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Workspace Awareness in Real-Time Distributed Groupware

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ABSTRACT

The rich person-to-person interaction afforded by shared physical workspaces allows people to maintain up-to-the minute knowledge about others' interaction with the workspace. This knowledge is *workspace awareness*, part of the glue that allows groups to collaborate effectively. In real-time groupware systems that provide a shared virtual workspace, the possibilities for interaction are impoverished when compared with physical workspaces, partly because support for workspace awareness has not generally been a priority in groupware design. In this paper, we present the concept of workspace awareness as one key to supporting the richness evident in face-to-face interaction. We construct a conceptual framework that describes the elements and mechanisms of workspace awareness, and then show several widgets that can be embedded in relaxed-WYSIWIS groupware systems to support the maintenance of workspace awareness.

Keywords

Workspace awareness, real-time groupware, widgets

INTRODUCTION

Recent work has shown how a shared physical workspace (such as a chalkboard, a control panel, or a tabletop) and the artifacts in that space act as stage and props for rich person-to-person interaction [8, 28, 32, 33] Information available in and through the physical workspace allows people to maintain an awareness of others' locations, activities, and intentions relative to the task and to the space—awareness that enables them to work together more effectively. We call this *workspace awareness*: the collection of up-to-the minute knowledge a person uses to capture the state of another person's interaction with the workspace. As will be shown, workspace awareness helps people move between individual and shared activities, provides a context in which to interpret other's utterances, allows anticipation of others' actions, and reduces the effort needed to coordinate tasks and resources.

Recently, real-time distributed groupware has been developed to emulate aspects of physical workspaces (e.g. [3, 18]). Its goal is to let people who are in different places work together at the same time in a shared *virtual* workspace. However, interactions within groupware workspaces are impoverished when compared with their physical counterparts, partly because maintenance of workspace awareness is not generally a design priority for groupware interfaces.

In our work building real time groupware, we want to support the rich interaction that is possible in a traditional shared workspace. Consequently, we are looking closely at the concept of workspace awareness, with the goal of supporting its maintenance through special groupware widgets. We believe that if such widgets can help people maintain their workspace awareness, the system can better support the subtle, fluid, and facile interaction that is evident in face-to-face collaboration.

The purpose of this paper, therefore, is to present and apply the concept of workspace awareness. It begins with scenarios from our observational study that explain what workspace awareness is and how it works in face-to-face situations. It then outlines the basic problem of supporting workspace awareness in groupware. The following section discusses previous work on awareness in CSCW. It then outlines a conceptual framework of workspace awareness, specifying the elements that comprise it and the mechanisms used to maintain it in face to face settings. We then apply the framework to the design of a variety of example widgets that we have constructed in GroupKit, a groupware toolkit [27]. The widgets serve both to illustrate the possibilities of computer support for workspace awareness, as well as the difficulty in designing adequate replacements for our natural awareness mechanisms.

WORKSPACE AWARENESS

This section looks at workspace awareness in actual face-to-face situations, and then considers the problems of supporting awareness in groupware.

Episodes from a study of group interaction

To help us understand workspace awareness, we observed pairs of people working together over a physical workspace. Each pair was assigned the task of composing a two-page

layout of a newspaper using materials we provided—paper articles, pictures, and headlines. The episodes that follow are a composite of those that we saw in our observational studies. Each episode shows how people contribute to or benefit from awareness of one another in the workspace.

Mixed-focus collaboration. Linda and Mark start the task together, with both attending to the same part of the workspace. As they talk, they decide that Linda will work on page one and Mark on page two, and they determine roughly which objects will go on each page. They then shift their focus of attention to their individual pages, and start laying out the material. As work progresses, their focus shifts back and forth between individual and shared activity, and between different parts of the layout.

Lightweight information gathering. Mark's attention is briefly drawn from his own work by Linda moving objects back and forth in her area. With a quick glance, he notices that she is working on article one, that she has moved from the top left part of the page to the top right, and that she appears to be having trouble getting two columns of the story to fit into the available space.

Integration of information with previous knowledge: Linda notices Mark move over to work on the headlines at the top of page 1. Recalling the instructions that the editor had given them earlier, she says, "Let's not forget to leave space for that picture that they want in there."

Anticipation of another's actions: Mark watches Linda position her first article down the length of the page, and thinks that this may be the way she plans to position all of her articles, so he speaks up: "Um, I think we should decide on sort of a consistent layout for the two pages together because I'm doing things in the top half and the bottom half, and it looks like you're going all the way down the page."

Using awareness of activity: Linda knows that Mark is working on article two, so when she finds a column from that story hiding under the desk, she hands it to him, saying, "I think this is one of yours."

Interpreting references: Mark and Linda are busy with their own tasks when Mark says, "Do you think that this should go down here?" Linda glances over to see what he is pointing at and then says: "It'd look OK, but I'm not sure it'll fit." Later, Mark hears the sound of paper being cut with scissors, and without looking up, says, "Can I have those when you're done?"

These episodes are ordinary and commonplace, and none of them on their own has any great effect. However, they are made possible by workspace awareness, and though small, will be joined by many other moments of opportune collaboration. Taken together, these actions allow a group to be significantly more effective than an individual. Workspace awareness lowers the overhead of working together, creates new opportunities for collaboration, and provides people with a larger context for their actions [13].

As the above scenario shows, workspace awareness can be seen both as a product and a process. The product is the state of understanding about another person's interaction with the workspace, that allows people to interpret events, anticipate needs, and interact appropriately. The process is the continuous cycle of extracting information from the environment, integrating this information with existing knowledge, and using that knowledge to direct further perception. The maintenance of workspace awareness involves several human cognitive processing skills including preattentive processing, attention allocation, perception, working memory management, comprehension, and projection [15]. These skills are the basis for higher-level mechanisms such as gaze awareness [22], gestural communication [32], and deictic reference [33].

While the process and product of workspace awareness in a face-to-face situation seem trivial, things become far less clear when trying to support workspace awareness in a real-time groupware system.

Workspace Awareness Problems in Groupware

When shared activity moves from a face-to-face setting to distributed groupware, many things change that impair people's abilities to maintain workspace awareness.

- The perceivable environment shrinks drastically. Where people could see all of a fairly large physical workspace, they now have only a tiny viewport through the computer screen.
- Some means of communication are weakened: our hands' capabilities for expression are only poorly approximated with a mouse cursor [20], and speech loses much of its audio quality and directional component over typical voice links.
- Common ways of interacting with computer applications, such as through menus or function keys, hide actions that are visible in a physical workspace.
- Computer systems cannot handle many of the ingrained perceptual and physical abilities that we use to maintain workspace awareness in a face-to-face setting, and must replace them with means of perceiving the environment that are comparatively slow and clumsy.
- Groupware approaches that allow participants to control their own views of the virtual workspace [30] can further obscure people's locations and activities.
- Video techniques that bring in people's hands and bodies into the virtual workspace are limited by

scalability and resolution problems (e.g. most cannot handle more than two people) [22].

Within this strange new situation, the groupware designer must try and recreate the conditions and cues that allow people to keep up a sense of workspace awareness. Unfortunately, many of the things that supported workspace awareness in face-to-face situations, such as peripheral vision, rapid glances, three-dimensional sound, and the ability to see the entire workspace, disappear in the transition to a groupware setting. Whereas face-to-face interaction has inherent mechanisms and affordances for maintaining workspace awareness, the groupware designer is faced with a blank slate—any support for building or maintaining workspace awareness must be explicitly determined and built into the groupware system.

It is not immediately obvious what information people need to maintain workspace awareness, or how that information should be presented within a groupware system. We have been forced to look more closely at these issues, and the next sections present the work that we have done in bringing together knowledge about workspace awareness that can be used in designing groupware widgets. The product of our investigations is a conceptual framework of workspace awareness that is detailed below. First, however, we step back for a moment to show the context that this framework fits into. The following paragraphs describe awareness in group work more generally and how various kinds of awareness have been looked at in CSCW research.

RELATED WORK ON AWARENESS

People are aware of many different things when they work in groups, some of which relate to the group, and some to the task or situation more generally.

For example, people maintain awareness of an association of people, their reasons for being together and their shared knowledge, which we call *organizational awareness*. Organizational memory is one way of tracking organizational awareness (e.g., [10]). Another example is *task awareness*, which involves understanding the purpose of a task, the specific goals and requirements of the group in pursuing the task, and how the task on hand fits into a larger plan. Project management software is one type of system that supports task awareness. *Situation awareness* is another area that has been extensively discussed in the human factors community (e.g. [2, 15, 17]), and refers to the state of knowledge that an individual requires to operate or maintain a complex and dynamic system (such as an aircraft or a nuclear generating station).

Within CSCW, researchers have proposed four types of awareness that apply more specifically to groups working face to face, and these are shown in Figure 1. We use a Venn diagram to indicate that these different kinds of awareness overlap, inform one another, and interact during group work.

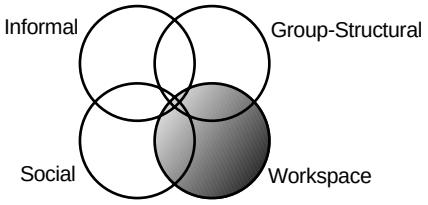

Figure 1. Types of Awareness in Group Work

Informal awareness of a work community is the general sense of who's around and what they are up to—the kinds of things that people know when they work together in the same office. Informal awareness is the glue that facilitates casual interaction. CSCW researchers have attempted to provide this sense of social presence to distributed groups through the use of media spaces (e.g. [6]). Media spaces use long-term links that show continuous video or snapshots of offices and common areas at a remote site.

Social awareness is the information that a person maintains about others in a social or conversational context: things like whether another person is paying attention, their emotional state, or their level of interest. Social awareness is maintained through conversational cues such as back-channel feedback, and through non-verbal cues like eye contact, facial expression, and body language. The maintenance of social awareness in distributed groups has been explored in CSCW through desktop videoconferencing (e.g. [7]), video tunnels [9], or the mixing of video and computational workspaces to allow eye contact within a worksurface [22].

Group-structural awareness involves knowledge about such things as people's roles and responsibilities, their positions on an issue, their status, and group processes. CSCW research has looked at support for meeting rooms (e.g. [34]), group decision-making (e.g. [23]), representation of arguments and positions (e.g. [10]), floor control (e.g. [19]), and explicit roles (e.g. [24]).

This brings us to *workspace awareness*, different from the other forms in Figure 1 because of the integral part played in the collaboration by the workspace. When interaction happens in a workspace, maintaining knowledge about others' interaction with the space and its artifacts becomes highly relevant. Workspace awareness has also been recognized in CSCW research (although under different names), and our work builds directly on these efforts [13, 6, 5, 4].

A FRAMEWORK OF WORKSPACE AWARENESS

We have built a conceptual framework of workspace awareness that structures thinking about groupware interface

support. We believe the framework necessary because groupware designers face two operational problems:

1. They must know what awareness information a groupware system should capture about another's interaction with the workspace;
2. They must consider how this information should be presented to other participants.

The framework presents a set of basic ideas that are critical for the design of awareness support, and that allow techniques for widget designs to be identified, described, and compared. The following sections detail the parts of the framework: first, the elements that make up people's workspace awareness, and second, the mechanisms that they use to gather awareness information.

Elements of Workspace Awareness

The first part of the conceptual framework is a list of elements that people may keep track of when they work with others in a shared space (see Table 1). Workspace awareness in a particular situation is made up of some combination of these elements (although we do not claim to have covered all the elements used in all situations).

Element	Relevant Questions
Presence	Who is participating in the activity?
Location	Where are they?
Activity Level	Are they active in the workspace? How fast are they working?
Actions	What are they doing? What are their current activities and tasks?
Intentions	What are they going to do? Where are they going to be?
Changes	What changes are they making? Where are changes being made?
Objects	What objects are they using?
Extents	What can they see?
Abilities	What can they do?
Sphere of Influence	Where can they have effects?
Expectations	What do they need me to do next?

Table 1. Elements of workspace awareness

The elements are for the most part commonsense things that can be seen in many kinds of workspace collaboration. Awareness of presence is simply knowing who you are working with, based on seeing and hearing others in the room. Several of the other elements can be put into two rough groups—one that relates to what is happening and one that relates to where it is happening. Elements that deal with "what" involve the amount of activity, the nature and content of actions, the changes that are made to artifacts, people's capabilities for action, and their expectations for action from each other. Those dealing with "where" involve where in the workspace people are focusing, the extents of what they can see, where they are making changes, the particular objects that are being used, and the extended area within which they can indirectly cause changes to the workspace (through connections and constraints between artifacts). The final element, intentions, deals with the future, and covers people's *intended* behaviour in many of the previous categories.

Several CSCW projects have implemented various support for elements of workspace awareness, although often in an application-specific, limited, or ad-hoc manner. Research has considered elements such as view location (e.g. [5, 4]), fine-grained location (e.g. [32, 20]), content of activity (e.g. [5, 13, 30]), presence (e.g. [14, 29]), changes (e.g. [14, 29, 30]), and activity level (e.g. [1]).

Although these elements provide a basic vocabulary for thinking about what to support in a groupware interface, they are not fully specified. The nature of the information in any element depends partly on the task domain. We have identified several ways that elements of workspace awareness can be further specified.

- Several elements relate to the past as well as the present. For example, awareness of past activities or past location is useful in many situations, especially when someone needs to bring themselves up to date on what has been going on in an area of the workspace.
- Awareness elements can constrain one another. For example, knowing where someone is working can limit what they can be doing.
- Some elements can be further specified in terms of the granularity at which the information is useful. For example, in a task that does not involve much close interaction, participants may only maintain a general idea of where each other are working.
- Awareness information will vary in character depending on the situation. For example, location information can be relative to a participant, absolute in terms of the workspace, or determined by the semantic structure of the artifacts (such as section numbers in an outline).

Workspace Awareness Mechanisms

After considering elements of workspace awareness, the next part of the framework looks at how people obtain the information that updates their state of knowledge. Determining precise mechanisms in face-to-face situations is difficult, however, since they can be subtle, hard to observe (sound cues, for example), or buried within several layers of inference. Instead, we present a general set of information-gathering mechanisms that have been discussed in previous literature, and discuss how they are used for maintenance of workspace awareness.

- *Direct communication*. People explicitly communicate information about their interaction with the workspace;

this communication is primarily verbal, although gestures [32] and deictic references [33] are also common.

- *Indirect productions*. People commonly communicate through actions, expressions, or speech that is not explicitly directed at the other members of the group, but that is intentionally public [13, 21].
- *Consequential communication*. Watching or listening to others as they work provides people with a great deal of information about their interaction with the workspace [28].
- *Feedthrough*. Information can also be gathered by observing the effects of someone's actions on the artifacts in the workspace [11].
- *Environmental feedback*. People also perceive higher-level feedthrough from the indirect effects of another's actions in the larger workspace. For example, in a control room situation, seeing some measured value decrease can provide evidence that another member of the team has initiated a particular procedure.

The conceptual framework now contains a set of elements that make up workspace awareness, several ways that the elements can vary qualitatively, and a set of mechanisms that people use to gather awareness information. Although this knowledge is preliminary and needs to be validated and detailed further, it provides a starting point for thinking about and designing support for the maintenance of workspace awareness in groupware. The next section relates experiences in using this framework to guide our designs, and also discusses issues that confronted us as we attempted to create groupware environments comparable to their physical counterparts.

WORKSPACE AWARENESS WIDGETS

We have been working to recreate, through groupware widgets and displays, the information-rich environment that people use to maintain workspace awareness in face-to-face situations. The following sections discuss our experiences in translating knowledge about workspace awareness to the design of interface components (widgets) in a groupware context. The widgets shown below are bottom-up experiments, and as such, they have not yet been subjected to extensive usability testing. We offer them as illustrations of how we can support awareness requirements in the conceptual framework described above.

We are particularly interested in widgets that can be used when the strict what-you-see-is-what-I-see (WYSIWIS) [31] is relaxed [30]. Because everyone in the group sees exactly the same view, strict WYSIWIS provides certain kinds of support for workspace awareness. Some awareness elements are constrained (e.g. location is easy to determine since everyone's is the same), and supporting feedthrough and consequential communication is relatively straightforward. Techniques such as multiple cursors [20] can also be built on top of strict WYSIWIS systems to provide further awareness and to support gestural communication.

However, strict WYSIWIS often constrains groups by preventing people from engaging in any individual work or from tailoring their views (e.g. [30]). Relaxing WYSIWIS allows people to work together more naturally, but complicates the problem of maintaining workspace awareness and group focus (e.g. [16, 13]). Two forms of relaxed-WYSIWIS can cause problems for maintaining workspace awareness: first, allowing people to set the location of their own views onto the workspace, and second, allowing people to change the display representation of the artifacts in their view.

Control Over Viewport Location

Allowing people to control the location of their own viewports creates situations where people cannot determine each other's locations and where they cannot see each other working. When people's views are not congruent, other means must be found to maintain awareness of location and activity. We have designed two classes of widgets to provide these: WYSIWIS-views and radar views.

WYSIWIS views operate at a fine level of detail, and support awareness of activity, precise location, intentions, and activity levels. Our *multiple-WYSIWIS* widget shows a scaled-down version of another person's view of the workspace (see Figure 2) [1]. All of the other person's actions in the workspace, including cursor movement and manipulation of artifacts, are visible within the display. This widget provides some of the benefits of the WYSIWIS approach, but allows people individual control of their main views. This display is designed to support the traditional action of lightweight glances to another part of the workspace.

In some cases, people need to see more detail about another's actions than what can be shown in a scaled-down display. Since limits on screen space usually preclude a full-size duplicate of another person's view, we have designed a "what you see is what I do" (WYSIWID) widget that provides full-size details, but shows only a limited part of the other person's view (Figure 3). The widget shows only the immediate context around another person's cursor, since most actions in graphical applications will involve the mouse. As a person moves their cursor on a remote machine, the background of the widget pans to keep the display centred around the pointer.

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[1] The figures below alter the resolution, relative sizes, and layouts of the widgets to improve presentation. In real use, the widgets have better resolution, use colour, and support more than two people.

Figure 2. Multiple-WYSIWIS display. The large window is a main view, and the small window is a miniature of a second person's view.

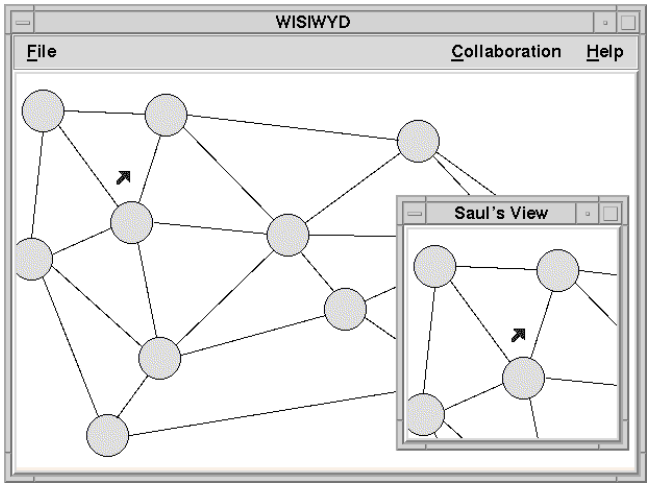

Figure 3. The WYSIWID widget. The small view shows a limited portion of the other person's (Saul's) view, centred around his cursor.

The second class of widgets, radar views, provide information about location and activity at a higher level. They are based on the idea of seeing what's going on in the entire workspace, and show a miniature of the complete space and the interactions within it. Although these have been seen before in video games and in a few groupware systems (e.g. [4]), they usually only show location, missing out on much of the information that people gather when they are "keeping an eye on" the whole workspace. Our extended radar views, therefore, can show view extents, multiple cursors, changes to artifacts as they occur, and evidence of activity.

We have explored several issues using variations on the radar-view idea. We have looked at the application of radar views to educational groupware [35], using multi-user scrollbars and text-based overviews. Another investigation involves showing people's past locations as well as their current position, and adding a slider to the radar view that allows people to "roll back" time and see where others have been (see Figure 5).

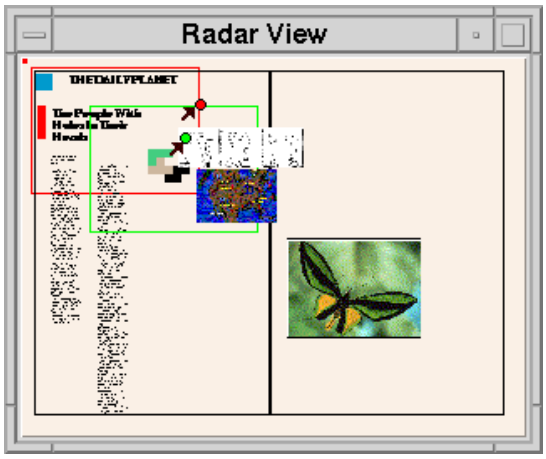

Figure 4. Radar view. The rectangles in the upper left correspond to two people's overlapping main views.

Our experiences with radar views also raised the problem of effort—how much effort are people willing to expend in order to stay aware? It appears that if workspace awareness information is hard to get in a groupware application, people may not bother to do so [13]. One of the problems with basic radar views is determining which view rectangle belongs to whom. To make this process more lightweight, we added people's pictures to their view rectangles in the radar display (also in Figure 5). This provides a simpler means of finding our where someone is, which corresponds better to people's abilities when looking around in a physical workspace. It would be even more interesting to replace these pictures with live video.

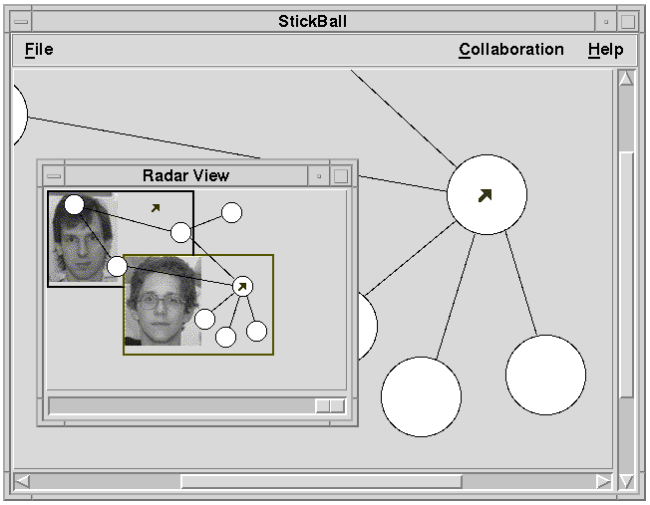

Figure 5. Portrait radar view with history. Moving the slider shows where viewports have been in the past.

A third issue with radar views is the screen space that they require, as many users may opt to remove secondary windows when they need more room. To minimize space usage, we are experimenting with a "head-up" display that combines normal and radar views. The widget in Figure 6 shows both the full-size workspace as the front layer, and a miniature of the entire workspace as the back layer, coloured grey to reduce distraction. The rectangles in the background show the extents of the detail view.

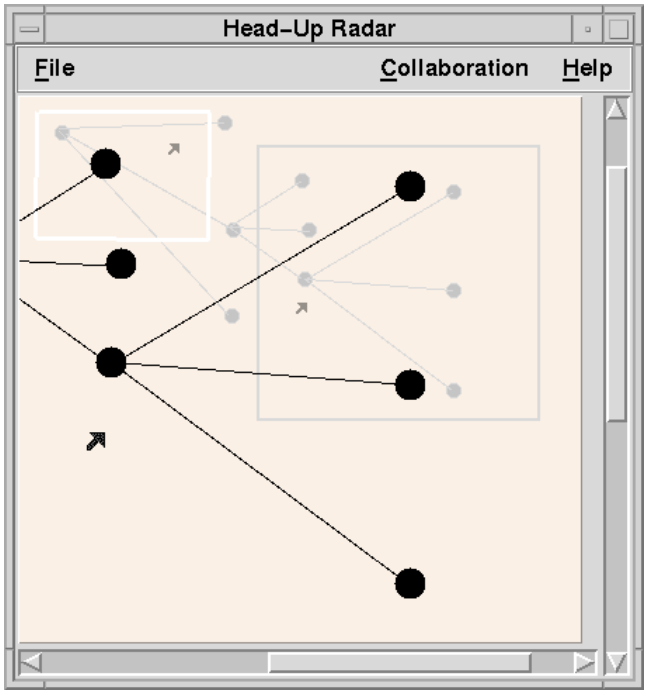

Figure 6. Combined normal and radar view. The detail view (in black) is overlaid on the radar view (in grey).

Control Over Representation

A different relaxation of WYSIWIS that can also reduce workspace awareness is that participants can change the way artifacts are displayed to suit the demands of their individual work or their personal preference. If display representations differ, however, literal actions may not make sense when directly transposed from one context to another. People may be unable to use feedthrough or consequential communication to stay aware of another's activity, even though their views are congruent. One problem in particular is that multiple cursors, which give an indication of location and activity, lose some of their meaning when local and remote artifacts look different or are in different places.

Semantic cursors address this problem. These are multiple cursors that are tied to the semantic form of workspace artifacts rather than a cartesian representation of the canvas on which they are displayed. A simple example using a text widget is shown in Figure 7. In addition to each person's insertion point, the widget provides a semantic cursor that tracks mouse movement, allowing limited gesturing and pointing. As a person moves their mouse, the widget broadcasts the letter underneath the cursor rather than its screen coordinates, and each remote application highlights that character. The cursor therefore shows the text location of where someone is pointing, regardless of how the window is formatted.

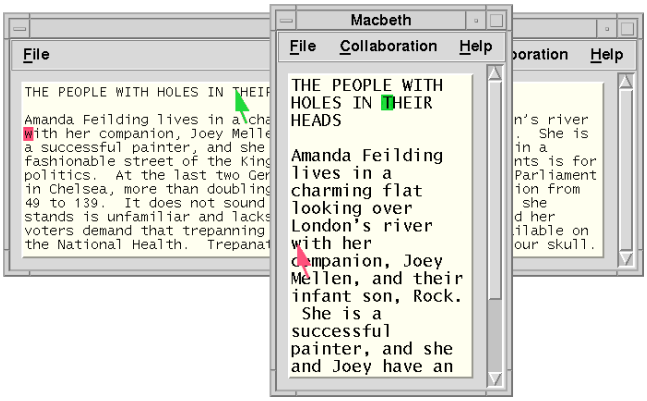

Figure 7. Semantic cursors in text widgets

CONCLUSIONS AND FUTURE WORK

In this paper, we have presented the concept of workspace awareness as a design concern for real-time groupware, and have constructed a conceptual framework that can be used by designers. We showed several awareness widgets that we have built using the framework, and discussed awareness problems caused by relaxations to the WYSIWIS approach. This work presents several avenues for further work, including:

- expanding and validating the framework through additional studies of face-to-face groups;
- evaluating the usability and effectiveness of our current widgets;
- building additional awareness widgets for other elements and mechanisms, such as a fisheye view that smoothly integrates radar and detail views;
- investigating other issues of applying the framework to groupware, such as the trade-off between awareness of others and distraction from individual work, and the possibilities of going beyond existing face-to-face mechanisms for maintaining awareness.

The widgets provide a starting point. While each has strengths in supporting particular awareness elements and mechanisms, we still have a long way to go before groupware workspaces approach the richness and simplicity of face-to-face practice.

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