Chapter 19
Visually Augmented Interfaces for Co-located Mobile Collaboration

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Abstract We explore the difficulties involved with tightly coupled collaborative work on mobile devices. Small screens and separate workspaces hinder close interaction, even for co-located users. We begin our inquiry with a set of user focus groups to determine collaborative usage patterns, determining that shared workspaces present an opportunity to overcome the barriers to collaboration. The case for integrating awareness information into such distributed systems has been well established. We present two conceptual designs using visualization cues to present user awareness information, the first for co-located mobile devices, and the second using a mobile projector.

Keywords Collaboration • Mobile devices • Awareness • Shared workspaces

19.1 Introduction

Research on collaborative workspaces has established the need for integrating awareness components in distributed user interfaces (DUIs) [1, 2]. Most of this work has focused on designing and studying awareness cues for remote settings [3, 4]. What has been less explored is the need for awareness cues in co-located settings, particularly for mobile devices. One logical reason for this gap in prior art is that co-located settings benefit from social, verbal, didactic and gestural protocols, which are assumed to sufficiently facilitate collaborative work practices.

Collaboration on co-located mobile devices shares certain characteristics with remote collaborative workspaces. Although physically co-located, the visual workspace and input modalities on mobiles remain separated. As a result, users have limited knowledge of the other's virtual footprint, activity or focus. This separation encourages loosely coupled collaboration and can lead to unnecessary overhead in

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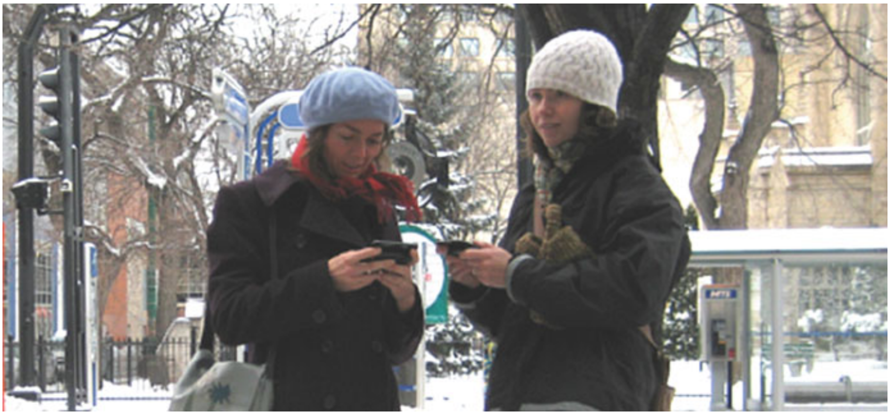

Fig. 19.1 In this scenario, two visitors use their mobile devices to search for a restaurant or a hotel. Their productivity would benefit from knowledge of what the other person is looking at, for example, in the same shared virtual workspace. However, common interfaces for mobile devices lack such awareness cues

the exchange of relevant information. The need for improved assistance for such settings can be best explained through a scenario.

Imagine two visitors to a city, both browsing a list of suitable restaurants or hotels on their mobile devices (Fig. 19.1). Because they are co-located, they have the benefit of verbal communication, facial expressions and gestures, which can facilitate tightly coupled interchanges of information. The pair of travellers will face difficulties, however, that may potentially result in a less-than-optimal product of their efforts. Each individual is focused on her own device, with no direct awareness of what the other is doing. It is awkward for one person to point out an item of interest, and not necessarily trivial for the other to navigate to the same location on her own view. The physical separation of the mobile workspaces creates an overhead for sharing detailed information, potentially leading to poor communication or redundant effort. The situation described here is not uncommon, yet adequate support for tightly coupled interaction does not currently exist for mobile device users.

In this paper, we first interview a number of mobile users to assess how often they engage in collaborative activities involving their mobile devices and to determine the barriers to collaboration. Based on prior literature, we make a case for the need for awareness cues in distributed interfaces. We then present two point designs for enhancing awareness through visual cues: (a) when the display spaces are separated across two devices (which is the most common setting), and (b) when the display space is shared, as in the case of recent developments with shared mobile projectors.

19.2 User-Centered Design

Our goal is to (i) identify, and (ii) design awareness cues for co-located distributed interfaces on mobile devices. Our initial focus is on casual users, very much like the scenario we presented above and for applications with spatial features, such as maps. Map browsing is a common task on mobile devices [5], and with improved interfaces we can expect this type of application to be highly popular among such groups of users.

To gain insight for our above stated goals, we conducted several informal user studies. We focused our inquiry to investigate the following questions:

1. What are the common usage patterns for current collaborative mobile activity?
2. How does co-located mobile collaboration differ from other settings?
3. What barriers inhibit tightly coupled work on mobile devices?

Our study participants were university computer science students who routinely use mobile devices. The studies included a survey (with 37 participants) and two sets of focus groups. In first set of interviews, we asked groups of five participants how they would go about engaging in map-based collaborative tasks using paper maps, desktop computers and mobile devices. The second set of interviews included an observation study. Pairs of participants were given two Nokia N900 smart phones and a route planning task, followed by discussion of their approach.

Our findings suggest that close collaboration is not common among co-located casual mobile users. This could partly be due to the lack of such interfaces to support such activity. However, a typical instance of co-located collaboration that was provided is the driver-navigator scenario, where a passenger looks up directions for a driver. In this case, work tends to be divided among collaborators in loosely coupled chunks. For instance, if there are several passengers with a single driver, group members might 'compete' on the same parallel search on their own mobile devices, or else choose to refrain from contributing until the navigator has narrowed the information to a few choices.

Likewise, in map collaboration scenarios, participants indicated they would organize their activity differently based on the medium of collaboration. With a paper map, people can work cohesively, with a common focus and tightly coupled interchanges in communication. On computers, work is likely to be split into independent parallel tasks. Desktop monitors, however, enable closer communication than mobile devices by allowing shared focus of attention and the use of frames of reference to point at objects.

Our primary findings highlight the two major obstacles listed by our participants for tightly coupled collaboration on mobile devices, (i) small viewport sizes, and (ii) separate visual workspaces:

> Small screens… Multiple people [are not] able to [view] input at the same time. Those are the two main barriers.

> When you have a map laid out or if you have a bigger computer screen, it's a lot easier to look over someone's shoulder…

In other words, mobile devices lack multi-user support, for both input and output. This was not overly surprising but hints at what users of such devices may expect. Their disconnected, individual nature is not suited for tightly coupled work. This separation can be partially overcome by shared workspaces, potentially provided by mobile projectors that are becoming widely available. Participants seemed to have an intuitive grasp of the shared workspace concept and were receptive to the idea of enhanced interfaces for collaborative map navigation:

> If the same 'map' could be looked at on multiple devices without forcing the same view between all the displays and give the user the option to 'point out' points of interest that other collaborators could look at…

> The screen size is no longer a limitation in that case, nor is everyone not being able to have input because you can each do your own thing.

These initial findings indicate a need for improved interfaces to assist with such collaborative tasks, and inform us of subtleties we need to consider for newly developed designs.

19.3 Awareness: A Basic DUI Feature

Research projects spanning at least two decades have generated numerous prototypes for multi-user applications, also known as groupware. Several groups (e.g. [1, 2]) have investigated awareness and its relation to group dynamics. Often the goal is to devise methods of raising awareness to facilitate tightly coupled work on groupware systems. Presently, research on awareness provision continues, for example, with systems that provide video links to facilitate remote collaboration [6]. More recently, awareness has been studied in the context of information retrieval (e.g. [3]) on desktop and tabletop systems. Our exploration focuses on co-located collaboration between mobile device users.

Greenberg et al. [2] break awareness into several types and single out 'workspace awareness' as a fundamental requirement for groupware systems. They identify three other forms of awareness, all of which intersect with workspace awareness: informal awareness concerns who's who in a work environment; social awareness pertains to physical and social cues, such as emotion and focus of attention; and group-structural awareness regards the roles of group members, including the division of labor. In contrast, workspace awareness is about changes to the physical state of the shared workspace and allows one user to be informed about the actions of another. Some forms of awareness are automatic in a real-world environment, but must be thoughtfully supported in groupware systems.

In the domain of collaborative Web search, Morris and Horvitz [3] identify awareness along with two other high-level user requirements: persistence and division of labor. Persistence supports disconnected and asynchronous modes of collaboration by allowing a user to 'take away' information from a session or revisit it later. In another sense, persistence is the extension of awareness over the time dimension. Division of labor is important for any group endeavor. Roles are often determined by the situation or the relationship between group members, but can also be made explicit by groupware systems [2]. Dourish and Bellotti [1], however, have observed that collaborative roles can be dynamic, thus groupware systems should be flexible. We believe that adequate support for awareness will allow existing social mechanisms to determine work delegation in the majority of circumstances, and ultimately optimize collaborative efforts.

19.4 Visual Augmentation for Awareness

The purpose of our work is to investigate methods for tightly coupling mobile collaborative work. To do this, we propose that DUIs rely heavily on awareness features. We present two particular design concepts that facilitate awareness information: (i) when the viewport is separated (as is commonly the case when two or more users have their own device), and (ii) when the viewport is shared. The latter case is possible with the introduction of projectors on mobile devices and its utility and limitations were demonstrated in systems such as that by Cao et al. [7] or by Hang et al. [8].

We group our proposed awareness features for both of these viewport 'platforms' based on their spatial and/or temporal properties.

19.4.1 Spatial Awareness

Spatial awareness is challenging on mobile devices, mainly because of their inherently small viewport sizes. Paper maps, in contrast, typically fold out to a relatively large size, allowing their users to view a large workspace together and to reference a wide range of locations. Desktop monitors are restricted in size, but compensate with interactive navigation support.

Researchers have attempted to mitigate the major disadvantages of a limited display area by devising ways to extend the effective area of the interaction space. For example, Greenberg et al. [2] have applied fisheye views for collaborative text editing. Unfortunately, the distortion caused by fisheye views on maps counters productivity gains. Overviews, which provides a scaled-down view of a large workspace (e.g. [9]) provide useful information about the relative positions of multiple objects but consume scarce screen space, making them far less practical for mobile device interfaces.

Alternatives to overviews include visual cues such as Wedge [10], which can provide spatial information about objects beyond the screen edge. Wedge provides both direction and distance information to off-screen objects, and can scale to multiple targets while remaining resistant to negative effects from clutter. We propose to repurpose this technique to provide *location awareness* information, such as the region of the document where another user is currently or was previously browsing. This form of cue may not be that compelling on a shared projector display, but could be replaced by a shared overview provided by a mobile projector.

Multiple users may choose to view a shared workspace at different scales. We use the term *intra-scalar* to describe an application that supports interaction between many possible scalar combinations. Communication would be hampered in a naïve application if two people view the same location at different scales, potentially unaware of differences between views. *Intra-scalar awareness* information would mitigate such difficulties by providing cues for differences in scale. For example, one way to convey information about scale is to display a bounding box indicating the scope of another user's intersecting view.

Table 19.1 A summary of awareness features and their corresponding visual augmentation cues

Type of awareness	Separate viewports	Projected overview	Figure location
Present location	Red wedge	Visible on overview	1
Previous location	Visit wear shown as anchor with blue wedge	Visit wear shown as anchor on overview	2
Point of interest	Star with orange wedge	Star on overview	3
Current activity	Sync to view	Entire overview	4
Past activity	Play history	Point cloud	5
Scale	Bounding box	Bounding box	6
Other information	Sketching	Sketching	7

19.4.2 Temporal Awareness

Temporal awareness is related to information about users' past actions. Corresponding features currently provided by single-user applications include history tracking, the ability to save and transfer a file and support for within-document revisitation. An example of the latter is the footprints scrollbar developed by Alexander et al. [11]. As a user navigates within a document, the application passively records locations where the user maintains focus for more than a few seconds. Under the assumption that people will likely view important locations more than once, such places are automatically marked with icons that allow for navigation. We repurpose visit wears in our conceptual design to provide two types of awareness, as determined by the context of the task: two users engaged in parallel search may choose to avoid areas visited by others in the interest of efficiency; or, a user may prefer to search these locations to retrace a user's history.

In some instances, a user may wish to deliberately provide awareness cues about a point of interest (POI), rather than relying on passive system features. Although co-located users can verbalize such information, a collaborative system can record the location for future reference, provide details to other users, and give others an option to quickly and easily navigate to and from a location at their convenience.

One further feature requested by our study participants is the ability to collaboratively sketch on a document using their device's touchscreen. While map-based applications currently provide features for calculating efficient routes, users may desire a simple way to communicate a path of their own choosing, analogous to tracing a route on a paper map with their fingertip. By enabling sketching, we can provide a flexible tool for route-tracing and unlimited other purposes.

When adding features to a user interface, such as those to support awareness, it is easy to produce a bloated and cluttered screen, leading to features that are confusing, under-utilized or completely ignored. Our aim is to encourage functionality that is intuitive and seamlessly integrated with the application environment. Table 19.1 summarizes a possible list of awareness features along with techniques for accommodating them. Figures below show the corresponding device view along with its conceptual shared workspace, when the viewports are distinct (Fig. 19.2), and when shared, such as on a projected overview (Fig. 19.3).

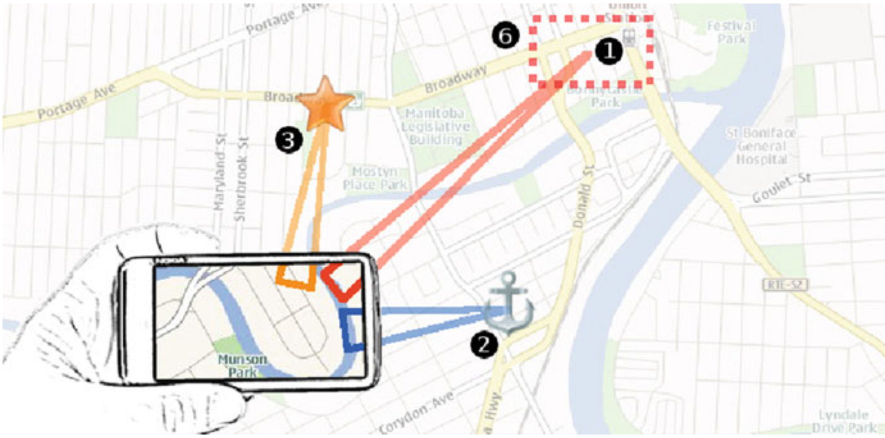

Fig. 19.2 The mobile display view and conceptual shared workspace. The second user's navigation region is shown by a bounding box and is indicated by a red wedge. Other wedges reveal the locations of a POI and a visit wear

Fig. 19.3 A shared projected display shows the location and scale of each user's view. Clouds provide information about their respective navigation histories

As noted earlier, awareness features in co-located shared viewports should be treated differently than those in distinct viewports. Wedge, for example, is very useful for expanding the effective size of a small screen, but provides no benefit on the projected view. On the other hand, the utility of the bounding box that represents a user's view location and scale is improved on a projection, because it is visible to all users at any time. The projected view is larger and more resistant to effects of clutter, giving us a larger degree of spatial freedom. For instance, we can conceptually expand the visit wear icons into a point cloud containing a greater breadth of history information (Fig. 19.3).

19.5 Summary

Shared workspaces open the door to collaborative activity for groups of mobile device users. Awareness is a fundamental requirement of such multi-user software system interfaces. Our design concepts for collaborative, intra-scalar systems explore two methods for expanding the effective area of interaction: first, the integration of information visualization cues into the user interface to bring distant information to the user's fingertips; and second, mobile projection as an avenue for providing group awareness by fitting a large display into a person's pocket.

In future work, we plan to develop a comprehensive design framework that will allow us to generate further options for implementing awareness features. With evaluative user studies, we can tease out the best design options and develop recommendations for designers. In the longer term, our goal is to develop a prototype system with which we can measure the utility and improvements to user experience that awareness cues can provide for co-located mobile collaboration.

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