S. Bødker, M. Kyng, and K. Schmidt (eds.). *Proceedings of the Sixth European Conference on Computer-Supported Cooperative Work, 12-16 September 1999, Copenhagen, Denmark*

Activity Awareness: A Framework for Sharing Knowledge of People, Projects, and Places

Koichi Hayashi[1], Tan Hazama[1], Takahiko Nomura[2], Toshifumi Yamada[1], and Stephan Gudmundson[3]

[1]IT Business Development Dept., Fuji Xerox, Kanagawa, Japan
[2]Knowledge Design Initiative, Fuji Xerox, Tokyo, Japan
[3]Dept. of Computer Science, University of British Columbia, Vancouver, Canada
hayashi.koichi@fujixerox.co.jp, Takahiko.Nomura@fujixerox.co.jp, hazama.tan@fujixerox.co.jp, Toshifumi.Yamada@fujixerox.co.jp, stephang@netinfo.ubc.ca

Abstract. In this paper we describe the concept of *activity awareness,* which gives workers indications of what is happening and what has happened recently in collaborative activities. The key feature of activity awareness is the use of individual workspaces, as opposed to shared workspaces We introduce an activity representation that can be extracted from workers' individual workspaces By using extracted activity information, it extends the scope of awareness from tight collaboration within a shared workspace to more loose collaboration. It enables workers to be aware of the latest information created within other members' individual environments and of the progress made by loosely connected groups We introduce three *awareness nodes people, projects,* and *places* In our model, individual activities interact at these awareness nodes. Our current implementation adopts a temporally threaded workspace model for representing individual activities and introduces an *awareness presentation schema* for representing the three awareness nodes. The temporally threaded workspace model captures a worker's activity as a sequence of changes to the information space of the individual's workspace An awareness presentation schema generates web pages to show awareness information about the monitored activities

Introduction

The recent revolutionary changes to information infrastructures have increased knowledge workers' opportunities to work collaboratively with people outside of their immediate workgroup. To perform jobs, workers can share and exchange information with others within the Internet and Intranet. The information accessed through the network reflects the activities of colleagues in companies, and friends in research institutes. Furthermore, changes to the information are available immediately. However, it is not easy for workers to know what is happening and what has happened recently in related activities from information on the network Preparation of information to deliver or publish is often so time-consuming that emails can become infrequent and web pages can become obsolete. A Workflow system provides status information only on predefined tasks.

Shared workspace systems are one of the most promising approaches for keeping groups distributed over space to focus on a collaboration (Dourish and Bellotti, 1992; Tolone et al., 1995; Roseman and Greenberg, 1996). A shared workspace is a virtual place (on the network) where workers can perform collaborative work Changes caused by any events, even including ad-hoc actions, within a space are immediately visible to other group members. Furthermore, workspace awareness has made these spaces more usable (Gutwin and Greenberg, 1997). Workspace awareness provides workers with a perspective on the current state of the collaborative work. It can help group members by succinctly presenting the state of a concurrent activity, hinting at upcoming events, and indicating when to communicate with others.

Employing the metaphor of a physical place or room for shared workspaces has both advantages and disadvantages. It provides users with an intuitive scope of communication and information sharing, but it limits the scope of awareness to explicit and intentional collaboration. This limitation negatively impacts workspace awareness in two ways.

First, awareness of the latest information of other group members is often not provided Recent progress of technology enables workers to store all of the information for performing their job locally. They work in their individual environments and use the shared workspace only to exchange completed documents. Since the latest (and often most important) information remains inside the individual's environment, shared workspaces do not provide awareness of the most recent changes to the information.

Second, shared workspaces do not support awareness of related activities for dynamic collaboration structures. When a worker does her individual work, even though the task initially may seem simple and isolated, it often ends up affecting several other activities in the organization, formally or informally, closely or loosely For example, suppose a worker wishes to publish experimental data on a web page. During preparation of the page, she might need to collaborate closely

with research colleagues to complete the data and with her supervisor to formally report progress within a shared workspace. When publishing the page, she might informally coordinate with the owner of a web site publishing similar information. She might maintain loose contact with sales staff who use her data in their sales proposals. For providing necessary awareness among this sort of concurrent and dynamic collaboration, the requirement of defining a workspace for information exchange before starting collaboration becomes unrealistic.

We believe that workspace awareness is essential to support dynamic collaboration, but that the scope of the awareness should not be as limited as in a shared workspace. To extend the scope of workspace awareness, we have proposed the concept of *activity awareness* and developed a prototype system called *Interlocus* (Nomura et al., 1998). The distinctive feature of activity awareness is that it provides awareness of a set of interrelated activities, each of which is executed within an individual workspace.

Activity awareness requires a framework comprised of an *individual activity representation* and a *dynamic awareness scope* to provide awareness without employing shared workspaces. It enables the generation of a *collective activity perspective* and *asynchronous progress notifications* as awareness functions to solve the problems identified above The individual activity representation defines a computer-manageable object corresponding to an individual activity. In this model we use the word *activity* to mean a human process of a worker to achieve some specific goal (e.g. writing a specific report) Generally, each worker will execute more than one activity. Dynamic awareness scope determines the scope of awareness as a set of individual activities related to a collaborative activity. This set of activities may change dynamically as the collaboration proceeds. An individual activity may be included in more than one awareness scope, allowing an individual activity to affect several collaborative activities. The collective activity perspective provides awareness of the most recent information in the individual activities involved within the collaborative work. Asynchronous progress notification provides awareness of changes to loosely connected activities.

In this paper we introduce *awareness nodes*, which provide perspectives on collaborative activities. We have introduced them to address limitations found through the usage of Interlocus, which is the first implementation of activity awareness. Interlocus adopts the *temporally threaded workspace* model (Hayashi et al., 1998) for supporting awareness based on individual activities and uses *workspace configuration* mechanisms to provide awareness. An Interlocus workspace is an environment in which individual workers can their own activities. In other words, it provides an individual view of an activity. The workspace configuration mechanisms add information about related activities into the individual view In usage, we observed that this approach does not adequately represent the relationships between activities. To provide viewer-independent

viewpoints for activity structures, we introduce three awareness nodes: *people, projects, and places.*

In the following sections, we first review related work about awareness on shared workspaces. Next, we illustrate experiences with the first implementation of activity awareness based on workspace configuration. We then introduce the three nodes of activity awareness. We also describe awareness presentation schema, which is the current implementation of awareness nodes. We then discuss the characteristics of activity awareness compared with previous work and show the possibility of the further extension of the activity awareness. Finally, we mention future work and give conclusions.

Related Work

Since awareness is the essential function for collaborating in a workspace, leading researchers in this field have been investigating awareness. Gutwin and Greenberg coined the term "workspace awareness" and pointed out that shared workspace systems should include this feature (Gutwin and Greenberg, 1997). Fuchs classifies modes of workspace awareness into four categories: synchronous-coupled, asynchronous-coupled, synchronous-uncoupled, and asynchronous-uncoupled (Fuchs et al., 1995). The synchronous mode provides awareness of what is happening currently; the asynchronous mode shows what has happened since the last visit. The coupled mode focuses on the actual scope of work; the uncoupled mode focuses on something important or of interest to the user.

The shared workspace approach is most effective when a coupled mode of awareness is required. The TeamRooms system (Gutwin et al , 1996) supports the synchronous-coupled mode of awareness. It provides shared workspaces, in which users can collaborate with certain tools, and supports awareness within the workspaces by tracking each member's telepointer and scrollbar The BSCW system (Hortstmann and Bentley, 1997), which provides shared workspaces entirely in the WWW, supports the asynchronous-coupled mode of workspace awareness A BSCW workspace maintains a set of documents and records actions performed against the documents in the space. BSCW records what has happened lately in each document space, as well as the current status of the space Although the shared workspaces implemented by these systems provide intuitive information about others' actions in the collaboration, the scope of awareness is limited to events that occur within the shared workspace. Therefore users cannot see the latest information on individual workspaces or the progress of other shared workspaces.

The uncoupled mode of awareness is an extension for supporting dynamic information exchanges between workspaces. GroupDesk (Fuchs et al., 1995) is a shared workspace system that further offers the functionality of event notification

between workspaces. It distributes local events via structural, operational, and semantic relations among actors and artifact-objects. A user receives an event if it matches an interest context, which is used to indicate what events interest the user. PoliAwaC (Mark et al., 1997) allows users to attach awareness profiles to shared objects. The awareness profile indicates what types of events should be presented to the user. Using awareness profiles, each user can obtain a personalized view that indicates what changes have been made to the specified objects and in which workspace these changes occurred Although the event distribution approach adopted in these systems is an effective way for extending the scope of awareness to outside workspaces, it requires users to predefine structured relationships, to specify shared objects, or to specify necessary events. These requirements make it difficult to apply the idea to individual workspaces, because it is difficult to predict which documents in others' workspaces will become important.

We think the essence of workspace awareness is notifying members in a collaboration of unpredictable events An individual workspace is the place where each user is doing the most creative and flexible activities. Our approach delivers awareness information between activities, which are executed in individual workspaces, to extend the scopes of awareness beyond that of shared workspaces.

Activity Awareness with Workspace Configuration

In this section we briefly describes Interlocus, which is the first prototype system to provide activity awareness, and describe our experiences from a trial with the system. Out of the observations, we identify the limitations of the awareness mechanisms and derive the requirements for additional awareness functionality.

Design and Implementation of Interlocus

Interlocus adopts the *temporally threaded workspace* model (Hayashi et al., 1998) for providing an awareness framework based on individual, activities, and introduces *workspace configuration mechanisms* (Nomura et al., 1998) to provide awareness functions.

Activity Model

The temporally threaded workspace model provides a way to extract activity from an individual workspace as a computer-manageable information structure.

In this model we use the word *activity* to mean a human process of a worker to achieve some specific goal (e.g. writing a specific report). We do not deal with activity classes (e.g. writing reports). Generally, each worker will execute more than one activity. This model provides a workspace for each activity of each worker. A workspace has two roles: to function as an environment for maintaining the set of information necessary for performing an activity; and to

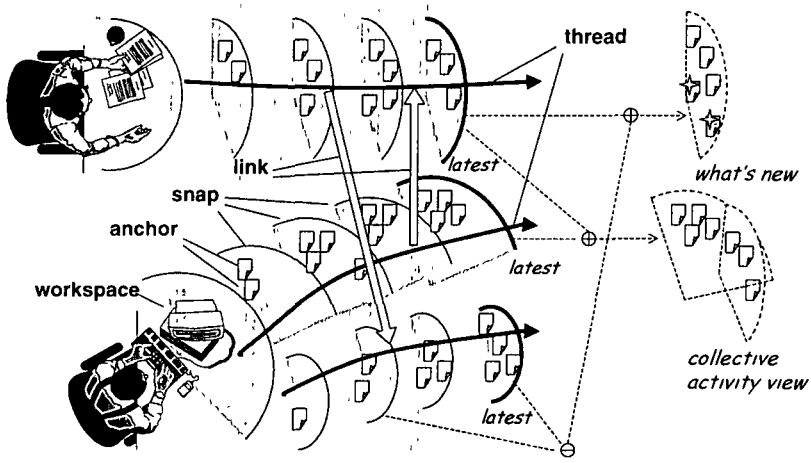

Figure 1 Temporally Threaded Workspaces and Workspace Configuration

record the process of the activity. Since the information in a workspace represents the present focus of the worker, it changes according to the progress of the associated activity. The temporally threaded workspace model represents an activity as a chronological thread of snapshots of the information in a workspace.

Conceptually, a workspace may be a physical desktop or a room, which maintains necessary paper documents and memos for performing a specific activity In the conventional information system, a workspace may be implemented as a computer desktop or a folder, which maintains necessary electronic documents and applications.

Interlocus Workspaces

Interlocus is a server/client system implemented in Java. Interlocus server maintains activity objects, which is based on the temporally threaded workspace model, and manages documents, which are referenced from workspaces. The Interlocus client provides a two-dimensional workspace, which is a worker's environment employing the desktop metaphor. A user organizes the set of documents and tools used for carrying out an activity (Figure 1).

Based on the temporally threaded workspace model, Interlocus adopts individual activity representation, which is comprised of threads, snaps, and anchors. A thread is a recorded sequence of changes to information on the user's graphical workspace. A thread is defined as a set of *snaps* bound with their creation times. A snap(shot) represents the state of an activity at a given time. Snaps are used for both current and recorded workspace states

A snap holds a set of document and tools placed on the graphical workspace. A snap is defined as a set of *anchors* bound with positions. An anchor is a spatial element on the graphical workspace that references a document or a tool relevant to the activity. There are two types of anchors: icons and regions. An icon shows

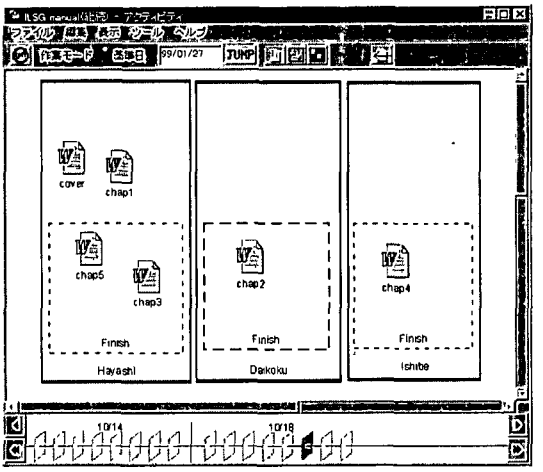

Figure 2 Example of Interlocus Workspace (Making Manual)

an image to reference documents or programs. A region shows a wider image that fills a region in which icons can be placed. A user can represent the state of an activity by placing document icons in appropriate regions of the workspace.

An Interlocus workspace is an environment on which users can carry out the associated activity and access past states of the activity. A workspace consists of the *spatial frame* and the *time line frame* (Figure 2). The spatial frame displays anchors on a two-dimensional desktop metaphor. Usually it shows the latest snap of a workspace to represent the worker's present state in the associated activity. In the spatial frame, a user can execute operations on anchors or documents to carry out an activity.

The time line frame presents the snaps comprising the chronological thread. A thread enables workers to restart at a past stage of the activity, to reuse documents from past activities, and to see the progress of others' activities. By selecting one of the snap symbols, the spatial view displays the state corresponding to the selected snap. With a selected snap a user can create another thread to restart the activity from the past state.

Construction of Thread Structure

Based on the temporally threaded workspace model, Interlocus has mechanisms for structuring threads as workers proceed in their activities. Each worker has more than one workspace, each of which is used for a specific activity. The mechanism that records snaps grows a thread. Snaps are both explicitly and implicitly recorded. In the trial use, they were recorded when creating a thread, saving a snap, closing a workspace, deleting an anchor, importing an anchor, and saving a document version.

In this model, an awareness scope is defined as a set of related threads.

Interlocus has two types of relationships among threads: document sharing between snaps in multiple threads and *links* connected between threads. Document sharing occurs when one copies or moves anchors from one workspace to another. Links are defined both implicitly and explicitly. The implicit definition mechanism is invoked when one executes specific operations. For example, operations for copying documents or starting new thread with a past snap implicitly define links. These links are used to determine the scope of awareness.

Awareness Functions

To provide awareness functions, *collective activity perspective* and *asynchronous progress notification*, Interlocus provides functions based on workspace configuration mechanisms. The mechanisms generate a virtual snap by applying set operators to related snaps, which are sets of anchors.

To present a summary of activities related to a collaborative activity, Interlocus provides *collective activity view* function. This function provides a synthesized view of the collaborative activity, in place of a shared workspace. Thus, collaborative activities are not represented directly by Interlocus, but are synthesized dynamically from their component individual activities. The scope of awareness is the set of workspace threads connected by links to the user's thread The synthesis function is simply the union of the latest snap of each linked workspace thread. Since the anchors are taken directly from others' individual workspaces, one always receives the most current information in others' activities Note that workspace thread binds only one worker as the owner, who can edit the workspace and thus further the thread. Therefore one cannot move or delete anchors collected from others' workspaces.

To notify people of progress in related activities asynchronously, Interlocus provides the *what's new* function. This function shows the changes to the workspace since the user last visited it. The scope of awareness of this function is the set of workspaces connected by links to the user's thread. For each referenced workspace, this function subtracts the last snap that the user accessed from the current snap in the thread. These anchors are then overlaid into the user's workspace. The overlaid anchors are for display only, and are not considered as part of the snap during other workspace configuration operations. Since a user can define links to any threads that they can access, she can get awareness on loosely related activities from her workspace.

Requirements through Usage

To evaluate the temporally threaded workspace and workspace configuration mechanisms, we performed short-term Interlocus trials in daily work situations Four workers used Interlocus for two months. One uses Interlocus for every

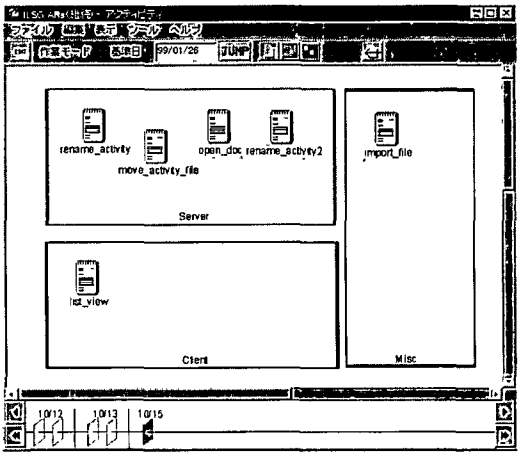

Figure 3 Example of Interlocus Workspace (Exchanging Action Requests)

activity to which Interlocus can be applied, while the others use Interlocus for collaborative activities only.

Individual Activity Monitoring

We observed that the temporally threaded workspace model recorded the worker's activities as designed. This model was designed to monitor the threads that have the following characteristics.

- Threads are separately extracted with different set of core documents.
- A thread grows snaps as the associated activity proceeds.
- Threads related to each other to form larger collaborative activities.

Throughout the trial, Interlocus recorded forty-one activities. We observed that each worker executes several activities, each of which is related to a different document set. Ten activities were short term and very simple activities that had less than five snaps. Almost all of them were the preparation of one or two documents, and were completed within a day. Thirteen activities that lasted over a week (five days) recorded more than ten snaps. Most of these activities included more than five documents. Except for a few personal notes, almost all of the recorded activities affected collaborative work (involved exchanging documents with others). For example, an idea memo created in an activity for preparation of discussion was used in the discussion meeting and then reused in another activity for writing a technical report.

Use of Collaboration Features

We observed two cases that used the collaboration features of Interlocus. Both cases were related to the implementation of a prototype system. One is a set of activities for making a users' manual and the other is a set of activities for exchanging action requests. For the manual, we observed collaboration that

assigns each member a specific role. One person supervised the whole process, and the others prepared the parts of the manual. The supervisor established a workspace with a region for each writer of the manual (Figure 2). As the figure shows, each writer produces the assigned part and moves it to their regions when completed. By placing document icons in appropriate regions, the whole process of making the manual proceeds. The workspace configuration mechanism was useful to gather portions of the manual from each writer's workspace. For sharing action requests, collaboration in equal roles was observed. The test users and developers reported action requests using a workspace with a region for each module of the system (Figure 3). The developer for each module collected the requests and fixed the problems. The workspace configuration mechanism was useful to obtain new action requests from others' workspaces.

Requirements from Usage

From this experience, we obtained several requirements for improving the collaborative features of Interlocus. We describe key requirements below. In particular, our observations of collective activities have motivated the development of a model of awareness nodes, as described in upcoming sections

- Interlocus should be integrated with other collaboration tools, specifically email systems. Interlocus successfully captured activities in which a user made documents as products of work. However, it could not monitor many activities related to writing emails. It is important to include such simple personal activities since they often fall into larger collaborative activities.
- Perspectives on collective activities should be provided. We observed that the workspace configuration mechanism lacks the capability to show the relationships between activities. A workspace is an environment for each worker to execute an activity. In other words, it provides an individual view of an activity. The configuration mechanisms work to add information to the individual view of each worker. To help understand the state of collaboration, we should present the overall progress of the collaborative activity at a glance. For example, to understand how the progress of the group members affects the supervisor's workspace, it is not enough to see the recent changes in the workspaces of each member.
- Alternatives to the spatial view are needed. When using the workspace configuration mechanisms, the limitation of the spatial representation is clear The amount of information, like action requests, rapidly increases and becomes impractical for display.
- A means to edit others' workspaces is needed. Since an individual workspace belongs to a specific worker, we have not allowed other members to alter the states of an individual's workspace. However, this restriction sometimes frustrates workers. We should relax this restriction or introduce some editing protocol.

Awareness Nodes for Activity Awareness

The key feature of our concept of activity awareness is that it uses individual workspaces to capture individual activities and to present awareness information. The experience described in the previous section shows that an individual workspace is useful for capturing activities, but not adequate for presenting awareness information. In this section, we introduce three viewpoints to provide three different categories of awareness: awareness of others, organizational awareness, and workspace awareness. The existing awareness functions, collective activity perspective and asynchronous progress notification, may be used in combination with these viewpoints. Within our definition of activity, a human process of a worker to achieve a specific goal, the types of awareness correspond to three types of nodes where a set of activities can interact. people, projects, and places (Figure 4).

Awareness of others

Awareness of others is an indication of what people are doing Each worker performs several activities, each of which has a different goal, such as writing a paper on a specific theme or making on a specific business plan. People are the nodes where activities are created and from which activities grow.

Awareness of activities from the viewpoint of people enables us to understand what our colleagues are doing. Passive-monitoring mechanisms provide this type of awareness. Since the activities to be recorded are varied, from personal work to collaborative work, from routine work to ad-hoc work, from trivial to long-term assignments, a collaborative tool must be flexible enough to support this variety of tasks in order to provide awareness of others. Our approach, extracting activity information from individual workspaces, is suitable for this purpose.

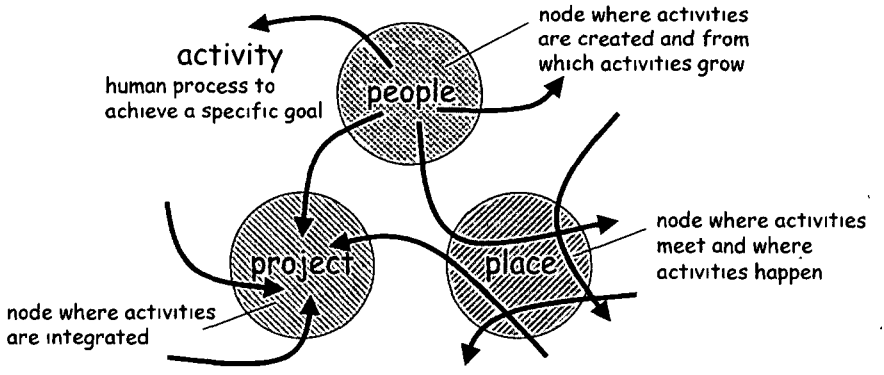

Figure 4 Awareness Nodes

Organizational Awareness

Organizational awareness is an indication of what the organization has effected. A worker in an organization often performs an activity that is a part of a higher level activity. For example, when writing a document collaboratively, the results of activity for preparing each section are used by an upper level activity for making a whole document. Projects are the nodes where activities are integrated.

The manual composition activities in the previous section are examples of this type of collaboration Each activity involved in the collaboration has specific goal, such as preparing a section, preparing figures, and composing the manual. Workers exchange information with each other according to a predefined structure. For this situation, the awareness mechanism must indicate how each activity contributes to the collaborative activity, according to the project structure.

Awareness of activities from the viewpoint of a project node enables us to understand what groups or companies are currently producing. The definition of a *project* must be useful in a conventional organization and in a virtual corporation or an ad-hoc task force.

Workspace Awareness

Workspace awareness is indication of what is happening and has happened recently in a place. A worker may join a network community and collaborate with members, who do not belong to the same project, do not share common goals, or perhaps do not even know each other. For example, in our daily life we exchange information about problems with a common information system in this style. Unlike projects, individual activities in this type of collaboration may not be part of a predefined activity structure. Places are the nodes where activities meet and where activities happen.

The action request activities in the previous section have the characteristics of this type of collaboration. Developers and test users share the action request information through the collective view. A developer for each part gathers necessary action requests from anonymous users' workspaces. Since this specific example was a short-term collaboration involving only a small number of activities, we were able to organize these activities with a single goal oriented activity structure. However, we may want to extend this collaboration to form a larger community and to exchange ideas for future functions. For this purpose, the awareness must help users to define shared themes or interests in the activities in a community.

Awareness of activities from the viewpoint of a place node enables us to understand past and current events in meeting rooms or workshops. The definition of place must cover virtual workspaces like electronic chat rooms and message boards as well as physical meeting spaces.

Implementation of Awareness Nodes

In this section, we present the current implementation of awareness nodes. We adopt the temporally threaded workspace for representing activities. In addition to the workspace configuration mechanisms presented earlier, we introduce *awareness presentation schema,* which is a mechanism to generate *awareness pages* representing the three awareness nodes.

Extensions to Interlocus

Awareness pages have two roles. First, they show the recent state of each node, even to non-Interlocus-users. Second, they can provide starting points for Interlocus users to search for activities related to their own. In the experimental system for awareness pages, we developed two additional components for Interlocus: Activity Store and Awareness Page Composer. Interlocus captures individual activities, which contain the set of information needed to generate the awareness pages. The Activity Store stores monitored activity objects as XML documents. By synthesizing the XML documents corresponding to the activities, the Awareness Page Composer generates HTML awareness pages and stores them on the WWW server. People can then see these awareness pages with standard WWW browsers.

To extract the information necessary for generating awareness nodes, we have extended the original activity representation of the temporally threaded workspace by introducing region structure and anchor comments. Region structure is a way to define logical structure within workspace snaps. In the original model, a region is just a type of anchor. Placing icons on some region may have certain semantics for people, but not for the Interlocus system. The region structure enables users to describe the state of documents to Interlocus; this information can be used by the Awareness Page Composer to extract only relevant information from activities. The anchor comments field of anchor allows users to attach information to a document-referencing anchor. By using comments, the user can indicate the reason for an action or requirements of the document that he processed.

Awareness Presentation Schema

An awareness presentation schema is a procedure for composing awareness pages corresponding to people, project, and place nodes. We have not yet developed a common language to describe these different types of schema. We are currently investigating what information should be presented for each type of awareness page

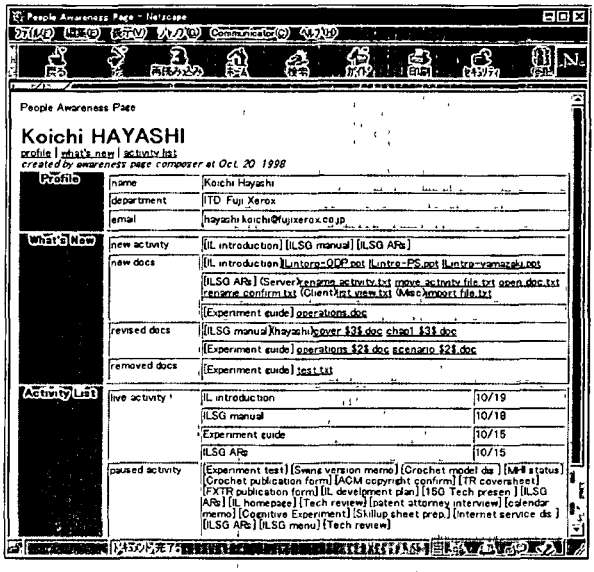

Figure 5 People Awareness Page

People Awareness Schema

A people awareness schema summarizes activities performed by a given individual. To determine the scope of awareness, this schema requires users to identify the person of interest. The scope of composition is then all of the activities owned by the specified person. Through a people awareness page, one can access documents created as products of a given person's current activity. To prevent exposing private information to the Intranet or Internet, awareness pages include only activities that the originator marked as "public".

Figure 5 shows an example of a people awareness page that presents a summary of the activities performed by Hayashi. This page contains *personal profile*, *what's new*, and *activity list*. *Personal profile* presents the name and affiliation of the person. *What's new* presents recent events, using information extracted from the activity representation. It shows recently created activities and recently created, revised, or removed documents (anchors). The document list indicates the region of the activity in which the document is located. The list of revised documents also presents document version information. Users can access documents via hyperlinks attached to the document names in the list. The activity list shows the lists of live and paused activities. The live activity list contains activities that have recently recorded new workspace snaps The name of a live activity is shown with the date of the latest snap. Activities move to the paused activity list when they remain unchanged for a determined period of time and disappear from the lists altogether if they remain unchanged after another period of time.

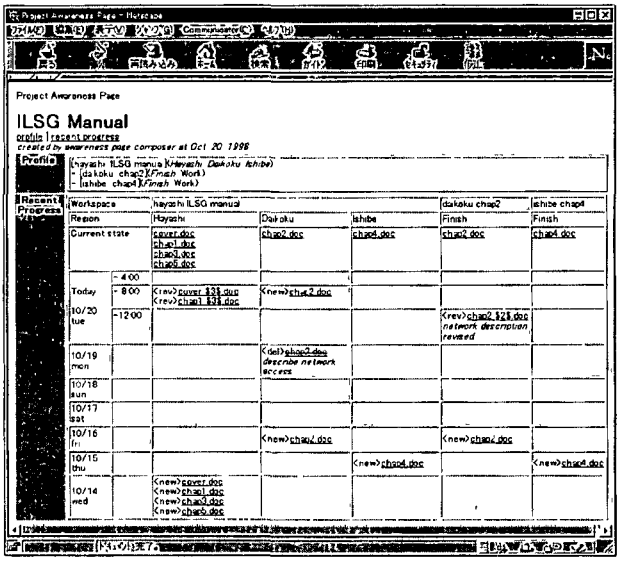

Figure 6 Project Awareness Page

Project Awareness Schema

A project awareness schema summarizes activities that are components of a given project. To determine the scope of activities, this schema requires users to specify a linked structure for the project. With this structure a user also specifies which regions within the workspaces are to be presented in the awareness page.

Figure 6 shows an example of a project awareness page that presents a summary of activities that are integrated into Hayashi's "ILSG manual", which is a supervisory activity for preparing a manual consisting of a cover page and five chapters. This page contains *project profile* and *recent progress*. *Project profile* presents hierarchical structure whose root is the "ILSG manual" activity. It has subordinate activities: Daikoku's "chap2" and Ishibe's "chap4". Following the activity name are the names of the regions placed in each workspace. A region name shown in italic fonts indicates that the project awareness schema monitors the region. Note that a user may define a structure of arbitrary depth. *Recent progress* presents recent events that have occurred in the monitored regions of each workspace. For example, the document "chap2.doc", which is revision 1 of chapter 2, appears in the "Finish" region in Daikoku's "chap2" workspace on Oct 16. Hayashi puts "chap2.doc" into the "Daikoku" region once, but the next week he adds a comment ("describe network access") to the anchor and removes it from the region. Daikoku revises the document and puts revision 2 of "chap2" into the "Finish" region with the comment "network description revised". In this way, this page summarizes the collective activities of two roles, supervisor and writer, and triggers actions for each role.

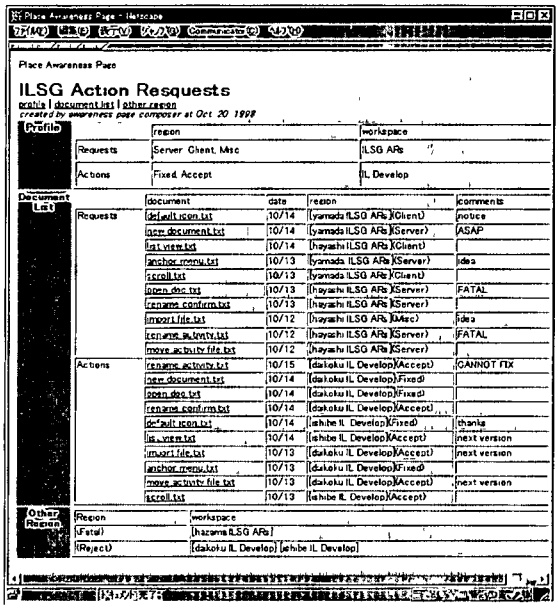

Figure 7 Place Awareness Page

Place Awareness Schema

A place awareness schema summarizes activities that interact at a place. To determine the scope of activities, the user specifies a set of region conditions. This schema then locates all activities whose workspace includes the regions indicated. This mechanism can be used to dynamically form structures among activities and allow users to refine region structures for more effective information exchange within a community.

Figure 7 shows an example of a place awareness page that presents a summary of activities that are related to action requests for a system. This page contains *place profile*, *document list*, and *other regions*. *Place profile* lists the set of region conditions used to select regions for inclusion on the page. In this page, there are two of region conditions: "Requests" and "Actions". "Requests" specifies the regions "Server", "Client", and "Misc" in the "ILSG ARs" activity. "Actions" specifies the regions "Fixed" or "Accept" in the "IL Develop" activity The *document list* enumerates all documents placed in the identified regions. In the example, the page lists documents collected from the regions in "Request" and "Actions" Each document list item gives the name of the document, when it was placed in the region, the name of the anchor's workspace, and any attached comments. *Other regions* shows the other regions included in the workspaces in this place. This list can provide candidate regions for refining the scope of the place.

DISCUSSION

Awareness Category based on Activity Model

In this paper we presented categories of activity awareness based on our activity model. Awareness is one of the most important concepts when designing CSCW systems. So far, several leading researches have proposed categories of awareness. Fuchs classified awareness into four categories: synchronous-coupled, asynchronous-coupled, synchronous-uncoupled, and asynchronous-uncoupled (Fuchs et al., 1995). Gutwin and Greenberg introduced workspace awareness, and identified the following types of awareness information. presence, location, activity level, actions, intentions, changes, objects, extents, abilities, influence, and expectations (Gutwin and Greenberg, 1997). Rodden proposed a classification of awareness based on the dynamic pattern of the interrelationship between each user's presence position (Rodden, 1996), and defined a protocol for user awareness via WWW clients to promote cooperative information sharing (Palfreyman and Rodden, 1996).

The distinctive feature of our model is that it bases awareness on activities, not people We have defined awareness in terms of information flow among activities. In this sense, the awareness node "people" is unique to our work Awareness nodes for projects and places correspond roughly to the coupled and uncoupled awareness characterizations introduced by Fuchs.

We have defined an activity as a structured collection of information (i.e. anchors and regions). However, BSCW (Bentley et al., 1997) takes another approach to providing activity awareness. This system provides information about other activities by listing events that have occurred on shared objects in shared workspaces. PoliAwaC (Mark et al., 1997) also handles awareness through events on shared objects. In general, the event approach is advantageous when one can predetermine the core objects used in collaboration. In contrast, our approach works well when workers cannot predefine the structure of the collaboration. Thus, these two approaches are complimentary.

Loose Constraint for Workspace Use

In our model, we have carefully avoided imposing rigid restriction on workers' ways of using workspaces since each individual workspace belongs to the user. However, for making awareness pages to present relevant information succinctly, users have to adopt a common set of regions. While the description of the projects and places are given outside the activities, workers define regions in a workspace to suit the activity. Therefore, it would be difficult to coordinate region names among related activities when the range of collaboration becomes large. However, we are optimistic that the natural structure of activities will influence their

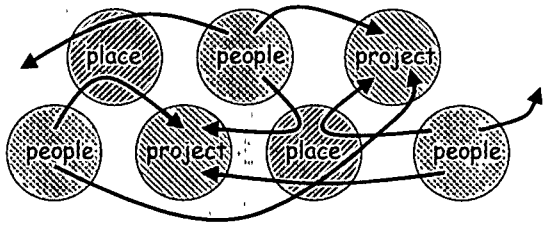

Figure 8 Awareness Node Network

description by users. Furthermore, we hope that users will change the way they structure their workspaces as they observe how the structure is used in awareness pages.

So far we have not introduced a predefined structure to control information flow among activities. Our model only uses relationships that can be defined by creating simple structural links, sharing documents among activities, and sharing region structures among activities. For enhancing project awareness nodes, it would be useful to introduce some predefined structure for distributing information, such as the semantic net adopted in GroupDesk (Fuchs et al , 1995) or workflow features.

Activity Oriented Perspectives and Analysis

An activity is an invisible human process. What we have proposed in our work is a way to extract human activity as a computer-manageable information structure without forcing workers to explicitly describe their activity states or to follow a predefined procedure. The discussion of activity awareness in this paper would be a starting point for investigating a larger theory of collaboration based on individual activities. Starting with our individual activity representation, we can derive a model of collaboration as a form of information exchange among activities. Such formalization could analyze the collaborations within an organization.

Furthermore, we can extend the model to consider the combination of the awareness nodes of people, projects, and places. Combinations of these nodes could produce higher level units, providing a complete understanding of an activity within the organization. Since our three awareness nodes are theoretical extremes derived analytically from the characteristics of activities, we would expect to find various mixed forms in practice. Further, they form an organization-wide network structure that is connected with shared activities (Figure 8). Representation of such a structure would provide perspectives on how organizations are really operating and help in decision making. As (Haeckel and Nolan, 1993) stated, "When information from previously unrelated source is structured in a meaningful way, human beings become capable of thinking thoughts that were previously unthinkable."

FUTURE WORK

To make activity awareness a realistic solution for supporting various forms of collaboration, we have to further investigate mechanisms for monitoring and presenting individual activities.

Although the temporally threaded workspace model does not limit the kind of information managed, the current Interlocus implementation monitors only the small range of activities that use conventional document files. To monitor a wider range of activities, we should integrate our system with other collaboration tools, such as email or workflow systems. We may further extend the system to handle multi-media documents to record the state of physical workspaces.

For providing users with sufficient awareness about activities, we must improve the current implementation in several ways. We have to introduce graphical representations that succinctly show how collaboration proceeds. We will also investigate a common language to determine scope, to extract information, and to present the awareness information.

Conclusion

As network technology accelerates innovation in social and corporate information infrastructures, the ability to collaborate with others via a shared information space becomes vital for knowledge workers. Activities, which are the source of change for information spaces, can provide a useful viewpoint for exchanging and sharing information with distant colleagues. In this paper we describe the concept of *activity awareness,* which gives workers indications of what is happening and what has happened recently in related activities. The key feature of activity awareness is that it is based upon individual, rather than shared, activities. To help collaborative work, activity awareness provides perspectives on *people, projects,* and *places,* which are nodes where activities can interact. Our current implementation adopts a temporally threaded workspace model for representing individual activities and introduces *awareness presentation schema,* which generate web pages to present the three different awareness nodes. We require further investigation on how the activities should be presented in the people, project, and place pages.

Acknowledgments

We would like to thank a number of colleagues in Fuji Xerox for their fruitful discussion In particular, we thank Mitsuhiro Ishibe and Yuji Daikoku for their contributions to this work I wish to thank anonymous reviewers for their many useful suggestions.

References

Bcntley, R , Appelt, W, Busbach, U , Hinnchs, E., Kerr, D , Sikkel, K , Trevor, J and Woeizcl, G (1997) 'Basic Support for Cooperative Work on the World Wide Web', *International Journal of Human-Computer Studies: Special Issue on Innovative Applications of the World Wide Web,* Academic Press, Cambridge, Vol 46, No. 6, June 1997, Pages 827-846

Dounsh, P and Bellolti, V (1992) 'Awareness and Coordination in Shared Workspaces', *Proceedings ofCSCW'92,* ACM Press, Toronto, November 1992, pp 107-114

Fuchs, L , Pankokc-Babatz, U , and Pnnz, W (1995): 'Supporting Cooperative Awareness with Local Event Mechanisms' The GroupDesk System', *Proceedings of ECSCW'95,* Kluwcr Academic Publishers, Stockholm, September 1995, pp 247-262

Grecnberg, S and Gutwin, C. (1998) 'From Technically Possible to Socially Natural Groupware', *Proceedings of the 9th NEC Research Symposium The Human-centric Multimedia Community,* Nara, August-September 1998.

Gutwin, C and Grecnberg, S (1997). 'Workspace Awareness', *CHI 97 Workshop on Awareness in Collaborative Systems,* hltp//wwwcpsc ucalgary ca/projects/grouplab/papers/1997/97-StudyingAwareness CHIWorkshop/gutwin html, Atlanta, March 1997

Gutwin, C , Roseman, M , and Grecnberg, S (1996)' 'A Usability Study of Awareness Widgets in a Shared Workspace Groupware System', *Proceedings of CSCW'96,* ACM Press, Boston, November 1996, pp 258-267

Haeckel, S and Nolan, R (1993) 'Managing by Wire', *Harvard Business Review,* Harvard Business School Publishing, September-October 1993, pp 122-132

Hayashi, K , Nomura, T , Hazama, T , Takeoka, M , Hashimoto, S , and Gudmundson, S (1998) 'Temporally Threaded Workspace A Model for Providing Activity-based Perspectives on Document Spaces', *Proceedings of HyperText'98,* ACM Press, Pittsburgh, May 1998, pp 87-96

Hayashi, K and Tamaru,,E (1999) 'Information Management Strategies Using a Spatial-Temporal Activity Structure', *Proceedings of CHI'99,* ACM Press, Pittsburgh, May 1999 (to appear)

Horstmann, T and Bentley, R (1997): 'Distributed authoring on the Web with the BSCW shared workspace system', *ACMStandardView,* ACM Press, Vol 5, No l,March 1997, pp 9-16

Mark, G , Fuchs, L., and Sohlenkamp, M (1997) 'Supporting Groupware Conventions through Contextual Awareness', *Proceedings of ECSCW'97,* Kluwer Academic Publishers, Lancaster, September 1997, pp253-268. ,

Nomura, T, Hayashi, K., Hazama, T., and Gudmundson, S. (1998) 'Interlocus Workspace Configuration Mechanisms for Activity Awareness', *Proceedings of CSCW'98,* ACM Press, November 1998, pp. 19-28

Palfrey man, K and Rodden, T (1996) 'A Protocol for User Awareness on the World Wide Web', *Proceedings of CSCW'96,* ACM Press, Boston, November 1996, pp 130-139

Rodden, T (1996) 'Populating the Application. A Model of Awareness for Cooperative Applications', *Proceedings of CSCW'96;* ACM Press, Boston, November 1996, pp 87-96

Roseman, M and Greenberg, S ,(1996) 'TeamRooms Network Places for Collaboration', *Proceedings of CSCW'96,* ACM Press, Boston, November 1996, pp 325-333

Tolone, W, Kaplan, S, and Filzpatnck, G (1995): 'Specifying Dynamic Support for Collaborative Work within WORLDS', *'Proceedings of COOCS'95,* ACM Press, 1995, pp 55-65