# An Analysis of Obstruction in Cooperative Work over a Computer Network

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### Abstract

*In a cooperative process of designing software specifications, various activities such as deciding, changing or validating a specification are performed. On such activities over a computer network, an efficiency of work or a quality of the software products seem to depend heavily on the environment. Those environments are characterized by the parameters such as face-to-face/distributed work space, verbal/textual media, synchronous/asynchronous communication. In this paper, we report results of the analysis to recognize obstruction in cooperative work over a computer network.*

## 1 Introduction

When several workers design the software specification cooperatively, they have to exchange information each other. They have various forms of communication by various kinds of media, such as a telephone, Fax, E-mail. But such working environments, such as forms or media of communication, would restrict the manners of work. And a quality of communication, an efficiency of work and a quality of the software products, would be often influenced by the forms or the media of communication. We call such kind of bad effects *obstruction* for communication. Especially the obstruction would be remarkable in cooperative work over a computer network.

In this paper, we report analytic results on relations between obstruction and working environments over a computer network. Concretely we have analyzed cooperative process of designing software specifications at the various kinds of environments. And we found several factors which were characterized by each environment and raised obstruction. We call such factors *obstruction factors*.

This paper is organized as follows. In Section 2, we introduce the objective and the design of our experiments, that are characterized by three parameters of communication. In Section 3, we present the methods of analysis for the experiments. In Section 4, we present obstruction of working environments, and the obstruction factors, that caused the obstruction.

## 2 Experiment Environments

We focus on the following three parameters of the communication;

1. face-to-face or distribution: workers work together in the same room or not.
2. synchronous or asynchronous: workers cooperatively work in the same time or not.
3. voice or text: workers use voice or text for their communication.

The value of each parameter would influence on the manner of work. By confirming this hypothesis, we designed the following working environments for analyzing obstruction in cooperative work.

**Environment#1**(Face-to-face Synchronous Voice)**:** Two subjects work together with voice at the same time and in the same room. The medium of communication is voice.

**Environment#2**(Distribution Synchronous Voice)**:** Two subjects work together at the same time and in the different room. The medium of communication is voice.

**Environment#3**(Distribution Synchronous Text)**:** Two subjects work together at the same time and in the different room. The medium of communication is text.

**Environment#4**(Distribution Asynchronous Text)**:** Two subjects work together at the different time and in the different room. The medium of communication is text.

Each group of subjects can share the drawings on wb[1], which is computerized blackboard facility.

As shown in Figure 1, we can analyze the influence of parameter#1 by comparing Environment#1 with #2, and the influence of parameter#3 by comparing Environment#2 with #3, and the influence of parameter#2 by comparing Environment#3 with #4.

According to these different environments, we have performed four experiments of software design processes. At each experiment, we set up the following same conditions;

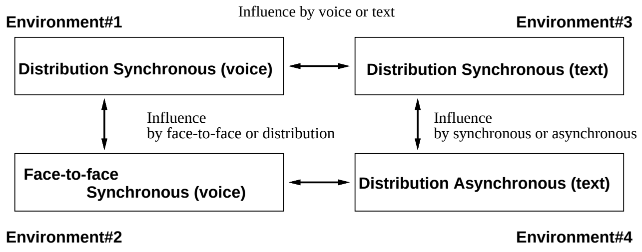


Figure 1: Set-up of Working Environment

**Task:** Developing the requirements specification from the system requirements written by the customer.

**Problem:** Swimming Club Manager System[2], a tool for supporting an accountant.

**Input:** Document written by the natural languages, about twenty-six sentences.

**Output:** Object Diagram(Rumbaugh's OMT[3]). Subjects develop a shared product.

**Subject:** Two students of the master's course in computer science. Note that they study Rumbaugh's OMT and have enough knowledge to design software specifications.

**Time for Work:** About three hours. Note that subjects can almost design Swimming Club Manager System in about three hours.

Each subject has to design in limited time. Before the experiment starts,

- To agree with subjects' recognition, they can decide the work they may perform at the experiment.
- An expert software developer, who is familiar to the task of the experiment, advises subjects on their analysis, and they can be aware of the problems. So they can accomplish a regular level and participate in each experiment.

They can use all information during the experiments.

To realize the above environments, we set up the equipments at each experiment(cf. Figure 2) as follows;

**Experiment#1(**Face-to-face Synchronous Voice**):** Two subjects work in a room and they talk with each other. They may use wb.

**Experiment#2(**Distribution Synchronous Voice**):** Two subjects work in each private room respectively. They may use wb and vat[1] for the communication, which is computerized voice phone system.

**Experiment#3(**Distribution Synchronous Text**):** Two subjects work in each private room respectively. They may use wb and E-mail for the communication. If one subject gets the e-mail from the other, he should reply the e-mail as soon as possible.

**Experiment#4(**Distribution Asynchronous Text**):** Two subjects work in each private room respectively. Moreover, they can not work in the same time. That is to say, they should work in turn and the turn is changed in every 30 minutes. Note that we think that subjects will be able to get their ideas in about 30 minutes. They may use wb and E-mail for the communication. Each subject can not communicate with his partner synchronously.

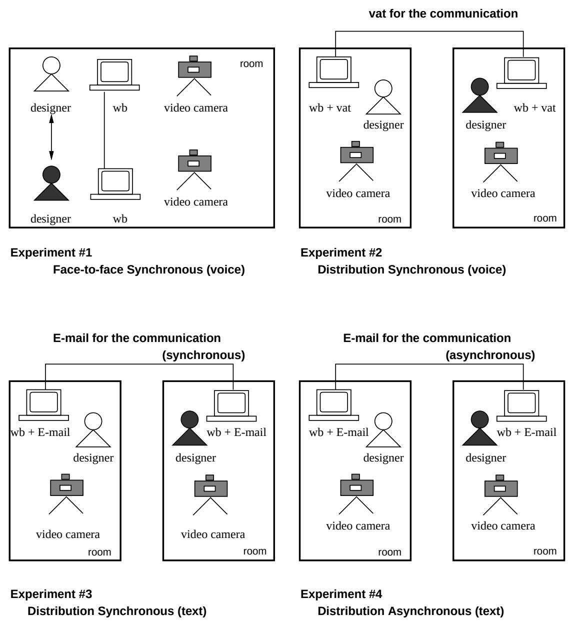


Figure 2: Each Experiment Environment

## 3 Method for Analysis

By comparing the activities of each experiment, we find obstruction of work and the factors at each working environment. To analyze subjects' activities in cooperative work, such as utterance, drawing process, gesture(cf. Figure 3), we need subjects' voice and picture recorded by two video cameras at each experiment. From their records, we count frequencies of the activities, calculate length of utterance, or analyze the ordering of utterance or the contents of conversation, etc. We compare their data of each experiment to search the differences between subjects' activities of each experiment. We focus on the differences which we may look on as obstruction and expect factors of the differences and relations between the factors and working environments.

Figure 3: A Subject's Activity

# 4 Results and Discussion

By analyzing the records of each subject's activities, we recognized the following characteristics.

## 4.1 Obstruction in Face-to-face/Distribution

By comparing the Experiment#1 with #2, we recognized the influence of the face-to-face/distribution condition. We analyzed both the ordering and the contents of subjects' actions, such as utterance in the conversation and drawing diagrams on wb. From the observation for Experiment#2, at which subjects work in each room respectively, we found several characteristics in such kind of communication. And this kind of communication will obstruct the mutual understanding of subjects. We present such disadvantages and their examples as follows;

1. Though a subject interrupted his partner to tell his demand, the interruption was refused. This is why he was not able to recognize his partner's activities well, hence the contents of the interruption did not relate to his partner's work.

   **Example:** When a subject proposed his partner, "Just a moment, please let me consider my own problem now," he replied.

2. Though two subjects share the same page or prints with each other, they can not smoothly communicate with each other.

   **Example:** Two subjects communicated with each other about the drawings on wb. Though one said pointing a diagram, "This is ...", because one was interested in the part except the other's diagrams the other did not replied to one.

3. Two subjects can not smoothly communicate with each other and they don't share the same page or prints with each other.

   **Example#1:** Because a subject replied ambiguously to his partner's proposal, the similar proposals were repeatedly proposed by him. In this situation, a subject read the printed matters, such as manual and/or prepared drawings, but his partner looked at the diagrams on wb.

   **Example#2:** Because a subject did not reply to his partner's proposal correctly, similar proposals were proposed repeatedly. In this situation, he was just engaged in his work, such as drawing diagrams on wb.

   **Example#3:** When a subject proposed about the diagrams on wb by pointing it, his partner was not able to understand and reply the proposal quickly. In this situation, he often considered the other topics, such as description on a printed matter.

4. To discuss the description on the printed matter or the diagram on wb together, two subjects have to point out them explicitly, whereas implicitly at Experiment#1.

   **Example:** A subject showed the printed matters which his partner had to look at to communicate with him.

To confirm the difference between Experiment#1 and Experiment#2, we count the frequencies of these four kinds of disadvantages in Table 1. Note that both the spending time of Experiment#1 and Experiment#2 are almost same. So we may simply compare them by the frequencies. For example, in the table, disadvantage#1, "Though a subject interrupted his painter to tell his demand, the interruption was refused.", is occurred two times.

Table 1: Comparison between Face-to-face and Distribution

| | Experiment#1 (Face-to-face) | Experiment#2 (Distribution) |
|---|---|---|
| 1 | 0 | 2 |
| 2 | 4 | 10 |
| 3 | 0 | 8 |
| 4 | 9 | 9 |

From these data in Table 1, we found the following characteristics;

- As shown in the line #1 and #3 in Table 1, a subject does not interrupt his partner's work in the face-to-face condition, and he can share the same information with his partner more easily. Two subjects can almost communicate with each other smoothly. Because a subject can easily recognize the state of his partner in the face-to-face condition, they can work together easily. The recognition would be accomplished by observing the other's working state.

- As shown in the line #2 in the Table 1, a subject merely loses his partner's markings in the face-to-face condition. Because a subject can easily recognize the event and/or action of his partner in the face-to-face condition, they can easily work together. The recognition would be accomplished by monitoring the other's motion.

  And two subjects can almost communicate with his partner smoothly in the face-to-face condition. Because a subject can easily recognize his partner's idea in the face-to-face condition, they can easily work together. The recognition would be accomplished by observing the other's facial expression or gesture, which are non-verbal media.

We recognized the following obstruction factors from the above characteristics.

**Obstruction Factor#1:** In the distribution condition, it is difficult for workers to understand their partner's working activities.

**Obstruction Factor#2:** In the distribution condition, it is difficult for workers to get information except their partner's voice.

### 4.2 Obstruction in synchronous/asynchronous

By comparing Experiment#3 with #4, we recognized the influence of the synchronous/asynchronous condition. We analyzed subjects' e-mail. From the contents of the e-mail, we found that a subject gave his partner "utterance" which was related to the current context, such as "question → answer", "suggestion → rejection → agreement". We define a sequence of utterance as *conversation*. We count the number of utterance in each conversation and calculate the average of the number at Experiment#3 and Experiment#4 in Table 2 respectively. We measure the length of conversation by the number of utterance.

Table 2: Average of length in a Conversation

| Experiment#3 (Synchronous) | Experiment#4 (Asynchronous) |
|---|---|
| 2.10 | 1.35 |

From the results in Table 2, we assume that conversation is not completed in the asynchronous condition. We should confirm whether short length conversation is really completed or not.

We think that the number of utterance in an e-mail will influence on the results in Table 2. For example, when a worker give the other a lot of utterance in an e-mail, uncompleted conversation may increase(cf. Figure 4). So we compare Experiment#3 with Experiment#4 by the number of utterance in an e-mail. We count the number of utterance in each e-mail, and calculate the average of the number at Experiment#3 and Experiment#4 in Table 3 respectively. We measure the length of an e-mail by the number of utterance.

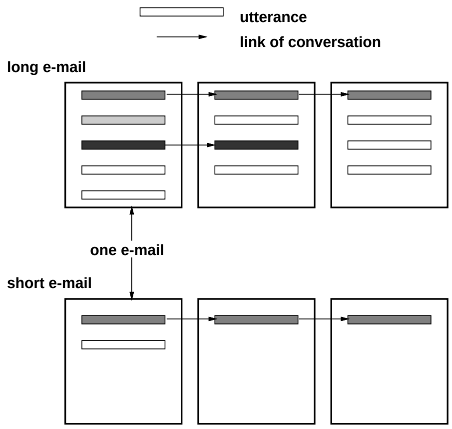


Figure 4: Long E-mail vs Short E-mail

Table 3: Average of length in an E-mail

| Experiment#3 (Synchronous) | Experiment#4 (Asynchronous) |
|---|---|
| 1.17 | 4.18 |

From the results in Table 3, we found that a subject gave his partner more utterance in an e-mail at Experiment#4. So we think that several number of conversation will tend to be occurred in the asynchronous condition.

We recognized the following obstruction factor from the above characteristics.

**Obstruction Factor:** A worker tends to give his partner the more different topics at once in the asynchronous condition.

To confirm this as obstruction factor, we should evaluate the quality of tasks and products.

### 4.3 Obstruction of Drawing on wb

Subjects were engaged in the several kinds of activities while they used wb, which is a computerized blackboard(cf. Figure 5). From the observation for Experiment#2, at which subjects work in each room respectively, and Experiment#4, at which subjects work at the different time, we found some characteristics in such activities. And these activities will decrease the efficiency of work.

We focus on the following activities;

1. A subject specifies a page for discussing the diagrams on the page. Note that subjects can use multiple pages on wb.
2. A subject explicitly points to the diagrams which he wants to discuss instead of pointing them orally.

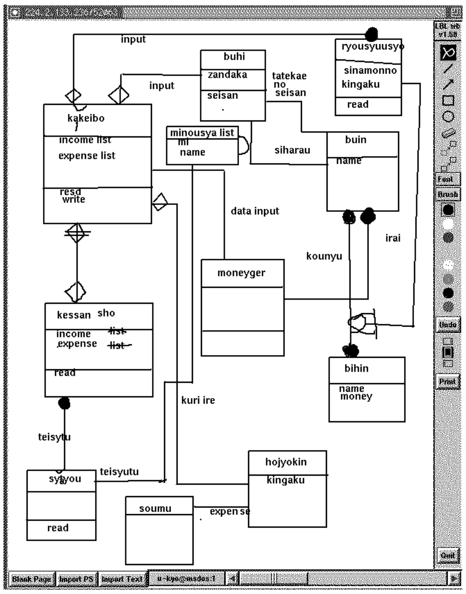


Figure 5: Diagrams on Wb

When workers specify a page especially while communicating with the other, they may interrupt their conversation. And it is not much efficient for workers to point to the diagrams instead of pointing them orally.

To recognize the factor of these obstruction, We count frequencies of these two kinds of disadvantages in Table 4 respectively.

Table 4: Frequencies of Obstruction of Drawing on Wb

| | Exp#1 | Exp#2 | Exp#3 | Exp#4 |
|---|---|---|---|---|
| | Synchronous | | | Asynchronous |
| | voice | | text | |
| | Face-to-face | Distribution | | |
| 1 | 5 | 6 | 2 | 8 |
| 2 | 5 | 14 | 0 | 0 |

- From the line#1 in Table 4, in the asynchronous condition, workers tend to specify a page for discussing the diagrams on the page. They would need to inform their partner of their drawing point.
- From the line#2 in Table 4, workers tend to point to the diagrams which they want to discuss in the non face-to-face and voice condition. In the face-to-face condition, it is easy to point to such kind of viewpoint, e.g., by turning his gaze on the viewpoint. But in the non face-to-face and voice condition, the explicit marking on wb would be in place of the eye gazing.

We recognized the following obstruction factors from the above characteristics.

**Obstruction Factor#1:** It is difficult for workers in the asynchronous condition to understand continuous working, such drawing on wb.

**Obstruction Factor#2:** It is difficult to point to the diagrams in the distribution condition.

### 4.4 The Characteristics in Drawing Diagrams

Subjects were engaged in several kinds of activities while they used wb, which is a computerized blackboard. From our observation, we have found the typical patterns of activities, and almost all communications for drawing on wb can be completely categorized by the following patterns;

1. A subject explicitly declares the topics which he would like to draw before drawing.
2. A subject explains the diagrams which was drawn for his partner by him.
3. A subject proposes the drawing contents.
4. A subject advises the partner on the partner's diagrams.
5. A subject has his partner make up for his diagrams.

The frequencies of each pattern of the communications would depend on the differences of working environments. So we would be able to regard the frequencies as the characteristics of each environment.

We classified the communications at each experiment into the above five categories and counted the number of them. Then we checked how many frequencies each kind of activities were occurred in each experiment. The results are shown in Table 5. For example, in Experiment#3, the frequency of category#1, "A subject explicitly declares the topics which he would like to draw before drawing ", is about 26.7% among the communications which can be classified in the above five kinds of activities.

From these data in Table 5, we found the following characteristics;

- From the line#1 in Table 5, workers tend to explicitly declare the drawing topics before drawing in the asynchronous condition. This tendency do not seem to depend on the textual or verbal

Table 5: Communication for Drawing on Wb

| | Exp#1 | Exp#2 | Exp#3 | Exp#4 |
|---|---|---|---|---|
| | Synchronous | | | Asynchronous |
| | voice | | text | |
| | Face-to-face | Distribution | | |
| 1 | 0.155 | 0.235 | 0.267 | 0.400 |
| 2 | 0.155 | 0.382 | 0.067 | 0.267 |
| 3 | 0.267 | 0.118 | 0.533 | 0.267 |
| 4 | 0.362 | 0.206 | 0.133 | 0.067 |
| 5 | 0.052 | 0.059 | 0 | 0 |

communication. So in the asynchronous condition, the workers tend to declare their action before acting, such as changing their working topic. That is to say, they can not understand the ordering of their drawing very much.

And workers do not tend to explicitly declare the drawing topics before drawing in the face-to-face condition. So it would be more necessary for the workers to declare their action before acting, such as the change of their working topic, in the face-to-face condition than the distribution.

- From the line#4 in Table 5, workers do not tend to advise the other worker on the other's diagrams in the asynchronous condition. So in the synchronous condition, the workers tend to advise on the other's diagrams. That is to say, they can not understand the ordering of their drawing very much.

  And workers tend to advise the other on the other's diagrams in the face-to-face condition. So the face-to-face condition would make it for the workers easier to advise on the other's diagrams than the distribution. Because they need to understand the contents of the other's diagrams in detail, it would be easier to understand them in the face-to-face condition than in the other condition.

We recognized the following obstruction factor.

**Obstruction Factor:** Is is difficult for the workers to understand information about the ordering of their drawing in the asynchronous condition.

## 5 Conclusion

In this paper, we present various kinds of obstruction factors in the cooperative software design processes. And these obstruction factors can partly be characterized by the conditions for the working environments, such as face-to-face or not, synchronous or not and verbal communication or not. We now plan to experiment and analysis in the more precise condition than the experiments in this paper. For example,

- In this experiments, we use E-mail for the sake of textual communication. But to compare the difference between the text and voice purely, we should use more synchronous communication media, such as textual phone or textual chat system.
- In all experiments in this paper, subjects can use wb, which is computerized blackboard, for describing diagrams of OMT. It is natural to use the shared drawing tool to draw the diagrammatic products. But the performance of wb itself would influence on the subjects' activities. So we should plan to experiment with other drawing tool or without the drawing tool.
- In these experiments, the differences in subjects' skill level would be able to be decreased by an expert's instruction. But we can not verify the decrease in the systematic way. So we should provide the method for measuring the worker's skill level.
- In these experiments, data are mainly represented by the tabular forms. But this forms are not enough good to understand the human activities intuitively. So we should develop the graphical notation for intuitive understanding.
- In these experiments, we used a local network in our building connected by Ethernet. But we are now working in the multi-vender/multi-platform environments and on the heterogeneous networks. So we should plan the experiments in such realistic environments. We have started the research project with Nara Institute of Science and Technology and Tokyo Institute of Technology and so on[4]. The goal of this project is to build models and systems related to tele-conferencing and distributed software development environments. In this project, the multi-vender/multi-platform environments and the heterogeneous networks are available for our experiments, such as ISDN, Ethernet and ATM network.


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