Mediating Awareness and Communication through Digital but Physical Surrogates

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ABSTRACT
Digital but physical surrogates are tangible representations of remote people positioned within an office and under digital control. Surrogates selectively collect and present awareness information about the people they represent. By having them react to physical actions of people, surrogates can control the communication capabilities of a media space. This enables the smooth transition from awareness to casual interaction while mitigating concerns about privacy.

INTRODUCTION
In this research, we apply the powerful concepts of tangible user interfaces[1] [11] and ubiquitous media spaces[2] [2] to a particular problem: how physical devices under digital control can support awareness and casual interaction between collaborators separated by distance.

Our approach uses *digital but physical surrogates:* digitally controlled physical surrogates of distant team members positioned within a person's environment. As we will see, surrogates can embody awareness and present opportunities for interaction. Our goals were to design surrogates that:

- support the smooth transition from awareness to opportunistic and one-person initiated casual encounters, to conversation and work;
- mitigate privacy and distraction concerns endemic to most awareness systems.

THE PROBLEM AND RELATED SOLUTIONS
The backbone of everyday coordination and work between co-located team members is *casual interaction*, the spontaneous and one-person initiated meetings that occur over the course of the day [13]. The glue behind these interactions is *informal awareness*, where people track and maintain a general sense of who is around and what others are up to as they work and mingle in the same physical environment [4]. Because casual interaction is problematic in distributed communities [13], CSCW researchers have developed a variety of methods for providing informal awareness and mediating casual interaction in distributed communities. These include media spaces [1], video glances [16], periodic video snapshots [6] and iconic presence indicators [10].

These traditional methods all channel awareness and communication through a single device [2], typically a computer. This raises several concerns.

1. Awareness displays compete with other computer programs. Dourish and Bly [6] report that Portholes users often could not see the video snapshots of others because they were hidden under other windows. Quite simply, the screen was too busy a place for awareness information.
2. For many people, computers are a peripheral, occasionally used device. People cannot attend to awareness information if they are not using the computer.
3. The single display may represent several people and communication channels. The consequence is an overly complex interface for establishing and switching between communication channels [3].

We can partially solve the awareness problem by using physical devices (separate from computer screens) to capture and display a remote person's activities. Related examples come from art installations. First, some promote interpersonal intimacy, where a traveler's manipulation of their partner's surrogate (e.g. a picture) is presented as events in their partner's environment e.g., a feather drifting within a cone or the release of a pleasant scent [15]. Second, some examples promote play, where manipulating one toy encourages another to respond on its counterpart e.g., Shaker [15] and Hand Jive [9]. Third, networked furniture can promote awareness between those who use them e.g., the 'Internet Bed' relays an abstracted sense of presence between intimates on different beds [5], and the 'Bench' warms one bench to reflect a person sitting on another bench, gradually opening a voice channel when strangers sit on equivalent spots [7].

We can also enrich direct communication by channeling it through a variety of everyday physical devices situated in one's environment, which Buxton described as *ubiquitous media spaces* [2]. These devices take advantage of architecture, where the media "preserves or builds upon conventional location-function-distance relationships". Buxton's work concentrated on integrating video into this space. Examples include his Hydra units for multiparty videoconferencing, where each unit (comprising a small

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[1] *Tangible user interfaces* couple digital information to everyday physical objects that can be grasped and manipulated

[2] *Ubiquitous media spaces* channel interpersonal communication through a variety of everyday objects and devices

video display, camera, speaker and microphone) acts as a video surrogate for a remote person. Some awareness is supported by situating these devices in strategic locations: mounting a Hydra unit above an office door means that people can “walk by” and “glance in” via video. The office occupant can see who is going by and responds if desired.

Our own solution of digital but physical surrogates combines into a single device the artistic community’s use of physical devices for awareness with Buxton’s use of video surrogates for communication. As mentioned in the introduction, we wanted to create surrogates that helped work collaborators (*vs.* intimates and strangers) move from awareness to encounters to communication to work. We also wanted to see how such surrogates could be designed to mitigate privacy concerns by transmitting only selected awareness information and by having people control what was transmitted by both explicit and implicit actions.

We first set the scene by illustrating with examples what we mean by these digital but physical surrogates. We defer discussion of these surrogates until the subsequent section.

EXAMPLES OF DIGITAL BUT PHYSICAL SURROGATES

In this section and in the companion video, we briefly describe several surrogates that we have built. We show:

- how surrogates can present awareness information;
- how they can be used to indicate interest in others; and
- how they can control communication in a media space.

Surrogates Presenting Awareness of Others

The first class of surrogates illustrates how activities of a remote person can be embodied within a physical surrogate located in a local office.

The dragonfly surrogate is a motorized model altered so that its motor is under digital control (Figure 1). The dragonfly’s activity corresponds with bursts of activity by the remote person. When the remote person is inactive or absent, the dragonfly too is inactive. As a person becomes active, the dragonfly flaps its wings furiously and audibly for a few moments, but then quickly slows to gentle and quiet wing motions for about a minute afterwards.

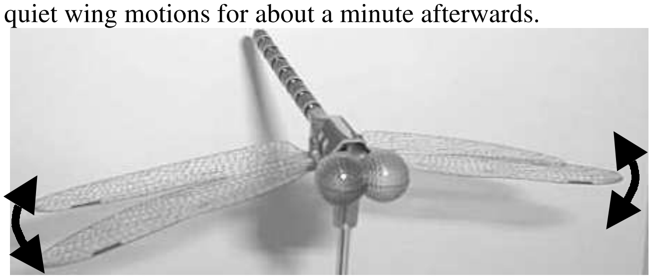

Figure 1. The dragonfly surrogate

The peek-a-boo surrogate combines a figurine and a servo motor (Figure 2). The surrogate faces the wall when the remote person is unavailable or inactive, but rotates to face the local person as the remote person becomes available. This also produces a slight sound, another awareness cue. One can sense another’s availability at any time by glancing at the surrogate’s orientation: the more it faces oneself, the likelier the other person is present and available for communication. Unlike the dragonfly, the surrogate represents state information continuously by its orientation.

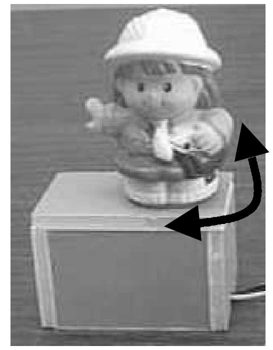

Figure 2. Peek-a-boo

The light surrogate displays other’s activities as the movement of light patterns across the ceiling of a room (see video). This illustrates that surrogates can be abstract entities as well as figurines.

Surrogates for Indicating Interest in Others

The next class of surrogates illustrates how a person can explicitly express different degrees of interest in others by manipulating a surrogate.

The mutant ninja surrogate is a figurine representing co-author Kuzuoka located in my office (see video). It transmits rather than presents awareness information. When I hold the figurine (which is instrumented with a heat sensor), Kuzuoka is notified that I am interested in him.

The responding surrogate is a figurine whose position relative to another surrogate defines the degree of interest one has in the remote person. In Figure 3, for example, the local person explicitly positions their surrogate (the one in the foreground) relative to the peek-a-boo surrogate. If positioned on the stage directly facing the peek-a-boo surrogate, the remote person will be notified that the local person is very interested in them. Moving it off the stage, or tipping it over, indicates progressively lesser degrees of interest (these positions are detected via light sensors.)

Surrogates for Controlling a Media Space

The final class of surrogates illustrate how they can be used to mediate communication.

The Active Hydra surrogate (Figure 3) embodies a video/audio connection to a single remote person. We instrumented Hydra units [2,3] with proximity sensors that measure how close a person is to it. Unlike the original Hydra, the presence or absence of the audio, the quality of the video, and the presence of groupware on the computer display is controlled implicitly by a person’s position relative to the surrogate. When both

Figure 3. The Active Hydra

people are close to their Hydra surrogates, they have a full audio/video channel, and groupware on the computer is activated (e.g., a shared sketchpad is made ready-to-hand to augment communication). As one moves away from the surrogate, audio is disabled. Moving even further away degrades the video to occasional glimpses into each other's space, and the groupware on the computer disappears.

Combining the Active Hydra and responding surrogate provides people with explicit control over the media space. In this case, a full two way communication channel is established only when both people are close to the Hydra unit and when both have positioned their responding surrogates on the stage (as in Figure 3). When a responding surrogate is off the stage, the communication and groupware channel is restricted as at least one of the people has not expressed enough interest in the other. Thus the permeability of the communication and groupware channel becomes a function of both implicit personal proximity to the surrogate as well as the explicit positioning of the responding surrogate.

MOVING FROM AWARENESS TO INTERACTION

In this section, we will argue that:

through surrogates, people can easily stay aware of others and move intuitively into casual interaction.

It should be self-evident from the examples how surrogates can lead from awareness of others (providing opportunities for conversation) to light-weight establishment of communication (necessary for casual interaction and work). To clarify this relation, we distinguish how different surrogates progress from awareness to interaction:

- surrogates that only indicate availability,
- surrogates used to explicitly manage communication,
- surrogates used to implicitly manage communication,
- surrogates that use both implicit and explicit acts.

Surrogates that only indicate availability

Some surrogates indicate availability information only, as they are completely disconnected from the communication channel (e.g. the dragonfly and light show). While these provide opportune moments to contact others, it is the person's responsibility to select and activate a communication channel. This is useful for one-person initiated actions, as that person can see when the other is around and take explicit action to communicate with them. However, opportunistic interaction would be rarer as establishing communications involves extra work.

Surrogates used to explicitly manage communication

More powerful are surrogates that people can manipulate explicitly to manage the communication channel. For example, people can use the responding surrogate not only to indicate availability to others but to control the 'quality of service' delivered over a communication channel [14] such as a Hydra unit. Table 1 shows one such configuration. For example, when both people place their surrogates on the stage (indicating mutual availability), a full video, audio and groupware channel is automatically

	On	**Off**	**Tipped**
On	Video, audio, groupware all on	Video only	Glimpses
Off	Video only	Video only	Glimpses
Tipped	Glimpses	Glimpses	Closed

Table 1. Responding surrogate state and quality of service

established. When one or both surrogates are off the stage, audio and groupware is disabled as at least one person indicated a lesser degree of availability. If both people indicate unavailability by tipping over their surrogates, the channels are closed completely. Thus people can express mutual interest in others and manage communication in a single act. However, these are all explicit acts which can interfere with opportunistic encounters.

Surrogates used to implicitly manage communication

Opportunistic encounters are mediated by surrogates that respond to implicit acts of people. One example is our Active Hydra, which uses the proximity of people [14] to control the quality of communication service. For example, if one substituted 'near', 'close by' and 'far' for the headers in Table 1, we would see how the type of communication and groupware channel created depends on the spatial relation between both people and their surrogates. The problem, however, is that implicit acts may display too much or too little information and violate privacy.

Surrogates using implicit and explicit acts

We can combine and/or merge all surrogate types to provide awareness, and to manage communication quality both explicitly and implicitly. We already described an example when we combined the Active Hydra with the peek-a-boo and responding surrogate. A slightly more complex state table than shown in Table 1 determines how communication is managed as a function of both the explicit placement of the responding surrogate, as well as the proximity of people to the surrogate. Thus, for example, two off-stage surrogates may show only video unless people are close to them, in which case the audio channel would be automatically enabled (equivalent to two people bumping into each other or moving towards each other with the intent of talking). When the communication channel is degraded (as with the glimpse and closed state), the peek-a-boo surrogate can still provide basic awareness information. This increases the chances of serendipitous encounters, decreases distraction, mediates privacy, and decreases effort (because implicit actions have consequences as well).

BALANCING AWARENESS, PRIVACY & DISTRACTION

Awareness systems must balance the information provided for casual interaction against the risks of distracting others and violating their privacy. In this section, we argue that

surrogates can mitigate concerns about distraction and privacy as they can portray limited and abstracted representations of another's activities, and as they can present different degrees of salience.

Limiting & Abstracting How Activities are Portrayed

When one can see exactly what another is doing, such as in always-on video, the risk of privacy violation is high. In contrast, surrogates (excepting the Active Hydra) are caricatures with only limited ability to express information. Consequently, surrogates are best suited for portraying only limited notions of availability that abstracts one's activity: while still providing a general sense of availability, this lessen the risk of intrusion. Thus surrogate design includes the decision of what measure of activity and availability is captured (e.g., by instrumenting an office: see video), and how those measures are mapped onto the surrogate (e.g., as light, sound, or motion). When done well, these abstractions can be quite expressive. For example, the orientation of the peek-a-boo doll implies a playful but fairly literal notion of how interested and/or available the remote person is for collaboration, even though the source of how that information is gathered is invisible. The light surrogate can present the same information in a more abstract and aesthetic manner. Still, there is a tradeoff. While abstract representations are more protective of privacy, inferring another's availability is more error prone, causing occasional interruption or lost opportunities.

Choosing an appropriate quality of service of communication also preserves privacy and minimizes distraction. In previous sections, we have already described how the Active Hydra limits our direct view into another's space by combining both explicit control of the channel with implicit acts, such as proximity to the communication device. To further guard against privacy and distraction, these are reciprocal views whose fidelity depends upon the state of both people's surrogates (e.g., Table 1) and proximity. This provides reciprocity, where mutual interest balances what is visible on the communication channel.

The Salience of Awareness Portrayals

The *salience* of awareness portrayals is the degree to which awareness information is perceived in the foreground of consciousness. This is not an absolute measure, for even inconspicuous information portrayals can be of high salience if one is waiting for it e.g., a lover's tap on the window [12]. The likelihood of distraction is greatest when displayed information is so conspicuous that high salience is unavoidable. At the other extreme are ambient displays with low salience [11] and minimal distraction, but which risks overlooked opportunities for collaboration.

Physical surrogates can express different levels of salience. First, the surrogate's position within a room affects its salience: when placed close by and within one's normal field of view, it is a foreground, highly salient device. If positioned further away and out of direct line of sight, it becomes a background less salient device [2,11]. Second, the actual design of the surrogate embodies different levels of salience. The furious beating of the dragonfly's wings, for example, is very noticeable and almost always attracts attention, while the gentle flapping does not. Similarly, very large visual changes within the light surrogate are noticeable, while subtle changes are not. With the peek-a-boo surrogate, salience corresponds with changes in state: small changes result in small movements and slight sounds; increasingly larger changes produce more salient movements and sounds.

SUMMARY

The advantages of digital but physical surrogates are many when compared to their computer counterparts. They cannot be covered by windows. They can be positioned anywhere within a room to take advantage of the way we use physical space [2]. They do not depend on the person using the computer. Finally, surrogates can embody some or even all of the communication channel, and the contents of the channel can be mediated seamlessly by how people interact (either explicitly or implicitly) with the surrogate.

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