Abstract

The creation, integration, and use of knowledge is inherently a cooperative process. This is especially true for today’s large, distributed organizations which increasingly make use of team work spread over dispersed locations. In this paper, we present hypermedia-based collaboration support systems as an approach to support the cooperative creation, integration, and use of knowledge in different settings and for different tasks. This support technology combines approaches from the research areas of hypermedia and CSCW (i.e., shared workspaces, group awareness, and situation awareness) to provide flexible and adequate support for cooperative knowledge production and use. We will illustrate our approach by concrete examples of hypermedia-based collaboration support systems buildt at GMD-IPSI and report our experiences.

Keywords: cooperative work, hypermedia, collaboration support systems

1 Introduction

In today’s migration from the industrial age to the information age, the creation, integration, and use of information becomes increasingly important. Economists identify information as an important production factor, and commercial success of enterprises is more and more dependent on their capabilities for gathering, integrating, and using information.

At a closer look, it is not only the amount of facts that enterprises have to deal with but more important is their ability to represent their “knowledge” about the environment, their customers, their competitors and their own experiences, strengths, and procedures to guide their behavior and to allow further improvement and adaptation to changing environments and markets.

One can use the term ”Knowledge Media” to denote means for the representation of facts and knowledge. Historically, this have been written documents, statistics, records, films etc. Today, a large part of these mainly paper-based artifacts are put into electronic form. Extended with new media technology such as digital audio, video, computer animation, simulation and visualization techniques, the repertoire of knowledge media is greatly expanded. These new knowledge media can be used to represent knowledge as organized collections of electronic information items. New forms of organizing these collections, such as hypertext and hypermedia, or generating views on large information collections, augment traditional linear organizations of information.

The creation of information, its representation in the form of knowledge media, as well as its use is a cooperative process. Teams are working together on extracting facts, creating information and representing their interim and final results using knowledge media. Other teams build on their results and produce new information. Two trends make it even more important to provide integrated support for knowledge media production and use by distributed teams: Organizations and teams are partially dis-
tributed within or between companies ("virtual company"), and there is increasing collaboration transcending single working teams or organizations ("virtual organizations"). The distribution of tasks over dispersed teams, themselves composed of team members at different locations, requires better support for collaboration within and between teams. Without adequate support, the emerging virtual organizations will not be able to achieve their tasks as effectively (in terms of time, cost, and quality) as it is required by today’s dynamically changing markets.

In this paper, we propose hypermedia-based collaboration support as one approach to support the cooperative production and use of knowledge media. It combines concepts from the areas of hypermedia and CSCW (Computer Supported Cooperative Work) to provide teams with shared access to knowledge media. Different cooperation situations, phases and styles can be supported.

The rest of the paper is organized as follows: Section 2 introduces the notion of collaboration support, analyzes the requirements for cooperative knowledge media production, and briefly reviews related work. Section 3 presents hypermedia-based collaboration support as an approach addressing these requirements and reports about our experiences. The paper finishes with a comparison to related work, conclusions and our plans for future work.

2 Collaboration Support

In this paper, the term "collaboration support" refers to computer-based support for a team working on a shared task. The goal of collaboration support is to provide comprehensive support that enable team members to work on a shared task effectively. In order to achieve this goal, support for changing cooperation situations needs to be provided. These cooperation situations can be characterized according to:

♦ the collaboration styles and procedures employed by the team,
♦ the (sub)tasks to be tackled by the team or its members,
♦ the organizational setting (e.g., the roles and relationships of team members and of different teams),
♦ the physical setting (e.g., locations of teams and team members),
♦ the infrastructure available (e.g., hardware/software/communication tools, office equipment).

Some basic requirements for collaboration support can be derived from the goal. To enable collaboration, team members must be able to

♦ access shared information,
♦ communicate with each other,
♦ coordinate their activities,
♦ work together on shared information.

These general requirements are complemented by more specific ones induced by the cooperation situations to be supported:

♦ The collaboration styles and procedures employed by the team determine the possible types of access to shared information (e.g., asynchronous vs. synchronous).
♦ The (sub)tasks to be tackled by the team or its team members determine the structure of the knowledge media. Additionally, any methodology employed by the group to solve the task will further influence the group’s coordination behavior and the required support for shared work.
♦ The organizational setting might further restrict permissions to access or change shared knowledge media. It might also influence coordination behavior (e.g., responsible team members may need to confirm certain decisions before others can continue to work).

♦ The physical setting imposes constraints on the communication means that can be used between team members, and it may lead to requirements on the amount of shared access, the necessary support for shared work, and the way coordination can be achieved.

♦ The office and computing infrastructure available to the team members provide the basis for implementing collaboration support, and thus constrain possible solutions.

In addition to these requirements specific to a cooperation situation, any solution providing comprehensive collaboration support must not only support a set of required cooperation situations, but also needs to support transitions between these situations. Generally, collaboration proceeds by progressing through these situations, and the sequences are often dependent on the collaboration styles and procedures employed by the team. Meetings, for example, involve a sequence of pre-, in-, and post-meeting phases. Each phase’s activities are performed in a specific situation. For example, the pre-meeting activity of preparing the meeting’s agenda is usually done at the individual workplace, whereas the meeting itself is conducted in a meeting room environment. Decisions in a meeting can lead to further work performed in subgroups using, e.g., desktop conferencing tools in the subgroup members’ distributed offices. Each of these situations requires different collaboration support, but any comprehensive solution must also address the transitions between them.

In the past, systems supporting various kinds of cooperative work have been developed in different fields:

Database management systems have been used to allow users individual access to a shared information base. Using features of multi-user and active databases, access to the database is no more purely asynchronous and, to a certain degree, users can be provided with group-awareness.

Shared editors (e.g. PREP Editor [NKC+90]) support the concurrent editing of documents by multiple participants. Application sharing (e.g. PictureTel’s LiveShare Plus [Pic96]) replicates the window (and its content) of an application running at one location to other locations. This enables multiple remote users to view, annotate, and edit shared documents, usually one participant at a time.

E-mail and electronic bulletin board systems (such as Usenet News) as well as electronic calendars are tools that are used for asynchronous communication within groups. Group calendars enable groups to schedule events, mail and BBSs support the bi- and multilateral exchange of information between group members.

Desktop conferencing systems enable bilateral and multipoint audio/video conferences between remote offices. Using application sharing, conference participants can collaboratively work on the documents brought into the conference. The audio/video communication channel helps to coordinate the work process. Using video conference studios or adequately equipped electronic meeting rooms, desktop conferencing is extended to meetings that span two and more meeting rooms. Like in a desktop conference, the meeting participants can talk to and see each other and refer to projected images of documents.

Shared document repositories with limited workflow functionality (e.g. Lotus Notes [Lot96]) support sharing and forwarding of documents and tasks and reintegrating the results of parallel, unsynchronized work. Full-scale workflow management systems (such as Digital’s LinkWorks [Dig96] or IBM’s
FlowMark [IBM96]) coordinate, monitor, and control strict sequences of activities performed by group members (or computational agents).

Hypermedia systems (e.g. NoteCards [HMT87] or KMS [AMY87]) have also been utilized to support collaboration. Most systems only offer asynchronous cooperation on different parts of the document. Due to the hypermedia concept of small units of information with references between them, the amount of isolated work can be kept low.

However, none of these systems address the problem of collaboration support in a comprehensive way. It is of crucial importance for the success of future virtual companies and organizations that the existing applications are integrated as building blocks into a larger framework. This facilitates effective and flexible collaboration in dynamically changing, distributed teams.

3 Hypermedia-based Collaboration Support

Creating and organizing knowledge media involves the handling of a large number of pieces of information which again consist of a multitude of different subparts. These various units of information are represented as different kinds of media, e.g. text, graphics, audio, or video. Various relationships may exist between these units, for example dependencies between different parts, part-of hierarchies, used-by hierarchies, and many more. Two constituent parts of knowledge media can be distinguished: a) units of information and b) relationships or references between them. Together, these two parts form an information network. Because of the multimedia aspect of the information units and since the references may not only occur between two units but also from within one unit into another, hypermedia suggests itself as an appropriate representation.

Desktop-based cooperative hypermedia authoring

SEPIA is a cooperative environment for the synchronous and asynchronous creation and processing of hypermedia documents (hyperdocuments for short) by a distributed group of authors. The basic hypermedia data model comprises typed links and nodes which may contain any kind of media content (e.g. text, graphics, audio, or video) and typed composites for the aggregation of links, nodes, and composites [SS90, SHH+92]. Access to the hyperdocument is provided by activity spaces. The content of an activity space (i.e., links, nodes, and composites, hypermedia objects for short) represents the hypermedia document. Different activity spaces can be regarded as different views on the same document.

These views are used to support different tasks of the overall collaboration process. For example, to support the process of authoring hypermedia documents SEPIA provides an activity space for each of the tasks of planning a document, developing argumentation structures, collecting information items, and creating the final structure of the hyperdocument from a rhetorical perspective [SHT89]). In the field of multimedia systems engineering ([HBK96, BLW96]), SEPIA supports the iterative tasks of modeling and validating technical systems by providing a specific space for the modelers and the validators to access the hypermedia document representing the model of the technical system. The respective tasks can be performed within these spaces.

Activity spaces are also used to implement task-specific access permissions. For example, a validator should be able to inspect the system’s model but he should not be allowed to modify it. A company’s classified data can also be protected this way. Similarly, the modeller has to be prevented from changing annotations made by the validator, e.g., test protocols.
The links, nodes, and composites in an activity space can be typed. The types are used to add semantics to the information network formed by links, nodes, and composites. For each activity space, the set of available types can be defined. Additionally, constraints on the types can be defined, e.g. that a link of a certain type may only connect a source node of a specific type with a destination node of another specific type. This way, the creation of a specified document structure is enforced, as can be seen in figure 1. In addition to the types of links, nodes, and composites, SEPIA also provides transformation rules which define how instances of object types are transformed when copied from one activity space into another.

The creation and management of large knowledge media is an activity that in general is performed by multiple authors whose collaboration needs to be assisted by the system. SEPIA is primarily designed for desktop-based collaboration. It is based on a persistent and shared data storage system and covers synchronous as well as asynchronous cooperation of physically distributed groups of authors. By sharing objects in loosely and tightly coupled modes, smooth transitions between individual work phases and different degrees of coupling for collaborative activities are provided [HN93].

The collaboration support functionality goes beyond standard shared screens. SEPIA provides group awareness by indicators on who is working in which activity space, on which composite and even on which individual node or link within a collection of information objects. Sharing of information is available at the hypermedia network level as well as at the individual node level. SEPIA offers three degrees of collaboration, termed "coupling modes". In the "individual mode" asynchronous collaboration, i.e. different authors working on the same part of the document at different times, is supported. In the "loosely coupled mode", authors can work on the same part of the document at the same time and see changes made by other authors, but they can still work independent of each other. Finally, in the "tightly coupled mode", authors are provided with full WYSIWIS (What You See Is What I See) functionality: Window sizes are identical for all authors, as are scrolling positions etc. With the integration of shared applications (e.g. the shared drawing tool WSCRAWL [HW92]) into SEPIA, collaboration at node level becomes possible. In the tightly coupled mode telepointers with user names allow
pointing at objects and areas. At the same time, audio and video communication links can be initiated. 
This also includes multipoint video conferencing. By introducing the notion of “sessions” the system 
can identify which authors are cooperating in which modes with whom. Authors can work in multiple 
sessions with different coauthors in different coupling modes at the same time.

Electronic meeting support

While many collaborative tasks may be performed in the desktop environment using cooperative tools 
such as SEPIA, working groups nonetheless convene face-to-face meetings for closer interaction and 
work tasks which require a more immediate interaction. Computer-based collaboration support should 
allow an integration of distributed collaborative activities with those activities related to or performed 
in meetings. For this, we developed DOLPHIN, a fully group-aware collaborative application provid-
ing hypermedia-based cooperation support and offering additional functionalities not present in SE-
PIA, such as additional information elements (e.g. text, graphics, images) which can be placed on a 
document’s pages.

The DOLPHIN software can be used in a specialized meeting room equipped with a large interactive 
public display (Xerox LiveBoard) and workstations provided to each meeting participant. An instance 
of the DOLPHIN software is then running on each of these machines. DOLPHIN is a cooperative soft-
ware, i.e. all systems running the DOLPHIN software are connected and provide cooperative access 
to a shared common artifact: the meeting document. Changes made to the document at one site are 
immediately communicated to all other DOLPHIN instances.

The DOLPHIN software can be used in all three major phases of any meeting: Meeting preparation, 
conducting the meeting and post-meeting activities. The meeting chairman can use DOLPHIN in his 
regular desktop environment to initialize the meeting document, e.g. by creating nodes representing 
the meeting’s agenda items. This meeting document can be accessed by the meeting participants before 
the meeting to browse the planned agenda and enter information items beforehand which they wish to 
present during the course of the meeting. In the meeting, the DOLPHIN software provides all meeting 
participants with shared access to the meeting document. Information can be entered into the docu-
ment’s pages, material prepared beforehand can be presented and discussed and cooperatively anno-
tated and edited by the group. After the meeting, the chairman can again access the meeting document 
to prepare the minutes of the meeting and reorganize the meeting document (e.g. by replacing sketches 
with the equivalent images or graphical elements). Also, a specific meeting activity space in SEPIA 
can be used to transform the meeting document’s untyped structure to a typed hypermedia structure 
conforming to the activity space’s constraints. The document can serve as the basis for subsequent 
meetings, e.g. when certain agenda items have not been discussed and have been postponed to a later 
meeting.

A DOLPHIN hypermedia document is made up of multiple “pages”, representing the contents of 
hypermedia “nodes”. A node consists of its name and the associated page, which can contain several 
different information elements, such as text items, graphical elements, images and handwritten 
“scribbles”. Hypermedia structures in the document can be created by placing a node’s label onto 
another node’s page, thereby creating a link between the source and target pages. Opening the node 
displays the associated page’s contents. Additionally, links between node labels contained in a page can 
be created to indicate a relation between these nodes. Unlike SEPIA, links and nodes in DOLPHIN are 
not typed, since the generation and maintenance of typed structures can be a complex task which might 
not be suitable for the early, mainly unstructured meeting activities.
Any set of information elements present on a document’s page (e.g. handwritten scribbles and a piece of text) can be turned into a node label. DOLPHIN automatically creates the node’s associated page and this can then be filled with additional information elements. In this way, users can cooperatively create a hypermedia structure, transforming the initially informal elements into more formal elements. It is important to note that informal elements (typed text, handwritten elements or drawings) can co-exist with the formal elements such as nodes and links within the same page (figure 2). In this way, complex documents can be created and the formal elements can for instance be annotated [HN93].

Interaction with the DOLPHIN document is performed in a DOLPHIN browser — a window displaying the contents of a document page. DOLPHIN provides the group with a common view on the document: the group window. The group windows on the users’ workstations are tightly coupled, i.e. they all display the same part of a DOLPHIN document. Changing the display, e.g. by opening a node or scrolling the page’s view is automatically performed in all group windows and the large public display. This provides the group members with a common view of the document, an important prerequisite for verbal discussions. Additionally, a user at a workstation can open individual browsers, which are then only displayed on this user’s workstation. These individual browsers still provide shared access to the document, but are loosely coupled, so that scrolling and navigation within the document is performed individually. Using this functionality, a meeting participant could, for example, prepare information in one section of the document, while the rest of the group is still discussing another agenda item.

While the mouse and keyboard may be adequate tools for interaction at the users’ workstations, this is not the case for the large interactive public display, which closely resembles a traditional whiteboard. Since users are more familiar with using a pen to interact with a whiteboard, DOLPHIN provides a pen-based user interface enabling the meeting participants to create hand-written elements on the DOLPHIN page using a cordless pen on the electronic whiteboard. Additionally, frequently used operations can be activated by gestures. Gestures are handwritten elements created using the cordless pen. An example for such a gesture is the delete gesture which consists of simply crossing out the element(s)
Figure 3: Distributed Electronic Meeting Rooms

to be deleted. DOLPHIN recognizes the gesture and performs the desired operation. This style of pen-based interaction can also be found in pen-pads and PDAs such as Apple’s Newton Message Pads.

In addition to the face-to-face meeting support, DOLPHIN can also be used in the desktop environment to connect external participants to a meeting. By using audio and video conferencing software and the shared access to the meeting document, the remote participants can actively participate in the meeting, creating or presenting information to the other meeting participants. The remote participants can either stay connected for the whole meeting or just for a short period of time, e.g., while the group discusses one agenda item.

Larger working groups are not necessarily located at the same place. In virtual companies, in virtual organizations and even for projects with several industry partners, dispersed groups of different size have to collaborate effectively. A so-called ‘virtual meeting system’ is able to bridge the spatial distribution between those groups by facilitating communication, discussions, coordination, presentations, as well as editing tasks. In the ‘Virtual Meetings’ project [GHHR96] ordinary face-to-face meetings are extended not only by external participants but also by remote groups using electronic meeting rooms (figure 3). In this case, the DOLPHIN software is combined with high quality audio and video conferencing technology. Hypermedia, activity spaces, and several modes of coupling the subgroups are used to implement a comfortable meeting environment that controls communication channels, provides floor control as well as access rights to the group’s material. The objective of the project is to keep the technology in the background and let the group concentrate on their work.

4 Conclusions and future work

In this paper, we introduced the requirements for collaboration support focusing on support for changing cooperation situations and the transitions between them. The approach proposed in this paper suggests to use hypermedia structures to represent information networks and to employ CSCW functionality (e.g. shared hypermedia workspaces, group awareness, joint viewing and editing capabilities) to support teams working in a specific cooperation situation. Furthermore, such a collaboration support system need to facilitate the transition between different cooperation situations when the situation at hand changes. Two examples of prototypical collaboration support systems have been described: SEPIA, a desktop-based cooperative hypermedia authoring environment, and DOLPHIN, an electronic meeting support system.

Both systems can be considered as prototypical environments for cooperative knowledge media production and use. While SEPIA aims on supporting dispersed coauthors to produce rigidly structured
information networks using their desktop environments (and the different cooperation situations necessary for doing it), DOLPHIN aims on supporting collaboration within and between meeting rooms. The information structures created and manipulated within such a meeting process can be also considered as knowledge media. Thus, the functionality provided by systems like SEPIA and DOLPHIN can be applied to support, e.g., the production of knowledge media in different phases, its reuse in other phases, its distribution across time and space, the creation of a corporate memory etc.

In its current state, cooperative hypermedia systems like SEPIA and DOLPHIN address the basic requirements for collaboration support systems: they enable access to shared information via shared workspaces, facilitate communication between collaborators via the shared document or synchronous communication channels, foster the coordination of activities using shared planning structures, and support joint work on shared information. However, there are still many open issues concerning the requirements induced by specific cooperation situations. Examples are: support for specific methodologies or procedures within and between cooperation situations, support for evolving information structures that often change during the process of working on a task, the integration of organizational rules and knowledge to guide or constrain system behavior, and the automatic adaptation of cooperation support according to the physical setting and available infrastructure.

Experiences with SEPIA and DOLPHIN were gathered by using them internally and in external projects as well as in the case of DOLPHIN by doing experimental studies. The use of SEPIA, e.g., for structuring articles and argumentation, for building a sample multimedia system description in the MUSE project [HBK96], and for modelling a sample collaboration between governmental agencies has provided evidence for its usefulness as a tool for constructing typed information structures. However, certain problems were identified, such as the comprehension and orientation problem that led to the development of a specific reader interface [THH95], the difficulty of communicating changes or status of work to other team members, the creation of alternative or variant structures that subsequently led to the integration of version support [HH93], and the problem of inadequate predefined structures to new problem domains. With DOLPHIN, we tested the differences between groups using DOLPHIN with hypermedia functionality against groups using DOLPHIN without hypermedia functionality (for details see [MHS95,96]). The results show that even novice hypermedia users can construct complex non-linear structures within short training time, hypermedia users create more elaborated and deeper structured information structures that were conceived by expert raters as more original, and that hypermedia groups employ different work strategies. Hypermedia groups using DOLPHIN tended to work to a larger degree in parallel and resynchronize their work in between whereas non hypermedia groups tended to work more sequentially.

Our work goes beyond related work in that it not only combines concepts and functionalities from areas like hypermedia, CSCW, and desktop teleconferencing systems but also adds the notion of situation specific cooperation support as well as support for the transition between these situations.

Currently, we are combining the concepts developed so far for different cooperation situations to form a comprehensive framework. As a basis for implementing collaboration support systems according to the framework we are continuing to develop COAST, the COoperative Application Systems Toolkit [SKS+96]. COAST will be augmented with components for supporting emergent document types, for defining and supporting specific collaboration processes, and for integrating existing legacy applications into collaboration support systems. It is of crucial importance for the success of future virtual companies and organizations that the existing applications are integrated as building blocks into
the larger framework. Together with means for flexibly adapting the collaboration environment this facilitates effective and flexible collaboration in dynamically changing, distributed teams.

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References


