Attending and withdrawing from an information flow can be freely done. When one participant notices the existence of a mail exchange by another participant attending the exchange, he/she can freely attend. When one participant does not send a mail to others, it means withdrawal from the information flow. Recently, there has become a *de fact* standard e-mail system, and it is not so difficult to attend this type of collaboration from an outside of one organization.

(2) **BBS system[10]:** A remarkable feature of BBS systems is that anyone in the participants set can attend the existing information flow (newsgroup). However, only some specific participants such as newsgroup managers[2] can create a new information flow and delete an existing information flow. All participants can read all elements of information and write elements of an information flow. Of course, attendance and withdrawal are at one's own will. Just like an e-mail system, there is a d*e fact* standard for the BBS system. Therefore, attending this type of collaboration is not so difficult.

As mentioned above, the **IfP** model can be used to describe typical collaboration systems as specific cases of the **IfP** model. Next, we describe some systems considered to be unrelated to collaboration as a specific case of **IfP** model.

3.3 Description of Database (DB) Usage by the IfP Model

Table 4 shows the description of DB usage as a specific case of the **IfP** model. Here, an information flow means the processing of a query to a DBMS or IRS; participants are the union of persons who have permission to access the DB and DBMS/IRS software. There are two kinds of elements of information. One is a query submitted by the users of a DB, and the other is a result of a query submitted by DBMS/IRS software. Any users who have permission to access DBMS or IRS can freely create and finish session (query). However, only specific users can update databases. Furthermore, from the security, accounting, and confidentiality points of view, only specific users can access all data and other users can access only subsets of database. Of course, corresponding to a user's position, one person's accessible subsets of a database is different from another's. Once a participant creates an information flow (query session), no one can attend or withdraw from this flow. However, since participants can concurrently access databases; there are concurrent information flows in the system.

Table 4 Description of DB Usage by the IfP Model

Operation		DBMSs/IRSs
Creation		A
Deletion		A
	Name	S
Read	Title	S
	Content	S
Write(submit)		S
Attend		N
Decline		N
Store		A

As mentioned above, using a DB is considered as collaboration between users and DBMS/IRS software. Therefore we can describe some advanced features of DBMS software from the viewpoint of collaboration. For example, adaptive features of a DBMS means the evolution of the participant of the collaboration. Usage of multiple databases corresponds to the model of collaboration with multiple participants.

4. New Types of Collaboration

We can formulate new types of collaboration as specific cases of the general collaboration model M_4 by providing appropriate values to each attribute. In this section, we describe some of them.

Table 5 shows new types of collaboration formulated by providing appropriate values for properties of information flows. For example, Type 1, only specific users can create information flows and other specific users can access (read/write) the elements of an information flow. Furthermore, as only specific users can read the name of an information flow (and, of course, contents of the information flow), another participants cannot perceive this information flow. Of course, attendance and withdrawal are highly restricted. This type of information flow is suitable for highly confidential collaborative work such as the development of new products. This type of collaboration is also suitable for an "*under the table*" (unofficial) project.

Table 5 Some New Types of Collaboration

Operation		Type 1	Type 2	Type 3	Type 4	Type 5
Creation		S	S	S	S	A
Deletion		S	S	S	S	A
	Name	S	A	A	N	N
Read	Title	S	A	S	N	N
	Content	S	A	S	N	N
Write(submit)		S	S	S	S	S
Attend		S	A	S	S	N
Decline		S	A	S	S	N
Store		S	A	S	S	S

Type 2 collaboration is suitable for notification and publicity, and is similar to current BBS systems except for submission to the information flow. This restriction concerns the responsibility of elements of information flow. Type 3 is suitable for managing official projects; anyone can notice the existence of a project, but only specified participants can read and submit information. Type 4 is suitable for monitoring a participant's activity. Here, someone (the participant's supervisor) creates an information flow and monitors participants of this information flow without notifying them. Monitored participants attend one information flow and create information. By bridging two information flows and submitting an element of information that a monitored participant creates to another information flow, the supervisor can seize the participant's activity. Type 5 is suitable for one participant's private activity; except for the creator of the information flow, no one can read, write, or attend the information flow, but he/she can share in using the collaboration support systems.

5. Conclusion

We have proposed a model of asynchronous collaboration called the **IfP** model that contains four elements. A set of information flows represents the topics of collaboration. A set of participants defines the participants contributing topics. A participant function defines members who contribute a topic. A commitment function defines one participant's commitment to a set of topics. Furthermore, each information flow has certain attributes. By providing appropriate values to the attributes, we can represent various kinds of asynchronous collaboration patterns such as e-mail and bulletin board systems (electronic news systems). Furthermore, we can represent the usage of DBMSs or information retrieval systems as specific cases of asynchronous collaboration. New types of collaboration can be derived by providing another combination of values to the attributes, and five new types of collaboration have been proposed in this article.

The following work is necessary as a next step.

- Determination of properties of participants: We should determine properties of participants. By defining properties of participants, we can control the security of information more precisely. For example, Type 4 collaboration proposes the monitoring of users. However, from an organisational point of view, this function should be used by those who have certain kinds of responsibility or title in the organisation. Abuse of this function often violates privacy. Introducing the properties of participants may control such problems.
- Development of a prototype system that adopts the **IfP** model: As the **IfP** model is a conceptual model, we should evaluate the validation of this model by developing a prototype system based on the **IfP** model. We have started to develop a generic software for collaboration support systems. This software can generate a specific collaboration support system by providing appropriate values to parameters of the system. Results of the evaluation will be reported later.
- Extend the **IfP** model to synchronous collaboration: The **IfP** model can be applied to asynchronous collaboration. However, rapid progress of computers and peripheral equipment such as digital video or digital signal processing chips enable us to easily use a synchronous collaboration tools such as network conferencing or desktop meeting. Therefore, the next step is to extend the **IfP** model to handle synchronous collaboration.

Notes:

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[2] Note that newsgroup manage is not a system manager of the computer system. System manager manages all of the computer system. Newsgroup manage manages only the newsgroup.

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