The User-centred Iterative Design Of Collaborative Writing Software

Ronald M. Baecker, Dimitrios Nastos, Ilona R. Posner, and Kelly L. Mawby

Dynamic Graphics Project, Computer Systems Research Institute
University of Toronto
Toronto, Ontario, CANADA M5S 1A4
Phone: (416)978-6983 E-mail: baecker@dgp.utoronto.ca

ABSTRACT

This paper presents the user-centred iterative design of software that supports collaborative writing. The design grew out of a study of how people write together that included a survey of writers and a laboratory study of writing teams linked by a variety of communications media. The resulting taxonomy of collaborative writing is summarized in the paper, followed by a list of design requirements for collaborative writing software suggested by the work. The paper describes two designs of the software. The first prototype supports synchronous writing and editing from workstations linked over local area and wide area networks. The second prototype also supports brainstorming, outlining, and document review, as well as asynchronous work. Lessons learned from the user testing and actual usage of the two systems are also presented.

KEYWORDS: Computer-supported cooperative work, groupware, user-centred design, iterative design, behavioural research, collaborative writing, writing software, synchronous and asynchronous writing.

INTRODUCTION

Most authors of documents work collaboratively from time to time; many write together with others most of the time. Yet very little is understood about how people write together, and very few systems are available to support this activity. This paper summarizes the results of our research on the process of collaborative writing, lists design requirements for collaborative writing software, and presents the user-centred iterative design of such software.

Our research on process consists of interviews with writers who have worked together collaboratively and a laboratory study of writing teams linked by different communications media. The taxonomy of collaborative writing that grew out of this work is summarized in the paper.

Our software design is user-centred in that it is based on this behavioural research. It is iterative, consisting of cycles of design, implementation of prototypes, and testing and evaluation. The first prototype, SASE, supports synchronous writing and editing in both focused and peripherally aware collaborative modes from workstations linked over local area and wide are networks. The second prototype, SASSE (Synchronous Asynchronous Structured Shared Editor), also supports brainstorming, outlining, and document review, provides a rich set of views of document structure, content, and revision process, and allows asynchronous work on a document.

TAXONOMY OF COLLABORATIVE WRITING

Previous Research

Although research has been conducted on individual writing [4, 10], only recently has attention been turned to collaborative writing. Surveys have shown that the majority of all written work is performed collaboratively [1, 7]. Physical proximity of collaborators was found to be key to successful scientific writing [16]. Computer technology affects the communication between participants as well as the final product of the collaboration [9, 12, 23].

A Survey of Writers

In order to understand the process of collaborative writing, we conducted 10 interviews with individuals who had participated in a number of collaborative writing projects. The backgrounds of the individuals surveyed included medicine, computer science, psychology, journalism, and freelance writing. The 22 projects discussed included journal articles, course assignments, a TV script, and a best-selling book. These projects lasted from several days to several years. The collaborating groups were formed either voluntarily or were organized in work settings. Participants varied in status from peers to student supervisor teams. Further details on the interviews may be found in [24, 25].

We encountered a wide range of attitudes towards collaborative writing. People had different expectations about the effects of collaboration, yet most felt that having several co-writers would improve the final product.

The relative status of group members, either similar or different, can lead to problems in working groups. Equal status groups may experience struggles for leadership and the problem of confronting members who are not contributing their expected share of work. In groups of unequal status participants may feel pressured to conform not on the basis of the alternative arguments but on the basis of the status of the individual proposing the alternative.

Different individual working styles can also cause problems. Some individuals like to leave the work till the last minute, while others prefer to complete the task in advance of the deadline. Individual preferences often need to be suppressed for the benefit of group harmony.

Writing technology can also cause problems for groups. Use of different machines by collaborators introduced difficulties when the document segments had to be merged into a single format. Participants complained of problems keeping track of different versions of the document. For example, one interviewee complained, "I would get email saying change page 4 line 2, but in my version page 4 is completely different." Communication bandwidth was a problem for groups working at a distance. For these groups physical proximity was often a solution. One interviewee said, "I was tempted to just fly there, instead of trying to cope with it over a distance."

Laboratory Study

A controlled laboratory study was conducted in order to see if we would observe in that context the same collaborative writing processes that our interviewees had reported. We also wanted to observe the effects of the communication medium on the writing process.

Pairs of subjects were asked to write instructions for the assembly of two simple toys. We informed the subjects that the resulting two chapters of assembly instructions were to become part of a single book; thus there needed to be similarity in writing style, terminology, and format between the two chapters.

Groups had two computers available and were free to choose any writing approach. Subjects worked in one of five scenarios: in the same room communicating face-to-face, in different rooms communicating with a speaker-phone, in different rooms communicating with an audio-video connection, in different rooms with the audio-video connection plus an image of the partner's remote screen, and in different rooms with the audio-video connection and the SASSE shared editor. In addition, subjects had available electronic mail, facsimile, and courier services.

Results of this study are discussed in [26]. Here we'll briefly list the highlights. We ran 4 groups in each condition, 20 groups in total. Given the small number of groups we did not necessarily expect to obtain statistically significant results, but we wanted to observe trends.

Individual differences in group behaviour dominated the results. Personalities of the participants had significant effects of the writing approach chosen by the group. Autocratic individuals who actively took control of the group insisted on joint work to monitor the progress and control the final document. Groups composed of two dominant individuals often faced interpersonal conflicts. Cooperative groups often divided the work between participants each one trusting the other to complete the required task.

As in previous research [12], document quality, i.e., the useability of the instructions, did not vary significantly with medium of communication ($F[4, 15]=1.237$, $p<.337$).

The type of communication between participants varied with the scenario. The discussions of subjects who could see each other's work focused more on higher-level issues such as writing style, tone, and audience of their documents. Subjects that could not easily see the other document frequently discussed lower-level details such as format and wording of their chapters.

The time to complete the task did not vary significantly with the communication medium ($F[4,15]=1.774$, $p<.187$). The medium did affect the amount of time spent working together compared to the total working time. Face-to-face subjects spent the most time working together (76%) while the speaker-phone groups spent the least (40%). The time spent working together was negatively correlated with total writing time ($r=-.418$, $p<.067$), but this may be as a result of the given task, which stressed consistency between documents.

Taxonomy of Collaborative Writing

The taxonomy of collaborative writing evolved out of attempts to categorize different components of the collaborative writing process that we observed in the interviews and again in the lab study (see Table 1). Each of the four categories of the taxonomy provides a different perspective for examining the writing process. *Roles* looks at process from the individual's point of view, at the part played by each individual on the writing team. *Activities* categorizes the actions performed while working on the project. *Document control methods* describes how the writing process is managed and coordinated. Finally, *writing strategies* focuses on the text creation process.

The choice of roles can depend on several factors including organizational structure, time constraints of the participants, relative status of the group members, and skills and expertise of the contributors:

- *writer*: converts ideas into text, records the text, freely makes changes to the text
- *consultant*: actively participates in different stages of the project but does not write the text
- *editor*: corrects text written by someone else
- *reviewer*: provides comments on the document.

Activities performed on a project can be affected by time constraints, task knowledge possessed by the group members, established organizational procedures, and participants' work styles:

- *brainstorming*: generating ideas
- *researching*: gathering information from sources external to the group
- *planning*: creating an outline for the document, and often dividing the work among group members
- *writing*: transforming ideas into text
- *editing*: making changes to the written text
- *reviewing*: generating comments about the text.

Document control methods describe how the document is managed and changes to it are made and coordinated.

- *centralized*: one person maintains the document while others make suggestions to the writer
- *relay*: one person controls the document at a time, but control passes between multiple authors
- *independent*: several people support segments of the document, while each one maintains control over an individual segment

	Interview	Lab. Study
Roles		
Writer	67%	95%
Consultant	43	75
Editor	57	80
Reviewer	85	88
Activities		
Brainstorm	82	100
Research	80	0
Plan	85	95
Write	82	95
Edit	78	80
Review	93	88
Document Control Methods		
Centralized	56	10
Relay	36	45
Independent	64	85
Shared	27	20
Writing Strategies		
Single Writer	59	15
Scribe	23	15
Separate Writers	86	90
Joint Writing	41	55

Table 1: Summary of writing approaches observed in interviews and the laboratory study. [1]

- *shared*: several people jointly control the document, having equal access and write privileges.

Writing strategies describe the document creation process, demonstrating how each segment of the text is created:

- *single writer:* text of document reflects thoughts and style of one individual with minimal assistance from others
- *scribe*: most often used in group meetings when one individual records the group's discussions with minimal guidance from the group
- *separate writers*: team members take different parts of the document and write them individually; later the parts are combined to form a whole
- *joint writing*: several team members compose the text together, where each word choice and sentence structure is decided through a group effort.

DESIGN REQUIREMENTS

The taxonomy presented in the previous section provides us with a vocabulary to describe systematically the processes of group writing. This work [24, 25], insights from our other research [19, 20], and an analysis of previous research results [16, 22, 25], have enabled us to formulate in six categories a set of design requirements for collaborative writing technology (see Table 2):

General Requirements for Individual Writing

Basic word-processing. A collaborative writing system must provide basic word-processing mechanisms.

[1] In roles, percentages are computed out of 60 individuals participating in projects discussed in the interviews and 40 subjects in the laboratory study. In the other categories, percentages describe how many groups employed certain activities, document control methods, or writing strategies.

Seamlessness with other work media. Users must be able to move smoothly between new groupware technology and existing single-user software [3]. Minimally, there must be a way to exchange documents with single-user applications.

General Requirements for Collaborative Writing

Preservation of identities. Collaborative writing depends upon contributions from several individuals. A collaborative writing system should record and display the identities of the contributors.

Enhanced communication. Essential to collaboration is communication among individuals who work together. They communicate about the object of their collaboration (*substantive communication*), exchange questions, revisions, and acceptances (*annotative communication*), and discuss courses of action and process plans to achieve their goal (*procedural communication*) [28].

Enhanced collaborator awareness. We define *collaborator awareness* as the knowledge of the state or actions of one's collaborators. Two dimensions that characterize levels of awareness are the degree of engagement and the amount of planning [14]. Depending on how focused and planned shared work is, collaboration may vary from focused collaboration (where people work together closely) to general awareness (where people know roughly what others are doing). We prefer the term *peripheral awareness.*

Annotations. Contributors such as reviewers of a document often record their suggestions as annotations. Ideally, a system should support several kinds of annotations — text, voice, or hand-drawn markings.

Undo. All interactive systems such as writing and drawing tools must provide the ability to undo changes made by a user. Undoing however becomes difficult when there are interleaved changes originating from multiple sources [27].

Session control. A collaborative writing system should allow users to create, join, or leave editing sessions at arbitrary times. It must also ensure that all users access the same version of the shared document.

Requirements re Roles

Explicit roles. A shared writing environment should support the different roles individuals may play in the process of document creation.

Requirements re Activities

Variety of activities. A document is created through a number of different activities including brainstorming, planning (including both outline and process plans), writing, editing, and reviewing. Each activity requires different support and functionality from a writing system. A shared writing system should be flexible enough to allow different writers to perform different activities at the same time.

Transitions between activities. A writing system should allow seamless transitions between activities, since they do not always occur in a sequential manner.

Requirements re Document Control Methods

Several document access methods. It may be appropriate to have different types, such as read-only, write, and comment.

Requirements	Aspects	GROVE	PREP	Quilt	ShrEdit	SASE	SASSE
Individual Writing							
Basic word-processing	++	–	++	–	++	+	++
Seamlessness with other media	++	–	++	++	+	+	++
Collaborative Writing							
Preserve identities	–	++	+	++	++	++	++
Enhance communication	+	–	–	–	+	–	++
Enhance collaborator awareness							
Focused collaboration	++	++	–	–	+	++	++
Peripheral awareness	–	+	–	–	–	+	++
Annotations	–	++	++	++	–	–	+
Undo	–		+	+	–	–	–
Session control	+	++	–	++	+	–	++
Roles							
Explicit roles	–	+	++	++	–	–	–
Activities							
Variety of activities							
Brainstorming	–	++	++	+	++	+	++
Researching	–	–	–	++	–	–	–
Planning (outline)	–	++	+	+	–	–	++
Planning (process)	–	–	+	–	–	–	–
Writing	++	–	++	+	++	++	++
Editing	++	–	++	+	++	++	++
Reviewing	–	–	++	+	–	–	++
Transitions between activities	+	–	++	++	+	–	++
Document Control Methods							
Several access methods	–	++	++	++	–	–	–
Separate document segments	++	–	+	++	–	–	–
Version and change control	–	–	+	–	–	–	++
Writing Strategies							
One or several writers	++	++	++	++	++	++	++
Synchronous writing	++	++	–	–	++	++	++
Asynchronous writing	+	+	++	++	++	–	++

Notation: ++ system provides good support + system can handle – system does not support

Table 2: Design requirements and comparison of collaborative writing tools.

Separate document segments. Individuals working collaboratively often subdivide the document and work on the pieces independently. Systems should provide support for multiple document segments yet maintain connections and access into the entire document.

Version control. Knowing who wrote or changed a certain part, what changes were made, and when they were made is essential.

Requirements re Writing Strategies

One or several writers. Although designed for multiple writers, a shared writing system should also support a single writer, so that one need not use a different systems for this.

Synchronous and asynchronous writing. Participants on a project may want to access the document concurrently or sequentially. Support for synchronous writing is essential especially during the stages of brainstorming and outlining. Support for asynchronous work is particularly important in the stages of writing, editing, and reviewing.

System Comparison

These requirements are summarized in Table 2, where existing shared writing systems are also evaluated. Aspects [2] is a collaborative conferencing system that runs on networked computers and provides writing, drawing, and painting tools. GROVE [8] is an outlining tool designed for users at remote sites working on networked computers. PREP [22] is a writing tool that provides asynchronous access to documents and can be thought of as a "spreadsheet for documents," because it provides a column based interface where text is presented in columns of visually linked chunks. Quilt [17] is a multi-user hypermedia communications and coordination tool which combines computer conferencing with multi-media email. ShrEdit [5] is intended for simultaneous writing by several users working on networked computers in a conference room.

THE FIRST PROTOTYPE

Our first prototype system for collaborative writing [19] was called SASE (pronounced "sassie"). This prototype was designed to support highly interactive synchronous collaborative writing.

SASE Design Requirements

Support for focused collaboration and independent work. Groups sometimes work together in focused collaboration, yet individuals or subgroups often break off from the main group to do independent work [8, 24, 25]. We felt that SASE should support both these approaches.

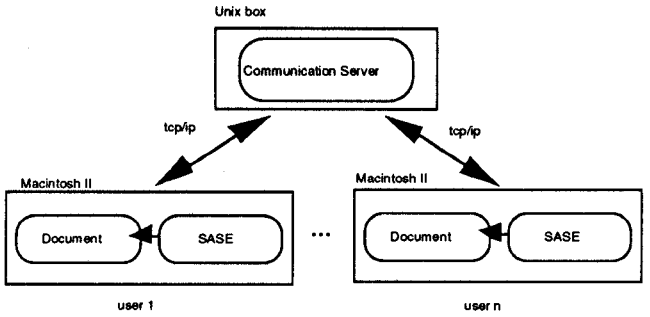

Figure 1: SASE's architecture.[2]

Support for collaborator awareness. In a synchronous writing environment, collaborators can simultaneously modify and add text to the document. Because there are multiple concurrent activities, collaborators may find it difficult to understand the changes that have been made and are currently being made to the shared document by others [6]. So SASE had to provide information to increase the individual's awareness and understanding of collaborators' actions.

Support conflict resolution. When multiple people edit the same document, it is conceivable that two or more people may attempt to modify a particular segment of text at the same time. Thus we felt SASE should provide mechanisms to help prevent users from making conflicting changes.

User Interface and Architecture

SASE allows two or more people to edit a document synchronously while working at their own Macintosh workstations. It is assumed that they will communicate via telephone or an audio/video connection.

So that collaborators can see and discuss each others' contributions as they happen, text modifications made by users immediately appear on their text windows and on the text windows of all other collaborators. Users can point to text using a hand-like pointing device called a *telepointer*. To help maintain collaborator awareness, users are provided continuous feedback of other collaborators' working locations in the document with colour coded text selections and scroll bars.

There is always one vertical scroll bar for each person currently collaborating in SASE. The rightmost scroll bar on a user's text window always belongs to that user and functions as a normal scroll bar. Additional colour-coded scroll bars indicate the current locations of collaborators, but are "read-only" and cannot be manipulated.

Users can work independently on a document in SASE, since actions such as scrolling and window sizing affect only the window of the user who initiated the action. They can also work together in a highly focused mode by locking together and synchronizing their views, thus achieving WYSIWIS (What You See Is What I See).

To avoid conflicting changes, SASE locks text at the user text selection level. This means that it is possible for collaborators to work within the same line of text. With this fine grain locking mechanism, we leave it to the collaborating group to decide how closely they will work within the shared document.

We chose a replicated architecture (Figure 1) in which a copy of the application and the shared document reside on each collaborators' workstation. This architecture is combined with a centralized communication server which resides on a Unix box. The application copies communicate via the TCP/IP communication protocol. All message traffic is routed through the central communication server which ensures that all copies of the application receive messages in the same order. This architecture supports simultaneous text editing, usually provides reasonable response, and supports conflict resolution.

User Testing

A usability study [19] was conducted with three two-person teams using SASE to perform a series of text editing tasks required to prepare collaboratively a newspaper article for publication. Subjects communicated via a CAVECAT audio/video connection [18]. All subjects were able to use SASE effectively after a brief introduction to the system.

The multiple scroll bars improved collaborator awareness. Subjects used these to match their view of the document with their partner's view, to determine how far away their partner was in the document, and to reduce the time needed to find text in the document.

When groups were asked to do a shared task such as scanning the document for typographical errors, they first negotiated how to divide the work in order to save time. When asked to collaboratively compose text, all groups used the scribe writing strategy.

Subjects liked the fact that they could work separately or together in the document. This allowed them to save time by dividing the task. They also liked that they could ask their partner for help when necessary. They suggested that the system should provide a way of seeing what changes have been made, and a way to change the text back to the original form if necessary.

THE SECOND PROTOTYPE

The second prototype, called SASSE [20], is an extension of the first, and is based on the requirements presented earlier in this paper. Our goal was to satisfy most of them, while leaving some (e.g., providing support for explicit roles) to be handled by social protocols.

Design Requirements

Support for a variety of activities. In designing the second prototype we felt that the system should support the writing activities presented previously. SASSE supports

[2] SASE's text editing functionality was implemented using the Word Solution Engine (WSE) [29] by DataPak Software, Inc. The WSE supports the text editing functionality of the Macintosh TextEdit Toolbox and also provides hooks into text editing procedures for purposes of customization, such as for maintaining multiple colour coded text selections .

brainstorming, outlining, and reviewing, in addition to writing and editing.

Enhanced communication and collaborator awareness. We designed views that provide information about who the collaborators are, where in the document they are working, and what they are doing.

Support for asynchronous writing. The first prototype was a synchronous shared editor. In order to support asynchronous writing, we added an annotation mechanism that allows authors to exchange notes and comments, a simple version control mechanism that shows which parts of the document were changed and by whom, as well as a centralized document storage mechanism that allows users to access shared documents easily.

SASSE User Interface and Implementation

Support for a variety of activities. SASSE's outline editor has been designed to allow writers to work with hierarchically structured shared documents. The outline editor allows users to see document structure, to display or hide parts of it, and to edit its structure as well as its contents. Baecker, et al., Colour Plate 1 shows SASSE in outlining mode. Baecker, et al., Colour Plate 2 shows the normal text display of SASSE.

During the reviewing phase writers solicit comments on versions of their document. Sometimes this results in a dialogue between the commenters and the writers, especially when the comments are unclear. SASSE's annotation mechanism allows users to write text comments that can be selectively displayed, hidden, or deleted.

Enhanced communication and collaborator awareness. SASSE's collaborator awareness mechanisms provide information about the co-authors of a document, their positions in the document, and their actions. As in SASE, colour is used to differentiate between users. Each collaborator is assigned a unique colour. This assignment is stored with the document so that the same author has the same colour each time a particular document is edited.

Collaborator awareness is further aided by views that provide information about the state or actions of collaborators. The collaborator list gives information about the authors of a document, as well as their colour assignment, and whether they are present or not present in the editing session. The shared scroll bars introduced in the first prototype were redesigned. Instead of having several scroll bars, which take up screen space, only two scroll bars are displayed: the normal scroll bar of the local user and one with multiple colour-coded indicators which correspond to the collaborators participating in an editing session. SASSE's shared scroll bars are shown in the colour plates.

Information about what user activities can range from the very abstract and global to the very concrete and local. SASSE provides two views at extremes of the spectrum. The *gestalt view* (Colour Plate 2) presents a condensed image of the entire document as well as all collaborators' positions and text selections. The *observation view* (Colour Plate 1) allows users to "look over the shoulder" of a collaborator and see exactly what they are seeing and doing. Additionally, non-speech audio cues [13] provide information about collaborators' actions such as scrolling and deleting.

Support for asynchronous writing. In order to support asynchronous writing we added an annotation mechanism. Users can selectively display or hide comments written by a specific author. The comments are colour-coded for easy identification. A simple version control mechanism (implemented but not yet installed) allows users to see which parts of the documents have been changed and what the changes are. A document server is used to store shared documents in a central storage space. Collaborators are thus able to access with ease the latest version of a document.

User Testing and Results

We conducted a usability study [20] with SASSE, again using CAVECAT to provide a voice and video link. Four two-person groups used the system to carry out a set of collaborative writing and editing tasks after a brief introduction to its functionality and user interface. The tasks were designed to test the outlining and collaborator awareness mechanisms of the system. During the first part of the study the subjects were asked to edit the outline of a travel guide. During the second part they had to do both shared and independent editing tasks on an article. Subjects were asked to use the system's awareness mechanism to obtain information about their collaborators.

Three methods were used to collect information from the usability study: observation during the study, recording it on video for later analysis with our VANNA video annotation and analysis system [15], and administration of a questionnaire and an interview with subjects after the study.

Subjects used the audio link continuously but made relatively little use of the video link. Most subjects were able to use SASSE's outlining and collaborator awareness mechanisms successfully. Yet, the character-level locking produced unacceptable delays during deletions. Some subjects could not understand why some operations were failing because they would not notice the padlock indicating that they were locked out. Finally, network delays resulting in slow system response made some subjects feel uneasy and in a few cases retry an operation.

Real Use

SASSE is becoming robust enough to be used for real work. We have done so over local area networks in our lab and over a wide area network between Toronto and California. This paper was written in part with SASSE. Observations are implied in the suggestions for future work listed below.

SUMMARY AND CONCLUSIONS

We have presented the user-centred iterative design of collaborative writing technology. The work is deeply rooted in behavioural research consisting of interviews, usability tests, and studies of the technology in actual use. This has enabled us to improve the design in successive iterations, a process which continues to this day.

Our user tests and usage suggest that a coarser locking scheme, for example, at the sentence or paragraph level,

would suffice. Alternatively, locking may not be needed at all because conflicts can be negotiated through use of the voice link. This would allow us to improve performance significantly. Further work is also required to achieve true "seamlessness" with other writing technology. We are currently designing and implementing an "undo" command [27] and mechanisms for automatically collecting usage data. Finally, much more work remains to be done on the design of effective visual and auditory views to enhance collaborator awareness, and on the design of better methods for the display of document changes [21].

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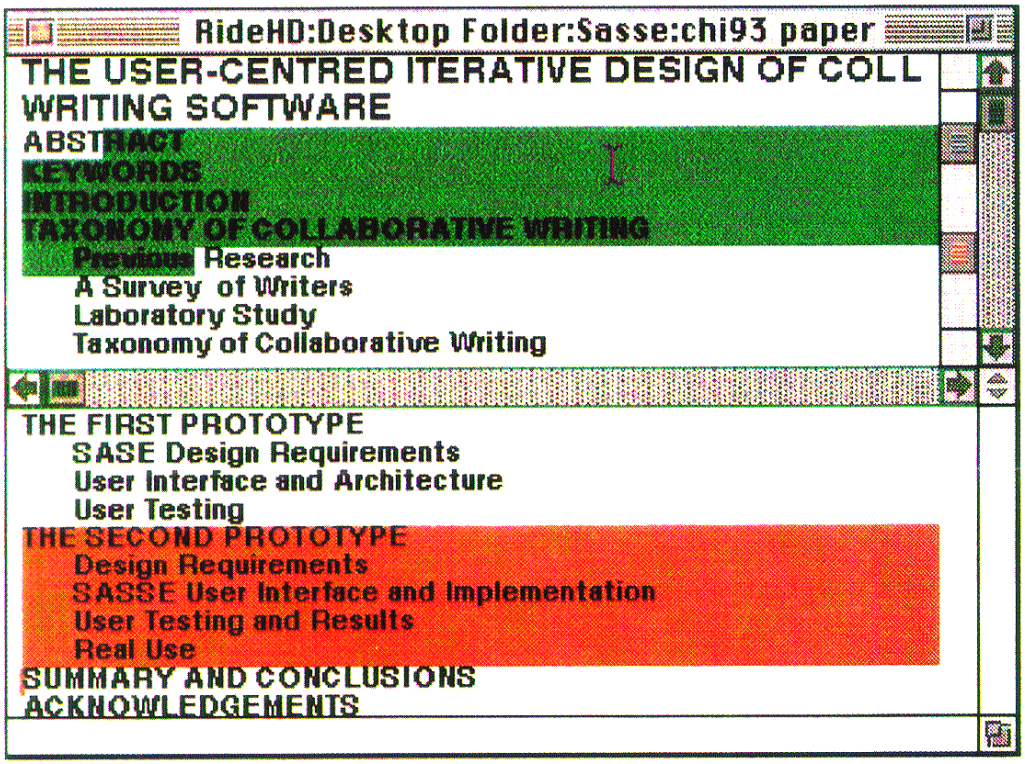
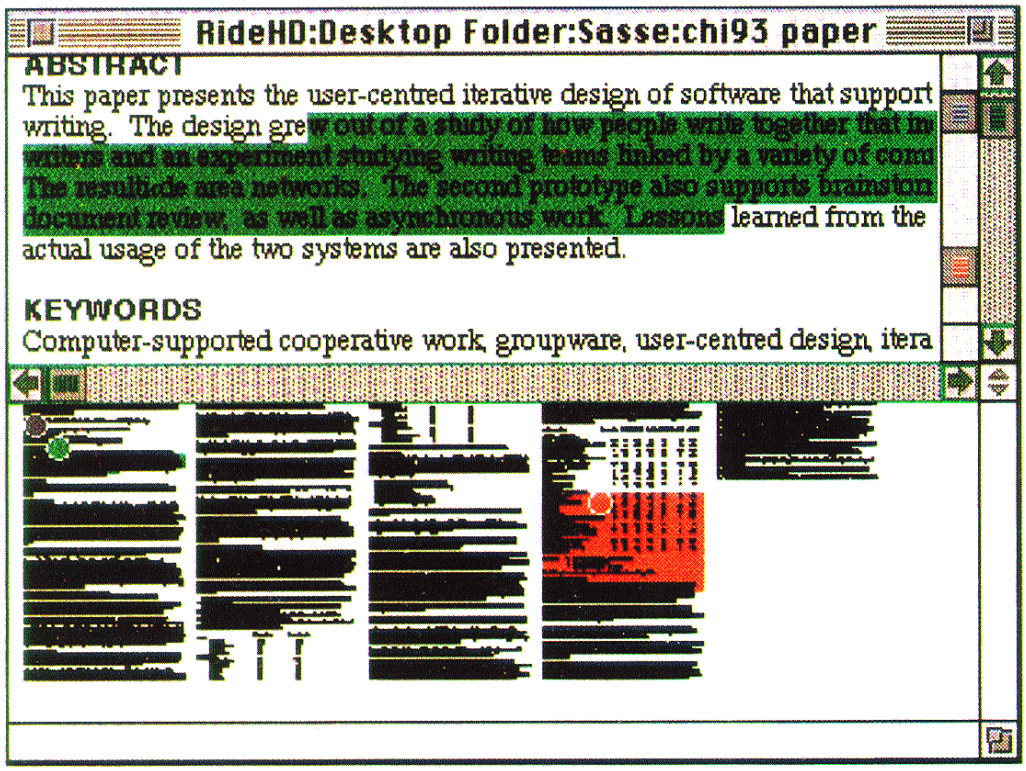


Baecker, et al., Colour Plate 1: SASSE is in outlining mode. The green user is working at the beginning of the document and her view appears in the upper half of the screen. An observation view of the red user appears in the lower half of the screen.



Baecker, et al., Colour Plate 2: SASSE's normal text display for the green user appears in the upper half of the screen. A gestalt view of the entire document appears in the lower half of the screen. There are 3 users (green, gray, and red) working concurrently on the document. The red user is working midway through the document and has selected a large region of text.