

Running head: Web-based Writing Systems

## **How the Web Is Used to Support Collaborative Writing**

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## **Abstract**

*We present 19 systems that have been developed over the past decade to support collaborative writing over the Web. The aim of this article is to present the state of the art on the use of the Web for collaborative writing and thus (1) help designers improve current systems or define future systems and (2) help users choose the most appropriate system to support their needs. Among available systems, groups can select from tools to write a document (on- or off-line), collect comments about a document, or maintain a Web site. The lack of experimental data concerning Web-based applications forces designers to use other sources of information to guide their design choices, such as a list of functions that an ideal collaborative writing tool should offer. This list has revealed several potential points for improvement.*

## **Keywords**

CSCW: Computer Supported Collaborative Work; Computer Supported Collaborative Writing; Groupware; Collaboration; Collaborative Writing; Web-based applications; Web-based Collaborative Writing.

## **Introduction**

Collaborative writing, in which at least two people work together in order to produce some text, is a widespread activity, as shown by Ede and Lunsford (1990). They reported that 85% of the documents produced in offices and universities had at least two authors. The popularity of collaborative writing may be due to some interesting advantages it offers over individual writing. It can help individuals save time and/or effort, it can lead to an increase in the number of ideas and viewpoints contributed to the project, and it can ensure that various subsections are written by experts in the field (Noël 2001, Noël and Robert in press). It is not surprising, then, to see that there have been so many attempts since the 1970s at developing computer applications to support collaborative writing.

The first of these attempts used local area networks (LANs) or wide area networks (WANs)<sup>1</sup> to keep collaborators in touch (see Noël and Robert 2001, 2002 for a description of some of these applications). However, these systems have not proven popular (Kim and Severinson-Eklundh 1998, Noël 2001, Noël and Robert in press). In fact, people still prefer using individual word processors and keeping contact with their collaborators through email, face-to-face meetings, and phone (Noël 2001, Noël and Robert in press).

One interesting alternative for supporting collaborative writing is the World Wide Web. The Web presents some valuable advantages over LANs and WANs. First, many people already have access to the Internet from their offices or their homes<sup>2</sup>, making it more likely to find others to collaborate with (Dix 1997). Second, Web-based applications are available to users of all types of computers, whereas LAN- and WAN-based applications are usually developed for one particular operating system, limiting the possible collaborators to those who use that system. These types of applications also need to be installed and maintained on each user's computer, which is not the case for Web-based applications (Grasso et al. 1997).

However, the Web is not a panacea when it comes to collaborative work. First, it is difficult, although not impossible, to implement synchronous work on the Web. Second, the Internet remains unstable and there is no guarantee that a user will be able to reach a Web site or that an established connection will not be

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<sup>1</sup> A LAN is a network of computers linked together spanning a relatively small area: a single building or a small group of buildings. When several LANs are connected together, they form a WAN.

<sup>2</sup> According to Statistics Canada, 40% of Canadian homes had at least one regular Internet user in 2000 ([www.statcan.ca](http://www.statcan.ca)).

interrupted. Third, the Web's user interface is much less evolved than that found in a graphical user interface (GUI) environment (e.g. Mac OS, Windows).

In spite of these limitations, researchers are turning more and more to the Web in order to support collaborative writing. Several systems have been developed since the mid-1990s. Our research has uncovered 19 such systems, which can be divided into two global types: (1) Web-based collaborative writing applications (WCWAs); and (2) infrastructure-modifying systems. The latter are not meant for direct use by the collaborative writers. Rather, they try to improve the collaborative experience by modifying or adding new features to the Web's infrastructure.

In this article, we present and compare these 19 systems. The goal is twofold: 1) help system designers draw lessons from the past, and engage in promising avenues for improving current systems or defining future collaborative writing systems; 2) help users select the support system that is the best adapted to their needs. The article is organised as follows. We begin by presenting some conceptual background knowledge concerning group work. We then describe the systems and compare them on the features they offer. We introduce a way of categorising the WCWAs. We suggest which tools a collaborative group can use based on its needs. We then present how co-writers actually use Web-based tools in order to collaborate. We finish by presenting some suggestions for the design of WCWAs.

### **Collaborative work**

Whittaker et al. (2002) deplore the state of affairs in human-computer interaction (HCI) research. They denounce an overemphasis on what they call 'radical inventions'. Most publications in HCI describe new paradigms or novel applications, or experiences and heuristics related to these radical solutions. By

constantly innovating, rather than building on previous work, researchers have ignored the needs of system builders, who are left without any principled design advice to guide them in their decisions. In this section, we attempt a first pass at correcting this situation by presenting some theories concerning collaborative work, some basics about how groups work together, and suggestions, based on this information, about how groupware should be designed. These suggestions can be used both by designers, when trying to create a new group application, as well as by potential users, when trying to establish whether they should adopt a particular groupware.

Collaborative work has been extensively studied in social psychology and sociology, and some of this knowledge is now being applied to understanding how groups work with artefacts such as computer programs. We will now quickly present two theories that seek to explain working groups and their use of artefacts: distributed cognition and the locales framework.

Distributed cognition (Hollan et al. 2000) recognises the impact of social factors on people's cognition. It places great emphasis on the importance of the outside world's features, both social and physical, when people are trying to accomplish a task. The physical aspects of a work artefact (not just its content) can be used as a source of information by people; for example, a writer can tell, just by looking at the position of comments on a page, where to concentrate his/her editing (Kim and Severinson Eklundh 2000). People post notes around their workplace to support their recall. For these reasons, this approach emphasises not only studying the members of a group, how they work and how they collaborate together, but also studying the workplace characteristics, the work artefacts and how they are manipulated or transformed during work.

The locales framework, based on sociologist Anselm Strauss' work (Fitzpatrick et al. 1995), describes a social world as 'a group of people with some common

purpose, a site for collaboration and some means to communicate' (Greenberg et al. 1999). A locale is the shared virtual space where a group of people can work together. A locale should offer what Fitzpatrick et al. call a foundation, that is not only a shared space, but also the tools and resources to support collaborative work. It should support mutuality, that is not only support interactions between group members and with the work artefacts, but increase awareness of others' work and changes to the artefacts. It should give users control over the locale aspects, help members co-ordinate and negotiate their work together. Fitzpatrick et al. also underline the importance of a communal level of interaction, suggesting that users should be able to create new locales, destroy old ones and navigate easily between existing locales. This framework can form a basis for choices to make when designers are creating new groupware (see for example Greenberg et al. 1999).

Ten years ago, Cole and Nast-Cole (1992) were already trying to guide groupware designers by introducing them to group dynamics. They suggested that understanding behaviour at the group level required studying eight different areas. The first is the group's purpose, the reason why the group was formed. In the case of collaborative writing, this is usually the production of one or several documents. Communication is another important aspect of group dynamics, as group members must share information in order to accomplish the group's purpose. During a collaborative writing project, communication needs vary: high when members work closely together (e.g. while planning the project or distributing the work) and low when they work alone (e.g. while writing a section of text) (Cerratto and Rodriguez 2002). Content and process are in effect the two sides of the same coin. While content refers to the group's work (e.g. the document), process is how the group works together (e.g. whether each member writes a different section or whether everyone works on the whole document). Task and maintenance activities are also important in group dynamics. Task activities are concerned with getting the job done: writing, editing, or

commenting a document. Maintenance activities are focussed on helping maintain the group and include socialising (off-topic communication), meeting the group's physical needs (finding a room to work in, getting food and drinks), settling conflicts within the group or providing support for the different members. Maintenance activities are just as essential to the group as task activities. Roles are 'simply positions or stances from which people operate for a period of time, and are not related to formal job titles' (Cole and Nast-Cole 1992: 49). One attempt at establishing the roles associated with collaborative writing has described those of writer, editor, reviewer, and consultant (Posner and Baecker 1993). Norms are the group's commonly shared beliefs, understandings, attitudes and viewpoints. They develop over time and may differ from one group to the next. By helping make at least some of these norms explicit, an application might help reduce potential conflict. According to Cole and Nast-Cole, effective leadership depends on different variables, such as how the group works together, the task, the group and individual needs and the demands of the environment. This suggests that a groupware should not try to impose a particular leadership model on groups. Finally, Cole and Nast-Cole note that a group goes through different stages during its life, that the relationships between members will vary during each stage, and that the way the group uses groupware will also vary.

Studying shared workspaces (a medium sized flat work surface where people collaborate by manipulating visible tools and task artefacts), Gutwin and Greenberg (2000) have identified seven major collaboration activities that should be supported by such a groupware application. The first of these is explicit communication, that is offering some way for group members to provide information to each other, whether the channel used be verbal or written. There is also another type of communication that needs to be supported: consequential communication. This refers to the traces left by others as they go about their activities. This includes information from artefacts while they are being

manipulated by others as well as information one acquires from watching others work. Another important activity is the co-ordination of actions, that is how people organise themselves so as not to enter into conflict with others. An example from collaborative writing is how to resolve conflicts when two people try to edit the same section of text at the same time. Planning refers to how the group divides up the task. In collaborative writing, this includes such things as determining who will write which section, who will edit the document, who has the 'official' copy of the document at any moment, and so on. Monitoring refers to knowing who is present in the shared workspace and being able to see what they are doing. In an asynchronous environment, this can be done by increasing people's awareness of the activities of the other group members (Dourish and Bellotti 1992). Another collaboration activity that needs to be supported is assistance. Offering help to others can be done opportunistically or someone can explicitly request it. Finally, protection needs to be offered to groups. It should be possible to recuperate work that has been inadvertently or deliberately altered or destroyed by another user. This is particularly important in collaborative writing. Even though all these collaboration activities were observed in the context of shared workspaces, they can be applied with only slight modifications to the needs of groups using collaborative writing applications.

The previous discussion suggests some important points that groupware designers need to take into account. Where appropriate, we also specify how computer-supported collaborative writing applications could follow these suggestions.

1. A shared virtual working space should offer at least some basic tools and some way of sharing artefacts. For collaborative writing, in particular, the application should help the group share documents somehow.
2. Explicit communication tools should be included. However, for collaborative writing, such tools may be less important, depending on which part of the task the designer wants to support. Writing, for example, tends to be a

solitary activity requiring little synchronous communication compared to a group activity like brainstorming.

3. Awareness should be promoted within the application. An asynchronous writing tool may not require that users be aware of who is currently present, but it is important to help group members know who has done what, and what has been done to the documents.
4. Helping members co-ordinate their actions is essential to any collaborative task. For writing, this can be done explicitly, by locking down a section or the whole document so that only one person at a time can edit the document, or implicitly, by showing members where others are working presently (Mitchell 1996).
5. Different work strategies need to be taken into account when designing a groupware tool. For writing, groups can use different strategies, such as having one person write the whole document while another group member edits it, or having each member write a different sub-section of the document (Posner and Baecker 1993, Noël 2001, Noël and Robert in press). A designer should ensure that his/her application supports at least one of the possible writing strategies.
6. The application should offer some form of protection for the user's work. For collaborative writing, this could be done, among other means, by keeping tab of all the modifications done to a document and giving users the possibility to undo anything, or by letting groups save several versions of the documents, or by automatically backing up the document.
7. Not everyone does the same task within a group project, and these different roles need to be taken into account by the designer. In collaborative writing, the same person can assume several different roles during a single project (Tamaro et al. 1997). This suggests that, if an application forces users to specify the role they will play, it should also let them modify that role easily (Dourish and Bellotti 1992, Sharples et al. 1993, Mitchell et al. 1995). However,

it may be preferable if the application does not force users to select a role at all (Sharpley et al. 1993).

8. Since groups can have different types of leaders, an application should not impose a particular style of leadership.
9. Planning is important for groups that are participating in a long-term activity, such as collaborative writing.
10. An application should let users participate in more than one project, move from one project to another, create new and destroy old projects.

Now that we have presented some theoretical background that should help us understand collaborative work and how to apply this information for developing groupware that can best support this kind of work, we turn to the description of existing systems that support collaborative writing on the Web.

### **Description and comparison of the systems**

Table 1 gives a quick overview of the 19 systems that support collaborative writing on the Web. This includes the system's developers (research groups or companies) and their country of origin, the language(s) the system supports, its type and current status.

[Insert table 1 about here]

#### *Infrastructure systems*

We will begin by presenting and comparing the three systems that modify the Web's infrastructure, as they differ greatly in the features they offer from the WCWAs. They are VTML, PIÑAS, and WebDAV.

VTML (Versioned Text Markup Language) was meant for storing information concerning the different versions of a document, which it did by adding its own

special markup language to HTML (Vitali and Durand 1995). By storing document changes externally, VTML made it possible to follow the history of the changes made to a document. It no longer exists.

PIÑAS (Platform for Interaction, Naming and Storage) and WebDAV are both aimed at supporting collaborative writing by adding new features to Web browsers and servers. While PIÑAS (Decouchant et al. 2001) is still in development, WebDAV (Whitehead and Goland 1999) has already been integrated into different servers and clients, such as Microsoft's™ Web server for Windows 2000 (Internet Information Services 5 or IIS 5) and Office 2000.

[Insert table 2 about here]

Architecture is the approach each system uses for storing the document, either only on the server (hybrid) or both on the server and the user's computer (mixed). Each system modifies some aspect of the Internet's infrastructure, except for PIÑAS, which is a middleware<sup>3</sup>. These systems require a special browser or server that understand their commands. However, PIÑAS can be used with an ordinary browser, although its special features cannot then be accessed. Versions refer to the possibility of having different versions of the same document. Only VTML keeps track of a document's evolution. Roles are used to control users' behaviour within a project (see below for a longer discussion of roles). They are supported only in PIÑAS. Locking, which consists of giving one person at a time editing privileges to either a section or the whole document, is one way of solving problems related with simultaneous access. Only WebDAV offers some sort of locking mechanism. VTML didn't require locking, since users worked on their own version of the document. The author name refers to the

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<sup>3</sup> 'Software that connects two otherwise separate applications', such as linking a database system to a Web server. Webopedia (<http://www.webopedia.com>)

name of the person who wrote a particular section, while the author list refers to the list of people who are collaborating on the project. PIÑAS keeps track of this information, while WebDAV ignores it. VTML kept track both of who did the modifications and when they were done, through the date feature. PIÑAS and VTML divide the text into smaller sections for writing purposes, which is not the case with WebDAV. The modification history lets the user see the document's evolution, which was only possible with VTML.

### *WCWAs*

The rest of this article will concentrate on the WCWAs, as they can be used immediately by collaborating writers, and as the needs for improving these applications should guide the design of infrastructure-modifying systems. We begin with a quick description of the 16 WCWAs we have found.

#### *Alliance*

Alliance (Decouchant et al. 1996) used the Web to propagate document modifications and to support group awareness. It was originally developed for a LAN network, then modified to use the Internet. A special editor application had to be placed on each user's computer. Documents were divided into fragments, which were then stored in separate files on each user's computer. Only one user at a time could modify a specific fragment. After a user had finished his/her modifications, he/she uploaded them. They were then automatically propagated to the other users' copies.

#### *AllianceWeb*

Recently, Alliance has been modified and renamed AllianceWeb (Decouchant and Martinez-Enriquez 2000). It uses the Web to propagate off-line modifications, as well as to support on-line editing and group awareness. It is

still in development. Because AllianceWeb stores documents both on the local machine and the Web server, users can work on a document even when they are disconnected from the Internet. Users can also choose when to integrate the modifications made by the others.

### BSCW

BSCW (Basic Support for Co-operative Work) uses the Web to help group members maintain contact, manage the group and its activities, and serve as a storage area for documents (Bentley et al. 1997a, b). It is not aimed specifically at collaborative writing, but can be used for that purpose. One person (the manager) creates a 'shared workspace' and sends invitations to others to join this workspace. Group members can then exchange information by uploading and downloading all types of documents (e.g. text, images, hyperlinks). BSCW also offers a calendar for scheduling events or meetings, and an address book where members' email addresses are stored.

BSCW is available at <http://bscw.gmd.de> in several different languages (among others, English, French, Japanese, Portuguese, and Estonian). It is possible to download the system (version 4.0.6) and install it on a server or use the German National Research Centre for Information Technology (GMD)'s public server. BSCW has approximately 80,000 registered users, with an estimate of several thousands who use it frequently<sup>4</sup>.

### COARSY

COARSY (Collaborative Asynchronous Review SYstem), which is still in development, uses the Web for supporting document reviewing through

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<sup>4</sup> Personal communication, Thomas Koch.

comments and for on-line editing (Ruiz and Favela 1998). COARSY offers two models of collaborative writing. In the 'co-authors' model, all participants play the role of authors. In the 'author-reviewer' model, one participant is the author, the others are reviewers. When a new project is created in COARSY, the user must determine the type of interaction between participants as well as whether participants will be anonymous or not. Then the user uploads a document. Only authors can modify the document; reviewers are limited to writing comments.

### Col•laboraciò

Col•laboraciò<sup>5</sup> (Rodriguez 2001) uses the Web mainly to allow group members to write and review a document through comments. It is presently being tested. Once a new project is begun, users can create a new document. The document is divided into different sections, which are displayed as links in a frame. Users can create, edit or delete sections, or even change their order. Group members can also write comments about the different sections. This system also offers two hyperlinks that have proven useful during testing (Rodriguez 2001). One is a link to a document that describes Col•laboraciò. Participants use the commenting section in this link to report bugs and suggest improvements to the system. The other is a link to a document entitled 'Ideas for this paper', where participants can hold a meta-discussion about the writing task.

### Contact

Contact (Kirby and Rodden 1995), which is no longer available, used the Web to manage the group. A user created a new project on Contact's Web site, where he or she could specify the group members, the sections composing the document,

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<sup>5</sup> Recently, however, Col•laboraciò's goal has been modified and it is now meant to support social navigation around common URLs instead of collaborative writing.

and each member's responsibilities. Members could consult the Web site in order to find out information about the project, the group and the document.

### DHS

DHS (Domain Help System) uses the Web to allow group members to review documents through comments (Rodriguez 2001). It was originally conceived in 1996 as a help system that would present information in an iceberg shape (a little at first, more if needed). However, it has since evolved into a system for adding comments to online documents. It is still in development. Documents are uploaded to a Web server (by the Webmaster), where other participants can comment on them.

### DocReview

DocReview (Hendricksen 1999) uses the Web for reviewing documents through comments. Its main goal is to encourage collaboration between scientists. A document is uploaded (by a technical specialist) to the Web server and it is then divided into review segments, either by an editor or by a technical specialist. A segment can be any size: a single line, part of a paragraph, or one to several paragraphs. Reviewers can then write 'annotations' (comments), which are attached to a particular segment. Password protection is possible, although it is not imposed by the system. DocReview is presently available for installation on a Unix server at

<http://students.washington.edu/veritas/papers/DRpaper/basedoc.html>.

### DReSS

DReSS (Document Repository Service Station), which is no longer available, used the Web as a document storage area (De Bra and Aerts 1996, Aerts et al. 1998). A

project would begin when a member uploaded a new document to the server. The project creator could specify who could only read and who could actually modify this document. Work on the document was done on each user's own computer with their favourite applications.

### EquiText

EquiText (Equipe in Portuguese and Text in English) uses the Web to allow group members to write and edit on-line, as well as to review the document through comments (Rizzi et al. 2000a, b). Its main goal is to support distance learning in Brazil. A collaborative writing project begins when a user (the 'theme proponent') creates a new theme (project). A project can either be accessible to anyone or limited to a specific group. The document is then created by adding new 'paragraphs', which can be composed of a title, one or several lines. Paragraphs can be edited, moved, or deleted. A deleted paragraph can always be retrieved and placed back into the text. It is also possible to attach comments, which Rizzi et al. call observations, to the different paragraphs. These observations are displayed on another page. EquiText is available (in Portuguese) at <http://equitext.pgie.ufrgs.br/>.

### MRGS

The FX Palo Alto Laboratory (Girgensohn 1999) has developed a Web-based monthly report generating system (MRGS). The Web was chosen because the lab already has an Intranet. This system uses the Web for on-line creation of rigidly structured documents.

The procedure for creating a report is the following. Each researcher fills out a Web-based form answering specific questions about what project(s) the researcher has been working on. This generates a Web page that the researcher

can modify using a standard HTML editor. The MRGS then collates these individual reports into a monthly project report and it also combines several project reports into a group report. The project and group reports created by the MRGS are rough drafts that must be edited by the project and group leaders using an HTML editor. This approach has led to a uniform structure for group reports. Because reports are available on the Intranet, one side benefit of using the MRGS has been improved awareness of research not only among the other researchers but also within the lab's parent company.

While the MRGS is a specific solution to a specific need at the FX Palo Alto Lab, it could easily be adapted to other groups who must frequently produce highly structured documents.

#### Office 2000 annotations

Microsoft's Office 2000 (Cadiz et al. 2000) can use the Web for document revision through comments, which are called annotations. Two servers are required, an ordinary Web server as well as a special annotations server which is in a company's Intranet and uses WebDAV (see above). After a document has been created using one of Office's applications (such as MS Word), it is then uploaded to the Web server using something like FTP (file transfer protocol). Group members can then write comments, which are stored on a special annotations server. If a new version of the document is uploaded, then these comments are transferred to the new version.

#### REDUCE

REDUCE (REal-Time, Distributed, Unconstrained Collaborative Editing) uses the Web to allow group members to write and edit documents on-line (Sun and Ellis

1998, Sun et al. 1998, Yang et al. 2000). It is the only Internet-based editing system that we are aware of that permits real-time, synchronous document editing.

Documents are created on-line, in the Web browser, although REDUCE requires a special plug-in to work. Users can work synchronously on the same document and see almost immediately what the others have written. REDUCE stores the shared document on each local site, which introduces the problem of controlling concurrency in order to maintain consistency within all distributed documents. The researchers do this through a specific consistency maintenance technique (operational transformation). REDUCE is still in prototype form and can be tested at <http://reduce.qpsf.edu.au/>.

### Sparrow Web

Sparrow Web (Chang 1998, Bier and Pier 2002) uses the Web to support minor editing, such as adding a new link or a new item in a to-do list. It is aimed at helping a community maintain a shared Web site. A 'page author' creates and manages the Sparrow Web pages. Templates make this job simpler. While the page author can change the page's overall layout, 'contributors' can only modify and add data items. Special icons on the page show which items can be changed. Sparrow Web can be downloaded for a 90 day trial from AlphaAve (<http://www.alphaAvenue.com/details.php?tech=Sparrow%20Web>).

### U-DL-A: Zeus and Poseidon

The Universidad de las Américas-Puebla in Mexico has been developing an initiative called University Digital Libraries for all (U-DL-A), meant to make students' and staff's life easier. This initiative includes document collections (such as theses, dissertations and university publications), different services

(retrieval, navigation, and so forth), and various user interfaces to the collections and services.

Zeus (Fernández et al. 2000) and Poseidon (Sánchez and Flores 2002) both use the Web to support document revision through comments. Zeus is aimed specifically at theses while Poseidon can be used with any type of document. Both applications work in a similar manner, which is why they are grouped together here.

A project starts with a group member uploading a document to the server. This person can then specify who can work on the document. Other group members can then add comments to the text. The presence of comments is signalled by highlighting the text (using different colours). The comments remain hidden until the user actually clicks on the highlighted text.

### Wiki Wiki Web

Wiki Wiki Web (Leuf and Cunningham 2001) uses the Web to support on-line editing of Web pages. Its approach is simple. Each Wiki page has a link called 'Edit this page'. This link opens up a new page that contains the page's text in a single editable text field. Wiki tries to simplify the user's task by having special codes that replace some HTML mark-ups. For example, four dashes at the beginning of a line represent a horizontal line (<hr>), two quotes represent emphasis (<em>) and three quotes represent strong (<strong>). Wiki is an open source server technology and has spawned clones (e.g. Twiki, Zwiki). It is possible to see an example of the Wiki approach at <http://c2.com/cgi/wiki?WikiWikiWeb>.

Table 3 gives a summary of some of the features available on the WCWAs. These features are related to some of the design suggestions made earlier<sup>6</sup>. The following paragraphs explain these features in more detail.

[Insert table 3 about here]

#### Sharing documents: Uploading/Downloading

Creating a document for a Web-based application can be done in two ways: either the document is created on the user's personal computer and then copied (uploaded) to the Web server; or it is created directly on the Web server through the browser (or a special application). Accessing documents can also be done in two ways: either directly within the user's browser or by copying the document to the user's computer (downloading) and then opening it with the appropriate application.

DReSS and BSCW use a similar approach, in which documents are created and edited on the personal computer, and the server is used to facilitate the sharing of documents, and so both these applications offer uploading and downloading functions. In Alliance, where document fragments were stored on every user's computer, a user had to choose when to upload changes to the document, but these changes were then automatically downloaded to the other members. In AllianceWeb, the documents are stored both on the individual computers and the server; in this case, users both decide when to upload and when to accept (download) modifications.

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<sup>6</sup> Because none of the applications support a particular approach to leadership, and only two support planning (BSCW, Contact), we have not included these two aspects in the following discussion.

Another approach to sharing documents on-line is to let users create the document on their personal computer but let other group members only access the document from within their browser (uploading but no downloading). This is particularly suitable when the application is meant to support a work strategy in which comments are collected on the Web (DHS, DocReview, U-DL-A, and Office 2000). However, COARSY, which lets users write on-line, also takes this approach, as it cannot support the creation from scratch of a new document.

If documents are created and edited on-line (Col•laboraciò, EquiText, REDUCE), then the application does not need to offer either uploading or downloading. This approach is particularly appropriate for applications meant to support the constant evolution of a Web site (Sparrow Web, Wiki Wiki Web).

The last approach we have seen is to let users create the document within their Web browser, but have users edit the document on their personal computer (downloading but no uploading). This solution is favoured by MRGS.

Finally, it must be noted that Contact did not offer document sharing within its features, as it was meant strictly for helping to manage the group.

### Communication

Perhaps because the WCWAs described here are almost all meant to support those activities that require the least interaction between collaborative writers (writing, editing, reviewing), none of them offers a specific communication function. However, some applications (Col•laboraciò, DHS, DocReview, and Office 2000) use email in order to notify group members when changes have occurred. This is a viable solution since email use is so widespread.

Incorporating a synchronous communication tool (such as a chat system) into a

Web browser is a complex task, which may explain why none of the WCWAs offer one.

Finally, it is important to note that comments can be used within a WCWA to support an asynchronous discussion.

### Comments

A commenting function in a WCWA not only reproduces the paper-based commenting strategy, but it can also be used to support communication, as mentioned previously. For example, by threading comments, both COARSY and Office 2000 support asynchronous conversations. However, only a minority of the applications offers commenting.

Applications meant to maintain a Web site (Sparrow Web, Wiki Wiki Web) might not really require a commenting function. Nor is this necessary for applications that expect the writing activities to be done off-line (BSCW and Contact). However, this absence is less understandable for WCWAs meant to support on-line writing/editing (Alliance, AllianceWeb and REDUCE).

When an application does offer commenting, it may let users attach the comments either to the whole document (COARSY, Col•laboraciò, DHS, and DocReview) or to a section (EquiText, U-DL-A). Only Office 2000 offers both options. These WCWAs can also be differentiated by the 'stability' of the comments and of the document: stable comments cannot be moved to another version of the document; stable documents cannot be modified. In most cases, the comments and the document are stable. The exceptions are Col•laboraciò and EquiText, where the document is dynamic (that is, it can be edited on-line), and Office 2000, where both the document and the comments are dynamic (in this case, a new version of the document can be uploaded and the comments are

transferred to this new version). This raises the problem of obsolescence, when a comment is no longer pertinent to the new version of the document (Cadiz et al. 2000).

### Awareness

Dourish and Bellotti (1992: 197) define awareness as ‘an understanding of the activities of others, which provides a context for your own activity’ (emphasis theirs). Among the factors that contribute towards awareness are sharing of information, knowledge of group and individual activities, and co-ordination. Several applications (see table 3) make no special effort at increasing awareness.

Those that do try to increase awareness, however, use different techniques. For example, AllianceWeb, BSCW and EquiText make it possible to see participants’ recent actions. In fact, with EquiText, it is possible to follow a paragraph’s evolution. REDUCE distinguishes participants’ contributions through colour coding, while U-DL-A uses colour in order to promote awareness of the different editing actions required in the text. Contact forced people to make explicit who was responsible for what and also showed what people had done recently.

### Co-ordinating actions: Locking

When a WCWA does not let people work on a document on-line, as is the case with AllianceWeb, Contact, DHS, DocReview, DReSS, or Office 2000, there is no need to take any special precautions in order to co-ordinate users’ actions within the application. But if more than one person can work on a document on-line simultaneously, then there exists a potential for conflicts. There are several ways of solving this problem, such as locking, improving awareness, or conflict resolution.

Locking occurs when the application limits work to only one person on part of or all of the document at any one time. Alliance would lock down fragments while DReSS locked down the whole document. Improving awareness is a social solution to this problem and is used by BSCW (the so-called 'soft lock'), where members can see that a document has been downloaded but can still download it. Conflict resolution uses software to decide which of any simultaneous changes to the document will be propagated to every version of the document. This is the solution preferred by REDUCE and Sparrow Web.

Working strategies supported: Activities

Collaborating writers must accomplish several different activities in order to create a document. These activities include brainstorming, research, planning, writing, editing, and reviewing<sup>7</sup> (Posner and Baecker 1993). What the group can accomplish on-line depends on which activities are supported by the applications. For example, brainstorming and planning, which require close coordination and high degrees of communication, are practically ignored by the WCWAs described here, although BSCW does offer some help with planning through a calendar function, while Contact supported planning by making participants specify on which sections they would work. This may be explained by the very nature of the Web, which is best suited for asynchronous work.

Research is supported only within BSCW, which lets users add hyperlinks to their workspace. These hyperlinks could point towards Web pages that are pertinent to the document being written. Considering the hypertext nature of the Web, it is a bit surprising not to find this feature offered more often, although, of

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<sup>7</sup> Editing differs from reviewing in that in the first, the editor modifies the text directly, whereas in the second, the reviewer suggests modifications but lets others make them.

course, users could always add URLs to their comments (where comments are possible).

As for writing (including writing, editing and reviewing), groups can adopt several different strategies, even during the life of a single project (Sharples et al. 1991, 1993, Sharples 1993, Posner and Baecker 1993, Noël and Robert, in press). Among the strategies that have been described by researchers are parallel, in which each person works on his/her section, sequential, in which one person at a time works on the whole document before passing it on to the next person, single or dual author, where one or two people do the actual writing, while other group members play other roles, joint, where the authors get together to work synchronously on the text, and scribe, where the group also works synchronously, but only one person writes down everyone's suggestions.

Depending on the three writing activities supported, a WCWA may or may not limit the strategies that a group can adopt. For example, the two synchronous strategies are only possible if an application lets people work synchronously; this is only available with REDUCE. Applications that only let users write comments (reviewing) limit the group to the single author strategy (DHS, DocReview, and Office 2000). However, applications which only let users write or edit, such as Alliance, Alliance Web, REDUCE, Sparrow Web and Wiki Wiki Web, make it more difficult for members to adopt the reviewer's role.

If an application offers all three writing activities (COARSY, Col•laboraciò, EquiText) or if it requires that members use their own word processors for these activities (BSCW, DReSS), then it does not impose any particular writing strategy. However, it must be noted that this is not the case for Contact, even though this application made groups work off-line. By supposing that the document would be split into different sections and that each person would work on that particular section, it imposed a parallel strategy on the group.

### Roles

Group members can assume different roles during a collaborative writing project, such as writer, consultant, editor, reviewer, leader/facilitator, or copy editor/typographer (Posner and Baecker 1993, Adkins et al. 1999). Although several WCWAs described here do offer roles, these roles are almost exclusively used to control access to the project or the document. For example, Alliance and AllianceWeb support four different user roles: the manager, who controls accessibility to the document by assigning roles, the writer, the reader, and the null role, used for barring access to confidential parts of a document. In BSCW, the roles include manager (workspace creator and only one who can create new roles), owner (creator of an object), member and restricted member (has only read access to objects). Roles are attached to each object, which means that one object's owner can have restricted access to another object, and so forth. DReSS offered two roles to group members, document creator and user. EquiText offers three roles: the manager, who deals with system installation and maintenance; the theme proponent, who creates a new theme (project); and the text writing collaborator, who can edit a document.

The only system that bases its roles specifically on collaborative writing research is COARSY, which lets members be either a writer (only one who can modify the text) or a reviewer (can only write comments). However, as noted earlier, there is some controversy over imposing roles in a collaborative writing application.

### Protection

Because of the very nature of collaborative work, a groupware application should offer some sort of protection for the work that has been done. If one

member's contributions are erased, accidentally or deliberately, by another without the first person's consent, this may lead to conflict within the group.

One way of protecting collaborating writers' work is by letting users save different versions of the document. This lets users have the assurance that deleted sections can always be recuperated later on (Kim and Severinson Eklundh 1998). BSCW, Col•laboraciò, DocReview, EquiText and MRGS follow this strategy. Another approach is to have the application save the work on a regular basis. Wiki Wiki Web backs up its pages automatically, making it possible to recuperate an old version if necessary. A more complex solution is to keep track of all the changes done to the text, thus permitting users to 'undo' these changes and go back to a previous version if necessary. Only EquiText offers this possibility.

### **Classifying WCWAs**

At first glance, the WCWAs described above seem to use different approaches to support collaborative writing. However, it is possible to classify them along two different axes: their overall function and how they support the basic writing activities. This classification should help potential users choose the tool best suited for their needs, and help designers see where past efforts have been concentrated and where gaps still remain.

In the first axis, WCWAs are divided according to their main function, that is what they are trying to do for the collaborative writing group. The WCWAs described here have five different main goals:

- (1) store documents on the Web server;
- (2) support group management;
- (3) support the collection of comments from other users about an existing document;

- (4) support Web site maintenance;
- (5) support on-line writing through the browser.

The second axis is concerned with the way each WCWA supports the three activities of writing, editing, and reviewing. This gives rise to eight possible sub-categories, depending on whether the WCWA lets users accomplish each activity on- or off-line. These are:

- (1) Web-based inclusive writing: on-line writing, editing, and reviewing (offers a section separate from the main text for writing comments);
- (2) Web-based exclusive writing: on-line writing and editing, off-line reviewing (does not offer a separate section for writing comments);
- (3) Off-line editing: on-line writing and reviewing, off-line editing;
- (4) Web-based authoring: on-line writing, off-line editing and reviewing;
- (5) Web-based inclusive editing: off-line writing, on-line editing and reviewing;
- (6) Web-based exclusive editing: off-line writing and reviewing, on-line editing;
- (7) Web-based reviewing: off-line writing and editing, on-line reviewing;
- (8) Off-line writing: off-line writing, editing, and reviewing.

Table 4 presents how each existing WCWA is categorised in this scheme. As can be seen, only five of the writing sub-categories are filled out since usually, although not always (as shown by MRGS), the systems permit both writing and editing in the same place.

[Insert table 4 about here]

Now that we have described the collaborative writing tools that exist, we use this information in the next section in order to suggest which tool groups should use in different collaboration situations.

### **Choosing a tool for collaborative writing**

A group that wishes to work collaboratively on a document over the Web has access to a few currently available solutions, making it possible to choose a tool according to which tasks the group wants to do on- and off-line.

For creating a document from scratch, a group could use BSCW, EquiText, or MRGS. With BSCW, participants must use their individual word processors, while the other two systems let people work directly in their browser. EquiText is meant for (Portuguese speaking) students working on collaborative texts for school assignments, although it could surely be used in other contexts. MRGS is meant specifically for creating rigidly structured documents. BSCW and EquiText let groups control who has access to the documents.

For reviewing an existing document through comments, a group could use EquiText, DocReview or MS Office 2000. The main difference between these systems is whether the document is static (DocReview) or modifiable (EquiText and Office 2000). When a document can be modified, this introduces two potential problems: (1) if a paragraph has been eliminated, its comments will be orphaned; (2) comments referring to an older version may no longer be pertinent to the new version. Also, Office 2000 requires WebDAV-aware servers and browsers, whereas EquiText and DocReview do not require any special server or browser.

For maintaining a Web site, a group could use Sparrow Web or Wiki Wiki Web. Sparrow Web is meant to support small, incremental changes to a Web site maintained by a community of people. Wiki is meant for editing Web pages that are in constant evolution, encouraging conversation and maintaining an on-line community, and seems particularly popular among IT specialists.

The tool with the most features (although it is far from complete, as will be seen below) is EquiText, which lets a group both create a document and write comments about that document in their Web browser. While this tool is aimed specifically at Brazilian students, Portuguese-speaking writers could surely profit from its many features. Another possibility is to use the latest version of a word processor such as Microsoft Word which offers many collaborative features and which can be combined with the annotations tool offered in Office 2000. However, this solution requires that every collaborator use the same word processor and have access to a WebDAV-aware server and browser, which negates one of the main advantages of using the Web (access to everyone, no matter what operating system or word processor they use).

Other systems that are still in prototype form include AllianceWeb, COARSY, Col•laboraciò, and REDUCE, which would be for on-line writing; and DHS, which would be for reviewing a document through comments.

While this section has provided some guidance to potential users of these WCWAs, it remains to be seen whether people are actually willing to use such tools to help them during a collaborative writing project. The next section presents the results found concerning this question.

### **Do people co-write using the Web?**

Although in our own research, the number of people who reported using collaborative tools during group writing was tiny (3 out of 42) (Noël 2001, Noël and Robert in press), other research suggests that people are, at the very least, capable of using Web-based writing tools under certain circumstances.

Anecdotally, Hendricksen (1999) reports that DocReview has been successfully used for the correction of meeting minutes. Ruiz and Favela (1998) did some

preliminary testing of COARSY. Users tried the commenting function and the search function. Users thought the system was useful mainly because all the participant's contributions are present at the same time and easy to access. The Wiki approach has proven quite popular, as there are 56 computer-related open public forums and 46 public forums on other subjects that all use the Wiki approach. There are also private forums (the Wiki web site lists 17 active ones, but there are probably more). And this doesn't even cover the Wiki clones!

More formally, Girgensohn (1999) described the use of MRGS at FX Palo Alto Laboratory by about 30 users for over a year. The system was used to create monthly reports, which were then posted to the lab's Intranet. This proved to be a bonus, as it opened up new dialogs between lab members and between the head office and the lab's researchers.

Cadiz et al. (2000) studied the use of Office 2000's annotation system by a large product team (over 1000 employees) at Microsoft. The team used the system primarily for developing specification documents or specs (descriptions of potential software features). Over 1000 specs were used during the ten-month period that lasted the study. The authors found that about 450 people made at least one annotation during the study's period. On average, few people made annotations to any particular document, while the number of annotations per document varied greatly. Usually, most annotations were made at about the same time as the first one, but there were many cases where documents were annotated for several months. Among the problems that users noted were annotation orphaning (this was the main reason people stopped using the system), change awareness (users said they wanted to know when new annotations appear, who made them and where), slow responsiveness (users felt that turn-around was not fast enough with annotations when a quick response was needed), public access (users hesitated to make comments that would make others look bad before everyone), and richness of annotations (users did not

make comments that were difficult to express in text or that were meant to clear up confusion).

Rodriguez (2001) studied the use of DHS in classrooms both as a discussion tool and as an annotation tool. He found that, over four years, students produced over 200 comments and over 200 annotations. However, it must be noted that use of the tool was mandatory in the classes.

Rodriguez also studied how people use Col•laboraciò. Groups worked on different writing projects: a poster, a technical report, a master's thesis proposal, a flyer, a report for a workshop, and a short conference paper. With the first versions of the system, people wrote comments mostly about the system itself (bug reports, suggestions, etc.), but as a more robust system developed, writers wrote more comments about the document. The most popular section was 'ideas for this paper' which produced meta-discussions about the project.

In summary, people are willing to use Web-based writing tools, although the most successful ones seem to be those meant to support creating documents for the Web (Wiki Wiki Web and MRGS). The Web-based annotations feature in Office 2000 has also proven popular with its users, although Cadiz et al. (2000) found several aspects that need improving. In the next section, we turn to the question of how best to design a collaborative writing tool that is based on the Web.

### **Designing a Web-based tool for collaborative writing**

This paper has already described several tools built to support collaborative writing on the Web. Under these circumstances, is there any real need for a new WCWA or should developers concentrate their energy on improving the ones that already exist? The very limited research on the real use of WCWAs makes it

difficult to answer these questions. Failing that, developers should base their decisions on how well existing WCWAs fulfil developers' and users' wish lists for collaborative writing systems.

We have already presented (see Introduction) a list of ten key features that groupware developers should take into account when designing their system. In addition to this, collaborative writing groups have their own specific needs in order to accomplish their task. We now present some further design suggestions based on results from experiments and advice from collaborative writing applications developers. This list is divided into four aspects: (1) the project in general, (2) the shared document, (3) the group, and (4) the software itself.

### *Project*

Sharples et al. (1991) suggest that a collaborative writing system should help writers externalise part of the cognitive process of writing by making more explicit such assumptions as intentions, constraints, guidelines and plans (see also Posner and Baecker 1993, Sjoerd 1995 and Berggren 1999). In our own research (Noël 2001, Noël and Robert in press), we found that collaborative writers found it useful to have access to some sort of collective schedule and thought notification for upcoming events should be included in a collaborative writing tool.

### *Document*

Apart from previous suggestions already made concerning the document (common access, protection, awareness of modifications), researchers have found that groups resort to drafts (Sharples et al. 1991, Tammaro et al. 1997, Cerratto and Rodriguez 2002, Noël 2001, Noël and Robert in press,) and templates (Tammaro et al. 1997) when writing. If a Web-based collaborative writing system is used for creating text (and not just storing it on a server), templates might prove very useful to a group about to begin a project. At the least, being able to

distinguish draft from finished versions would be of great help to group members.

### *Group*

Because group membership can be variable during a collaborative writing project (Beck 1993, Noël 2001, Noël and Robert in press), being able to display who is a member of the group at any one time, and making it easy to modify group membership are two important features that a collaborative writing application should offer. Although we have mentioned that imposing a particular type of leadership would not be productive, many collaborative writers believe that it is important to have someone in charge (Noël 2001, Noël and Robert in press), and so it may be a good idea to make it possible to designate a leader.

### *Software*

If the system offers templates to its users, then it should also let users create new templates. Printing remains an important part of any writing project, both to let people access the document when away from the computer and because reading on monitors can cause eyestrain. The system should let users create a printable version of the document at any time.

Table 5 shows how well the seven presently available WCWAs<sup>8</sup> cover this wish list.

[Insert table 5 about here]

None of the WCWAs offer even a majority of the functions that an ideal collaborative writing system should have. In some cases, this is due to a

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<sup>8</sup> We do not include systems in development since their functionalities are still being determined.

philosophical choice. For example, including a schedule makes little sense for a tool like Wiki Wiki Web, which is meant to support an on-going conversation in a Web site.

One place where the available WCWAs could be improved is at the project level. While none of these systems offer specific places to enter such things as constraints, guidelines, intentions, or plans, users can always supplement this lack by creating clearly identified documents (e.g. an HTML page in a Wiki site). However, Rodriguez (2001) has shown the usefulness of offering a specific place for holding a meta-discussion about the document. Such a feature might be enough to entice users to make explicit their goals and plans, helping group members share a common vision for the document. Only BSCW offers a schedule, and none of these applications have ways of warning users about upcoming dates (such as when a first draft should be handed in).

At the document level, only two systems have templates (MRGS and Sparrow Web). However, templates are only useful for applications that let groups create new documents. Only EquiText lets users create draft versions, although members could always resort to a labelling scheme in order to distinguish drafts from final versions (also, Web maintenance systems such as Wiki Wiki Web and Sparrow Web do not really need drafts).

At the group level, group membership depends on the application. Thus, DocReview does not limit the people who can access a document in order to widen the pool of potential reviewers. BSCW and EquiText take a more traditional view of collaborative writing (people getting together to create a document due for a particular date) and so impose group membership. Because MRGS is used within an Intranet, only authorised personnel will have access to it, and so there is no need to control membership any further, while Office 2000 limits comment creation to those users who can access the annotations server.

Both Wiki Wiki Web and Sparrow Web offer both free and limited group access. Modifying group membership is easy for all applications that can impose membership, although with Sparrow Web only the page author can add or remove members. As to leadership, BSCW, EquiText and Sparrow Web show who the leader is.

At the software level, only Sparrow Web lets users create new templates. Yet, being able to add new templates would be useful for groups who need to write the same type of document over and over again, but do not have a template for it. Only one system (EquiText) lets people create a printable version, although printing is not really necessary for systems that create Web sites, such as Wiki Wiki Web or SparrowWeb.

## **Conclusion**

There have been several attempts at supporting collaborative writing on the Web, designers using either an indirect approach, by modifying different aspects of the Web's infrastructure, or a direct approach, by building a Web-based application.

The existing WCWAs differ on their overall function, the way they support writing, editing, and reviewing, and the features they offer. This gives a choice to collaborative writing groups looking for a Web-based tool to support their project. Presently available WCWAs can be used to store a document on a Web server (BSCW), write a document on-line from scratch (EquiText and MRGS), collect comments about a document (EquiText, DocReview and Office 2000 annotations), or maintain a Web site (SparrowWeb and Wiki Wiki Web). The most complete WCWA is EquiText, available strictly to Portuguese-speaking writers, although it does not offer a majority of the features that an ideal WCWA should have. These available WCWAs permit only asynchronous writing,

although there is one in development (REDUCE) which will give users the chance to write synchronously.

Faced with the plethora of WCWAs that are available or being developed, the designer may wonder if there is any real need for a new collaborative writing system on the Web. However, since none of the presently available systems offer even a majority of the features and properties that an ideal collaborative writing system should offer, there is at the least an obvious need for improvement. One aspect that has been systematically ignored by WCWA designers is the need to support the project itself, for example by letting users create explicit goals or plans that can be referred to throughout the project's duration. Such explicit goals and plans help ensure that everyone in the group is in agreement over what the final product should be like or who the document's potential audience is. Such knowledge would help reduce potential conflicts and misunderstandings within a collaborative writing group.

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Table 1. Overview of the systems that support collaborative writing on the Web.

System	Developer	Country of origin	Language available	System type	Status
Alliance	LSR-IMAG, CICESE and CINVESTAV-IPN	France and Mexico	English	WCWA	No longer available (replaced by AllianceWeb)
Contact	Computing department, Lancaster U.	United Kingdom	English	WCWA	No longer available
DReSS	Computing Science department, Eindhoven U. of Technology	The Netherlands	English	WCWA	No longer available
VTML	U. of Bologna and Boston U.	Italy and USA	-	Infrastructure	No longer available
AllianceWeb	LSR-IMAG, CICESE and CINVESTAV-IPN	France and Mexico	English	WCWA	In development
COARSY	CICESE	Mexico	English	WCWA	In development
DHS	Interaction and Presentation Lab, Royal Institute of Technology	Sweden	English	WCWA	In development
PIÑAS	LSR-IMAG, CICESE and CINVESTAV-IPN	France and Mexico	-	Infrastructure	In development
Col•laboraciò	Interaction and Presentation Lab, Royal Institute of Technology	Sweden	English	WCWA	Prototype
REDUCE	School of Computing and Information Technology, Griffith U.	Australia	English	WCWA	Beta-testing
BSCW	Fraunhofer-FIT and OrbiTeam Software	Germany	Many	WCWA	Available
DocReview	Charles Hendricksen, U. of Washington	USA	English	WCWA	Available
EquiText	PGIE, U. Federal do Rio Grande do Sul	Brazil	Portuguese	WCWA	Available
MRGS	FX Palo Alto Lab	USA	English	WCWA	Available
WebDAV	IETF WebDAV working group	USA	-	Infrastructure	Available
Wiki Wiki Web	Ward Cunningham	USA	English, others (e.g. German, Hebrew)	WCWA	Available
Office 2000	Microsoft Corp.	USA	Many	WCWA	Commercially available
SparrowWeb	Xerox Palo Alto Research Center and AlphaAve	USA	English	WCWA	Commercially available

*Legend: WCWA: Web-based Collaborative Writing Application*

Table 2. Comparison of the infrastructure modifying systems.

	<b>PIÑAS</b>	<b>VTML</b>	<b>WebDAV</b>
<b>Architecture</b>	Mixed	Hybrid	Hybrid
<b>Modifies</b>	Middleware	HTML language	HTTP protocol
<b>Special browser or server</b>	Ordinary browser can be used; special server	Both	Both
<b>Versions</b>	No	Yes	No
<b>Roles</b>	Yes	No	No
<b>Locking</b>	No	No	Yes
<b>Author name</b>	Yes	Yes	No
<b>Author list</b>	Yes	No	No
<b>Date</b>	No	Yes	No
<b>Work on sections</b>	Yes	Yes	No
<b>Modification history</b>	No	Yes	No

Table 3. Features available on 15 WCWAs.

Application	U/D	Communication	Comments	Awareness	Locking	Activities	Roles	Protection
Alliance	U, Automatic D	No	No	No	Section	Writing Editing	Access	No
AllianceWeb	U/D	No	No	Yes	No	Writing Editing	Access	No
BSCW	U/D	No	No	Yes	Soft	Research Planning	Access	Version
COARSY	U	No	Document	No	No	Writing Editing Reviewing	Writer Reviewer	No
Col·laboració	No	Email notification	Document	No	No	Writing Editing Reviewing	No	Version
Contact	-	No	No	Yes	-	Planning	No	No
DHS	U (technician)	Email notification	Document	No	-	Reviewing	No	No
DocReview	U (technician)	Email notification	Document	No	-	Reviewing	No	Version
DReSS	U/D	No	No	No	Document	-	Access	No
EquiText	No	No	Section	Yes	No	Writing Editing Reviewing	Access	Version, Undo
MRGS	D	No	No	No	No	Writing	No	Version
MS Office 2000	No (FTP)	Email notification	Section Document	No	-	Reviewing	No	No
REDUCE	No	No	No	Yes	Consistency maintenance	Writing Editing	No	No
SparrowWeb	U	No	No	No	Manual resolution of conflicts	Editing	No	No
U-DL-A	U	No	Yes	Yes	No	Reviewing	No	No
Wiki Wiki Web	No	No	No	No	No	Writing Editing	No	Back-ups

Legend: U/D: Upload/Download.

Table 4. WCWAs categorised based on their main function and how they support writing, editing, and reviewing.

	<b>Document storage</b>	<b>Group management</b>	<b>Reviewing tool</b>	<b>Web maintenance</b>	<b>Writing tool</b>
<b>Web-based inclusive writing</b>			COARSY** Col•laboració** EquiText		COARSY** Col•laboració** EquiText
<b>Web-based exclusive writing</b>				SparrowWeb Wiki Wiki Web	AllianceWeb** REDUCE**
<b>Web-based authoring</b>					MRGS
<b>Web-based reviewing</b>			DHS** DocReview Office 2000		
<b>Off-line writing</b>	BSCW* DReSS*	Contact*			Alliance*

*Legend: \* no longer available; \*\* in development.*

