Finding Symptoms of Misunderstandings in Drawing Software Design

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ABSTRACT

It is difficult for cooperative workers to complete software specification and design successfully if they misunderstand with each other. In this paper, we propose a method for finding symptoms of misunderstanding from the records of their interaction. By the method, each part of their products is characterized by the superficial phenomena among their interaction. And one can distinguish misunderstood parts of their products. Because this method uses the superficial records of interaction, automated support for detection can be expected. Finally, we confirm its efficiency and inefficiency and discuss its limitation from the analysis of the experiment.

KEYWORDS

Mutual Knowledge, Interaction Analysis, Drawing Process, Software Design

1 INTRODUCTION

When several people should work together to develop some products or documents, they have to share the mutual knowledge with each other, e.g. goal and assumption of the work, background knowledge of its domain and/or language for communication. If workers fail to have mutual knowledge and it has been never repaired, it would be difficult to finish their task successfully. Especially, if the work takes long-term, misunderstandings in early stage give serious influences on the rest of the work and products. So we should prevent the workers from misunderstanding with each other.

The causes for such failures are assumed as follows;

1. In spite of the workers share the different knowledge, they believe they share the same one or they do not find they should share it.
2. They do not have the method for detecting others knowledge and/or for judging and repairing the difference.

These causes seem to be observed from the records of communication or interaction among the workers.

In this paper, we propose the method to find symptoms of misunderstanding from the records of workers' interaction. Several linguistic theories provide the features of conversation where mutual knowledge is established. And one can also find symptoms of misunderstanding by these features. But one should deeply step into the contents of interaction to use the theories, hence it is difficult to put them into the practical and every day's use. In contrast, workers' misunderstandings are characterized by the superficial phenomena among their interaction in this method. Hence automated detection for their misunderstandings can be expected.

The outline of the method is as follows;

1. Identifying the parts of a product for testing whether it is a consequence of misunderstanding or not, from the intermediate products during the worker's interaction.
2. Identifying the activities which refer to each part during their interaction respectively. The examples of such activities are drawing, pointing and erasing the part of their products.
3. Deciding indices of each part from the sequence of activities. These indices are designed to reflect the degree of the worker's mutual understandings. In

this method, the following four indexes are introduced; number of references, number of conversation, rate of cooperation and occurrences over the phases.

4. Judging each part with these indexes whether it is misunderstood or not.

We make an experiment for confirming the efficiency and inefficiency of the method and discuss its limitation. As a results, the method is not enough efficient, but we can distinguish misunderstood parts of products from the others to some extent. So we discuss the need for additional information to refine the ability for detection.

The organization of this paper is as follows. In the next section, we introduce theories related to this paper, and based on these theories, we propose the method for detecting the misunderstandings. Next, we present an experiment and its analysis for validating this method. And the results and discussion of the experiment follows.

2 RELATED WORK

2.1 What is Misunderstanding?

If the workers have mutual knowledge about their work with each other, they can successfully coordinate their plans and/or ideas. Mutual knowledge is also called as shared information, common ground, mutual beliefs or mutual assumptions [1]. Clark and his colleagues gave detailed condition of mutual knowledge, but Krauss[2] gave more simple its definition, that is,

> *Mutual knowledge is knowledge that the communicating parties both share and know they share.*

We regard *misunderstanding* as the failure in having mutual knowledge.

2.2 Taxonomy

One can classify mutual knowledge into several categories. For example, all of the workers assumes that all of them has the ability to speak and understand a language, e.g. English or Japanese, and that all knows the fact. This kind of mutual knowledge depends on the social categories to which the workers belong. Issacs and Clark suggested that speakers make inferences about what their addressees are likely to know from the categories [3]. Another kind of mutual knowledge does not depend on the social categories. For example, while several workers are developing some kind of products, e.g. documents or machines, mutual knowledge about the intermediate and/or final products depend not only on their social categories but also on more volatile and temporary knowledges.

Another kind of classification depends on the representation of knowledge. Some kind of knowledge has the canonical form. For example, "referential communication task" [4], which is a task that one of workers formulate a message about something (typically a visual stimulus of some sort, hence it has a canonical form) that will enable another worker to select that thing among a set of similar things, is a typical one. But another kind of knowledge do not have such canonical form. For example, the design of software system can be regard as a knowledge. But modern design methods normally have multiple viewpoints of design [5], [6], hence one knowledge is represented by several forms of documents.

2.3 Mutual knowledge and Communication

As mentioned in many literatures, mutual knowledge is deeply related to communication. This is because they assume that communicative act rests on a base of mutual knowledge. Communicative act is intended by the actor to convey information, and important thing that happens in communication. During the communication, communicating parties need to update their mutual knowledge moment by moment, especially the knowledge is not based on the social categories. Hence the evolution (or degeneration) of mutual knowledge is observed from the records of communication. So many researchers of mutual knowledge focus on the communication of cooperative workers [7], [4], [8].

2.4 Features of Mutual knowledge

In several linguistic theories [9] [10] [11], the features of conversation are discussed for clarifying the establishment of mutual knowledge. So such features are useful to detect misunderstandings of cooperative workers. Here we briefly introduce the Clark's theory[1]. In his theory, contributing to conversation divides into the following two phases:

- Presentation phase: A presents utterance *u* for B to consider.
- Acceptance phase: B accepts *u* by giving evidence *e* that she understands what A means by *u*.

And the evidence of having mutual knowledge mostly appears in the acceptance phase. The typical patterns of positive evidence are as follows;

- Acknowledgment: e.g. "uh huh" or "yeah" in continuing utterances.
- Initiation of the relevant next turn: e.g. answer is relevant next turn of question. This kind of pair is also called *adjacency pair* [10].
- Continued attention: The listener shows that she is paying attention to the speaker in some way, e.g. eye gazing.

If one wants to find the evidence about mutual knowledge by the theory above, he should deeply step into the contents of conversation. For example, one should decide what pair of utterances becomes an adjacency pair, or what activities reflects the attention of the listener. So it is difficult to put the theory into the practical use for detecting the misunderstanding, especially into the automated support for the computer system.

3 METHOD

In this section, we introduce the method for finding symptoms of misunderstandings during the cooperative work.

3.1 Domain of the method

This method is applied to the following kind of tasks.

- Several parts of a product are produced by several number of workers. Each part reflects the different feature of a product, e.g. functional feature, behavioral feature or structural one, hence one can not easily find the existence of misunderstandings among the parts. Normally, each part is assigned to different worker.
- Several times of meetings and preparations for the meetings are repeated for refining the product and for resolving the differences among the parts. In these meetings, shared workspaces like blackboard for writing documents and/or figures are available for communicating with each other.
- Phases in meetings can be categorized into the following three kinds.
  - Phase-A: A worker draws his parts of products on the shared workspaces for his explanation respectively. Mostly in this phase, no interaction among the workers is held. This phase is often included in phase-B below.
  - Phase-B: A worker explains his parts on the shared workspaces to the others. Mostly, the worker has the initiative of this phase, and no one except him utters and/or draws something on the whiteboard. All worker holds his own phase-B in turn.
  - Phase-C: Workers coordinate their parts for resolving the inconsistencies and for making up insufficiencies. This phase is sometimes included in phase-B above.

  It is easy to divide the meeting records into the phases above because each phase has the objective features, e.g. no conversation, clear initiative and else.

Tasks in the software development, especially requirements capturing, can be regarded as the examples of this kind of tasks.

3.2 Measuring activities

For detecting misunderstandings of workers, we should identify the relationship between the workers and misunderstood or understood parts of products. So we focus on the activities in workers' interaction, where the workers refer to the parts of products, e.g. drawing a part of diagrams, pointing the part of diagrams, giving verbal comments to the part and so on. We call such kind of activities as *reference* to a part. We can identify the following features of reference objectively; a worker who act the activities, a part of products where the worker refers to, and the time when the worker refers to the part. But it is not easy to identify the intention or the aim of a reference objectively, so we mainly focus on the three features of references above, to detect the misunderstandings.

Moreover, it is not also easy to measure the activities if the activities are performed by the verbal form, but is easy to measure them if they are performed as the drawing, writing or pointing actions on the shared workspace. We call the record of latter kind of activities as *superficial or rough record*, and we mainly focus on such records. For example, on the blackboard, drawing the rectangles representing the class of OMT, is typical activities we focus on. These activities can be detected by the board-type computer [12] automatically today, but it is difficult to detect the utterances and their contents by the current technology in contrast.

3.3 Indices of Misunderstandings

From the measured features of the workers' interaction, we construct the following four indices for deciding whether a part of products is the consequence of misunderstandings or not.

- Index1: **Number of reference**: As mentioned in many literatures, mutual understanding is deeply related to communication. The most simple indicator of communication is the number of participants' reference to a knowledge. So we assume that the number of their references to a knowledge would be reflect their mutual understanding about it. The more the number of references to a product part, the smaller misunderstandings are occurred.
- Index2: **Number of conversation**: This index is simple extension of above index. Normally, in a meeting, a knowledge is referred several times in the meeting by the sequences of activities, and each sequence is semantically connected sequentially. We regard such sequence as conversation, and we assume that the number of conversation about a knowledge rather reflects the misunderstanding than the number of participations. The reasons are as follows; First, it is too small to regard each reference as the unit of communication. Second, the strict number of references would heavily depend on a personal habit of talking, e.g. one talks something tediously but another briefly, but the number of conversation would not depend on such personal habits.

  In general, it is difficult for identifying conversation from the meeting. For identifying it, several techniques were available and based on the verbal data in the meeting. For example, for identifying *meta-utterances*, e.g. "next", "by the way", in the meeting, the segment of context could be identified[13]. And the changing of turn in the conversation also gives hints for identifying it[10]. But in such way, one should deeply step into the contents of conversation. In contrast, we simply identify each conversation with respect to the interval time between the references, which are referred to same parts of a diagram.
- Index3: **Rate of cooperation**: Communication can not be organized without references of more than one participants. Moreover, the listeners' responses affect the semantic content of a speaker's messages [2], hence this kind of responses would be contribute to accomplish the mutual understanding. For example, if a participant in conversation talks about a topic and another also talks about the same topic, another can easily formulate and arrange his messages for the first participant. So we focus on how many participants do contribute to communication about a knowledge. And we assume that the number of participants reflects their misunderstanding about it. In other words, we assume that all of participants would participate in conversation about a part if the part is mutually understood by the participants. And not all would if it is not. With respect to this assumption, we define *the rate of cooperation* as the rate of how many participants except the proposer participate in conversation about a part. The rate is zero when only proposer refers the part, and the rate is one when all of participants refers the part.
- Index4: **Occurrences over the phases**: If a part of a product is discussed both during phase-A or B and phase-C like in Figure1, we assume that the workers would have the mutual understanding about the part. In contrast, if a part is discussed during only one kind of phase, we may assume that misunderstanding about the part is occurred.

Clark's and other theories tend to focus on the activities during the short term,

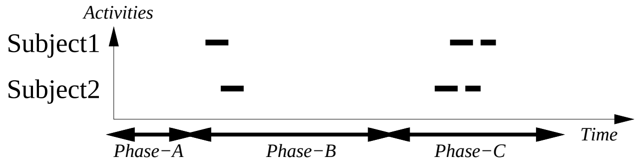

Figure 1: Example of multi-phased

e.g. among conversation. One of the few example is the simplification of referring expression during the long term use [2]. In contrast, the index reflects long-term properties.

This index is mainly based on the continued attention of the listener. That is, if a part is discussed during both phases, some of participants would have attention to it continuously, e.g. finding inconsistency between his product and others. Hence he would be able to show rich evidence of his understanding. But if a part was discussed only in phase-A or B and not in phase-C, the listener have a little chance to show his continued attention. And if a part was discussed only in phase-C, it is feared that the part is volatile idea hence it would be difficult to confirm the understanding with each other.

4 EXPERIMENT FOR VALIDATING THE METHOD

The objective of this experiment is to validate the method in Section3. For validating it, we compare the *real* misunderstood parts with detected parts. So we design the experiment so as to identify the *real* misunderstood parts of products. And we select *designing by graphical languages* as the task of this experiment, because it is easy to collect the superficial activities. And we also select *software development* as the domain, because its products normally have multiple forms of viewpoints and it takes long-term for completing.

4.1 Subjects

Four pairs of graduate school students, who attended and passed a lecture of OMT[6]. The subjects in two pairs had acquaintance each other, and the others did not have.

4.2 Products

We select OMT as the design method for subjects. OMT has three viewpoints for modeling software; object modeling, dynamic modeling and functional modeling. And object diagrams(OD), transition diagrams(STD) and data flow diagrams(DFD) are produced by each modeling view point respectively.

In this experiment, the inputs to each pair are requirements document(RD) written by the natural language and simple OD. RD consisted of about 30 lines, and OD consisted of both 10 nodes, each of which had no attributes and no methods, and 11 arcs. In RD, the tasks about “wholesale store” were described, and the subjects instructed to model the tasks of an accountant in the store by either DFD or STD.

4.3 Procedure of the experiment

In Figure2, we illustrates the procedure of the experiment in DFD-like style.

1. **Pre-meeting Stage**: An experimenter gives the RD and OD to each subject respectively with the following sheet of instructions;
   - Based on RD and OD, specify the tasks of an accountant in the wholesale store by either functional modeling technique(DFD1 in Figure2) or dynamic modeling technique(STD2 in Figure2) of OMT.
   - The other modeling will be accomplished by a partner of you, but never contact your partner until the meeting day.
   - The meeting for negotiating with your partner is scheduled in *Aug. XX, 19XX*, so complete your modeling task until the meeting day.

   For the convenience of the experiment, the experimenter assigns modeling techniques to each subject. And the subjects can spend about five days for their tasks.

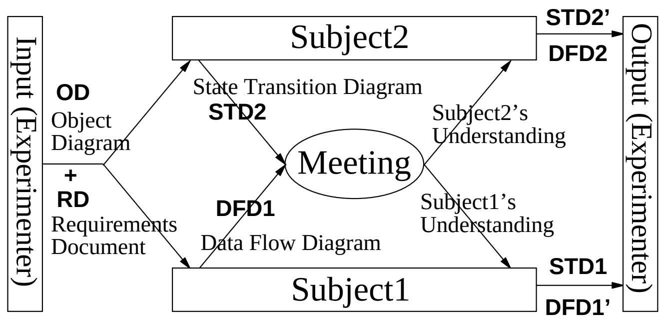

Figure 2: Overview of experiment flow

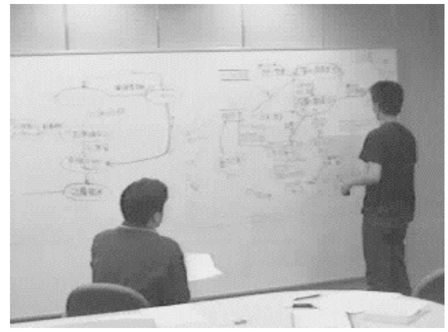

Figure 3: Meeting Room

2. Each subject draw the diagrams (DFD1 or STD1 in Figure2) in the five days respectively.
3. **Meeting Stage**: The meeting is held in the following room;
   - Table for writing and reading is available.
   - Big whiteboard (4.2 meter width and 1.7 meter height) and three colors of markers are available for discussion (Figure3).
   - The activities in the room can be recorded by two video cameras, which can be changed the focus, zoom and the destination by remote control.
   - The utterances in the room can be recorded by two wireless microphones respectively.

   And just before the meeting, the experimenter gives the following sheet of instructions to the two subjects;
   - No one except you (two subjects) attends this meeting.
   - The purpose of this meeting is to resolve the difference among your diagrams through discussion.
   - Explain your diagrams to your partner by drawing your diagrams on the whiteboard again.
   - If you have some question, opinion or others, please ask your partner on the spot.
   - If you find a difference and either of you should modify the diagrams, please keep your own modification to a minimum.
   - You can spend two hours for this meeting but not limited.
4. The subjects hold the meeting.
5. **Post-meeting Stage**: Just after the meeting, the experimenter gives the following sheet of instruction to the two subjects;
   - Based on the results of discussion in the meeting, complete the whole kinds of diagrams (STD and DFD) respectively as soon as possible.
   - Modify the diagrams which you prepared for the meeting if necessary.
   - Please draw the diagrams which are not your portion of work, from scratch.

   Note that each subject can not get the copy of the other's diagrams.
6. Each subject draws the two kinds of diagrams (DFD1' and STD1, or DFD2 and STD2' in Figure2) respectively right after the meeting.

4.4 Procedure for analysis

As mentioned above, we should find the *real* misunderstood parts among the products for comparing them with detected parts. In this experiment, we regard the differences between STD1 and STD2' and between DFD1' and STD2 shown in Figure2, as the *real* misunderstanding among the subjects. Because STD1, DFD1', STD2' and DFD2 were drawn by the subjects just after the meeting, the influence of forgetting the contents would be able to be minimized.

Each diagrams consists of many kinds of *parts*, e.g. nodes, arcs, annotations and/or figures. So we decide whether each part is mutually understood or not, with respect to whether it appeared in the diagrams and the meeting as shown in Table1. In this table, "○" denotes "appearing in one's diagrams or in their meeting", "–" denotes "not appearing" and "*" denotes "○" or "–".

Table 1: Definition of Real Misunderstanding

Type number	1	2	3	4	5
In Subject1's Diagram	○	–	○	–	*
In Subject2's Diagram	○	○	–	–	*
In the meeting	○	○	○	○	–
Misunderstanding	no	yes	yes	–	–

Table 2: Results of the experiment

	Pair#1	Pair#2	Pair#3	Pair#4
Acquaintance	yes		no	
	Size of each Diagrams, the number of nodes + arcs			
(DFD1', STD1)	(15+21, 7+10)	(11+14, 10+25)	(13+16, 7+10)	(10+14, 11+18)
(DFD2, STD2')	(12+16, 7+10)	(9+11, 7+11)	(13+16, 6+12)	(10+14, 13+24)
Spending time (sec.)	50	70	140	81
Number of mutually understood parts	39	37	63	50
Number of misunderstood parts	16	15	27	6

If the parts do not appear in the meeting, we can not predict whether they are the consequence of misunderstanding or not. So we remove the parts of type5 from the analysis. We also remove parts of type4 because one can not decide whether they are the consequence of misunderstanding or not. The parts of type1, which both subjects draw in each product and which appear in the meeting, are regarded as the mutually understood parts. In contrast, the parts of type2 or 3 are regarded as the consequence of misunderstanding.

5 RESULTS AND DISCUSSION

5.1 Existence of Misunderstanding

Table2 shows the size of the diagrams, the spending time during the meeting, the number of mutually understood parts and the number of misunderstood parts. Subject1 and Subject2 in the table correspond to those in Figure2, and the size of each diagram is represented by both the number of nodes and arcs. Note that subjects in pair#1 and #2 were acquainted with each other, but the subjects in pair#3 and #4 were not. From these results, whether subjects are acquainted with each other or not, they have several misunderstandings about the software design.

5.2 Index1: Number of References

Based on the method in Section3, This index of a part is large if the subjects mutually understand the part, and small if not. So we compare the average number about mutually understood parts with the average about misunderstood parts. Table3 shows the results. The assumption seems to be true because the average number of mutual understanding is larger than one of misunderstanding in all pair. But half of them are not significant on the condition that a significant level, α is 0.1, in spite of the condition is very week.

From this results, we assume that the strict number of references would heavily

Table 3: The average number of references(par a part)

Pair Number	#1	#2	#3	#4
Mutually understood parts	4.5	7.6	8.3	5.3
Misunderstood parts	2.5	5.6	3.0	2.6
Significance of difference	Yes	No	Yes	No

Table 4: The average number of conversation (par a part)

Pair Number	#1	#2	#3	#4
Mutually understood parts	2.6	3.8	4.4	3.8
Misunderstood parts	1.5	2.7	2.3	2.2
Significance of difference	Yes	No	Yes	No

Table 5: The percentages of parts which takes the rate of cooperation one

Pair Number	#1	#2	#3	#4
Among mutually understood parts(%)	30.8	46.0	41.3	40.0
		$\wedge$		
Among misunderstood parts(%)	25.0	60.0	37.0	0.0
Significance of difference	No	No	No	Yes

depend on a personal habit of talking, e.g. one talk something tediously but another briefly. So we confirm the number of conversation in the same manner, which would not depend on such personal habits in the next subsection.

5.3 Index2: Number of Conversation

Table4 shows the average number of conversation. We decide the interval time to one minutes in this experiment, and can successfully identify each conversation with respect to the interval time between the activities. The assumption also seems to be true in all pair. Unfortunately, half of them are also not significant on the condition that α is 0.1. But the significances are slightly improved from the results of index1, e.g. the difference of Pair#4 can be significant when α is 0.2.

The number of references and conversation do not take account for the response of the listener. For example, if one participant make an one-way speech repeatedly but others do not so attention it, the number of conversation becomes large, this is not fit to basic assumption.

5.4 Index3: Rate of Cooperation

In this experiment, the number of participants in the meeting are two, hence this rate becomes one or zero. Based on the method, mutually understood parts would mostly take the rate one, but misunderstood parts would takes the rate zero. So we compare the percentage of parts which take the rate one in each case; case about mutually understood parts and case about misunderstood parts. Table5 shows the results. Unfortunately, most of all differences are not significant on the condition that α is 0.1, moreover the percentage of misunderstood parts is lager in the pair#2.

The reason is that listeners responses such as acknowledgment are likely to formed by the utterances. But this method can not detect the cooperation of participants.

5.5 Index4: Occurrences over the phases

Based on this method, mutually understood parts are repeatedly discussed over the different phases. So we compare the percentages of the parts discussed over the different phases in each case. Table6 shows the results. The first four lines show the spending time in each phase, and the rests show the percentages of each case. The assumption seems to be true in all pair, and all differences except pair#2 are significant on the condition that α is 0.1. All are significant on the condition that α is more than 0.14.

Because we want to detect the misunderstood parts for notifying communicators of them, we should pick up such parts without omission rather than exactly. In other words, recall of the detection are more important than its precision. From this viewpoint, we investigate the contents of detection errors and refine the indicators. As shown in Table6, several parts (6.3, 40.0, 29.6 and 16.7% of misunderstanding) are regarded as mutually understood parts though they are not mutually understood in fact, i.e. they are detection errors.

In Figure4, we show an example which is regarded as mutually understood part

Table 6: Spending time of each phase(sec.), and the percentages of index4

Pair Number	#1	#2	#3	#4
Phase-A(sec.)	0	0	0	8
Phase-B(sec.)	30	39	51	14
Phase-C(sec.)	20	31	89	59
Total time(sec.)	50	70	140	81
Among mutually understood parts (%)	53.9	56.8	50.8	52.0
Among misunderstood parts (%)	6.3	40.0	29.6	16.7
Significance of difference	Yes	No	Yes	Yes

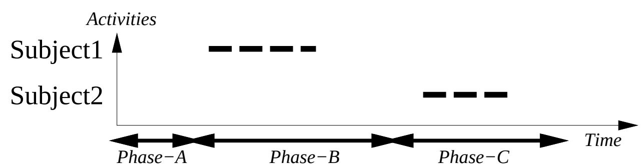

Figure 4: Example: problem of index4 and index3

by index4, but which can be regarded as misunderstood part intuitively. In this example, only subject1 refers a part during phase-B and only subject2 refers it during phase-C. One may regard the part is occurred over the phases, hence we can assume that the part is mutually understood. And one can also regard the part in the same way by index3. But subject2 may refer the part without enough understanding in Phase-C, because the subjects had shared a permanent workspace, i.e. whiteboard, during the meeting, hence the subject2 had a change to refer the part without enough understanding in Phase-C.

So we mix index4 with index3 for avoiding this kind of problem in Figure4. That is, if a part is discussed both during phase-A or B and phase-C, and all of participants participate in each discussion, we regard the part as mutually understood part. Table7 shows the results refined by mixing index4 and 3. Only by the concept of index4, we failed to identify about 25.0% parts, which are in fact misunderstood parts but which are judged mutually understood parts by index4. But mixing the concept of index3, we can considerably refine the ability of detection to 6.3%.

6 CONCLUSION

In this paper, we introduce the method for finding the symptoms which reflect the misunderstanding among the cooperative workers, from the superficial records of meeting, e.g. records of pointing, drawing and erasing the parts of figures. And we evaluate the method by making the experiment and the analysis. Because these superficial records are selected with respect to the flexibility for dealing with computer system directly, the ability of detection is largely limited. But some of indices can be reflect the difference between misunderstood and mutually understood parts. For example, if a part of products is not occurred in several phases, we may suspect it as misunderstood part.

This method could be refined in cooperate with the other kinds of observational

Table 7: Reparing the detection errors

	Pair Number	#1	#2	#3	#4	Total
(A)	Num. of actually misunderstood parts	16	15	27	6	64
(B)	Num. of detection failures among (A)	1 (6.3)	6 (40.0)	8 (29.6)	1 (16.7)	16 (25.0 %)
	Num. of detection failures among (A), refined by mixing index4 and 3.	0	2	2	0	4 (6.3 %)

phenomena. For example in this experiment, the syntax of products are definitely defined and relationships among different kinds of products are also made clear [14]. Hence one can utilize such relationships for the detection.

From the results of the experiment, acknowledgment of listeners tends to represented as verbal form, e.g. utterance, hence the symptom by cooperation is not accurately observed. It is difficult to detect the contents of utterances but is not difficult to detect the existence and actor of utterances [15]. So detecting utterances is partly cooperated to this method.

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