A Pilot Study of CZTalk: A Graphical Tool for Collaborative Knowledge Work

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Abstract

Research in face-to-face communication has identified a variety of largely unconscious patterns of behavior that are used by collaborators to coordinate their conversation, build common ground, and repair errors of understanding. These provide a communication metachannel that is not explicitly supported in current collaboration environments. Without this metachannel, conversants must overburden linguistic channels with explicit communication strategies and codified behaviours e.g. "netiquette".

One approach to solving this problem is to attempt to reproduce face-to-face collaboration with VR, video, etc. We have taken an alternative approach, using visualization techniques to create a graphical network representation of patterns of reference in collaborative discourse. A preliminary user study suggested that the CZTalk proof-of-concept prototype provided improvements in both interpretation and authorship.

1. Introduction

From its origins in USENET and email, text-based conferencing has expanded to fill a variety of niches ranging from informal chat rooms to online learning and collaborative work. As an alternative to audio/video communication, text conferencing has advantages of much lower bandwidth and hardware requirements, support for asynchronous communication, and easy archiving, indexing, and manipulation of content. These advantages come at the cost of an interface that has neither the visual and conceptual structure of a conventional document nor the natural interaction of video or voice conferencing. This paper examines a design approach to improve the effectiveness of this limited bandwidth medium for communication.

As with other collaborative learning and knowledge work environments, conferencing tools have as their primary design goal support for a positive change in the cognitive, communicative and (sometimes) perceptual state of the end users. This shift in the goals of system design from usability per se to cognition and communication clearly has implications for the processes embodied in the design-and-test iterative software engineering cycle [11].

We feel that the unique goals of building environments that support cognitive processing (e.g. learning and knowledge work) of collaboration call for greater integration of theories and methods from Cognitive Science in software design [9][15]. At the system prototyping stage, the knowledge that informs design must expand from measures of efficiency and ease-of-use (e.g. Fitts' Law) to include theories about the nature of the cognitive processes that constitute the end goal of the system. Thus, development should be grounded in a reflective design practice that incorporates methods and theories from a range of cognitive and social sciences [8].

While previous work by this group [10][12] has concentrated on cognitive and metacognitive aspects of the construction of multimodal texts, this paper will concentrate on adapting the same visualization techniques to scaffold metarepresentation and effective communication.

In previous studies we have argued that these effects can also impact the production and interpretation of user reports, and an alternative interface might work to improve their accuracy by manipulating the perceived communicative situation [13]. Here we extend that work to explore methods to improve the design and testing of collaboration systems.

In this view, the failure of many learning environments in practice can potentially be attributed to the fact that their design process has no mechanism to take into account the ways in which learners process and represent domain knowledge, metaknowledge of their own cognitive processes (metacognition), and understanding of the knowledge states of collaborators (metarepresentation).

In asynchronous communication environments, the ability to reformat and manipulate text supports the development of a range of visualization approaches. Some approaches [23][24] combine discourse analysis and social network

analysis to generate rich representations of patterns of interaction in large discussion spaces.

While integration of Psycholinguistics theories and methods into software design models is an ongoing process, the following initial set of guidelines describes our approach to evolving a design practice specialized for these classes of applications:

- Examination of Psycholinguistics literature, concentrating on the pragmatics of face-to-face communication— e.g. patterns of discourse such as "adjacency pairs" (following of a statement by an acknowledgement of understanding), leading to "action ladders" (sequences of statements and actions that are dependent on the previous exchanges) culminating in "common ground" (metarepresentation of another's' knowledge and belief state in the context of the topic of discussion) [5][6].
- Selection of "discourse design goals" for the present application from the communication processes described in Psycholinguistics theory, thus prioritizing which aspects of communication will be most clearly supported by the visualization.
- Mapping those key sequential and temporal patterns of discourse onto visual analogs to create a visualization of the users' communicative processes. This visual representation must serve as a proxy for the more natural processes in face-to-face discourse that cannot be supported due to the nature of the medium.
- Testing of the prototype or application, again from the perspective of the Psycholinguistic processes that gave rise to the design goals.

For example, in situations where interaction is asynchronous, time of posting must be mapped onto visual cues. We can then test how effective those cues are in supporting a particular aspect of communication, adapting the visualization to better support the processes. As the application evolves, user testing can begin to focus on more domain-specific summative evaluation metrics such as learning outcomes, to insure the overall effectiveness of the application.

The rest of this paper describes the initial stages of the application of this approach, mapping visualization methods [4] to communicative functions to adapt our CZWeb hypermedia authoring application to support collaboration and communication. Our purpose is to explicate the process we have briefly described above rather than to propose that the CZTalk prototype is a solution for conferencing or that the visualization methods used are novel. Our goal instead is to show how visualization techniques can be selected and applied to meet Psycholinguistic design criteria. The implementation is best thought of as a "toy world" communication prototype to help establish methods that will later be used for applications focused on a user group and situation.

Section 1.1 describes the initial stages of the iterative development of CZTalk, outlining potential interface issues that relate to the mismatch between patterns found in face-to-face communication and those supported by current online discussion software.

We then introduce a method of visualizing patterns of communication that enables users to generate and interpret conversations by direct manipulation of the representation. Finally, we test users' creation and interpretation of messages using this interface versus a more familiar threaded discussion format.

1.1 UI Concepts and goals

The "knowledge work" environments that are the target for this paper pose interesting challenges for software design. In addition to the familiar design goal of "user friendliness" these systems have as their primary goal support for a change in users' knowledge states and cognitive abilities that arises from collaboration with others. This in turn leads to the requirement to support the more complex patterns of communication that are more likely to give rise to collaborative knowledge work and learning.

This analysis suggests that theories of cognitive processes and individual differences in abilities and learning styles--in particular learners' knowledge of their own knowledge and cognitive processes (metacognition) [20] and representation of the knowledge states of collaborators (metarepresentation) [[14] 1994] should be taken into account when designing and testing applications for collaboration.

Lack of support for metacognition (e.g. Schoen's [25] reflection-in-action) can lead to shallow processing and poor communication. Our previously reported CZWeb project [9] began an ongoing evaluation of current collaborative knowledge work and learning environments and development of technologies to support it.

Lack of support for metarepresentation can also impede the communicative process and result in unproductive collaboration [1]. Psycholinguistics models [4][6][16] often suggest that communication is to a great degree mediated by conversants' mental models of each other's beliefs, goals and attitudes and the shared knowledge referents that generate their "common ground". In face-to-face conversation, much of this is established extralinguistically, through tone-of-voice, gaze, expression, and gesture. In designing a collaborative environment, care must be taken to insure that the communication metachannel that enables users to

disambiguate their language and establish shared meaning (a process known as "grounding") is maintained (e.g. through video conferencing) or an adequate substitute provided.

The first challenge for this project is thus to provide a way to help maintain metachannel activities across a low-bandwidth (in this case text-only) channel:

Goal 1: Create perceptual cues to support metarepresentation of the knowledge states of conversants, a basic requirement for developing the "common ground" to support increasingly effective collaboration over time.

In face-to-face communication our senses enable us to quickly and easily identify speakers, fellow participants, and bystanders. As described in Clark [5], this enables us to easily interpret referents within messages based on previous experience with that individual. For familiar participants this is done by automatic visual and auditory recall, with little drain on attentional resources. In online environments, however, the author name is typically the only cue provided, in a display cluttered with other text (such as the message itself). As a result, discussion participants are unable to use automatic grounding mechanisms. Message interpretation in this situation requires cognitive effort, which may impede their ability to perform their task. Similarly, as speakers, we automatically adjust our communication to ensure all participants understand our meaning. Lacking bottom-up grounding cues, this too may require cognitive effort. Thus, a Psycholinguistic analysis would suggest the lack of clearly visible evidence of participants and their roles may make it difficult for participants to use automatic processing of metachannel information, thus increasing the load on cognitive processing [8].

Goal 1 is derived from an analysis of the ways in which messages are situated in a social and communicative context, drawing on our automatic metarepresentation skills for effective communication. A related focus of our work examines the impact of the richness of message content context on collaboration. Current designs typically require users to choose a single organization for messages: sort by date, sort by author, or sort into threads of reference. This one-dimensional context hides the complexity of message embedding and limits the ability of users to determine at a glance multiple characteristics of the relationship of a given message to the larger discussion.

Goal 2: A visual method for simultaneously representing multiple types of message relationships—e.g. authorship, thread, and time.

Traditionally, online discussions are biased towards organizing information as topics and subtopic threads. (see Figures. 1 and 2). This was a rational response to large-scale environments such as USENET, where many casual participants might post from time to time. Building common ground in these many-to-many communicative situations is inherently problematic, and probably contributes little to the nature of the communication, which typically takes a question-and-answer or general discussion form. An active newsgroup will have discussions on many topics overlapping in time, and a threaded presentation enables users to focus their attention on a small number of these threads. This format persists in many current small-group discussion forums that allow users to sort by topics of the messages, their authors and their time of postings. Fig. 1 shows the messages of a conference sorted by dates of posting while Fig. 2 shows the same discussion with messages sorted by threads. In displays where messages are sorted by dates or threads, users are required to mentally reconstruct the various alternative relationships between messages, or to use the interface to explicitly toggle between alternative sorting methods.

All Messages Sorted by Date — Top

#	S	Subject:	Author:	Date:
2	R	Education or Exploitation?	Janet Smith	Tue, 13 Mar 2001 (21:39)
3	R	Re:Education or Exploitation?	John Turvey	Tue, 13 Mar 2001 (21:41)
4	R	Improper Consent	John Turvey	Tue, 13 Mar 2001 (21:43)
5	R	Re:Education or Exploitation?	Jayce Salloum	Tue, 13 Mar 2001 (21:44)
6	R	Re:Education or Exploitation?	Lincoln Clarkes	Tue, 13 Mar 2001 (21:47)
7	R	Re:Improper Consent	Lincoln Clarkes	Tue, 13 Mar 2001 (21:48)
8	R	Education	Lincoln Clarkes	Tue, 13 Mar 2001 (21:49)
9	R	Is Exploitation too strong a word	Janet Smith	Tue, 13 Mar 2001 (21:51)
10	R	Why shoot only women?	Janet Smith	Tue, 13 Mar 2001 (21:52)
11	R	Re:Is Exploitation too strong a word	Lincoln Clarkes	Tue, 13 Mar 2001 (21:53)
12	R	Re:Education	Al Arsenault	Tue, 13 Mar 2001 (21:55)
13	NEW	Or Stereotyping?	Bernadette Phan	Tue, 13 Mar 2001 (21:57)
14	NEW	Re:Improper Consent	Judy McGuire	Tue, 13 Mar 2001 (21:59)
15	NEW	Re:Why shoot only women?	Lincoln Clarkes	Tue, 13 Mar 2001 (22:00)
16	NEW	Re:Or Stereotyping?	John Turvey	Tue, 13 Mar 2001 (22:01)
17	NEW	Re:Improper Consent	Al Arsenault	Tue, 13 Mar 2001 (22:03)
18	NEW	Re:Or Stereotyping?	Jayce Salloum	Tue, 13 Mar 2001 (22:04)
19	NEW	Message to the world!	Al Arsenault	Tue, 13 Mar 2001 (22:05)
20	NEW	Personal Involvement	Lincoln Clarkes	Tue, 13 Mar 2001 (22:06)

All Messages Sorted by Date — Top

Figure 1: Current discussion group display—sorted by date.

By nature of the file structure display in Fig 2, existing threads can give rise to one or more new threads. Since users can only reply to one message at a time, there is no interface support for a complementary converging structure [9]. This emphasis on divergence is in contrast to face-to-face discussions where participants pull ideas from different threads of discussion to summarize or to create new ideas. In fact, drawing conclusions, reaching agreements, creating hypotheses and summarizing results are the main objectives of the more complex communication that underlies collaborative knowledge work. When these converging occasions arise in an online discussion using a file structured display, the inability to reply to multiple postings forces users to break the

threading structure to generate what is called a "weaving message" [6] . This leads us to our third challenge:

Goal 3: Provide support for more complex patterns of reference that are found in collaborative communication such as the convergence of multiple threads that characterize so-called "weaving messages".

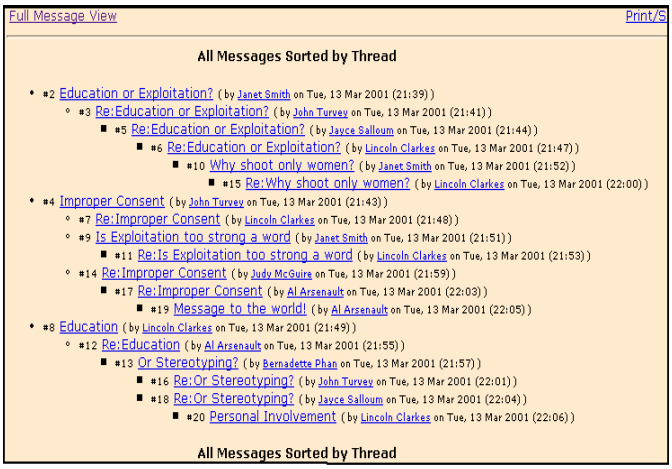

Figure 2: Current discussion group display—sorted by thread.

To summarize, if we are to build effective discussion environments, the interface must support mental representations of the knowledge states of other people, display messages within multiple contexts of time, authorship, and thread, and provide a rich set of referents for each message, and support users in developing their understanding of the discussion by interactively structuring information. The rest of the paper proceeds as follows: Section 2 describes a more visual mechanism for representing and for interacting with ongoing online discussions; section 3 describes the resulting design; section 4 reports on a preliminary user study to investigate some of the properties of this mechanism and we conclude in section 5 with some recommendations for next steps.

1.2 Visualization mechanisms and goals

Our proposed online discussion visualization software, CZTalk, applies some of the techniques used in our previous CZWeb application for visualizing and organizing information [26] [9] [22]. CZWeb's goal was to provide users with a "knowledge workbench" to organize visible structures of information nodes pointing to files or URLs in ways that reflect and help to support the user's conceptual understanding as reflected in annotations and the evolving complexity of relationships between information nodes. It generates a visual map consisting of a hierarchically organized network of nodes that point to web pages. Content (e.g. Web page) nodes are added to the display as they are loaded in the companion browser, displayed inside a container (cluster node) that groups together pages found on a given server as a default.

The CZWeb display itself uses some interesting inset zoom and auto-layout algorithms to conserve screen space while maintaining flexibility in terms of the number and organization of information nodes selected by the user. However, much of the later development effort focused on how those graphical transformations and user operations could support the user to build their individual understanding of the knowledge space as reflected in their organization and annotation of elements in the workspace. As detailed in [12] this required us to design and test the interaction within the context of perceptual and spatial cognition, spatial attention, "chunking" of information [1][21] into higher-order structures. etc. This provided perceptual and interactive support for operations that are considered important for development of expertise. CZWeb later gave rise to a commercial product by ThoughtShare Communications Inc.

This paper takes an alternative approach to visualizing the discussion by applying the same methods for visualizing information that were applied to individual items in CZWeb to the structure of the conference itself. These methods include hierarchical structure, graphical interface, "Detail-in-Context" display [3][18][19] and dynamical spatial layout. While CZWeb concentrated on cognitive operations, CZTalk seeks to optimize the application of the same set of visualization methods to social and communicative interaction, using a restricted set of patterns of reference in communication rather than the much larger set of possible patterns of relationships between information nodes in CZWeb.

The hierarchical network visualization used in both applications is advantageous for representing discussions as it frees the interface from the limitations of the file structure displays. File structure interfaces display information as sorted linked lists, with most of the information presented in the form of text and some structural and relational information conveyed by the ordering of the lists. As discussed earlier, users can only view one of these lists at any one time. In contrast, CZTalk's visualization (Figure 3) conveys structural and relational information in addition to the textual information by the spatial grouping and location of the nodes, either independently or in most cases, as clusters. As a result, information can be presented in a more flexible and coherent manner than the file structure used by most online discussion interfaces today.

Despite its shortcomings, organizing messages by topic or sub-topic does provide a very compact method of displaying information. In addition, the threaded structure of message organization provides a sense of

"where-to-start" and "where-am-I" (from one perspective at least) in a large number of messages. It can, however, overload screen real estate with a large number of perceptually similar text strings, making orientation, message selection and reading more difficult. Thus, an important design goal might be:

Goal 4: Strive to efficiently utilize limited resources of screen real estate and user attention while displaying a richer set of linkages between messages.

Dynamic Spatial Layout: As with CZWeb's knowledge work, online discussion is by nature fluid and dynamic. It is therefore impossible to predict the course of a collaboration in order to generate a specific spatial layout for the message displays. One solution might be to ask the users to place the messages in the workspace. The location can then serve as an additional cue to message identification, along with the message's subject, author and date of posting. The main disadvantage of this approach is the cognitive and interactive burden put upon the user to categorize the message, and decide where it should be located. They must then move it to the desired location and adjust the neighboring messages accordingly. The combination of these activities may be unacceptable to users.

When applied to a discussion group, CZTalk's dynamic spatial layout (inherited from CZWeb) provides a compromise. By organizing the discussion topics into meaningful clusters of topics and subtopics, the initial cognitive burden is reduced. However the user is free to reposition the messages within a cluster and to reposition the clusters. In this way, the discussion process can become an interactive and effective learning process for the user. Further, as the record of discussion is shared among participants during the discussion, more than just messages are being shared. Being able to share the structure of the discussion in addition to the discussion itself is particularly important when the record is viewed at a later date as the structure will facilitate understanding and put the messages in a more meaningful context.

A message annotation capability allows personalizing the map, useful in online discussion for adding comments or impressions.

In discussion groups, messages relate to each other by the predicate "In–Reply-To", which is the electronic counterpart of "address to" in face-to-face conversation. In CZTalk, directional links between nodes represent this predicate, thus visually showing the "flow" of the discussion.

2. CZTalk design

From an informal user profile, the main tasks performed in an online discussion are (re)reading messages, posting messages, searching for a particular piece of information from a discussion and summarizing information gathered from a discussion. Common usability issues related to these tasks are:

- Online discussion interfaces do not offer enough cues to the audience and the speaker as to their presence and identity [9].
- The file-like structure of online discussion interfaces impedes the flow of discussion and learning, as users are restricted to processing information sequentially, not logically [2][3].
- It is tedious to quote previous authors as only one message may be opened at any one time.
- Users cannot respond to more than one message, limiting interaction among participants, impeding idea convergence and structuring. [8]

The design of CZTalk is an attempt to address these issues, in the context of the overall goals developed in section 1. The general layout (Fig. 3) uses three panels: discussion map, participant list and message view.

We should point out that this is a first exploratory design effort to study the use of a dynamic detail-in-context method and should be viewed more as a pilot study than as a finished product.

2.1 Discussion map

The discussion map is the main display and user interaction area (main panel on left in Fig. 3; map shows messages from Fig. 1). The discussion itself is about a controversy surrounding a local newspaper's use of images of drug addicts and prostitutes. Supporting views held that the coverage was educational, putting faces behind statistics to warn and alert citizens of the reality of drugs. Opponents were concerned about the validity of subjects' consent, and stereotyping of both subjects and the neighborhood.

Messages are represented as "page nodes", oval, rounded-rectangular or rectangular shapes, and are grouped by topic into "clusters". Clusters may be "closed" to save screen space and shown as a folder icon. They may be re-opened as needed.

The first message is the introduction, shown as a closed cluster with the "start-here" icon and title "Education or exploitation", abbreviated as "Education…" in the map. Three threads stem from the introduction and are labeled numerically n the map:

1. Arguments for exploitation of the subjects (shown as a closed cluster "Exploitation").
2. Concerns about improper subject consent (shown as open cluster "Improper Consent").
3. Arguments for the educational value provided by the media coverage (on the left of the introductory node, shown as a closed cluster titled "Education").

The exploitation thread (1) further developed into two sub-threads: one explores the controversy of only involving women subjects in one of the project portraying Eastside Vancouver (shown in the cluster, "Why just women?") and the other thread questions the validity of the term "exploitation" in describing media involvement (shown in open cluster "Perhaps exploitation is too strong a word"). The latter thread (initiated by Message 9 in the map) is related to two prior topics, "Exploitation" and "Improper consent", and is therefore linked to both. The last thread that stems from the introduction (3) voices supports for the media and is attacked by their opponents who doubt the claimed educational value in the media coverage and argue that the coverage is more of a stereotyping than education. This new topic is shown as closed cluster "Or Stereotyping" in the far left, linked to closed cluster "Education".

We believe this graphical representation of the three main threads and their common ancestry is a more effective representation than the conventional display (Fig. 1 and 2). The "Detail-in-Context" feature of CZTalk allows users to focus on areas of interest (e.g., in Fig. 3, the clusters titled "Improper Consent", "Why just Women?" and "Perhaps exploitation is too strong a word") without losing the general context.

In addition, CZTalk allows convergence of ideas: Message 9--"Perhaps exploitation is too strong a word"--links "Exploitation" and "Improper Consent" by replying to two messages simultaneously. This multi-message reply is not possible in most conventional online discussion software available today: in our sample discussion (Fig. 1 and 2), the same message (Message 9) had to be posted as a new topic, unrelated to any previous message.

Messages: The first message of a discussion is represented as an oval shape (not shown in the map), while the first messages in subsequent topics/subtopics are represented as rounded-rectangular shapes (e.g., John Turvey's message in the topic "Improper Consent"). Other messages are represented as rectangles.

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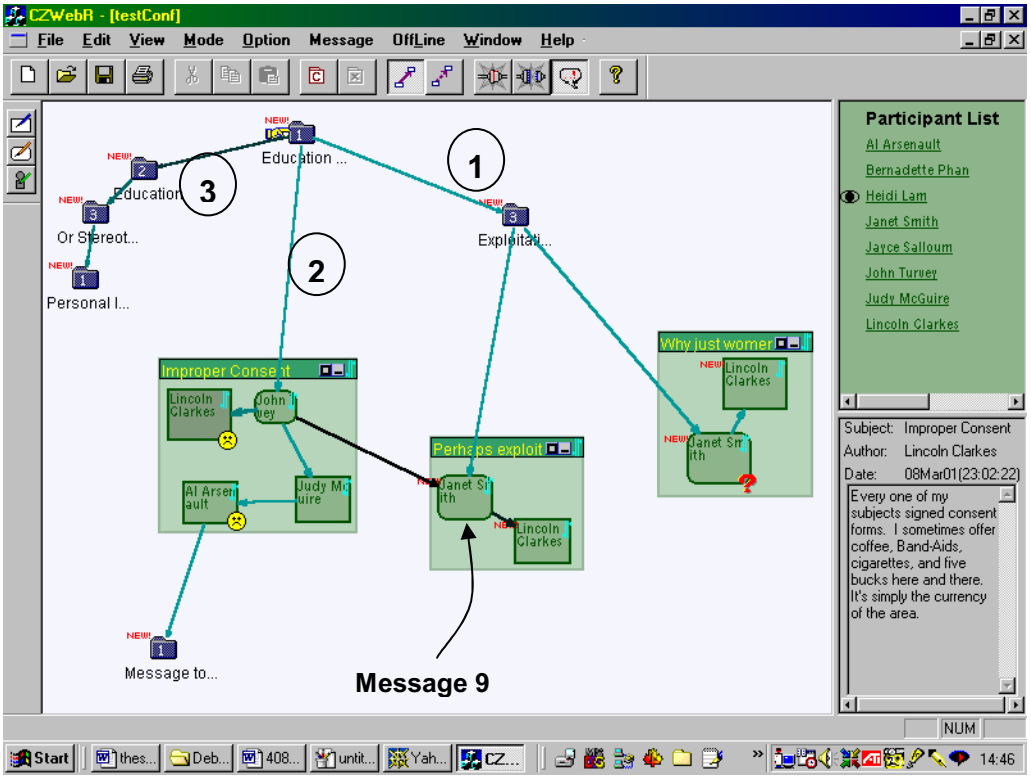

Figure 3: Screen shot of CZTalk

CZTalk also groups messages by topics. In our discussion example, the topic "Improper Consent" contains four messages. More specifically, Turvey's original message (titled "Improper Consent") received two replies, one from Clarkes and the other, from McGuire, whose message was then answered by Arsenault. All four messages shared the same topic. When the topic changed (e.g., the reply to Arsenault's message titled "Improper Consent"), a new cluster would appear (e.g., the "Message to the World" cluster).

When messages of a discussion are displayed as a tree/network, it may not be obvious where the discussion starts. To unambiguously identify the first posting, a "start-here" icon is used. Highlighting the node whose message the user is currently reading provides additional "location" information.

To further aid visual context and to allow rapid visual message "typing", the poster may add an identifying icon at the time of posting. This appears both on the message node and in the message window header (Fig. 4).

Posting and Replying: Two of the main tasks in online discussions are posting a new message (starting a new topic or subtopic) and replying to an existing message. Since these are frequently performed tasks, users can accomplish these goals in different ways. The main methods to reply to an existing message are:

1. When a message node is selected, the user can reply via the usual context menu, toolbar button or Message menu.
2. When the message is displayed as a modeless box, the user can reply via the "Reply" button.

Posting a message as a new topic or subtopic to an existing thread is essentially the same as outlined above, except the user replaces the default message subject (e.g., "Re: Improper Consent" in Fig. 4) in the reply dialog box) by a new topic or subtopic. If the message is a new thread (in other words, if the message is a reply to the first message), the user can use a global context menu item, the Message menu or the *new* topic button in the tool-bar to post the message.

Participant List: Most of today's online discussion software presents no cues to identify the audience and the "speakers" in a discussion, a lack addressed by CZTalk's "participant list" (see upper right of Fig. 3). Note the support not only for normal participants, but also for observers via the "eye" icon, which gives users a better sense of the audience. This list is also linked to the home page, email address and a brief profile of the participants if they wish to share this information. As a result, the audience can easily refresh their memories on the identities of the speakers without the need to search among the messages for the speakers' introductory messages.

Participant Identification: In an online discussion, it is easy to lose track of the identity of the "speaker" as the only cue is the author name associated with the message. Also, it would be difficult to quickly locate all the messages posted by a particular participant in a discussion if the user wished to follow a participant's train of thought (an instructor observing a student, for example). To help with this, a color-coding option highlights all messages posted by a given participant. If the message is embedded in a closed cluster, the cluster will "open" to reveal its content.

The user may also request a list of messages posted by a participant sorted in posting order. Selecting a message highlights and locates the corresponding message node in the discussion map and a double click opens it.

2.2 Message view

Message text can be displayed either as a sub-panel (lower right in Fig. 3) by selecting the node, or as a modeless box by opening with a double-click. The latter allows viewing more than one message at a time, especially useful when replying to multiple messages or quoting from previous messages. Many current discussion interfaces take up the whole screen with a reply/post form, imposing a severe memory load on the user to remember discussion threads, participants and details of the message to which he wishes to reply; the modeless message box and separate reply form reduces this memory load.

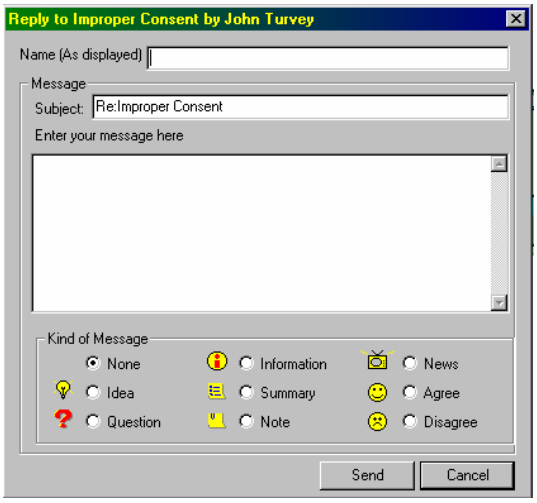

Figure 4. Dialog box for posting/replying to messages.

3. User testing

We performed a preliminary usability study to compare CZTalk's ease of interpretation and ease of authorship with a typical online discussion interface. The control system was the Virtual-U interface developed at SFU [17]. Visual displays for the control and CZTalk are shown in Figs. 1-2 and 3 respectively. A pre-test questionnaire solicited subjects' computer usage habits and online discussion experiences and a post-test questionnaire solicited impressions and opinions of the software. All 10 subjects (half assigned to CZTalk, half to the control) were undergraduate students and frequent users of computers and the Internet. The discussion had 19 messages, was reasonably well-threaded and open-ended so as to present opportunities for further message postings. Subjects were asked to answer 10 multiple-

choice questions, designed to test their understanding of the discussion, using the control or CZTalk.

Subjects were then asked to post three pre-defined messages. In doing so, they needed to decide if the new messages should be posted as a new topic or, as a reply to a single message or, in the CZTalk group, as a reply to more than one message. Replies could be posted as continuations of existing topics or as new subtopics.

Table 1: Ease of interpretation results

	Score (# correct out of 10)		Time to answer questions (min)	
	CZTalk	**Control**	**CZTalk**	**Control**
Mean	8.9	8.2	15.6	19.6
StdDev	0.22	0.57	6.66	3.65
Range	0.5	1.5	15	10
p-value	0.034		0.273	

3.1 Analysis

Ease of interpretation was quantified using the score obtained in and time to complete the test questions. CZTalk was better in both measures (Table 1) with the difference in score suggesting a better understanding of the discussion. Given the small sample size, achieving statistical significance is difficult; the large absolute time difference however does lend credence to our belief that a larger study will find evidence for a difference between populations. The difference in accuracy on the test for CZTalk versus the control group was 0.7, with 95% confidence interval ranging from 0.068 to 1.332. In a two-tailed t-test this difference was statistically significant ($t = 2.5560$, $df = 8$, standard error of difference = 0.274). The time for test completion showed a 4 minute trend in favor of CZTalk, but this difference was not statistically significant in a two-tailed t-test ($t = 1.1785$, $df = 8$, standard error of difference = 3.394).Ease of authorship was quantified using appropriateness of placement of pre-defined messages and time required for the posting (Table 2). Scores were out of 6: 2 for each of the three postings, according to the appropriateness of the message locations. One specific location (i.e., reply to a particular message(s); new topic/continuation of existing topic) was predefined to be the most appropriate. Scores were 2 points for the same place, 1 point for replies to a different message but in the same cluster, and 0 points otherwise. These results suggest that CZTalk was better in both measures but that the difference in scores was not statistically significant, likely for the reasons noted above. The difference in time required for CZTalk versus the control group was 5.0 minutes, with 95% confidence interval ranging from -8.99 to -1.01. In a two-tailed t-test this difference was statistically significant ($t = 2.8868$, $df = 8$, standard error of difference = 1.732). The difference in message posting score between CZTalk and the control group was 0.9, with 95% confidence interval ranging from -0.331 to 2.131. In a two-tailed t-test this difference was not statistically significant ($t = 1.6859$, $df = 8$, standard error of difference = 0.534).

In sum, CZTalk appears to provide better support for both interpretation and authorship when compared to the control software interface.

Table 2: Ease of authorship results

	Message Posting Score		Message Posting Time (minutes)	
	CZTalk	**Control**	**CZTalk**	**Control**
Mean	3.9	3.0	9.0	14.0
StdDev	0.74	0.93	3.0	2.4
Range	2.0	2.0	6.0	6.0
p-value	0.1303		0.0203	

3.2 Observations

Initially, most subjects were attracted to but a bit overwhelmed by the CZTalk discussion map. However, after a brief introduction, they were able to interact with the software with reasonable ease and comfort. On the other hand, most subjects in the control group recognized the file structure display.

Interestingly, among subjects who read all the messages, CZTalk subjects tended to follow the threads while control subjects tended to follow by date (usually using the "View all Messages" feature of the control software). Most subjects, whether using CZTalk or the control, found replying to a single message a simple task. Not all CZTalk subjects remembered the "multi" reply feature in CZTalk, and most who did found it difficult and tricky due to an awkward selection sequence. Most subjects in the control group found the "new topic" task simple. Not all the subjects in the CZTalk group knew how to start a new topic, even though they knew it was possible.

All CZTalk subjects found identifying a participant "Very Easy" in contrast to the control group. According to CZTalk subjects, the *best features* of the software were: ability to classify discussion topics, use of arrows to indicate relationship between topics, ease in following discussions and posting messages, showing the participant list and highlighting the messages by a particular participant, and the "kind of message" icons.

The *worst features* of the CZTalk were considered to be: difficulty in keeping clusters open, lack of search support,

difficulty in replying to multiple messages, and difficulty in reading text displayed inside message nodes (the identifiers). Most of these are straightforward to address.

4. Conclusions

We have described CZTalk, an interactive prototype application designed to address some of the communicative pragmatics issues found in present online discussion interfaces. In addition to textual inputs (author names), CZTalk offers a view that enables users to more easily identify the "speaker" of a message and the audience of the discussion. In addition, users can choose to highlight all the messages posted by a particular participant so as to trace out his or her train of thought. These features were designed to support the ability of users to build a mental representation of other individuals' (side participants as well as active participants) roles, knowledge and belief states, and to use that metarepresentation as a basis for building richer and more effective communication.

Traditionally, messages in a discussion are displayed as a file structure. In many cases, messages displayed using existing online discussion software are sorted by date or thread. Displaying by time emphasizes the temporal relationship between messages, instead of the more pertinent relationship of "in-reply-to", and can mislead users into assuming that the author has read all previous messages, which may not be the case if their organization was by thread or by author. Similarly displaying by thread removes context from a message, and does not reflect the richness of communication—summing up, contrasting two points of view, use of metaphor etc.

Unlike existing online discussion interfaces, CZTalk displays messages as nodes in a network structure. In doing so, messages are visually organized to provide a global structural view of the discussion in addition to views of individual messages. To alleviate restrictions of existing online discussion software, users can view and reply to more than one message at a time, allowing ideas to converge.

While the CZTalk interface arguably provides a richer set of visual cues to the structure of the discussion, some information is less visible than in a more conventional interface. For example, our emphasis on supporting multiple referents for messages results in a de-emphasis of the overall timeline of messages across threads. Thus it can be more difficult to determine whether a particular message preceded or followed another message that is in a parallel thread. We felt that this information can be misleading in that it creates the expectation that the poster has read all preceding messages in other threads and predicated their message as well as their communication style and referents on that knowledge [16]. There are cases where the overall timeline is important, for example, when a particularly important posting or other synchronous event takes place. In those cases an alternative view onto the information space may be needed. The results of our user study suggested that test users found CZTalk to be a better environment than the control interface for interpretation of discussions and for support for message posting. Future work will build upon the results of this user study to further enhance the utility and usability of the interface. This work will take the form of more focused testing of the interaction within the context of the theories and methods from Cognitive Science that inspired this design. Future work will also include mail client support and integration with the more sophisticated media-rich message format of the CZWeb environment. We hope that the application of Cognitive Science methods and theoretical perspectives will enable us to contribute to the design of collaborative knowledge work and learning environments that effectively utilize visualization techniques for human cognition and communication.

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