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ACTIVEMAP: A Visualization Tool for Location Awareness to Support Informal Interactions

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Abstract. ACTIVEMAP is a visualization tool that enables users to gain greater awareness of the location of people in their workplace environment, increasing each person's ability to seek out colleagues for informal, face-to-face interactions. Our initial implementation of the tool places images of each person's face on a map of the building. We have explored variations on how to best represent a range of features: the "freshness" of location information, groups of people in a single office, and the movement of people throughout the environment. We describe the context of the environment in which the tool is used, the features embodied in this tool, variations we have implemented for representing location and movement information, and some potential extensions for future versions of the tool.

1. Introduction

Informal interactions constitute a frequent and crucial aspect of accomplishing work [Isaacs, *et al*., 1993]. A number of other researchers have explored issues of awareness [Dourish & Bellotti, 1992] and how video and audio technology can be used to provide interaction capabilities for *distributed* workgroups [Dourish & Bly, 1992; Fish, *et al.*, 1993; Tang, *et al.*, 1993; Hudson & Smith, 1996; Nakanashi, *et al.*., 1996; Lee, *et al.*, 1997]. The developers of all of these systems acknowledge and seek to address the problem of users' perceptions of privacy invasion that often accompanies the deployment of cameras and microphones in the workplace.

People are generally willing to sacrifice some amount of privacy for commensurate benefits, as is evidenced by the widespread use of credit cards. For *distributed workgroups*, the benefits of the awareness provided by cameras and/or microphones may well outweigh the potential privacy costs. In contrast, we are primarily interested in exploring how ubiquitous – but less invasive – technology [Weiser & Brown, 1997] can be used to better support *physically proximate workgroups*. Although people in

adjacent offices often have a high level of awareness of the location of their neighbors, people in non-adjacent offices experience a horizon effect and do not have much awareness of their physically distant colleagues. The degree of awareness is often mirrored in the number of interactions: people tend to interact more with their neighbors than with people further away [Kraut, *et al.,* 1990]. By expanding the sphere of awareness, we hope to expand the scope of regular interactors.

ACTIVEMAP is a tool that enables users to visualize the location and movement of all people within a workplace environment, providing large-scale, real-time awareness of that environment with minimal need for explicit interaction: *awareness at-a-glance*. The tool displays a window with a background showing a map of the physical layout of the workplace. In the foreground, images of the faces of people in that workplace are superimposed over the locations in which they were last seen.

Researchers at Xerox Palo Alto Research Center developed a program named "locations" that also superimposed images over a background of a map of their workplace [Spreitzer & Theimer, 1993]. However, few details were reported on this program, which was part of a larger research effort into developing a mobile and context-aware computing infrastructure [Schilit & Theimer, 1994]. In particular, very little was reported with respect to how the program represented different aspects of location information.

In contrast, our focus is on how best to visualize location information, given an existing infrastructure for providing location information. ACTIVEMAP provides users with a set of parameters that specify how to represent the freshness (or recency) of location information, how to represent collocated groups of people, and whether and how to represent movement of people throughout the workplace environment. We want to investigate how useful these representations are by finding out how people use them, which we are learning through both interviewing users and examining logs that show how users set these parameters.

Our larger goal is to investigate what effect this tool has on interactions in the workplace. By providing greater awareness of where people are, and who is with them, we create more opportunities for face-to-face interactions. Using the taxonomy proposed by Kraut, *et al.*, [1990][1], we believe that the use of ACTIVEMAP will allow people to engage in more *intended* interactions, possibly while creating the appearance of *opportunistic* or even *spontaneous* interactions.

This paper will describe our ACTIVEMAP tool. We first describe the context within which ACTIVEMAP operates; we next describe some of the basic features of the tool; we then present the different methods we have implemented for visualizing information about the location and movement of people; we report on some initial user ex-

[1] The four types of interpersonal communication are *scheduled* (planned by both parties), *intended* (planned by one party who seeks out the other), *opportunistic* (unplanned interaction regarding a planned topic of discussion), and *spontaneous* (unplanned interaction regarding an unplanned topic) [Kraut, *et al.*, 1990].

periences with ACTIVEMAP; we conclude with a discussion of some of our plans for extending the tool.

2. Environmental Context

The environmental context in which we have designed and built the ACTIVEMAP is the physical space occupied by the Center for Strategic Technology Research (CSTaR®), a 16,000 square foot section of the second floor of Accenture Technology Park, in Northbrook, IL, USA. The CSTaR area includes 30 individual offices, four laboratories, two large conference rooms (the Group Discussion Lab, or GDL, and a Videoconference room), two small conference rooms, a break area with kitchenette and vending machines, three furnished open areas used for informal meetings and numerous hallways. There are approximately 30 members of the CSTaR group in Northbrook,[2] including researchers, programmers, technical writers and administrative staff.

We have installed an ArialView™ Awareness System [Arial Systems Corp.] within the CSTaR area, consisting of a network of over 70 ceiling-mounted nodes, each housing an infrared sensor, radio frequency receiver and audio speaker, and a set of badges that transmit infrared identification signals every two seconds.[3] In addition to this hardware, the ArialView system includes components to process the signals and maintain badge location information in a Microsoft SQL Server 6.5 database, and a web browser interface for accessing and administering this information.

Some members of CSTaR have voiced privacy concerns about wearing a badge that allows them to be located in real-time or tracked over a period of time. Fortunately, we work in a profession in which our location does not reveal a great deal about our work (or play) activities: time spent in a colleague's office could represent an intensive exchange of project-related ideas, or a heated debate over whether a president committed impeachable offenses. One of the nice things about a badge system, is that anyone who objects to being located or tracked can simply not wear a badge, although this admittedly may not be the case in other professions. Ubiquitous cameras and microphones are not so easy to avoid (though one can presumably at least control the devices installed in one's office).

We believe that most people are willing to relinquish some degree of privacy for what they perceive as a compensating benefit. For example, most people in the United States are willing to let grocery stores track their purchases via some kind of

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[2] There are six members in another CSTaR group in Palo Alto, CA, USA, but their workspace is not yet incorporated into the environment(s) served by ACTIVEMAP.

[3] The ArialView system is similar in many respects to the Olivetti Active Badge System [Want, *et al.*, 1992; Harter & Hopper, 1994], except that the current ArialView badges have a single two-position slider switch rather than two buttons, and the ArialView sensor nodes include RF receivers and speakers.

preferred shopper's card in exchange for small discounts received when they present the card to the cashier. It remains to be seen whether the members of CSTaR will perceive enough benefits from ACTIVEMAP and other tools within our suite of active environment applications (e.g., EventManager [McCarthy & Anagnost, 1999]) to warrant their continued wearing of badges. [4]

3. The ACTIVEMAP Tool

ACTIVEMAP provides at-a-glance awareness of the location and movement of colleagues within a workplace environment by superimposing an image of each person over the location in which that person was last seen. [5] The tool runs under Windows 95/98/NT and has been installed on over 30 different laptop and desktop computers, which communicate with the ArialView servers via TCP/IP.

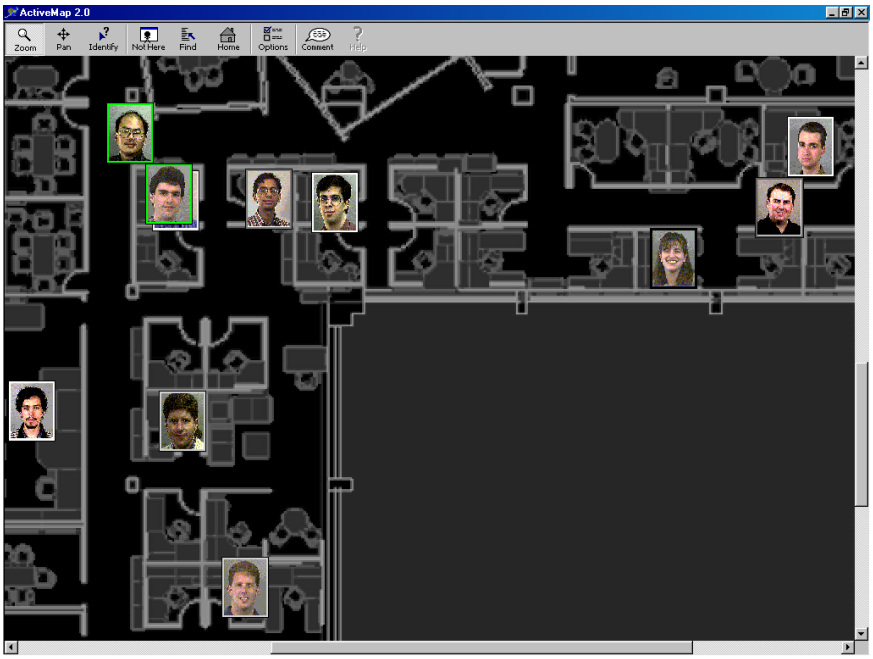

Figure 1: ACTIVEMAP displaying a region of the CSTaR workspace.

[4] See Harper [1992], for a more thorough discussion of acceptance issues with respect to the use of badges in a research lab context.

[5] More precisely, the location in which that person's badge was last detected by the ArialView sensors.

Figure 1 shows a snapshot of ACTIVEMAP depicting 11 people in a small region of the CSTaR area; this snapshot illustrates a number of representational features we have implemented in the tool. The following sections describe these features in greater detail.

3.1. Representing Information Freshness

ACTIVEMAP shows where each person's badge was last seen. However, a variety of factors can prevent the ArialView system from seeing a badge: a badge may be occluded by a body part or article of clothing (including a person's pocket); a person may be moving through (or stopped at) a "blind spot" not well covered by any sensor; or the person may have left the area covered by sensors. [6] Note that in the first case, the person is still in the location he or she was last seen, in the second case he or she may be close to the location last seen, and in the third case he or she may be long gone. In all three cases, the location information for a person is out-of-date, and we provide two different mechanisms for representing how fresh the information is for each person: image fading and frame shading.

Image Fading. One mechanism for representing freshness is to reflect the quality of the information in the quality of the image – clear images indicate people who have been sighted recently, faded images indicate people who have not been seen in a while. The intuition behind this metaphor is that a quick glance at ACTIVEMAP shows clearly who is currently located by the system; if you have to look closely at an image, it may be due to that person not being in the last seen location.

The user specifies a time interval over which fading will occur, between 1 and 24 hours, and selects a fading scale, either linear or [decaying] exponential. For the linear scale, we divide the total number of minutes in this interval by 256 to determine a fading change interval, and lower the brightness value (using the Hue, Saturation and Brightness, or HSB, color scheme) used to display the image by one for each elapsed interval value. For the exponential scale, we use the following darkening formula to adjust brightness:

$$\left[\frac{1}{1-e^{-2}}\right]\cdot\left(e^{-2t}-e^{-2}\right)$$

where t is the normalized time interval. At the upper limit of the user-specified fading period, the image will have faded to black.

Frame Shading. A drawback to using the image quality to represent information quality is that images that are faded may in some cases represent people who are still at the location they were last seen, i.e., the location information is still valid even though their badges have not been detected recently. We therefore created an alterna-

[6] For simplicity of exposition, we will often speak of "a person being seen" rather than "a person's badge being detected by a sensor," even though the latter description is technically more accurate.

tive view option that does not degrade the image quality but uses differential shading of the frame around an image to indicate information quality. White frames indicate people who are currently seen by the system. As time passes since the last sightings, these frames are progressively darkened, using the same formulae as in the image quality representation, until they appear black after the maximum length of time has passed.

In Figure 1, the frame shading option was selected, with an interval setting of one hour. The person in the far right portion of the picture (white frame) is being seen right now; the person immediately below and slightly to the left (gray frame) was last seen 20 minutes ago; and the next person below and to the left (black frame) has not been seen for over an hour.

Users also have the option of specifying a maximum lapse of time (between 1 and 24 hours) for considering a person "here" – after a person's badge has not been sighted for that period of time, the person is considered "not here" and his or her image is displayed in a separate "Not Here" window pane. Mousing over the images in the "Not Here" window will bring up tool-tip windows showing the names and times last seen, just as within the main ACTIVEMAP window.

3.2. Representing Groups of Inhabitants

One of our design goals was to create a visualization tool to facilitate awareness-at-a-glance, i.e., one look at ACTIVEMAP would provide information about all the inhabitants within the intelligent environment. However, we also wanted ACTIVEMAP to scale gracefully from small physical spaces to large ones, and to accommodate varying levels of magnification (zooming). One area in which a conflict arose between these two goals was in our representation of groups of inhabitants gathered together in a single location. We provide the user with two options for representing collocated groups: tiled and stacked. In Figure 1, the tiled representation was used; however, Figures 2a and 2b illustrate why we have provided both alternatives.

Tiled Groupings. The tiled representation places images of inhabitants around the center point of the location in which they are located; they are separated by as much space as possible, maximizing the difference between their respective angles from the center point of that location. The advantage of this representation is that it exposes as much of the images as possible; the disadvantage is that for locations with little space, such as individual offices, it is sometimes difficult to discern exactly where a person is located, since images sometimes overflow into adjacent offices or hallways.

Figure 2: Groups in (a) Tiled representation and (b) Stacked representation

Stacked Groupings. The stacked image representation, in which multiple collocated images are stacked on top of one another in decreasing order of recency (the topmost image is of the person who was most recently seen), represents the reverse tradeoff. With a stack of images, only the topmost image is clearly visible, but since the bottommost image is centered in the location, it is easy to see how many people – though not which people – are in a given location. Although moving the mouse to that location will reveal all the people currently there in a tool-tip window, the interaction requirement diminishes the "at-a-glance" functionality we desire.

3.3. Representing Movement

We wanted to represent movement on ACTIVEMAP to help provide some context: when one or more images suddenly shift from one location to another on the map, it is often difficult to discern which image(s) moved. By adding movement into the representation scheme, we hoped to differentiate stationary people from those who are moving or have recently moved. However, we wanted to minimize the risk that inhabitants would feel they were being "tracked" by the system – concerns over privacy are likely to be heightened if the system maintains (and displays) a history of movement rather than an instantaneous snapshot of current locations. We also wanted to avoid cluttering the display, a situation that might arise by representing the movement of many people over a considerable amount of time.

Our initial representation for movement in ACTIVEMAP simply distinguishes images that have moved from those that have not by coloring the frames of recently moved images bright green. Users can specify a maximum elapsed time to allow since the most recent movement – in the range from 0 to 60 seconds – so that they can define "recent" for themselves.

We also provide an option that allows a user to hear audio cues that represent movement. One sound indicates that someone has been sighted for the first time that day, another sound indicates that there has been some movement by one or more people. These audio cues can be independently enabled and disabled.

3.4. Interaction through ACTIVEMAP

Although the primary purpose of ACTIVEMAP is to provide hands-free at-a-glance awareness of people in the workplace, we have provided a number of ways that users can interact with the system. ACTIVEMAP users can shift the view in any direction by using the mouse to drag the map. Users can also zoom the view in or out to one of eight levels of magnification. Moving the mouse around the map can generate "tool-tip" style windows (such as the balloon help windows that are used in Windows 95/98/NT) that label information on the map: placing the mouse over an office or meeting room on the map pops up a window that labels that location; placing the mouse over an image on the map pops up a window that lists the people in that location.

A "Find" button pops up a list of people known to the system, and then re-centers the map over the image of the selected person wherever he or she was last seen. We also provide a "Home" button (and an option to "Set Home" position) so that users can easily revert to their "normal" view of the map.

The ArialView system provides a capability to send *directed audio* messages to people in the environment: a user types in a text message, which is then processed by a speech synthesizer and the resulting output is sent to an audio speaker in the ArialView ceiling node closest to the person to whom the message is directed. ACTIVEMAP provides an interface to this capability by popping up the text message window whenever a user double-clicks on the image of a person.

4. Initial User Experiences

ACTIVEMAP has been available to members of CSTaR for only a short time. While we have solicited feedback from a few people about the utility of various features, we have not yet conducted extensive interviews to learn how or why people are using these features. We also have a log of what settings people are using, so that we hope to conduct a quantitative analysis of features based on how people are really using the tool (which may be slightly different than how they say they are using it). This section highlights some of the early feedback we have received.

4.1. How, When and Where ACTIVEMAP is Used

We have installed ACTIVEMAP in a kiosk machine in a heavily trafficked hallway of the CSTaR workspace. It turns out that this installation of the program is accessed *far* more frequently than copies installed on individual desktop and laptop computers. Many individuals report accessing ACTIVEMAP on this kiosk several times per day, and people outside of the CSTaR group have been observed using ACTIVEMAP on the kiosk to locate people on numerous occasions. In contrast, only two individuals report accessing ACTIVEMAP on their personal computers more than a few times per

week. One of these frequent users (who coincidentally happens to be one of the authors) has ACTIVEMAP running all the time on a second desktop machine in his office, almost as a screensaver type of application. This user also reports running ACTIVEMAP all day whenever he is working from a remote location, as it provides a significant degree of awareness of what is happening on-site. The other frequent user reports accessing ACTIVEMAP on his single desktop computer at least five times daily.

The lack of more widespread frequent use on personal computers may be due a number of different factors. We have released several versions of the tool, and unsatisfactory experiences with early releases may have led to a lingering image problem. Due to the pace of new versions being developed and tested, the application is a moving target, and so we have not expended much energy [to date] in marketing the application and training people how to use it effectively. Finally, our research group also produces a screensaver application that is used by most members of the research group (and several thousand people throughout the rest of the organization); while we believe that ACTIVEMAP might make a nice screensaver type of application, at this point we don't want to compete with our colleagues for screen real estate and attention.

4.2. Option Preferences

We have referenced a number of different options or parameters that users can vary to adjust the visual or aural aspects of ACTIVEMAP. In informal discussions with some of our users, we detected certain trends in how people like (and don't like) to visualize the information.

ACTIVEMAP displays the names and times last seen in tool-tip windows that popup during mouseover events. One option was to depict time last seen as absolute time (e.g., Joe McCarthy; 01:49PM) or elapsed time (Joe McCarthy; 1 minute ago). Different people expressed different preferences for displaying this information; no clearly preferred option emerged.

There was a clear tendency among users to prefer frame shading to image fading in representing information freshness. Users also tended to prefer stacked groupings to tiled groupings (but one suggested using tiled groupings in rooms that were large enough to accommodate multiple images, such as meeting rooms and open areas). Most users use the logarithmic falloff option for representing time since last seen – the difference between someone not being seen in 5 vs. 10 minutes is often not interpreted the same as the difference between someone not being seen in 65 vs. 70 minutes – with a falloff range starting from 0-15 minutes up to 1-2 hours.

Sounds emanating from ACTIVEMAP were generally perceived as distracting. Only one person enabled the audio cues to indicate any movement by anyone throughout the workplace, though a few users enabled the audio cues that represent the initial arrival of people at the workplace.

5. Future Work

We are considering extending the capabilities of ACTIVEMAP in a number of directions: alternate representations of time, movement through space and collocated groups of inhabitants; new sources of information to supplement the location information provided by our badge system; and new mechanisms for interacting with inhabitants through the tool.

5.1. Alternate Representations of Freshness, Movement and Groups

The progressive darkening of the image to represent freshness is probably not the best way to degrade image quality. We plan to experiment with other mechanisms for representing freshness in the image quality that still permit recognition of images of people who have not been seen in a long time, e.g., inserting lines of varying thickness at regular intervals across the image.

We would like to represent movement using slime trails – a notion borrowed from turtle graphics, wherein a line (usually, with some maximum length) trails behind an object as it moves about on the screen – to show each person's movement over the course of the last 0 to 60 seconds. We believe that this range of settings provides sufficient context while minimizing screen clutter, and we do not believe that the addition of this small amount of movement history will be perceived as unduly invasive.

The two methods we use for representing groups of people in the same location – tiling or stacking – each has disadvantages, both of which stem from the fixed size of locations within the map. We plan to investigate the use of non-linear magnification techniques [Keahey & Robertson, 1996] to see if we can relax the rigidity of location boundaries without compromising the ability to easily interpret the map.

5.2. New Sources of Activity Information

We have found that providing simple awareness of the location of people throughout the workplace environment to be useful. However, for reasons outlined above, the accuracy of the infrared badges and sensors is not perfect. We would like to incorporate other kinds of information to augment the information provided by our badge system, to help compensate for inaccuracies and provide more information about the potential availability of people in the environment. Other sources of information we are considering include motion or noise detection within offices, detection of whether the telephone in an office is currently in use, and keyboard/mouse usage monitoring (similar to the awareness provided by AOL's Instant Messenger (AIM) application).

5.3. New Interaction Mechanisms

Our initial implementation of ACTIVEMAP provides only one mode for interacting with inhabitants: sending a directed audio message by double-clicking on a person's image. We would like to add additional capabilities, e.g., initiating a telephone call directed to the closest telephone to the person viewed in ACTIVEMAP, or perhaps linking to EVENTMANAGER [McCarthy & Anagnost, 1999], a tool that allows users to notified of the occurrence of specified events based on people and locations, so by clicking on Ted's image I can ask to be notified "when Ted returns to his office."

5.4. Speech-Enabled Interface (Kiosk)

One of the machines running ACTIVEMAP is a public kiosk machine with a large display. This kiosk has an infrared keyboard and touchpad, but the physical layout of the kiosk space makes it awkward to use direct manipulation of the ACTIVEMAP interface. We plan to enable ACTIVEMAP to accept spoken commands, so that someone viewing ACTIVEMAP from the kiosk can tell the application to "Zoom In" or "Shift Left." We also plan to enable a kiosk user to ask "Where is Eric" and have the ACTIVEMAP zoom in to the location where Eric was last seen, or to "Send an audio message to Eric" to invoke the directed audio capability.[7]

6. Conclusion

ACTIVEMAP is a tool that provides real-time at-a-glance awareness of the locations of people throughout the environment based on information provided by a system of infrared badges and sensors. Our initial implementation of the tool incorporates several features for representing location information freshness, movement and groups of people. We plan to investigate the perceived utility of these features, explore other possible representations, and incorporate other sources of information in future releases of the tool.

Our goal for the tool is to facilitate more informal, face-to-face interactions among workers within the same physical workplace, while minimizing the intrusiveness of the technology we use to accomplish this goal – essentially providing the maximum social benefit for the minimum privacy cost. While the authors have experienced an increase in such interactions, further research will be required to determine whether the CSTaR user population as a whole, experiences similar benefits, and whether the tool provides other, unanticipated functionality with respect to the interpersonal relationships and communications within the group.

[7] Though obviously, in this case, we'd record a spoken message directly into a WAV file and send it, rather than using speech recognition to translate the spoken words into a text file, and then using the text-to-speech synthesizer to translate the text into a WAV file before sending it.

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