Review and functional classification of collaborative systems

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Abstract

E-collaboration and collaborative systems bring geographically dispersed teams together, supporting communication, coordination and cooperation. The paper presents a review of research in the area of creating collaborative application taxonomies. We analyze previous literature, and examine commercial products and research prototypes in the domain of collaborative computing. Our survey provides a list of basic collaboration services, and the tools are presented with regards to the services they provide. All surveyed tools are then classified to four categories of functional services. In conclusion, the paper highlights a number of areas for consideration and improvement that arise when studying collaborative applications. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Collaborative services; Electronic workspace; Workflow; Taxonomy

1. Introduction

The worldwide web technology and electronic networks have created an environment, where place no longer matters. E-collaboration and collaborative tools bring geographically dispersed teams together for virtual meetings across great distances. This results in tremendous time and cost saving, greatly decreased travel requirements, faster and better decision-making and improved communications flow throughout the organization. Even organizations whose parts live all in the same building, often experience difficulties, which real-time collaboration from desktops could improve. Broadly defined, the field of collaborative computing, encompasses the use of computers to support coordination and cooperation of two or more people who attempt to perform a task or solve a problem together (Borenstein, 1992; Schooler, 1996).

The objective of this paper is to study the existing systems offering collaboration services, group them in functional categories based on the kind of services they provide, perform a review of the

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literature in the domain of creating collaborative taxonomies, define areas for improvement and set the basis for future considerations.

The paper is structured in the following manner: The next section gives a short overview of previous literature concerning taxonomies and classifications of collaborative systems. In Section 3 some of the most common collaboration services are described, and a correlation of the systems and their features is provided in Section 4. In Section 5 the functional categories as well as their basic attributes are identified, and the systems are classified to the predefined categories. Finally, Section 6 presents the conclusions and indicates future research issues.

2. Collaborative application taxonomies

A first approach to providing a taxonomy of collaborative systems, is to distinguish them by *when* and *where* the interaction takes place (time/space taxonomy, see DeSanctis & Gallupe, 1987; Ellis, Gibbs & Rein, 1991; Johansen, 1988). In this context, two primary dimensions are identified (see Fig. 1).

In the horizontal dimension we order collaborative tools by the location of participants: they can be either at the same place (also referred to as co-located) or at different places (remote). Similarly the vertical dimension makes the distinction, whether the interaction happens at the same time (synchronous) or at different times (asynchronous). These dimensions provide four communication scenarios: synchronous, co-located; asynchronous, co-located; synchronous, remote and asynchronous, remote.

Grudin (1994) also provides a classification of collaborative systems in terms of *time and place*. Time and space settings in groupware can be classified as *same, different but predictable and different and unpredictable*. Accordingly, emerge nine different categories of collaborative systems.

A review of the literature reveals several other classifications of systems that support group work. DeSanctis and Gallupe (1987) discuss a taxonomy based on *group size* (smaller, larger), and *task type* (planning, creativity, intellective, preference, cognitive, conflict, mixed motive).
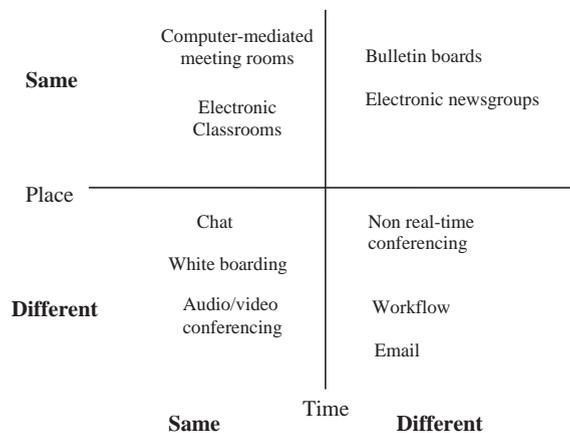

Fig. 1. The time/space classification.

Kraemer and King (1988) provide a classification of the Group Decision Support Systems (GDSSs). GDSSs are categorized with regards to the hardware they need, the software required, the people they involve and the organizational data needed.

Apart from the space/time taxonomy, Ellis et al. (1991) describe a taxonomy based on *application-functionality* and Coleman (1995) also provides twelve categories of collaborative systems in the same domain.

Coordination systems have been also classified by Ellis et al. (1991) by one of the four types of control models they embrace: form, procedure, conversation, or communication-structure oriented.

Jarczyk, Loffler, and Volksen (1992) developed a taxonomy to characterize collaborative systems, where five major classes of criteria are defined: *functional, technical, application, usability and ergonomics and scalability*. The functional criteria describe the features of systems, the technical characterize the platform, the environment and the architecture of the systems, the application criteria help to define the application domain, usability and ergonomics are important for the acceptance of a tool and finally, orthogonality and scalability are meta-criteria, which focus on the flexibility of the system with respect to the other criteria.

Mentzas (1993) classifies collaborative software based on four major criteria: coordination model characteristics, type of processing, decision support issues and organizational environment.

McGrath and Hollingshead (1994) deal with a task framework, where group tasks are classified in four quadrants. Each quadrant is characterized by a general performance process (action of a group): *generate*(alternatives), *choose* (alternatives), *negotiate* and *execute*. The quadrants are then subdivided in two types of tasks each, and as result eight different types of tasks arise. The task circumplex is a two-dimensional representation. The horizontal dimension shows a contrast between behavioural or action tasks to the right and conceptual or intellectual tasks to the left. The vertical dimension reflects a contrast between cooperation or facilitative compliance at the top and conflict at the bottom.

Malone and Crowston (1994) define a taxonomy based on the *coordination process* collaborative systems support. According to their framework, six levels of processes are defined: managing shared resources (task assignment and prioritization), managing producer/consumer activity relationships (sequencing prerequisites), managing simultaneity constraints (synchronizing), managing task/subtask relationship (goal decomposition), group decision making and communication.

Ellis (2000) provides a categorization of collaborative systems according to the underlying technology. Thus, four aspects are determined: keepers, coordinators, communicators and team-agents. Briefly, the first aspect, keepers, groups all functionality related to storage and access to shared data. The second aspect, coordinators, is related to the ordering and synchronization of individual activities that make up the whole process. The third aspect, communicators, groups all functionality related to unconstrained and explicit communication among the participants. Finally, the fourth aspect, team agents, refers to intelligent or semi-intelligent software components that perform specialized functions and help the dynamics of a group.

Table 1 sums up all the above references in the literature. Four major dimensions are identified: Time/space, application, group issues, and technical criteria. Several sub dimensions are also provided. Under group issues, for instance, we can distinguish group size (smaller-larger groups), characteristics of the group and types of group tasks. Group characteristics include the existence

Table 1
Classification dimensions in the literature

Other		Technical			Group issues			Application	Time/Space	Classification criteria/authors
Usability and ergonomics	Mode of interaction	Scalability	Software	Hardware	Types of group tasks	Characteristics of group	Group size			
					X		X			DeSanctis and Gallupe (1987)
			X	X		X				Kraemer and King (1988)
									X	Johansen (1998)
	X							X	X	Ellis, Gibbs and Rein (1991)
X	X	X	X	X			X	X		Jarczyk, Loffler and Volksen (1992)
	X		X						X	Mentzas (1993)
					X					McGrath and Hollingshead (1994)
									X	Grudin (1994)
					X					Malone and Crowston (1994)
								X		Coleman (1995)
			X					X		Ellis (2000)

or non-existence of a facilitator, and the group composition, which in turn determines the cohesiveness of the group and the relationships between the members. There are eight types of group tasks: planning, creativity, intellective, decision-making, cognitive conflict, mixed-motive, competitive and performance/psycho-motor tasks.

Technical criteria include hardware, software and scalability.

The mode of interaction among users (implicit–explicit, formal–informal, communication, collaboration, perception of common objects) and the usability/ergonomics criteria are equally important.

The classification discussed in this paper is based on the services systems provide to their users, therefore, it is a functional taxonomy and could fit in the "Application" row of Table 1.

3. Collaborative services

Attempting to define the most commonly encountered services collaborative systems provide, we have reviewed 47 systems that are either available commercially, or are research prototypes. Table 2 provides company and URL information for the examined systems whereas, in Appendix A a more detailed description of each tool is supplied.

The following list of services arose as a result of our survey:

Bulletin board: a message board, where a conversation can be carried on over time. The user can leave a message for someone, and they can answer it and the initiator can respond back to them later.

Discussions: the subject is set and the discussion is carried on, either with all participants online, or over time, where anyone can share his or her opinion at any time, as long as the subject is still open.

E-mail: the most common and widespread communication tool. It allows wide contact over the Internet and its primary use is for text messages, normally relatively brief. Often the messages are accompanied by file attachments.

E-mail notifications: email notifications are sent to inform about changed project information, entries in the calendar and to-do list, new activities in the group, or revisions and changes in documents.

Online paging/messaging: instant alerts "pop up" on the user's screens, serving as informal messages, or notifying about scheduled meetings, etc.

Chat: real-time text talk, where messages appear on both users screens. Usually, a split screen is used, where the local typing appears in one part and the remote in the other. There is no particular subject set and it does not scale to more than a very few users.

Whiteboard: whiteboards allow two or more people to view and draw on a shared drawing surface. This may be used for discussing or describing objects, which are difficult to verbalize. Most shared whiteboards are designed for informal conversation, but they may also serve structured communications, or more sophisticated drawing tasks, such as collaborative graphic design, publishing, or engineering applications. Shared whiteboards can indicate where each person is drawing or pointing, by showing tele-pointers, which are colour-coded or labelled to identify each person.

Table 2
Collaborative systems: Company and URL information

Tools	Organization/country	URL
CommonSpace	Sixth Floor Media, USA	http://www.sixthfloor.com
DocuTouch	DocuTouch Corporation, USA	http://www.docutouch.com
Documentum	Documentum, USA	http://www.documentum.com
TeamNow	TeamNow, Denmark	http://www.teamnow.com
CentraNow	Centra, USA	http://www.centranow.com
Consencus @nyWARE	SoftBicycle, USA	http://www.softbicycle.com
CuSeeMe Conference Server	CuSeeMe Networks, USA	http://www.cuseeme.com
DOLPHIN	GMD, Germany	http://www.darmstadt.gmd.de/
Evoke Collaboration	Evoke Communications, USA	http://www.evoke.com
Facilitate.com	Facilitate.com, USA	http://www.facilitate.com
Grouputer	Stepup Systems, Australia	http://www.stepup.com.au/
HelpMeeting	HelpMeeting LLC, USA	http://www.helpmeeting.com
MeetingRoom	GroupSystems.com, USA	http://www.ventana.com
PlaceWare	PlaceWare, USA	http://www.placeware.com
Web-4*	JDH Technologies, USA	http://www.jdhtech.com
aspSmartForum	Advantys, France	http://www.aspsmart.com
FirstClass	Centrinity, Canada	http://www.softarc.com
Instant!TEAMROOM	Lotus, USA	http://www.lotus.com
Intranets	Intranets.com, USA	http://www.intarnets.com
Project place	Projectplace International AB, Stockholm	http://www.projectplace.co.uk
TeamTalk	Trax Softworks, USA	http://www.webcom.com/
vJungle	Vjungle, USA	http://www.vjungle.com
WebBoard	O'Reilly Software, USA	http://www.webboard.oreilly.com
MeetingPlace	Latitude, USA	http://www.latitude.com
NetMeeting	Microsoft, USA	http://www.microsoft.com
PictureTalk	Pixion, USA	http://www.pixion.com
Sametime	Lotus, USA	http://www.lotus.com
BSCW	GMD, Germany	http://bscw.gmd.de
Business Manager	Info Parc, Austria	http://www.infoparc.com
Caucus	Caucus Systems, USA	http://www.caucus.com
Collab Fab	Collaboration Fabricators	http://www.collabfab.com
CVW	Mitre, USA	http://cvw.sourceforge.net
Cybozu Office 3	Cybozu, Japan	http://cybozu.com
DIVA	GMD, Germany	http://orgwis.gmd.de/projects
eRoom	eRoom Technology, UK	http://www.eroom.com
Forum	SiteScape, USA	http://www.sitescape.com/
Groove	Groove Networks, USA	http://www.groove.net
GroupPORT	GroupServe, USA	http//gp1.groupport.com
GroupWise	Novell, USA	http://www.novell.com/
HyperOffice	myWebOS.com, USA	http://www.hyperoffice.com
InfoWorkSpace	General Dynamics, USA	http://www.infoworkspace.com
Intraspect c-Business Platform	Intraspect Software, USA	http://www.intraspect.com
JointPlanning	Bridgeline Technologies, USA	http://www.jointplanning.com
QuickPlace	Lotus, USA	http://www.lotus.com
TeamOn	TeamOn, USA	http://www.teamon.com
TeamWave	TeamWave Software, USA	http://www.teamwave.com
VEGA	Universities of Berne, Lausanne	http://vega.vptt.ch

Audio/Video conferencing: use of audio or video to enhance human presence in meetings. Video is advantageous when visual information is discussed, and may also be used in less direct collaborative situations, such as for providing a view of activities at a remote location.

Task list: lists of actions to be performed, pending activities, unresolved problems and scheduled meetings are kept and the user is notified for new items in the list.

Contact management: an address book is provided, where contact information about meeting participants or project partners can be found.

Screen sharing: both people have the same view of the screen and possibly the remote user can take control of the other user's system. Screen sharing can mean either that only the view of the screen is shared—essentially a graphic representation of one screen is passed to the other screen—or applications can be shared, in which case events from the remote keyboard and mouse are used to drive the local input and pointer.

Surveys/polling: decisions are made online, and surveys on different topics are conducted. Occasionally voting results are graphed and disseminated.

Meeting minutes/records: minutes are disseminated among participants, action items are posted, or the team's thoughts are gathered so as to constitute the starting point for subsequent meetings.

Meeting scheduling tools: creating meeting agendas and lists of issues or using calendars for organizing meetings.

Presentation capability: users can conduct presentations, i.e. show and annotate PowerPoint slides.

Project management: projects and project milestones, meetings, memos and project interactions are tracked. Project management with the traditional meaning of the term, i.e. creating Gantt or Pert charts and calculating the project budget is not considered.

File and document sharing: documents and files are available to a group of people to view. In the simplest form, files come as email attachments and users can work with them using their local applications. Alternatively, files are uploaded to a site/server.

Document management: document management includes sharing of documents. Documents are stored in a central server and users can work on the documents, either using their local applications, or the tool's functionality. Occasionally, there is possibility for version control, search, electronic signing and access control.

Synchronous work on files/documents: files/documents can be edited simultaneously by a number of users, either on each other's screen, or on a whiteboard.

Consecutively, we were able to range the tools with regards to the services they provide and present the results in Table 3.

4. Categories of collaborative tools

For a more accurate definition of the categories in our classification, a graphical representation of them in relation with their most important characteristics is provided (see Fig. 1). The four categories feature in a two-dimensional graph. The *x*-axis represents the level of functionality concerning collaboration. This axis commences with services providing simple communication functionality and leads to these services, which enhance collaboration and human interaction. The *y*-axis on the other hand, represents the document management capability. Document

Table 3
Collaborative tools and their characteristics

Products	Bulletin board	Discussions	E-mail	E-mail notifications	Online paging/ messaging	Chat	Whiteboard	Audio/video conferencing	Task list	Contact management
CommonSpace		●								
DocuTouch				●						
Documentum										
TeamNow										
CentraNow		●	●	●		●	●	●		
Consencus @nyWARE		●		●					●	
DOLPHIN							●	●		
CuSeeMe Conference Server				●				●		
Evoke Collaboration						●	●			●
Facilitate.com		●								
Grouputer		●						●		
HelpMeeting				●		●	●			
MeetingRoom		●								
PlaceWare						●	●	●	●	
Web-4**		●				●	●	●		●
AspSmartForum		●	●	●						
FirstClass		●	●							
Instant!TEAMROOM		●	●	●						
Intranets		●	●		●					●
Project place		●							●	
TeamTalk		●								
VJungle			●			●				●
WebBoard		●			●	●				
MeetingPlace		●						●		
NetMeeting		●		●		●	●	●		
PictureTalk				●				●		
Sametime		●		●		●	●			●
BSCW		●		●						
Business Manager		●							●	●
Caucus		●						●		
Collab Fab		●							●	
CVW						●	●	●		
Cybozu Office 3	●	●	●	●		●	●	●	●	●
DIVA	●	●				●	●	●		
ERoom		●		●	●	●				
Forum		●	●	●		●				
Groove		●			●	●	●			

Products	Screen sharing	Polling	Meeting minutes/ records	Meeting scheduling	Presentation capability	Project management	File and document sharing tools	Document management	Synchronous work on documents/ slides
GroupPORT		●	●						●
GroupWise		●	●	●					●
HyperOffice			●	●		●		●	●
InfoWorkSpace		●	●	●	●	●	●	●	
Intraspect c-Business Platform			●	●					
JointPlanning		●	●	●				●	●
QuickPlace		●				●			
TeamOn	●	●	●						●
TeamWave	●						●	●	●
VEGA		●							●
CommonSpace							●	●	●
DocuTouch							●	●	
Documentum									
TeamNow									
CentraNow	●	●	●		●				
Consencus @nyWARE		●		●					
DOLPHIN		●	●	●	●		●	●	●
CuSeeMe Conference Server				●			●		
Evoke Collaboration	●	●			●				
Facilitate.com		●	●	●					
Grouputer		●	●	●					
HelpMeeting				●	●		●		●
MeetingRoom		●	●	●					
PlaceWare	●				●				●
Web-4**					●		●		
aspSmartForum							●		
FirstClass							●		
Instant!TEAMROOM							●	●	
Intranets			●				●	●	
Project place			●				●	●	
TeamTalk							●		
vJungle							●		
WebBoard							●		
MeetingPlace							●	●	
NetMeeting	●						●		
PictureTalk	●	●			●		●		

Table 3 (*continued*)

Products	Features								
	Screen sharing	Polling	Meeting minutes/ records	Meeting scheduling	Presentation capability	Project management	File and document sharing tools	Document management	Synchronous work on documents/ slides
Sametime	●		●						●
BSCW			●		●		●	●	
Business Manager						●			
Caucus					●		●	●	
Collab Fab			●				●	●	
CVW							●	●	
Cybozu Office 3							●		
DIVA							●	●	●
eRoom		●				●	●	●	
Forum				●			●	●	
Groove							●		
GroupPORT							●		
GroupWise							●	●	
HyperOffice		●					●	●	
InfoWorkSpace	●				●		●		
Intraspect c-Business Platform							●		
JointPlanning		●					●		
QuickPlace							●	●	
teamOn				●	●		●		
TeamWave	●	●		●			●		
VEGA		●		●		●	●	●	

management systems enable users to directly manipulate documents, index and store in order to retrieve them when needed, communicate through the exchange of documents, collaborate around documents and even model and annotate the flow of documents (Zantout & Marir, 1999). The services are ranked beginning with the file and document sharing facility concluding to the synchronous work on documents, from bottom to top (Fig. 2).

The four categories can now be properly defined by citation of the typical characteristics of each category.

4.1. Group file and document handling

The core functionalities of this category involve working with documents and files. In the simplest form, users only have a shared view of files/documents, while advancing, there is also possibility for individual editing, document/file management and storing in a central database, as well as collective authoring and revision of documents. Synchronous work on documents can also be a part of a group document handling tool. In addition, basic communication capabilities, such as e-mail notifications and e-mail, are provided.

4.2. Computer conferencing

Space for asynchronous and threaded discussions as well for real-time text talk and real-time discussions is provided, and files and documents are shared. There is a possibility that users see and work on documents simultaneously, or on each other's screen, or on a whiteboard (Coleman & Ward, 1999) and mailing capabilities are also provided. Audio and video conferencing are quite common.
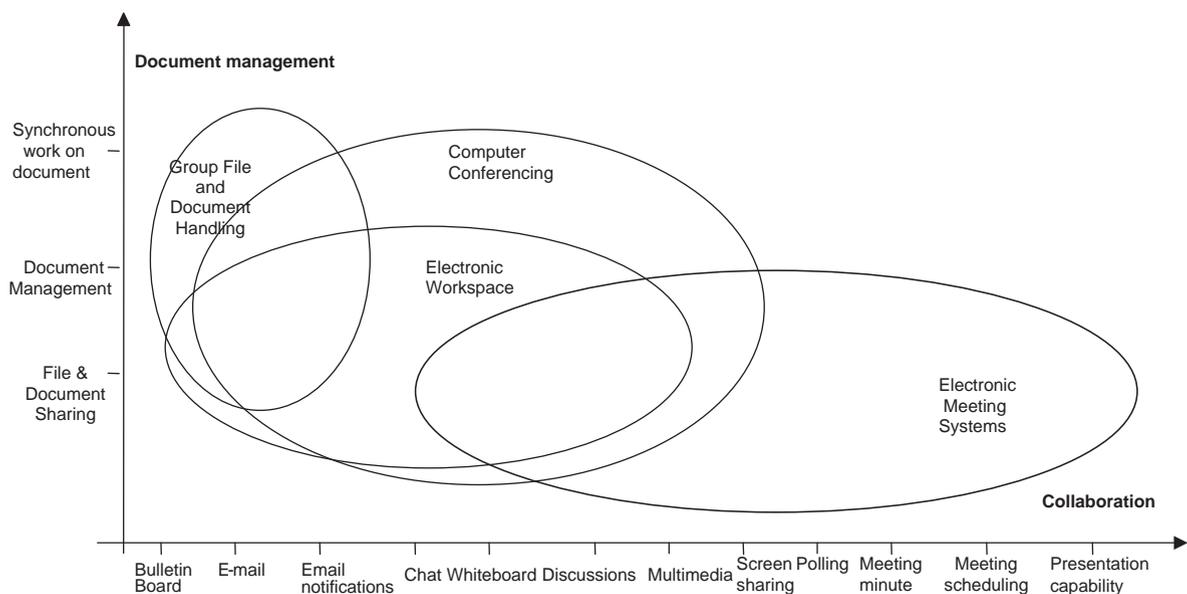

Fig. 2. Categories of tools.

4.3. Electronic meeting systems (EMS)

Meeting conduction is the basic functionality of the EMS category. Meetings can either be regular (same time, same place), synchronous (same time, different place), or asynchronous (different time, different place) (Stenberg, 1995). Meeting participants are notified through email, and have the possibility to chat, conduct real-time discussions, use audio and video conferencing facilities, write or draw in real-time on a blank slide, participate in surveys-anonymously if preferred-and make group decisions, share documents and files, show and annotate PowerPoint slides, share live software applications and even work simultaneously on documents. Apart from the work-centered activities, the team also engages in team-centered activities including greeting, seeking additional participants, introduction and parting. Finally, meeting-centered activities support the meeting process including its set-up, maintenance of the agenda and minutes, and distribution of the minutes after the meeting (Poltrock & Engelbeck, 1999).

4.4. Electronic workspace

The primary idea is to provide teams with a common space to coordinate and organize their work. Groups can centrally store documents and files, work with them, solve problems through discussion, keep to-do lists and address books with information about group contacts, and even track project milestones and project interactions. There are workspaces for different groups, and users may be members of several workspaces with each workspace corresponding to each project a user is involved with (Bentley et al., 1997).

Table 4 gives a full list of the systems examined as well as the category each tool belongs to. Obviously the borders between the categories are not strict, and some tools can fit in more than one category. In this case, we have tried to select the category that more accurately represented the tool's functionality. Anyhow, it should be noted that slight "movements" of tools from one category to another, can easily occur.

Certainly, the above classification is not exhaustive. There are several other function-level categories we could easily identify: Electronic mail, Electronic calendaring, Workflow, Group decision support, Collaborative writing, Electronic learning. Yet, these categories are neither part of our graphical analysis, nor were examined representative tools as they are too specialized, that is, they include a very small number of the characteristics analyzed in Section 3.

However it would be useful to cite some of them and also include a brief description for reasons of completeness as shown in Table 5 (Kock & McQueen, 1997).

The combination of features of several of the above categories would create new categories, which could be added to the taxonomy. Also, as more group functions are supported by computer systems, the taxonomy by service can be easily extended.

By adding to our initial taxonomy the temporal and spatial dimensions described in Section 2 (Nickerson, 1997), we can create a more complete collaborative taxonomy, including further sub-categories (see Table 6).

As demonstrated in the above table, group file and document handling is always remote, but can be either synchronous or asynchronous, the same stands for conferencing, while electronic meetings must always be conducted on real time, but can be either co-located or remote.

Table 4
Classification of collaborative tools

Tools	Categories			
	Group file and document handling	Computer conferencing	Electronic meeting systems	Electronic workspace
CommonSpace	X			
DocuTouch	X			
Documentum	X			
TeamNow	X			
CentraNow			X	
Consencus @nyWARE			X	
CuSeeMe Conference Server			X	
DOLPHIN			X	
Evoke Collaboration			X	
Facilitate.com			X	
Grouputer			X	
HelpMeeting			X	
MeetingRoom			X	
PlaceWare			X	
Web-4**			X	
aspSmartForum		X		
FirstClass		X		
Instant!TEAMROOM		X		
Intranets		X		
Project place		X		
TeamTalk		X		
vJungle		X		
WebBoard		X		
MeetingPlace		X		
NetMeeting		X		
PictureTalk		X		
Sametime		X		
BSCW				X
Business Manager				X
Caucus				X
Collab Fab				X
CVW				X
Cybozu Office 3				X
DIVA				X
eRoom				X
Forum				X
Groove				X
GroupPORT				X
GroupWise				X
HyperOffice				X
InfoWorkSpace				X
Intraspect c-Business Platform				X
JointPlanning				X

Table 4 (*continued*)

Tools	Categories			
	Group file and document handling	Computer conferencing	Electronic meeting systems	Electronic workspace
QuickPlace				X
teamOn				X
TeamWave				X
VEGA				X

Electronic workspaces on the other hand, usually provide both for synchronous and asynchronous communication and support remote collaboration.

5. Discussion and concluding remarks

Without any doubt, collaborative work based on information sharing is becoming a necessity. All four categories of tools providing group communication and collaboration, address some of the coordination problems that decentralization, joint ventures, mobile working and outsourcing of business functions have created (Bentley et al., 1997). Widely dispersed working groups can jointly author, comment and annotate documents (group file handling), organize and conduct electronic meetings (EMS), and engage in synchronous or asynchronous group discussions (real-time/non-real-time computer conferencing).

File and document sharing is clearly the most common and at the same time most needed collaboration service. The majority of the examined tools provide file and document sharing functionality and often, document management facilities. Geographically dispersed work groups, either consisting of project team members, usually working in different organizations, or of interactive employees of the same company, have the common, compelling need to share the information included in documents and files of various formats and to be able to work with that information, preferably using their local applications. Therefore, basic file/document sharing and management functionality should be integral part of all collaborative tools.

Non-real-time collaborative software is not necessarily intended for professional activities. More often, people use it to create discussions around any issue they are interested in. It is commonly integrated in e-commerce sites, to attract frequent visitors, or it can be part of a company intranet to involve employees. Services provided by non-real-time collaborative tools are usually also included in systems belonging to the other categories.

Electronic meeting systems enable people to work together more effectively—mostly during face-to-face meetings with many participants. They are especially useful if sensitive issues need to be discussed, which participants may be reluctant to talk about openly and in case of extreme opinion differences among dominant personalities. Also, it is considered best to use EMS, when consensus is needed before going forward, when there is limited time to collect information from a large group of people, a very complex decision based on many criteria must be made, and the meeting content needs to be quickly documented and used for desired impact on the organization.

Table 5
Application-level categories and their description

Electronic mail	Electronic mail is by far the most used group service and systems providing electronic mail functionality were of the first computer systems to be developed with the aim of supporting communication among people
Electronic calendaring	Electronic calendaring supports improved group coordination through the use of shared access to appointment diaries on networked computers. People are allowed not only to record information about their own appointments but also can access other people's information. This information sharing functionality is normally extended with features that enable one person to book appointments for another and even to find out if a meeting with several people is possible regarding their own particular appointments
Workflow	Workflow systems control, assist and expedite the coordination of activities that must be performed in a specific order to fulfil certain group goals. A representation of the process is embedded to the system and is used to synchronize steps of the process, to execute automatic activities, to provide helpful data and notification to human users who are executing manual activities, and to keep track of important information, such as state of a job or process, and deadline dates. If necessary, reminders may be sent to people, when deadlines are missed (Ellis, 2000)
Group decision support	Group decision support systems assist the type of activities that normally take place in structured business meetings, such as development of plans and budgets. Discussions usually take place in a special decision room, which has a networked computer available for each user, but also supports visual and verbal interaction among participants. The main purpose of group decision support systems is to aid in sharing of information, ideas and opinions, and making these available to all participants. Brainstorming, voting, ranking and classification of ideas are examples of tasks supported by a typical group decision support system. A fundamental element for its effective use is the "facilitator" who provides technical and procedural support to the members of the group. Some studies suggest group decision support systems can improve the overall quality of decisions as well as reduce the time to reach them
Collaborative writing	Two or more authors can jointly prepare and revise a document. The status of the document along with author's comments and identification of modifications are provided. Through collaborative writing systems any of the authors is able to keep track of the document evolution and identify who changed the document and to what extent. Comments associated to parts of the document can be attached by some of the authors and viewed by the others. Collaborative writing systems can be synchronous and asynchronous, respectively providing support to same-time and disconnected-time interaction
Learning tools	E-learning systems deliver education and training using deploying and managing instructional material through computers linked to the Internet. An e-learning environment usually includes: self-paced training delivered over the web; many virtual events (which could take place in virtual classroom, virtual lecture hall, or expert-led discussion); mentoring (which might entail coaching, help desk, office hours, periodic check-in, email exchanges); simulation; collaboration, either joint problem-solving or discussion among study groups via discussion groups and chat rooms; live workshops for some topics that are best taught in the real world by an instructor or expert; assessment, both for initial placement and for opting out of topics the learner has already mastered; competency roadmap, a custom learning plan based on job, career, and personal goals; and finally authoring tools, to develop and update content. E-Learning systems are used by educational institutions as well as by corporations

Table 6
Temporal and spatial dimensions of collaborative systems

Functional category	Temporal dimension		Spatial dimension	
	Synchronous	Asynchronous	Co-located	Remote
Group file and document handling	X	X		X
Computer conferencing	X	X		X
Electronic meeting Systems	X	X	X	X
Electronic workspace	X	X		X

However, the real need for electronic meetings is located in case of remote participants, where important decisions for the work progress need to be made, without physical contact being possible. EMS should be more effective during such meetings, also supporting the social activities necessary for building trust in geographically distributed teams and enhancing team awareness. The use of video-conferencing could provide a solution, although it can be quite costly. Other ways, possibly more effective and at less cost, could be maintaining a collection of background information about team members, including photographs and/or video segments. This information could be accessed during the introductory phase of meetings and participants would learn to associate the voice with the face. Of course, this approach requires work to create and maintain it (Poltrock & Engelbeck, 1999).

The electronic workspace category of tools combines some of the basic features of the other three categories. Access to shared information is provided at any time and place, using minimal technical infrastructure.

There is a continued challenge to support not only small groups or moderate-sized organizations, which have traditionally been the focus of most collaborative tools, but also much larger scale tele-collaboration, such as inter-organizational communication. People from across a company and from customer, supplier and partner companies need to get together to innovate, resolve issues, make decisions and get work done.

A shared, web-based workspace can best address that need, when it includes workflow functionality. Using web-based workflow technology, business processes, part of which are initiated or performed by users via a web browser, are automated. The systems we reviewed do not explicitly handle workflow, that is why we did not include workflow in the examined characteristics.

However, for business to business transactions, web based workflow provides many advantages. Workflow technology allows companies to extend their organizational boundaries to seamlessly include their customers and suppliers (Mentzas & Halaris, 1999). All types of traditional documents, as well as the new non-traditional digital forms of information, such as voice messages, e-mails, video, and web pages, can constitute input to the workflow process. A work item can move through multiple organizations linked over the Internet to achieve the required goal. In addition, authorized users can track workflow activity through the various heterogeneous organizations from their desktop.

Although there are some tools-members of the electronic workspace category that offer basic workflow functionality, mostly dealing with the routing of documents through a predefined review

or approval cycle, there is a clear need for an extension of the category to include integrated workflow services, which need of course to be customized to the needs of particular organization and application domains. These services could include notifications to the users of activities to be performed, visualization of the context of an activity, complete handling of the action flow (e.g. calculation of the next step, routing of the involved data, etc.), and monitoring of the state of the work process (Agostini & De Michelis, 2000). Research toward that direction has been performed see e.g. SupplyPoint System (Halaris, Kerridge, Bafoutsou, Mentzas, & Kerridge, 2002) and BSCW-Flow (Kreifelts, Hinrichs, & Woetzel, 1999).

Appendix A. The systems reviewed

A.1. Commercial products

CommonSpace (*Sixth Floor Media*, *USA*)—A collaborative writing software that allows a group of users to create and revise an electronic document together. The work on documents is independent of the word processing program used for the document creation, or the platform the user has been working on. Users also have the option to record their voices as sound annotations and merge a set of documents to consolidate a set of reviews, or to organize a set of suggested changes. CommonSpace also includes real-time conferencing. Users connected via a network, can have a discussion on their computer screens and a written record of the group's shared communication can be preserved. http://www.sixthfloor.com

DocuTouch (*DocuTouch Corporation*, *USA*)—The DocuTouch platform authorises designated users to view and approve electronic documents over the Internet. The user's identity is established through a digital certificate and documents can be digitally signed using that certificate. Digital signatures and documents are held in a format agnostic, ''read-only'' storage area. http://www.doutouch.com

Documentum4i (*Documentum*, *USA*)—At the heart of Documentum 4i is the eContent Server, which implements the Documentum content repository as well as workflow, process automation services and lifecycle automation services for controlling and managing content and processes throughout and between distributed enterprises. eContent enables the managing and control of the end-to-end lifecycle of content, from its creation and capture, to routing for approval and publishing in the preferred format. http://www.documentum.com

Teamnow (*TeamNow*, *Denmark*)—TeamNow allows instant access to specific documents at the same time for all team members irrespective of IT platform or geographic borders. Documents are stored on a central server and free storage space is provided. An online message board and a user profile generator are also provided. http://www.teamnow.com

CentraNow (*Centra*, *USA*)—A service that enables users to create and attend live, interactive meetings and business events over the Web. CentraNow allows hearing, talking, exchanging of text messages, showing and annotating PowerPoint slides, and sharing live software applications. http://www.centranow.com

Consensus @nyWARE (*SoftBicycle*, *USA*)—A series of integrated Web-based, Java-enabled tools that allows teams to conduct meetings, planning, visioning and decision support sessions online anytime, anywhere. Minutes and action items are disseminated among multiple

participants, action items can be posted and the status of tasks can be tracked. There is also support for threaded conversations, voting and graphically viewing voting results. The number of participants is unlimited, but the tool can be best used by teams with no more than fifty participants. http://www.softbicycle.com

CuSeeMe Conference Server (*CuSeeMe Networks, USA*)—CuSeeMe Conference Server allows the creation of a virtual conference room on an existing IP network using the H.323 and T.120 conferencing standards. Voice and visual communication and data collaboration in a variety of diverse applications are a possibility. Application sharing, Internet-based group video chat, meeting scheduling tools and e-mail notifications to meeting participants are also some of the offered services. http://www.cuseeme.com

Evoke Collaboration (*Evoke Communications, USA*)—A tool for facilitating electronic meetings, offers screen views of any active desktop application, and provides services for writing or drawing in real-time on a blank slide and capturing data about participants, including attendee contact information. Real-time text talk and conduction of planned or live polling are also a possibility. Access to presentations is controlled and thus privacy is preserved. http://www.evoke.com

Facilitate.com (*Facilitate.com, USA*)—Facilitate.com's solutions provide an electronic conference centre where multiple meetings and discussions can be conducted at the same time. Participants can be in the same physical conference room or join in from networked locations. Group leaders can set up meeting agendas and access to the meetings can be restricted to team members, a department, a corporation, or the topic can be made available to anyone with Internet access. Any list of items can be transformed into a vote or survey. Voting results are automatically calculated and graphed for all to see, if appropriate. http://www.facilitate.com

Grouputer (*Stepup Systems, Australia*)—A suite of three meeting applications, which run on the Windows platform. Teams can meet face-to-face and remotely. Prior to meetings teams can select form pre-prepared meeting agendas, or create their own agendas. Each person has a personal window, which is visible on the screen, where ideas are created. All ideas go to a common team space, where they can be reviewed every few minutes. Work can be performed simultaneously. All the discussion is saved in a database. http://www.stepup.com.au/groupute/group.htm

HelpMeeting (*HelpMeeting LLC, USA*)—HelpMeeting enables application and desktop sharing, collaboration over shared applications, chat, file transfer, white boarding and meeting scheduling with e-mail notifications sent to all participants. Applications may include slide presentations, document, spreadsheets or CAD programs. File transfer enables any participant to distribute files to all or some of the participants during the data conferencing and white boarding allows participants to view and create images and drawings. http://www.helpmeeting.com

PlaceWare Meeting Center 2000 (*PlaceWare, USA*)—Meeting Center 2000 is an online meeting service designed to offer virtual offices to employees. Each virtual office has a capacity for ten participants. Live, interactive meetings, presentations, seminars or software demonstrations are enabled. Services for chat, real-time collaboration on text slides, drawing on whiteboards and screen sharing are also provided. http://www.placeware.com

Web-4M (*JDH technologies, USA*)—A comprehensive collaboration and groupware environment. Virtual meetings with distributed presentations and streaming audio can be held, files shared and surveys created, addresses and calendars managed. http://www.jdhtech.com

AspSmartForum (*Advantys, France*)—It enables the exchange of information between people sharing the same interests. The information shared between the users can be either messages or

files. Discussion rooms can be created, where messages are exchanged that can also include file attachments and file rooms, where files and/or URLS are shared, are also a possibility. http://www.aspsmart.com

Instant!TEAMROOM (*Lotus*, *USA*)—A central repository for documents, comments and discussions. Threaded discussions can be conducted, documents created, updated, managed and stored using this product of Lotus. Sharing attached files and capturing the history of a project are also a possibility. The e-mail feature can be used to notify the team when new information is posted. It is service users can subscribe to, and payment is demanded only for the time it is used. http://www.lotus.com

Intranets (*Intranets.com*, *USA*)—Intranets give their members the possibility to send and receive e-mails, collaborate on critical documents and create an online library, keep group calendars, conduct live discussions, have access to a Member's Directory or keep contact information to a personal directory, make announcements, customize their news feed to their professional interests and finally get stock quotes, track a portfolio or check the indices. Also, users can link to business services like banking, and purchase business supplies and equipment. Intranets is a free service and also provides free storage space. http://www.intranets.com

ProjectPlace (*Projektplatsen*, *Sweden*)—A collection of Web services for project collaboration and document management. ProjectPlace enables document and file sharing, meeting and project scheduling, with to-do items, time charts and online discussions. http://www.projectplace.co.uk

TeamTalk (*Trax Softworks*, *USA*)—TeamTalk is a group discussion and collaboration application designed to enhance communication among workgroups or entire organizations. It provides a graphical forum environment for groups of people working together on the network to share information and supporting documentation on their various ongoing projects and tasks and can be used by anyone with access to the shared files. http://www.webcom.com/~traxsoft/teamtalk.html

vJungle (*Vjungle*, *USA*)—A free service that offers e-mail, file storage and sharing, contact list, bookkeeping, calendaring and chat services. It also gives the possibility for notifications about new calendar entries. http://www.vjungle.com

WebBoard (*O'Reilly Software*, *USA*)—A web-based discussion and chat software that facilitates communication among people with common interests. Each "board" or "forum" can contain unlimited discussion topics, messages and attachments related to them. Information is stored by topic and a search engine is included for finding specific text in message topics and message bodies, or finding messages by a specific author. http://www.webboard.oreilly.com

MeetingPlace (*Latitude*, *USA*)—A system providing the ability to talk and share electronic information in real-time over any enterprise network (voice, data or Internet). MeetingPlace includes voice and data conferencing that are typically not centrally managed and do not interoperate. Information can be shared and discussed over the phone and PC in real-time. http://www.latitude.com

NetMeeting (*Microsoft*, *USA*)—NetMeeting provides services for video and audio conferencing, online collaboration via graphic information (whiteboard), online conversations, file transferring, program and desktop sharing. http://www.microsoft.com

PictureTalk (*Pixion*, *USA*)—PictureTalk enables real-time audio-visual conferencing. The primary application is to facilitate software demonstrations. Files as well as computer screens can be shared, slide shows can be performed and meeting/seminar attendees are notified through email. http://www.pixion.com

Sametime (*Lotus, USA*)—A family of real-time collaboration products providing instant awareness, communication, and document sharing capabilities. Users are provided with online conversation facilities and can keep personal lists of people or groups they are interested in conducting conversation with, set up or attend meetings, share applications with others or make use of the whiteboard facility. http://www.lotus.com

Business Manager (*Info Parc, Austria*)—A web-based Internet database for contact management, project tracking and team collaboration. Business Manager provides a web address book for contact storage that also includes a contact interaction history, a project manager that tracks projects, project related tasks, meetings, memos and project interactions. A to-do list for an unlimited number of users presents work items, pending activities, unresolved problems and scheduled meetings. It is targeted at enterprises with more than 50 concurrent users. Pricing depends on the number of users, software customizations and integration efforts needed for each individual site. http://www.infoparc.com

Caucus (*Caucus Systems, USA*)—Caucus Systems helps distributed organizations work via the Internet by creating virtual environments for collaboration and communication. Caucus Virtual Teams provides tools for project management, group creation, online conversations, e-mail, calendar, task lists and e-mail notifications for new items in the list. Users can integrate presentations, spreadsheets and databases in the team environment allowing them to work and share data. The Virtual Team environment is structured and graphically customized to match the organization. http://www.caucus.com

CollabFab (*Collaboration Fabricators, USA*)—CollabFab is a collaboration tool designed for small workgroups. Using CollabFab, information can be organized by project, providing a Meetings section, a Discussion section and Documents section for every project. Meeting minutes and action items can be recorded, project-related messages are exchanged in a single place and relevant documents are stored and exchanged in one central location. http://www.collabfab.com

CVW (*Mitre, USA*)—A collaboration software environment that provides a ''virtual building'' where teams can communicate, collaborate, and share information, regardless of their geographic location. Applications, documents and people are directly accessible in rooms, floors and buildings. People can gather in rooms to talk through chat or audio/video conferencing, and to share text and URLs with one another with their chat. Documents that can be edited through the user's local applications are managed through a document server within CVW. http://cvw.mitre.org

Cybozu Office 3 (*Cybozu, Japan*)—A web-based groupware aiming at information sharing, collaboration and communication among workgroups/companies. It offers address book, to-do list, mail, discussion, project and people tracking and document sharing and management facilities. http://cybozu.com

eRoom (*eRoom Technology, UK*)—eRoom is a digital workspace enabling the collaboration and communication between buyers, sellers and the rest of the parties involved in supply chains, so that information and the coordination of their activities can be streamlined. Sharing documents with others is done by dragging and dropping a file from the Windows desktop into the browser. Once a document is in the eRoom, users can continue to edit it just as if it were on their local machines. eRoom provides tools for discussions, which are automatically preserved and indexed, so that, over time, a complete history of the team's thoughts, opinions and decisions is created. Polling allows the team to vote and take surveys on any topic. There is also possibility for

conducting real-time conversations. Project deliverables, deadlines and project participants can be tracked, using eRoom's lists, and users get notifications, each time something changes. eRoom includes the ability to move documents through a pre-defined approval cycle and full text search within documents is also possible. http://www.eroom.com

Forum (*SiteScape*, *USA*)—Forum provides a way to communicate, share resources and collaborate with groups of people within a company or across organizations. Users can conduct threaded discussions and there is also a chat capability as well as support for creation of private work areas, where tools for team discussion and document sharing are included. Documents can be reviewed, modified and co-authored. Most uploaded documents are also searchable. E-mail notifications are provided for replies to discussion topics and maintenance of calendars is also supported. The Newspaper application stores Internet newsgroup articles, e-mail news articles and tracked web pages. Articles of personal interest can be stored to private folders. The search engine used is that of AltaVista. The new release, Forum 5.1, links directly to PlaceWare's synchronous collaboration service to provide web conferencing facilities. http://www.sitescape.com/forum.html

Groove (*GrooveNetworks*, *USA*)—Software supporting small-group interaction, provides services for communicating, sharing artefacts and collaborating. Instant messaging, voice, text chat and threaded discussions are a possibility while using Groove. Files and pictures are shared, a whiteboard can be used for sketching, a notepad and a calendar are also provided. http://www.groove.net

GroupPort (*GroupServe*, *USA*)—A wireless-enabled, browser-based collaboration tool that provides a virtual meeting space, where mobile groups can collaborate. Comments and documents are shared between team members, a centralized database keeps the group contacts and critical group communications are sent in the form of email notifications to all team members. http://gp1.groupport.com

GroupWise (*Novell*, *USA*)—A seamless, cross-platform collaboration and messaging system for businesses of all sizes. With GroupWise communication across intranets and the Internet is possible. GroupWise manages all information, including e-mail, faxes, documents, spreadsheets, images, schedules, discussions, and tasks. A single mailbox holds all information types. Users can see when messages are delivered, opened, and deleted; who has viewed and who is holding a routed message, who has accepted, rejected, or delegated a scheduled request. They can also retract, modify, and resend scheduled requests, scheduled tasks, and unopened e-mail messages. All messages can be searched to locate specific information. Document management features are also provided as well as calendars for scheduling appointments, meetings and events. Users can publish documents to the World Wide Web or to the intranet and can have their own address books, apart from the main address book. Multiple languages are supported on the same system. Finally, GroupWise includes GroupWise Workflow for managing collaboration processes. http://www.novell.com/products/groupwise

HyperOffice (*myWebOS.com*, *USA*)—HyperOffice is an intranet and extranet for any community of people to have mailing, and calendaring capabilities. They can hold online conversations, manage their documents, keep their own address books and to-do lists, send and receive e-mail reminders for scheduled tasks or events, or take part to a voting. By storing files on-line, they are always accessible from any computer connected to the Internet. The Documents feature allows the user to create folders, upload and download files. Files can also be attached to e-mails. HyperOffice is a free service. http://www.hyperoffice.com

InfoWorkSpace (*General Dynamics, USA*)—A collaborative server-based software system facilitating online communication, data access, and knowledge management. The collaboration environment is complete with multimedia tools that allow for interactive work. Files are stored on a central server and all technical and maintenance support is provided for the user. InfoWorkSpace uses a physical metaphor to add context to the "virtual" world. Users meet to collaborate in persistent virtual buildings, floors, and rooms. Chat, group chat, Voice-Over-IP, whiteboards, online presentations, desktop conferencing asynchronous as well as real-time communication are also enabled. http://www.infoworkspace.com

Intraspect c-Business Platform (*Intraspect Software, USA*)—A platform for implementing collaborative solutions within the Business-to-Business (B2B) communities. It provides companies with the ability to develop and deploy a collaborative environment that allows users easily find, share, and reuse information. Intraspect's c-Business platform connects people and the ideas they capture through web-based collaborative workspaces. Within the secure workspaces, all users continue using the standard computing tools they are comfortable with—such as email and web browsers. With the use of access policies, participation is granted only to the appropriate employees, customers, suppliers and partners. Workspaces and user pages are customized to specific needs of the work environment. Participants receive email notifications to stay informed about ongoing activities. http://www.intraspect.com

JointPlanning (*Bridgeline Technologies, USA*)—JointPlanning enables the creation of private groups, maintaining and viewing of personal and group calendars, to-do lists, address books, holding private group discussions, file sharing, voting and receiving of e-mail reminders for the personal calendar entries, to-do lists and new group activities. Users are not charged for this service. http://www.jointplanning.com

QuickPlace (*Lotus, USA*)—QuickPlace is a Web-based teamware application that lets users create an instant shared workspace on the Internet or their corporate intranet, where team members can centrally communicate, share, and organize information, documents and schedules around any project or initiative. Documents can be authored using QuickPlace, MSOffice or other applications. QuickPlace also captures the applied structure and knowledge of a workspace into a reusable asset that can be shared through the organization for maximum value. http://www.lotus.com

TeamOn (*TeamOn, USA*)–A web-based e-mail and collaboration solution designed especially for small businesses, organizations or any group of people, who work together. It enables the creation of a workplace, where announcements can be issued, documents stored, calendars shared and discussions posted. Users have also access to address books, where all contact information is stored. http://www.teamon.com

TeamWave Workplace (*TeamWave Software Ltd., Canada*)—TeamWave Workplace uses a client-server solution to provide locations where people can gather to work and form communities. The "room" metaphor is used and each space or room can serve library or archival as well as conferencing needs.

The shared whiteboard feature, apart from the usual whiteboard properties, also has the ability to store and retrieve its contents and to retain the current contents, until someone needs it. A shared address book and a calendar for entering appointments are provided. Any type of files can be stored, retrieved and opened by applications that created them, text files can be viewed simultaneously by several users, images can be drawn on and annotated. Newsgroup-style

discussions can be conducted and a simple messaging tool can be used to place reminders. Slide presentations are created and viewed on the whiteboard and individual slides are annotated. A to-do list helps keep track of what needs doing, meeting scheduling facilities are offered and questions can be posed and voted on. http://www.teamwave.com

A.2. Research prototypes

BSCW (*GMD FIT*, *Germany*)—BSCW (Basic Support for Cooperative Work) enables collaboration over the Web. It is a 'shared workspace' system, which supports storage and retrieval of documents, event notification and group management. To access a workspace, users need a standard web browser. Development of the BSCW system takes partially place in the *CESAR project*, funded by the European Commission through the Telematics Applications Programme. In 1996 and 1997 the developments have been partially funded through the *CoopWWW project*. *URL:* http://www.bscw.gmd.de

DIVA (*Research project conducted by the German National Research Center for Computer Science* (*GMD*))—DIVA is based on a virtual office metaphor. It offers tools for shared tasks, facilities to support communication in both the synchronous and asynchronous modes of work and interface mechanisms to provide awareness of co-workers. The elements of the interface and the operations performed on them have real world counterparts wherever possible.

The standard office was used as the organizing metaphor for DIVA. Four principal elements of real offices are modelled: people, rooms, desks and documents. Rooms are containers of people, desks and documents. They also control the audio/video communication status of users. People in the same DIVA virtual room hear and see each other and rooms also serve to indicate availability and communication willingness: they can be in different states (open, closed or locked), providing different levels of access and visibility of their inhabitants. People represent the users of the DIVA system and are implemented as small snapshots with a name beneath. They can be moved by their owner to change their virtual location and thereby determine what they are doing and whom they are in visual contact with. Documents represent the objects people work on in the virtual office. Multiple copies in different places are simply access points for a single shared document. Desks serve a variety of purposes: they are the arena for work within a room, they control the coupling mode of a cooperation, and they can be used to preserve working context.

The actual tools for working in DIVA include a text editor, spreadsheet, structured drawing tool, music editor, and a chess editor. Facilities to support synchronous group editing include group awareness in the form of visual representation of others' actions, unlimited multi-user undo/redo, multiple coupling modes, embedded annotations, optimistic concurrency control, and conflict resolution. No special actions are necessary to start or join a synchronous groupware session. For instance, whenever a user opens a document, which is already in use by another person, a synchronous session is started.

Real-time person to person communication is supported in DIVA through audio/video conferencing. Support for asynchronous communication is also provided by giving the users the possibility to attach notes to all the objects in the virtual office: people, rooms, desks and documents. URL: http://orgwis.gmd.de/projects/POLITeam/poliawac/ms-diss/diva.htm

DOLPHIN (*Project developed inside the German National Research Center for Information Technology -GMD*)—The DOLPHIN software supports the preparation and management of

team meetings in different application scenarios: face-to-face meetings as well as meetings with remote participants. Activities that are supported include meeting management, brainstorming, rating and organizing of ideas, decision-making and presentations. Most of these activities are based on documents, which were prepared before the meeting (e.g., agenda, list of issues, proposals, charts), presented and changed within the meeting, and have finally resulted in new documents (e.g., minutes, decisions, annotated proposals). This material is quite often processed after the meeting and will be the starting point for subsequent meetings. Individually created documents can be made public, i.e. presented on the electronic whiteboard as well as discussed and annotated by the group. Finally, audio/video connections over ATM, Ethernet or Internet technology enable remote participants to join the meeting and to communicate with each other. URL:http://www.darmstadt.gmd.de/publish/ocean/activities/internal/dolphin.html

VEGA—An Internet-based co-operation platform that provides support for virtual enterprises. Shared workspaces are created, which support the project manager in initiating, configurating and completing projects. Services include a news section with a listing of new documents and discussion items, address book, meeting agenda and discussion forum for interaction between project team members. Joint decision-making is allowed through voting facilities, and documents can be structured and shared between team members depending on access rights. The VEGA Business Community reflects a market space for small and medium-sized enterprises (SMEs) related to the Information Technology sector. It provides information about business related events and links, enables discussions, and the companies-users can search the community for suitable business partners, and also give their own profile of what they provide and what they are looking for. VEGA is based on the Lotus/Domino platform and the server is housed in Berne. VEGA is a joint project by the Universities of Berne (Institute of Information Systems) and Lausanne (HEC INFORCE) as well as the Swiss Federal Commission for Technology and Innovation and the main contractor Swisscom. http://vega.vptt.ch

References

Agostini, A., & De Michelis, G. (2000). A light workflow management system using simple process models. *Computer Supported Cooperative Work*, *9*, 335–363.

Bentley, R., Appelt, W., Busbach, U., Hinrichs, E., Kerr, D., Sikkel, K., Trevor, J., & Woetzel, G. (1997). Basic support for cooperative work on the World Wide Web. *International Journal of Human–Computer Studies*, *46*, 827–846.

Borenstein, N.S. (1992). Computational mail as network infrastructure for computer supported cooperative work. *Proceedings from the ACM conference on CSCW*, *Toronto* (pp. 67–73). ACM Press: Canada.

Coleman, D. (1995). *Groupware; technology and applications*. Englewood Cliffs, NJ: Prentice Hall. ISBN# 0-13-727728–8.

Coleman, D., & Ward, L. (1999). Taking advantage of real-time collaboration tools. *IT Professional*, *1*(4), 25–30.

DeSanctis, G., & Gallupe, R. B. (1987). A foundation for the study of group decision support systems. *Management Science*, *23*(5), 589–609.

Ellis, L. (2000). An evaluation framework for collaborative systems. Colorado University Technical Report CU-CS-901-00.

Ellis, L., Gibbs, S. J., & Rein, G. L. (1991). Groupware: Some issues and experiences. *Communications of the ACM*, *34*(1), 38–58.

Grudin, J. (1994). Computer-supported cooperative work: *History and focus*. IEEE Computer, May, 27(5), 19–26.

Halaris, C., Kerridge, S., Bafoutsou, G., Mentzas, G., & Kerridge, S. (2002). An integrated system supporting virtual consortia in the construction sector. *Journal of Organizational Computing and Electronic Commerce* (Special Issue on "B2B eCommerce and e-Supply Chain Management), forthcoming issue.

Jarczyk, A., Loffler, P., & Volksen, G. (1992). Computer supported cooperative work (CSCW)-state of the art and suggestions for future work. Internal Report, Version 1.0, Siemens AG, Corporate Research.

Johansen, R. (1988). *Groupware. computer-support for business teams*. The Free Press: New York.

Kock Jr., N. F., & McQueen, R. J. (1997). Using groupware in quality management Programs. *Information Systems Management*, *14*(2), 52–56.

Kraemer, K., & King, J. (1988). Computer-based systems for cooperative work and group decision making. *ACM Computing Surveys*, *20*(2), 115–146.

Kreifelts, T., Hinrichs, E., & Woetzel, G. (1999). BSCW-flow: Workflow in web-based shared workspaces. *Proceedings of the workshop on cross-organizational workflow management and co-ordination of the work activities coordination and collaboration conference (WACC'99)*. San Francisco.

Malone, T., & Crowston, K. (1994). The interdisciplinary study of coordination. *ACM Computing Surveys*, *26*(1), 87–119.

McGrath, J., & Hollingshead, A. B. (1994). *Groups interacting with technology*. Thousand Oaks, CA: Sage.

Mentzas, G. (1993). Coordination of joint tasks in organizational processes. *Journal of Information Technology*, *8*, 139–150.

Mentzas, G., & Halaris, C. (1999). Workflow on the Web: Integrating e-commerce and business process management. *International Journal of e-Business Strategy Management*, *1*(2), 147–157.

Nickerson, R. C. 1997. A taxonomy of collaborative applications. *Proceedings of the American Information Society 1997*, *Americas conference on information systems*, *August 15–17, 1997*. Indianapolis, Indiana, pp. 560–562.

Poltrock, S., & Engelbeck, G. (1999). Requirements for a virtual collocation environment. *Information and Software Technology*, *41*, 331–339.

Schooler, E. (1996). Conferencing and collaborative computing. *Multimedia Systems*, *4*, 210–225.

Stenberg, K. (1995). The effect of EMS on group work. Masters Degree Thesis in Economics at the Swedish School of Economics and Business Administration, Helsinki.

Zantout, H., & Marir, F. (1999). Document management systems from current capabilities towards intelligent information retrieval: An overview. *International Journal of Information Management*, *19*, 471–484.

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