Coherence and Interactivity in Text-Based Group Discussions around Web Documents

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Abstract

This paper reports on a study of text-based communication in a Web-based groupware system, DHS. The system supports annotation of a set of shared documents, where the annotations are gathered in a common dialogue space for each document. Since the system does not support threading of messages, it is of interest to explore how participants use the referential space to connect to each other's contributions. The analysis reveals that the evolving dialogues are characterized by a dual discourse context of documents and comments. The modes of linking are conversational and often implicit, which may lead to coherence problems. We present a visualization tool designed to explore interactivity and referencing strategies in these document-centered dialogues, and discuss implications of our findings for the design of computer-mediated communication systems.

1. Introduction

Text-based communication on the Internet is increasingly mediated by the Web, which has opened up for new forms of interactivity. In both educational and work-related contexts, discussions are often focused on shared documents, as part of a collaborative task. These discussions can be interconnected in many ways through the Web infrastructure which gives rise to potentially complex discourse environments. In these contexts, it is central for participants to obtain a global understanding of what has been said so far in a discussion. Supporting coherence is important to promote active participation and interactivity, a fact that places requirements on the systems used for communication.

In this paper we look at text-based communication in a context where a collection of documents was discussed by a group of students as part of a course assignment. The system used, DHS, has been designed for collaborative reviewing of documents within small groups on the Web. In the context studied, participants had to develop their own strategies for coherence in the absence of specific system support for linking of messages. The evolving dialogues turned out to be complex due to the multiple discourse references occurring across messages and documents. We analyze these data with respect to coherence strategies as well as general response patterns and interactivity. We then present a visualization tool designed to support coherence and navigation in document-centered discussions. Finally, we discuss some implications of the study for the design of CMC systems.

2. Coherence in computer-mediated discussions

A central aspect of coherence in asynchronous computer-mediated communication is how a message connects to previous messages in a dialogue. Especially in multiparty discussions, a message may be separated both in time and place from the message it responds to, leading to a fragmented conversational structure [6]. Because of the time delay and the fact that several conversations may be going on simultaneously, the participants in an online discussion may need support for placing a message in a discourse context. This goes both for the reader of a message, who must grasp where the message belongs in a complex dialogue, and for the author/sender, who needs to indicate how a message connects to the previous discourse when posting it. In addition, coherence of a discussion may be important to establish in a retrospective, offline sense, when a user is trying to obtain an overview of what has been said.

In spoken, face-to-face conversation, the sequential organization of turns of talk is a result of intricate coordination between speakers [3]. Coherence can be seen as actively constructed by participants across speaking turns [7, p. 315]. The structural regularities and real-time character of the conversation are essential elements in this process, so that participants tend to recognize with little or no effort that a contribution is oriented to a previous initiative as a response. To signal which contribution is being responded to in a group discussion, non-verbal gestures and gaze are important elements. Utterances contain elliptic and anaphoric expressions to refer back to objects introduced earlier in the discourse. More formal mechanisms for linking are descriptive referential expressions, pointing directly to a previous utterance or paraphrasing it: "what Max said", "in

response to your argument about X," etc.

In standard email and newsreading software, the coherence of a discussion is supported by a threading mechanism, which emphasizes the reply-to relationship and shared subject between messages (see e.g. [15]). The structure of a discussion is sometimes visualized through indentation of messages that belong to the same dialogue thread. As a discussion proceeds, this hierarchical message structure grows, and participants may have difficulty getting an overview of the entire discussion due to its complexity and the limited screen space.

The relevant context for a reply can also be specified by the author of a message through quoting parts or the whole of previous messages, a strategy that is used and supported differently in different CMC contexts. Quoting gives an immediate context for a reply to a message, but has the disadvantage of increasing the length of a message. In a survey of Usenet users about email habits, it emerged that quoting increases the sense of dialogue in a CMC discussion for a majority of users [14]. Another study compared quoting patterns in two sets of data, one email corpus and one excerpt from a Usenet newsgroup [13]. It was shown that quoting was used in both contexts, but in newsgroup discussions, quoting was used both more frequently and more selectively, including mainly text parts actually responded to.

In addition to the kind of coherence that concerns the initiative-response structure of dialogues (sequential coherence, cf. [6]), there are other kinds of coherence that may be of importance for participants to make sense of an online discussion, such as establishing a link between several messages by the same person, or messages written in a common temporal or spatial context. In general, the need for system functions for establishing coherence is likely to be dependent on many factors such as the overall purpose of the communication, the relationship between participants, the number of parallel conversations, and the frequency of new messages.

3. Web-based tools for communication around documents

The emergence of the World Wide Web, with its flexible hypermedia platform for computer-mediated discourse, has meant that the discourse context of a computer message has become potentially much more complex. A message may not only refer to previous text messages in a local dialogue sequence; it can also be anchored in a hypermedia document or a set of interlinked documents which provide a context for ensuing dialogues. For example, email messages often include deictic references to Web pages by citing their URL [4], and Web documents are made the subject of online discussions through specially designed annotation tools [see e.g. 2].

For several years, we have been engaged in the development of a set of Web-based groupware systems, designed to support collaboration around documents in small or medium-sized groups [11]. The systems are based on the idea of shared annotation of a set of documents or document sections, where the annotations are gathered in a common dialogue space for each document or section. The three systems, DHS, Col•laboració and Col•leció, have basic interface features in common, based on a layout of four frames (see Figure 1).

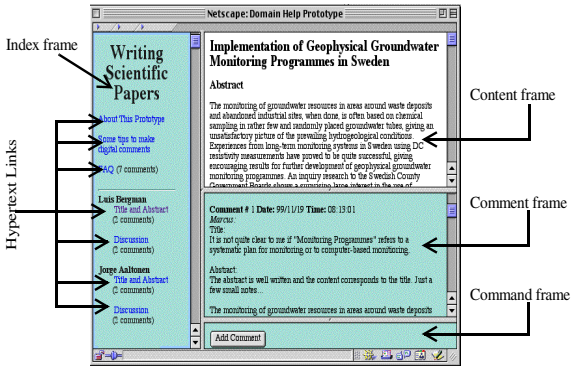

Figure 1. The screen layout of the DHS system.

Here, we will be concerned with the DHS system, which has been developed through a set of longitudinal case studies within an educational context [11]. The system is typically used for discussion of a set of documents, each submitted by a member of the group. Each document has a separate dialogue space for text-based discussion. When a comment is added in the dialogue space, the author of the corresponding document gets an email message to support awareness and promote interactivity of the discussion. This email message also contains the text of the new comment.

The screen layout of DHS consists of four frames (see Figure 1): an index frame, a content frame, a commenting frame and a command frame. Clicking on a link in the index frame will result in the corresponding document being presented in the content frame. Simultaneously, the comments made on this document are shown in the commenting frame. The command frame contains a button which activates a window for creating a comment.

With respect to dialogue features, the design of the DHS system has been kept deliberately simple, although the commenting interface has been gradually improved to address user demands. Importantly, there is no threading facility, mainly because the purpose of the system has been to support communication around the shared documents. Thus, each comment is expected to be oriented towards a particular document, and longer threads are not expected to occur. In the system, comments are therefore displayed by the system as they occur in a chronological sequence, and

users must create their own strategies to link to the surrounding discourse.

DHS has similarities to the system WebAnn [1], which supports shared annotation of Web documents. However, WebAnn supports threading of comments. Another difference is that WebAnn allows comments to be associated with a particular part of a document, such as a word or paragraph, whereas the DHS links a comment with the entire document. This difference has consequences for the evolving communication. In a comparative study where WebAnn was used along with a traditional discussion board system [1], it emerged that the discussions in WebAnn were more concerned with specific points in the papers discussed.

4. The referential space of a DHS domain

A site in the DHS is called a *domain*, and consists of a collection of documents and a set of comments in connection with each document. As a discourse environment, this means that we are considering a set of parallel, but related dialogues, each emanating from and discussing a separate document. A salient feature of the dialogues evolving in a domain is their potential referential complexity. Possible references include the following:

1 Usually, a comment refers to *the document* defining the particular dialogue space (henceforth the top document). We have found that in all contexts where the system has been used, a majority of all comments in some way (implicitly or explicitly) address either the content or the form of the top document.

2 A comment may also refer to *previous comments on the same document*, replying to what has been said by someone else in the group.

3 The comment may refer, implicitly or explicitly, to *other documents* in the domain. For example, a group member may compare the document to another document, e.g. the one written by himself.

4 The comment may refer to *comments on the other documents* in the domain.

5 The comment may refer to the DHS system itself. In fact, there is a separate dialogue space in each domain for such comments, connected to an instruction document ("About this prototype") which describes the basic properties of the system. In the case studies performed of DHS, the system developer (the second author of this paper) regularly responded to questions within this dialogue space and took part in discussion about the system.

6 Comments may be given on a meta-level, referring to the ongoing discussion.

The extent to which these types of references actually occur depends on the particular context of the dialogues: the purpose and nature of the collaboration; what aspects of the document are being negotiated etc. In the two main educational contexts where the system has been used and evaluated so far, only one developed into a *discussion context*, where the participants interactively discussed each others' experiences as expressed in a submitted document. The other was predominantly an *annotation context*: each comment addressed the document, but there was virtually no interaction between participants about the documents [11]. This difference can be explained by the character of the tasks involved. The discussions between users and developer about the system itself has been analyzed as a case of participatory design in a recent study [12].

5. An analysis of multi-referential dialogues in two DHS domains

Since there are few features in the DHS system to support coherence, it is of interest to explore how participants use the referential space to connect to each other's contributions, and how they cope with the potential ambiguity caused by the dual referential context of documents and comments. For this purpose we have analyzed a corpus of data from two case studies in which DHS was used for discussion in an educational context.

In the group discussions analyzed, each participant had submitted a short essay (about 1 page) about a personal experience of group collaboration with technology as an introductory assignment for a university course. The participants (20 men and 10 women) were 4th year students in computer science or engineering, specializing in human-computer interaction. The assignment included reading and responding to other students' essays in the DHS system during a period of approximately two weeks. An instructor followed the discussions and also provided system support in a separate dialogue space. With one exception, the discussions were held in Swedish.[1]

The total material collected includes data from five consecutive versions of the course [11]. The two sets of data we shall focus on here are CSCW01 and CSCW02. The domain CSCW01 consisted of 13 documents, and 89 comments[2]. CSCW02 consisted of 17 documents and 66 comments. In total, the material analyzed here contains 30 documents and 155 comments, where each document is authored by one of the participants in the discussion.

The purpose of the assignment was both that the students should get feedback on their own experiences of collaboration as expressed in the document they had submitted, and that they should interact with each other by

1. One person who did not speak Swedish chose to write his document in English. The four comments on the document, of which he wrote two himself, were also made in English.

2. One comment was disregarded because its author was the system designer, who was not part of the group.

sharing and discussing these experiences. This double purpose is reflected in the nature of the resulting discourse, in which contributions contain references to both documents and previous comments. Below, we will examine the dialogues with respect to the following questions:

• How do participants connect to each other's contributions, while preserving the integrity of the document as a discourse context?

• How do participants achieve coherence in the discussions without having access to a threading mechanism, considering their referential complexity?

We will go through the patterns of conversational linking exhibited in the comments, and consider aspects of coherence and interactivity relevant to the nature of the communicative task.

5.1. General patterns of reference to documents and comments

In order to assess the modes of conversational linking in the corpus, we have coded the comments according to their way of referencing previous comments and documents. Two judges read the documents and discussions, and assigned each comment one or more of the following codes:

D	refers to the top document of the same dialogue space,
Kn	refers to the n:th comment in the same dialogue space,
DocX	refers to another document (docX) in the domain,
DocX:n	refers to the n:th comment on Document X in the domain.

The cases where coding differed in some aspect between the two judges (less than 10%) were resolved by one of the judges while reconsidering the relevant part of the discussion.[3]

A comment often received a complex coding. For example, a coding for a comment could be [D,K1,K3], meaning that it contained three identifiable references: one to the document, one to the first comment in the same dialogue space, and one to the third comment in the same dialogue space.

Table 1 shows the distribution of comments in the general categories D (reference to the document), K (reference to one or more comments), DK (both references), and Doc X (references to other documents in the domain). There were no references to comments in another dialogue space in the material coded. It is clear from these results that the discussions satisfy the requirement of dual reference: they both deal with the content of the documents and they are also interactive, i.e. comments refer back to other comments. In other words, the participants regularly respond to each other's comments while also addressing the content of the documents.

Table 1. References to the top document (D), to previous comments (K), and to both (DK) in the two sets of data.

	D	K	DK	Doc X	Total
CSCW01	46	25	18	6	95
CSCW02	29	20	17	1	67
Total	75	45	35	7	162
%	46.3	27.7	21.6	4.3	

The distribution of the categories is similar across the two sets of data: the largest category is D (reference to the document only), where as the other parts are about equal. If we distinguish only between the categories D and K, we find that most of the comments refer to their top document (68% in total), and a large part of them (49%) also refer to one or more previous comments.

The total number of references identified within one comment varied between 1 and 4. (See Table 2.) The mean number of references identified in a comment was 1.4 across the two domains.

Table 2. The number of references to previous discourse contributions identified within one comment.

Ref.	CSCW01	CSCW02	Total	# of ref.
1	62	42	104	104
2	24	14	38	76
3	3	9	12	36
4	1	1	2	8
Total	90	66	156	224

The degree of activity varied a lot among participants, with the number of postings by one person ranging from 0 to 15 comments during the task (mean=5.17; median=4). There was no difference between women and men with regard to posting activity (mean number or postings 5.1 and 5.2, respectively, t=0.07). An interesting factor is the number of comments that an author makes within the dialogue space of his or her own document. It is reasonable to expect that authors want to monitor the discussion on their own essay and respond to comments made. However, only 17 out of 30 discussions actually contained a response from the author to other participants' comments, and there were many cases of direct questions to the author that remained

3. We are aware that this kind of categorization of discourse references has certain problems. Just as in a spoken discussion, a contribution in a computer-mediated dialogue can refer implicitly to several previous utterances with a common topic. The references made by participants may also make use of aspects of the context not available to the analyst.

unanswered. A possible explanation is that the author considered the assignment completed and did not enter the system in spite of the fact that the comments made on the document were sent to him/her by email to support awareness.

In summary, the analysis of these data showed that the DHS discussions across two subsequent course assignments had a similar character with regard to the pattern of references across comments and documents. In both domains, participants engaged in interactive discussion which was both focused on the shared documents and simultaneously addressed other participants' comments. In about half of the discussions, the author of a document took part actively in the discussion of her/his document by responding to comments made.

According to Rafaeli & Sudweeks [10], interactivity in CMC "describes and prescribes the manner in which conversational interaction as an iterative process leads to jointly produced meaning". In their account, interactivity is related to engagement and sociability, and requires more than just mutual participation, or two-way communication where both parties have the possibility of interruption and feedback. Fully interactive communication "requires that later messages in a sequence take into account not just messages that preceded them, but also the manner in which previous messages were reactive". In their large-scale study of discussion groups on the Internet, interactivity in this sense varied from 0% to 40% across groups. Applying their definition to our data, we find that messages in the categories K and DK, which refer to previous comments on a document, can be said to satisfy this strong requirement of interactivity. Thus the number of interactive messages in our material was quite high. However, the fact that only about half of the authors actively contributed to the discussion of their own document seems to limit the extent to which the discourse in DHS can be characterized as sociable and engaged on the part of the students who participated.

5.2. Conversational linking strategies

In this section we describe the linguistic strategies used by participants to connect a comment to previous discourse contributions. In general, the dialogues in the corpus have an informal, conversational character. The individual comments are short (mean length 86 and 109 words in the two sets of data, respectively) and context-bound in their linguistic form. Some of the linking strategies used are explicit, i.e. they attempt to point out the specific comment referred to. Others are implicit; they rely on topic relations, ordinary conversational principles and deictic references for linking, and do not give much help to the reader to establish the reference. The following categorization is an attempt to order the references found from the most explicit to the most implicit ones. When messages are assigned to one of these categories, it means that the most explicit reference of the message belongs to the category in question.

Explicit references

1. Message number

Using the unique message number can be seen as the most explicit way of referencing. This category is included here for the sake of completeness. However, in contrast to other DHS contexts (such as the discussions about the system carried out in a special dialogue space), the data examined here did not contain any example where a message was referenced by its number.

2. Author

a. Name of author

A common strategy, especially for comments, is to name the participant who authored the text referred to. This is done in several different ways. Many of them mention the addressee in third person:

"Even though Fred may be right…"[4]

"Michael's dilemma is…"

"the same problem that Jenny describes…"

Sometimes a name is given in a header text before the response to a comment:

"A question to Clare:"

Others address another participant directly, by their name:

"Axel, I would like to tell you…."

A comment may also start with a salutation to connect to a previous contribution*:*

"Hi, Anne!"

b. Referring to a previous contribution written by oneself.

"as I wrote in another comment"

3. Subject

This category includes references by describing the subject matter of a particular previous message. This is done in two main ways: by quoting, and by paraphrasing the message.

a. Quoting

Only 8 cases were observed, quoting a short passage from the document or a comment (4 cases each). This low number may be due to the fact that the system did not give support for selective quoting, and that it is generally difficult to find a short quoted passage in a long document. The cases found varied from quoting just a word or a phrase, to copying a whole sentence (such as a question) in the response.

The following is an example:

4. All examples have been translated from Swedish. The names of participants have been changed.

"it would be interesting to know how this 'information of less importance' was planned to be captured?"

b. Paraphrasing part of a message or specifying the subject matter

"what you said about the stars…"

"about the use of the subject line:"

Implicit references

1. Deixis

There are numerous cases when a general deictic or anaphoric reference is used, which may sometimes make the link to a previous comment ambiguous or unclear.

"as you mention"

"you wrote that"

"this is an interesting tool!"

When the pronoun "you" is used without further specification, it usually refers to the author of the top document. Similarly, the pronoun "this" is very frequently used in the comments to refer to statements or objects in the top document.

2. Conversational sequencing

In this category we place messages in which references to other contributions rely on the regularities of conversation in the form of relationships between turns.

a. A question or other elicitation without specification of the addressee

It is common that one or more questions are posed without any explicit indication of the addressee. Often, the content reveals that the writer of the top document is the intended recipient.

b. A response move (e.g. an answer to a question) without explicit reference to a preceding initiative

Sometimes, a comment refers back to a preceding initiative by stating agreement or making a positive evaluation. However, the reference may be ambiguous because there are several potential candidates for the antecedent:

"I must agree that"

"Yes, that's correct"

In a number of cases, an answer just begins with one or several statements of fact, and the relationship with the question has to be inferred from the previous conversation. This happens in several cases when a question does not immediately precede the answer.

3. Topic relatedness

This is a category of implicit references where the content of a message connects to the topic of a previous message in a general way, without attempting to paraphrase part of it. For example, participants sometimes respond to a comment by sharing their personal experiences of a subject discussed in the comment.

Apart from the references mentioned above, operating within one and the same dialogue space, there are cases when a comment refers to an external discourse context outside of the current dialogue.

External references

1. References to other documents in the domain

This category includes six comments, half of which refer to the author's own document submitted to the domain (for example, "in my report…."). For the rest, the reference may be difficult to separate from between-comment references, as in the following example:

"The same problem that Jenny describes"

"The project work that Leif told us about"

2. References to group experiences outside the system

Occasionally a comment refers to shared experiences outside the system, such as discussions held in class:

"As we saw during the lecture"

"As I mentioned in class"

5.3. Summary of observations

Below we summarize our observations in a way that reflects the difference in status between documents and comments in the DHS discourse.

• Explicit reference by naming the author is used in 43 cases, 34 of which are references to a previous comment, 6 to the top document, and 3 to another document in the domain. In other words, this is the preferred strategy to make an explicit reference to a previous comment.

• Implicit reference by deictic terms such as "you" and "this" is frequently used when referring to the document and its author. There are at least 25 cases when "you" is used in this way. Although ambiguous in many contexts, this strategy in practice constitutes a unique reference when it is used in the initiating comment of a discussion of a document.

• In total, the categories of implicit reference we have listed above are used predominantly for referring to the document (50 cases), but also to comments (21 cases).

Altogether, these observations seem to suggest that the document is perceived as the salient object of the conversation, and is therefore most often referenced implicitly. In fact, the document is always visible above the dialogue space, which means that it constitutes an ever-present context of the discussion. In contrast, when referring to previous comments in the dialogue space, participants often choose an explicit reference. In these cases, naming the author is the most frequent strategy, which is done in many different forms.

There are many cases showing that participants do not always succeed in using these reference mechanisms in a coherent way, or that the references are unspecific so that the resulting message is ambiguous. Below, we illustrate the use of some of these referential mechanisms in mes-

sages extracted from the corpus.

5.4. Examples

The following is an example of two comments initiating the discussion on a document which describes a "virtual meeting place for project work". Note that both comments are linked to their discourse context through the deictic phrase "this tool". The author of the document is addressed in a direct question in the first example, and by the pronoun "you" in the second one.

```
---------------------------------------------------------
(01:1:1) Date: 01/02/05 Time: 19:28:15 Bill K.
It would have been interesting to see how this tool would
be used in a workplace where all users are personal and
are online all the time. Then I think it would work much
better.
Was it possible to add that everyone would get a notifi-
cation when something had been changed?
---------------------------------------------------------
(01:1:2) Date: 01/02/05 Time: 22:03:58 Julia G.
This seems to be a great administrative tool for
projects!
That the flags showing when an object had been modified
did not work would have been solved if you had had nine
users instead of three. But I understand that you did not
want to pay to get access to more users.
---------------------------------------------------------
```

These examples show that the participants take advantage of the spatial proximity between documents and comments, and rely on coherence mechanisms such as deictic and anaphoric reference, rather than paraphrasing the text referred to. This may not be a problem, but occasionally a message is ambiguous, so that it is unclear if the response is oriented to the top document or a previous comment, or both. In other cases, such as the following, an author is apparently aware of the potential ambiguity, and provides an explicit link to a previous comment by pointing out the addressee:

```
---------------------------------------------------------
(01:1:5) Date: 01/02/11 Time: 13:09:32 Anne S.
In response to Leif:
There is something called "activity reports". These are
sent by e-mail, once a day. When I used the Web site it
was only the project leader that got these reports, i.e.
I got them and thought they were good. Now they have
changed it so that all registered users can get
them…(etc.)
---------------------------------------------------------
```

Sometimes both a document and one or more comments are simultaneously referenced in the same message. The resulting dialogue may be confusing if no effort is spent on the clarification of discourse context. In the example below, the author of the top document responds to three previous contributions, establishing a link to these by explicitly naming their authors. The first reference ("as Charles describes") points to something stated in the document, whereas the others point to previous comments.

```
---------------------------------------------------------
(02:4:3) Date: 02/02/08 Time: 00:01:44 Martin L.
We experienced almost exactly the same problem in our HCI
group as Charles describes. Email can really be the per-
fect solution when you don't know each other very well
(it's easier to write email), and above all, to reach
everybody in the group at the same time. Sara writes
about problems with different "email mentalities" and I
can only agree to that. I also think that email contact
is usually much better during the first part of a
project, and then it slowly gets worse, maybe more so in
larger groups (up to 10 people).
A question to Clare: Does it usually work to stick to the
rules you've decided on?
---------------------------------------------------------
```

In some of the dialogues, formal linking mechanisms are invented or borrowed from other CMC genres. In the following comment, two different comments are referenced explicitly by quoting and a "pointer" naming the addressee. Also, a third comment is referenced implicitly. The top document is a story about experiences of computer games, and the message below is posted by the author to follow up and answer questions asked.

```
---------------------------------------------------------
(01:5:7) Date: 01/02/12 Time: 23:29:40 Greg L.
Mary> Have you tried games like Baldur's Gate?
Don't know if it is similar to Diablo2, but it sounds
similar, if you play over a LAN you can always pause and
talk to each other. If you however play with people that
possibility goes away.
I agree that in Quake it can be a bit hard to communicate
because it's so fast, but in Counter-Strike for example
it is possible. The simplest is to use the programmed
radio messages, and hope that the ones you play with will
understand.
Bill> Isn't it common that clans in e.g. Quake have pre-
set patterns for how they should move?
That's true, every person has a task that they have prac-
ticed and are very good at.
Playing games doesn't have to take a lot of time, but it
easily gets too much. I more or less succeeded to ruin my
first year at the university with too much MUD….
---------------------------------------------------------
```

Apart from the two quoted text parts, a third comment is implicitly referred to by the sentence "Playing games doesn't have to take a lot of time…", which follows up on a topic in a previous comment. One reason that this comment was not quoted may be that it did not contain a question or other direct elicitation. The study of quoting in [13] showed that in newsgroup discussions, participants often select a direct question or other elicitative act to be quoted in the reply, deleting the entire rest of the message.

Examples such as (01:5:7) show that some participants are prepared to put in significant work to create coherence in the discussion. However, it is also very common in the corpus with comments that refer only in an implicit and conversational way to the preceding discourse. In these cases the discussion is reminiscent of an informal round-table group discussion, where participants connect to each other's contributions through content, gestures, and ordinary conversational principles. Our analysis shows that when such linguistic strategies are used in an asynchronous, text-based environment, with several parallel discussions and in the absence of a threading mechanism, the resulting dialogue may be partly incoherent.

6. Visualization of the discussion in the DHS

We have created a visualization tool, DID (Domain Interactivity Diagram) to help clarify the conversational activity exhibited in the DHS system. The purposes are mainly exploratory: to assess the interactivity and referential relationships within a particular domain, and as a tool for comparison between different discussions in this regard. However, we believe that visualizations like the ones we are using might also be helpful to participants themselves as optional coherence tools. This would increase the accessibility of the discussion space, and thereby its "social translucence" [5], i.e. the degree to which other people's activities are immediately available and visible to a user.

The DID presents a domain at two levels. The first level is a general overview of the domain; *the panorama view*, and the second level focuses on the discussion of a single document; *the document interactivity view*. Common to both views is that each participant in a domain is assigned a color. Objects created by him or her, that is comments or documents, are presented in the same color. With this information it is easy to see how each person has spread out his/her activities among the different discussions. As a social navigation feature [9] this may both support coherence and promote the group's discussion when the number of participants increases. For example, a reader could benefit from reading all the comments by a particular person. However, it could be a problem to distinguish between colors when the number of participants increases, and therefore other means to identify users are also necessary.

The DID has been designed taking into account the results of case studies using the DHS system, in terms of the characteristics of conversations actually occurring. For example, in the cases analyzed, only 5% of the documents (N=40) had more than 10 comments; no more than 10 members took part in the discussion of one document (which means that not many colors might be needed to represent them in our visualization); 95% of the comments were no longer than 200 words; and 50%, 68%, and 80% of the comments were submitted within one, two, and three days respectively. It is important to indicate that, in another context, the information in a domain could diverge from the one that we had in mind when the DID was designed.

6.1. Panorama view of a domain

The panorama view is generated automatically by the system (see Figures 2a and b). Each entry on the x-axis represents a document, and the y-axis presents the number of comments that each of the documents in the domain received. The bars in the chart are built up by colored blocks, each of which represents a comment. If one color appears many times, this indicates that the participant in question has been very active in the discussions. If the bar is rich in different colors, the document has been discussed by many of the participants. The size of the bar also gives valuable information. For example, at a glance it can be seen that a particular document was hardly discussed at all.

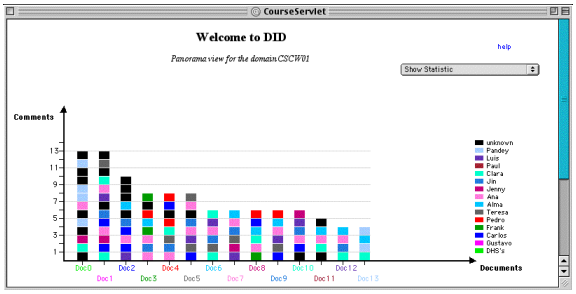

Figure 2a. Panorama view of the domain CSCW01.

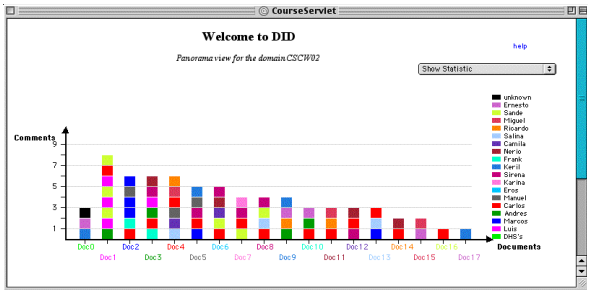

Figure 2b. Panorama view of the domain CSCW02.

6.2. The document interactivity view

To reach the document interactivity view, users select from a menu list presented in the panorama view. Once the user has requested a document, a new layout is displayed. The upper frame presents the document interactivity chart (see Figure 3), which shows the time sequence in which comments on this document have been received, and the reference links between the comments and the document. To generate the document interactivity chart, the help of an analyst (a person) who will create the links between the comments, is needed.

The bottom frame is divided into two vertical frames. The left frame displays the Web document that has been selected by the user. The right frame presents the text of the comment that the user might select from the document interactivity graph. The purpose of the bottom frame is to support navigation within the text-based communication associated with a document. It also gives some support for "rebuilding" the context in which the comment was made as the document in question is presented.

The document interactivity chart is two-dimensional- The x-axis (the baseline) represents the document under discussion, and shows the time sequence in which the comments on the document were received. On the y-axis, we

have the names of those who made at least one comment in the discussion of the document in question, and within parentheses the number of comments made by him/her. This number is used to sort the list. The closer a participant's name is to the baseline, the more comments he/she has posted in that discussion. This allows the reader to see at a glance how many members participated in the discussion and who were the most active. This principle has one exception, however. The author's name is always part of the list and it is placed closest to the baseline regardless of whether he/she took part in the discussion. Thus, one can easily see how the author has interacted in the discussion about his/her document.

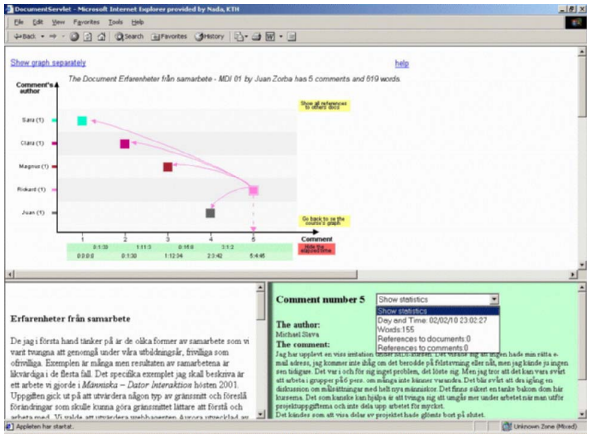

Figure 3. The document interactivity view of the DID visualization module

If a comment (represented as a square) makes direct reference to the selected document, a perpendicular dotted line is drawn from the comment to the baseline. Having a glance at the baseline and seeing how often it is intersected by a perpendicular line provides an easy way to determine the extent to which the discussion has indeed been focusing on the top document.

If a comment makes reference to a previous comment, this is represented by a line and an arrow that links the comments in question. These links can be used to identify conversational threads within the discussion, and altogether, they show the interactivity of the discussion around a particular document. Figures 4a and 4b show two different dialogues from the domain CSCW02. We can see that the author has participated actively in both discussions, but with different reply strategies. In 4a, the author commented on each previous message separately, whereas in 4b, the author made only one comment referencing two previous messages. We can also see that several of the comments include references both to other comments and to the top document.[5]

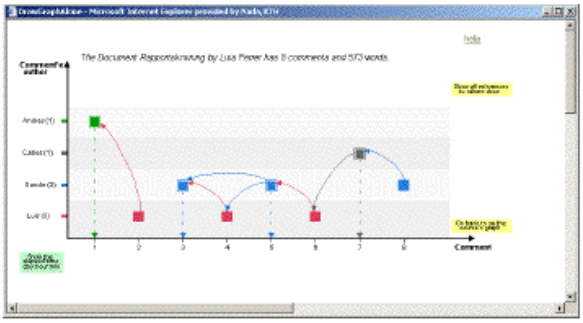

Figure 4a. Visualization of a discussion in the domain CSCW02.

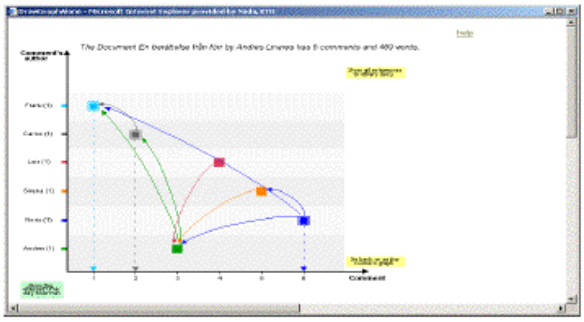

Figure 4b. Visualization of a discussion in the domain CSCW02.

In summary, this perspective gives a detailed view of one selected dialogue at a time. It is targeted specifically to the kind of group discussions exhibited in the DHS system, with relatively few participants, and including a moderate number of comments on a specific document. So far, the DID system has only been used within the research group, and no formal evaluation has been made.

7. Summary and design implications

This study has been focused on the issue of how users handle the referential complexity of a DHS domain, a discourse environment based on a collection of Web documents, each with its own, unthreaded discussion. Our analysis of the discussions has shown that messages have intricate referential relationships, resulting from the dual context of documents and comments. The fact that the system does not support threading of messages forces participants to create their own strategies for linking discourse

5. A comment can also make a reference to the content of another document in the domain, or to a comment made on another document. As this is a rare case in our data, it is not included in the visualizations here, but there are conventions covering this case in the system. A reference to an external document is represented by a square in the periphery of the diagram and it is labelled with the document's title. The link to this document is represented by a dash-dotted line. This link may also present a tag with a number, n, within parenthesis. This indicates that the comment makes reference to comment #n of the other document.

contributions. Many of these strategies are implicit and conversational, and the resulting dialogues are sometimes incoherent.

We have developed graphical representations both of an entire domain and of a particular dialogue around a document, which give an instant view of the participants' activity and clarify the structure of discussions. They also emphasize the particular role of the author of the document in the discussions. However, these visualizations have so far only been used as research tools, and part of them require manual work by an analyst. A central issue for future research is if and how a graphical representation can be used as part of an active coherence mechanism for users, which could be automatically created when a reply comment is posted. This would give the possibility to both preserve the document-focus of the environment, and to provide for increased interactivity.

An important issue is how traditional threading would affect communication in DHS. The questionnaires and interviews with users showed that threading is a desired feature for many participants. Threading can be expected to contribute to the sequential coherence of a CMC discussion, by relating messages with the same topic. We avoided threading in the design of DHS, mainly because the discussions as a whole were expected to focus on the shared document, and we expected that threading might contribute to the topic drifting away from the shared document. Separating threads can also impose an additional burden or "cost" on the user, who has to indicate to which thread a contribution belongs [8]. On the other hand, there may be alternative interface designs that could be used to emphasize the structure of the discussions. For example, Venolia and Neustaedter [15] have developed a graphical interface for email that simultaneously keeps the sequential order and shows the hierarchical structure of conversational threads. In summary, we believe that there is a design tradeoff between the simplicity of making a comment on a document, and the coherence and accessibility of discussions. The nature of this tradeoff will depend on the context of communication and the role of annotations and documents, making complex interface features unnecessary for many kinds of document-centered discourse.

8. Acknowledgements

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