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ORIGINAL ARTICLE

Mobile map interactions during a rendezvous: exploring the implications of automation

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Abstract Location awareness can help facilitate a rendezvous of two or more persons. To further enhance the rendezvous experience, we conducted two complementary field studies to identify *what* information in a location-aware map application is important to rendezvous individuals (study 1) and to explore the use of *autofocus*, our automation technique to reduce user interactions with the rendezvous application while still providing relevant information to assist users with their navigation task (study 2). Overall, our results highlight the importance of maintaining the visibility of the user's location in relation to that of their partner(s) and rendezvous location. Additionally, we show that automation is useful in the context of a rendezvous application, but that the considerations are significantly more nuanced than originally conceived. We discuss unique instances *when* and *why* the automation process broke-down or did not perform as required by users. The results of this work demonstrate the potential for automation in a location-aware rendezvous application and identify important design considerations for future work in this area.

Keywords Location awareness · Rendezvous · Map interaction · Automation · Field study · Autofocus

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1 Introduction

The idea of a location-aware device in every person's pocket will someday become a reality given that mobile devices are becoming increasingly pervasive. Using radio frequency positioning (e.g. Intel's Place Lab and POLS) or GPS, a mobile device can quickly and easily learn its own location. Previous research has illustrated ways in which the user may utilize the available location information to augment their daily social and personal activities [1, 2], in particular when rendezvousing[1] with others [3, 4].

The potential for mobile location-aware applications are numerous, however providing users with effective ways to interact with position information on a handheld device remains a difficult design challenge. The small screen on handheld devices limits the amount of content that can be presented to users simultaneously and impoverished input capabilities may impede user interactions with a location-aware application.

The goal of this research is to identify facets of a location-aware map application that can be automated or semi-automated, thereby making effective use of the display space and reducing the amount of manual interaction required. In order to do so, we first need to determine what types of information people require while rendezvousing and how much detail they need during various points of the rendezvous process. In this paper, we present two complementary field studies. In study 1, we explored *what* users of a location-aware map application chose to view and the interactions they performed on the interface as they attempted to meet up with another person. Our observations and participant feedback

[1] A rendezvous is the social activity of people meeting at a given location and time.

emphasized the importance of maintaining a visual, on screen awareness of the user's location relative to that of their rendezvous partner and the rendezvous locations. Additionally, participants actively maintained their map view, continuously refining the map (using zoom and pan) as the proximity between their location, their partner's location and/or rendezvous location changed. In study 2, we used insights learned from study 1 to implement and evaluate an automated zoom and pan map feature called *autofocus*. Our evaluation of autofocus shows that automation is appropriate for a location-aware rendezvous application; however, the current implementation of autofocus did not fully meet the nuanced information and navigation needs of all our users. We identify and discuss unique instances *when* autofocus did not work as required by users and *why*.

2 Related work

2.1 Location sensing

Numerous technologies and systems support location sensing. The majority of these systems are based on Wi-Fi access points [5], GSM cellular towers [6], infrared [7], ultrasonic [8, 9] and GPS.

Infrared and ultrasonic positioning used in technologies such as Active Badge [7], the Bat [8] and the Cricket [9] benefit from accuracy but are not widely available. These technologies are handicapped by their cost and the infrastructure constraints needed to implement them. RF or wireless positioning used in systems such as Intel's Place Lab [5] and POLS [6, 10] are widely available to the public. The infrastructure to support these systems, Wi-Fi access points and GSM cellular towers, are ubiquitous and the infrastructure is already in place. Although less accurate than GPS, infrared, and ultrasonic positioning, RF positioning provides users with the benefit of relatively unconstrained boundaries. RF works both indoor and outdoor. However, the accuracy is highly dependant on the density of available access points [5, 6] and the environment. GPS is arguably the most accurate general-purpose location platform commonly used today. However, GPS suffers problems in metropolitan areas, 'Urban canyons' created between buildings can reduce GPS's accuracy, often making it unreliable.

2.2 Location disclosure

Location information can be sensitive and should be protected [11]; however, revealing one's location also can be useful in social situations [12]. Disclosing location involves a value tradeoff; protecting the user's privacy yet maintaining the usefulness of the information she discloses. There are a number of factors that need to be taken into consideration that influence a user's willingness to disclose her location. These factors include social and organizational context [13], the relationship and geographic distance between the *requester* and *sender* [14, 15] and what the *sender* perceives the *requester* needs [14]. Reilly et al. [16] explored information need from the perspective of the location requester. Their findings suggest that location need spans several contextual dimensions (e.g. location, relationship, activity and emotional state) that are highly intertwined and should not be considered in isolation.

2.3 Mobile adaptive maps

Mobile map services that use sensed location information provide users with an awareness of personal location [17] and the location of others [12]. Adaptive maps, as described by Reichenbacher [18] and Zipf [19], provide a fundamental shift from location based services to context based services. In addition to providing information relative the user's current position, mapping applications need to adapt to the context surrounding their use. Reichenbacher [18] provides a simple example of friends going to a bar in town. Although seemingly one task, it can be broken into smaller micro-tasks; choosing a bar, identifying the bar's location, finding your friends, and getting directions to the bar. Each micro-task may require a slightly different representation or view that the map application should support. Similar to the focus of this paper, Zipf [19] discusses the idea of 'focus maps', where important information is given focus, directing the user's attention. In our study, we identify the information of importance to users, and typical user behaviours such that we can better draw the users' attention to this information.

2.4 Visualizing position

When location-aware applications run on mobile devices with a small display, it can be difficult for users to discern the distance and relative position between several locations on a map, particularly if one or more of the locations are off the screen [1]. To better illustrate relative distance and position, visualization techniques have been used to augment the map [19–24].

Zoom-able user interfaces (ZUI), such as Google Maps [20] and ZoneZoom [21], allow users to focus on a specific map region by zooming the map in or out to gain more or less map detail. ZoneZoom [21] partitions the information space into regions, where each region corresponds to a key on the mobile device numeric keypad. By selecting a key, users specify a corresponding map region in which to zoom. Zooming techniques facilitate feature recognition [22] (e.g. buildings, roads) and allows users to refine their map view to gain greater detail.

Non-zooming user interface techniques such as fisheye views [23], Halo [24] and City Lights [25] provide an awareness of off-screen locations without having to zoom or pan the map. Fisheye views condense areas of non-interest by distorting the information space. This possibly could make it difficult for users to understand relative distances between items of interest. Halo and City Lights do not distort the information space. Visual cues are placed along the border of the display to provide an awareness of off-screen locations. Halo uses a partial ring where the position, circumference and arch of the ring convey the position and relative distance to off-screen locations. City lights does not give an indication of distance, but provides selectable cues that move the current view to that of the off-screen location. Irani et al. [26] developed a hybrid technique called *hop* that uses halos and proxies to provide an awareness of off-screen locations and select them.

3 Study 1: Observing information focus

Rendezvousing is an application space where location information has been shown to be useful [3]. However, little research has examined the design considerations for a rendezvous application and what information is needed to facilitate a rendezvous. Despite the numerous possibilities of what information *could* be provided to the users, we want to identify what *should* be provided and *how* to effectively present this information. In this section, we introduce our field study and report our observations with accompanying discussion.

3.1 Participants and setting

Twelve participants (five female) took part in our field study. All were daily computer users, but had varying experience with mobile devices and location-aware technologies (e.g. GPS). The majority rarely used a mobile device for anything other than placing phone calls and had never used location-aware technology. The study took place during the summer of 2005 on the Dalhousie University campus in Halifax, Nova Scotia, Canada. Participants were recruited from within the university community to ensure they all were familiar with the campus, because previous research [4, 27] has shown that the majority (65–78%) of rendezvous occur in familiar or previously visited locations.

3.2 Study design

The participants (individually) completed three artificial, yet typical rendezvous scenarios, which were specifically tailored to a university environment:

- *Scenario 1: meeting at a previously agreed location*. The premise for the first scenario was that the participant and a partner, earlier in the day, agreed to meet later in the day at a specific time and place. The participant was instructed that she should rendezvous with the partner and was provided with the rendezvous location by the experimenter.
- *Scenario 2: a spontaneous rendezvous*. The premise of the second scenario was that the participant and her partner agreed, earlier in the day, that they should meet. However, they did not specify a time and place. The participant was instructed that now she should locate and meet-up with her partner. For this scenario, the partner's location was constantly moving.
- *Scenario 3: rendezvous at a mistaken location*. The premise of the third scenario was that the participant and her partner had agreed to meet. However, the participant's partner, at the time of the rendezvous, proceeded to the wrong location.

Participants were given a location-aware map application developed in C# running on a HP IPAQ h4155 Pocket PC to assist them with their rendezvous. To ensure consistency between participants, we used a fellow researcher from our lab to play the role of the participants' partner. The partner's movement was scripted in order to reduce the high degree of variability possible in these scenarios. Participants were not informed that their partner was not a participant and that their movements were scripted.

3.3 Rendezvous software

The HP IPAQ h4155 Pocket PC used in this study ran a custom map application (see Fig. 1). The application displayed a colour map of Dalhousie University campus; the location of the participant, indicated by an orange circle; the location of the participant's partner, indicated by a green circle; and when a rendezvous location had been specified, the rendezvous is indicated by a red and white bulls-eye. Three levels of zoom were available: low, medium and high. The levels were accessible using the '+' (zoom-in) or '–' (zoom-out) widgets in the top right hand corner of the display (see Fig. 1). Participants could pan the map using a tap-and-drag technique.

Prior to the study, we recorded the location and movement of the scripted partner and stored this information in logs accessible by the map software. The scripted partner was given the same Pocket PC device as the one used by

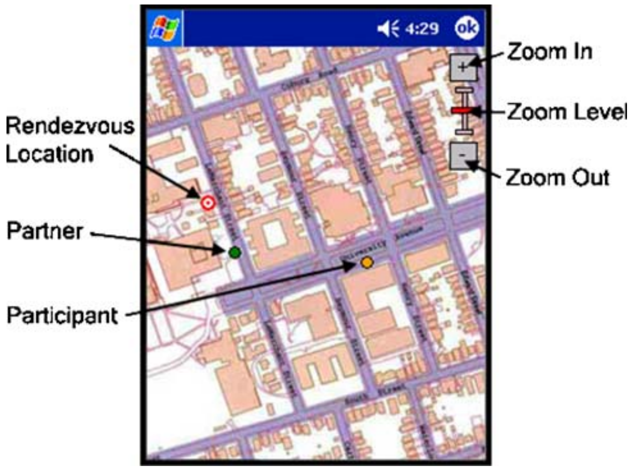

Fig. 1 The interface for the location-aware map application used in study 1

the participant to ensure she was in the correct position at all times. These steps ensured consistent conditions across all participants in the evaluation.

Rather than implementing a fully functional location-aware application and relying on a functional positioning technology (e.g. GPS or PlaceLab), we employed a wizard-of-oz technique to provide the participants location information. We modified the technique developed in an earlier study by Dearman et al. [3] to use a single wizard; two wizards were not required because the partner's movements were scripted. Our wizard followed the participant, along with the experimenter, updating the participant's movement via a Pocket PC wirelessly connected using Bluetooth to the participants handheld.

3.4 Procedures, data collection and analysis

To begin, we required each participant to fill out a background questionnaire, following which, we debriefed her about the nature of the study and the type of tasks they would be required to complete. We informed the participant that she would be performing three different rendezvous scenarios, where for each scenario, she would have to meet up with a partner. We then introduced the participant to her partner (our colleague) who then proceeded to his starting location for the first scenario. We then gave the participant an introduction to the mobile device and the location-aware map application. We explained the application's features and interface in detail. After the introduction, we instructed the participant to explore the application and its interface until she felt comfortable with what the application presented to her and how to interact with it. At the start each scenario, we read a script outlining the scenario's motivation and then asked the participant to proceed with the rendezvous. At the beginning of each scenario the application defaulted to the highest level of zoom with the participant's location centered in the screen. After each scenario, we conducted a post-scenario semi-structured interview. When the participant completed all three scenarios, we conducted a concluding semi-structured interview.

The map application kept data logs of all the participant's interactions with the application. Post-study, we harvested the log file for each participant and created a step-by-step visual reconstruction of the participant's mobile device screen. This data allowed us to identify both map interactions (i.e. transition between detail levels and screen positioning) and what information the user chose to have displayed on the screen (i.e. their personal position, the partner's position, or the rendezvous location). Post-session interviews provided a qualitative perspective of the participant's map usage and perceptions across scenarios. We analysed the transcripts from all interviews and used them to justify specific actions and trends observed in the data logs.

3.5 Results

Although each participant's experience was unique, numerous trends were observed within and between scenarios. In this section we report on the trends observed for each scenario, followed by a discussion of the overall trends across scenarios.

*Scenario 1: Meeting at a previously agreed location***.** In this scenario participants were instructed to meet up with their partner at a specified rendezvous location. Two participants chose not to use the map application for this scenario. They were familiar with the rendezvous location and did not need the application.

All participants who did use the application (ten in total) started the scenario by initially panning or zooming the map so that the location of their partner or the rendezvous was visible. Following this, the majority of participants (eight) maintained an almost continual awareness of all three available locations: theirs, the partner's and the rendezvous. Six of these participants always had the three locations visible. The other two zoomed-in briefly to gain greater map detail around the location of their partner and the rendezvous; then they proceeded to immediately zoom back out, resuming their previous view. As the proximity between the participants and the rendezvous location decreased, six zoomed in to gain region specific details, but did so while ensuring all three locations were still visible. Two others maintained a consistent zoomed-out view for the entire scenario.

Of the remaining two participants, one initially chose a detailed view showing the location of his partner and the rendezvous. The other chose what is best described as a 'sliding view'. He zoomed the map to the highest level of detail, focusing on the region he would eventually navigate into. When his personal location marker would become visible in the region of focus, he would progressively pan the map in the direction he was heading. Only his personal location marker was visible and even still, the marker was only visible for a brief moment before he would pan the map. Partway through the scenario, both participants abandoned their initial view and zoomed-out the map such that all three locations were visible. As they approached the rendezvous location, both used the zoom feature to gain greater map detail, but maintained the visibility of all three locations.

Scenario 2: A spontaneous rendezvous. In this scenario, participants were asked to find and meet their partner, but no specific rendezvous location given at the start of the task. All participants (12) used the application to initially find the location of their partner. Most participants (11) maintained an almost continual visual awareness of their location and that of their partner. Eight of these participants always had their personal and partner's location in view. The other three zoomed in briefly to gain greater detail around their personal location, in addition to the location of their partner, then immediately zoomed back out to resume their previous view. In addition, as the proximity between the participants and their partner decreased, 6 participants used the zoom feature to access greater map detail, but did so while ensuring both locations remained visible. Five others maintained a consistent zoomed-out view for the remainder of the scenario.

The remaining participant, after initially zooming out on the map to find the location of his partner, zoomed back in to gain map detail surrounding his personal location. He briefly maintained this view as he walked in the direction of his partner, eventually panning the map such that both locations became visible. He maintained this view for the remainder of the scenario.

*Scenario 3: Mistaken location***.** In this scenario, participants were asked to rendezvous with their partner at a provided location; however, their partner goes to the wrong location. Five participants chose not to go to the rendezvous location, but proceeded directly to the location of their partner. Half the participants (six) initially used the map to find the location of their partner. These participants maintained an almost continual visual awareness of all three locations: their personal location, the partner's location and the rendezvous. Four of these participants always viewed the three locations, while the other two zoomed-in briefly on their personal location and the rendezvous. The same two participants who zoomed-in, proceeded to then either zoom-out, or pan the map to view the location of their partner. The other six participants (five of which went to the location of their partner and did not manipulate the map) had their personal location and the location of the rendezvous initially visible. All (six) either zoomed or panned the map in search of the location of their partner. Five of the participants, as they progressed towards their partner, positioned the map to ensure they could view their personal location and that of their partner. As the proximity between the participants and their partner decreased, half of the participants (six) used the zoom feature to gain greater map detail while maintaining the previously visible locations.

3.6 Discussion of usage

Participant usage suggests the importance of the relationship between their personal location, the location of their partner, and the location of the rendezvous. Additionally, we observed a consistent trend of continual manual refinement of the visible map detail as the proximity between the participant, their partner and the rendezvous decreased. It is evident from this study that there are many different ways to use both a location-aware map application and the application specific features (zoom and pan). In this section, we discuss our findings.

Maintain relative awareness. Regardless of the scenario, the participants' usage of the application and comments in the interviews clearly demonstrated that maintaining a relative awareness of the participants personal location relative to location of their partner and/or rendezvous is important. In all instances when the map application was used (34 of 36 scenarios), participants initially sought out the location of their partner and/or the rendezvous. In most instances (27 of 34 scenarios) participants accessed this information by initially zooming out; zooming out provided a map view where all location could be viewed at once. However, the zooming out perspective provided limited map detail, but it allowed participants to easily ascertain the location of their partner and/or the rendezvous relative to their personal location. This information was particularly important at the start of a scenario because it allowed each participant to determine how she should proceed. One participant commented:

> (P11) "I just kept it zoomed out … I liked knowing where I was in relation to where he was."

When participants made their first movement towards their intended goal (depending on the scenario this was either their partner or rendezvous), most (29 of 34 scenarios) choose to have all relevant locations visible on the display. Many (22 of 34 scenarios) continuously maintained this view, ensuring all relevant locations were visible throughout the entire scenario; however, there were several instances when participants zoomed into the map. Interviews revealed three main reasons why participants zoomed into the map (see Table 1 for quotes): (a) to see gain map

Table 1 Quotes from participants justifying their choice to zoom into the map for study 1

	Participant quotes
A	"I just wanted to zoom in to see if I could see a shortcut to my partner."
B	" … I zoomed in to get a street reference, to pinpoint where I was. Then I zoomed back out to figure out [again] where he was …"
C	" … to see which direction I am heading … [zoomed out] if I just stand there it does not indicate much about where I am heading … I need to move a long distance to see [where I am heading] … I will [zoom in] when I confuse my direction."

detail; (b) to see their personal location relative to a specific objects in the environment; and (c) to help determine direction and orientation. Participants zoomed into the map to access information that could help facilitate their navigation, thereby ensuring they could make informed navigation decisions. A zoom-in action was often followed by an immediate zoom-out. None of the participants used the application to solely focus on their personal location or the location of their partner or rendezvous for an extended period of time. One participant commented:

> (P10) "… you get more information from it being zoomed out … because you can reference things better … than when you are zoomed in."

Our observations suggest that the need for detailed information is not the primary focus, but a supplemental action to help facilitate successful navigation. The need for detailed map detail was momentary, not continual and was less important than the need for the 'bigger' picture; maintaining a visual awareness of their personal location relative to that of their partner and rendezvous.

Continuously refining the map. Given the importance of maintaining a visual awareness of the participants personal location relative to that of their partner and rendezvous, it is obvious that participants would spend a great deal of time with the map zoomed-out. However, as the proximity between the participants and their goal (whether it is their partner or the rendezvous) decreased, we would expect that having a more detailed view would be beneficial, particularly if all of the relevant locations were still visible. The results for our study show that the majority of participants (6–8 depending on the scenario) actively refined the map as they progressed through the scenario, zooming into the map to gain greater region specific detail. Several participants commented:

> (P12) "… as soon as I figured out where he was, I zoomed in enough so that both of us were visible on the map …and then at that point just kept zooming as I got closer to him."

There were 2–6 participants in each scenario that did not continue to refine the map. Further probing into why they did not continuously refine the map revealed that: (a) their familiarity with the area was sufficient such that they did not need the map to help them navigate, but simply to show the relative position of their partner or rendezvous relative to their own location; (b) the simplicity of the scenarios; and (c) the overhead involved to manually pan and zoom the map.

4 Study 2: Autofocus field study

Based on the results of study 1, presented in the previous section, we developed a simple automated zoom and pan feature for our location-aware map application called *autofocus*. Our intent with autofocus is to design an automation process that will perform the majority of the user's typical interactions as observed in study 1. Through automation we can reduce the number of interactions required by users to access the information they require to rendezvous successfully. Additionally, we wanted to identify aspects of the automation process that were problematic, not properly designed to suit the participants' information needs. Study 1 showed us that although there is a similar thread that interconnects the majority of users' behaviors, unique trends and individual behaviours are evident. In addition to evaluating the appropriateness of autofocus for a rendezvous application, we used autofocus as a tool to help us identify subtle, non-obvious user interactions and information needs. The results of this second study can inform a well-rounded, robust and intelligent automation for the future. This section describes autofocus and our field study.

4.1 Autofocus

Autofocus is a simple automated pan and zoom feature for our map based location-aware application that maintains the on screen visibility of *focus locations.* We define a focus location as a point of interest that can be defined by the application's user. For our location-aware application, we specifically defined these points to be the location of: the participant; their partner; and the rendezvous. Users are able to directly turn the focus of a location on and off by selecting a location's on-screen visualization (see Fig. 2a, b). Any number of locations can be selected at a given time; including none.

Once a location is selected as a focus location, autofocus will ensure that the location is always visible on the map in

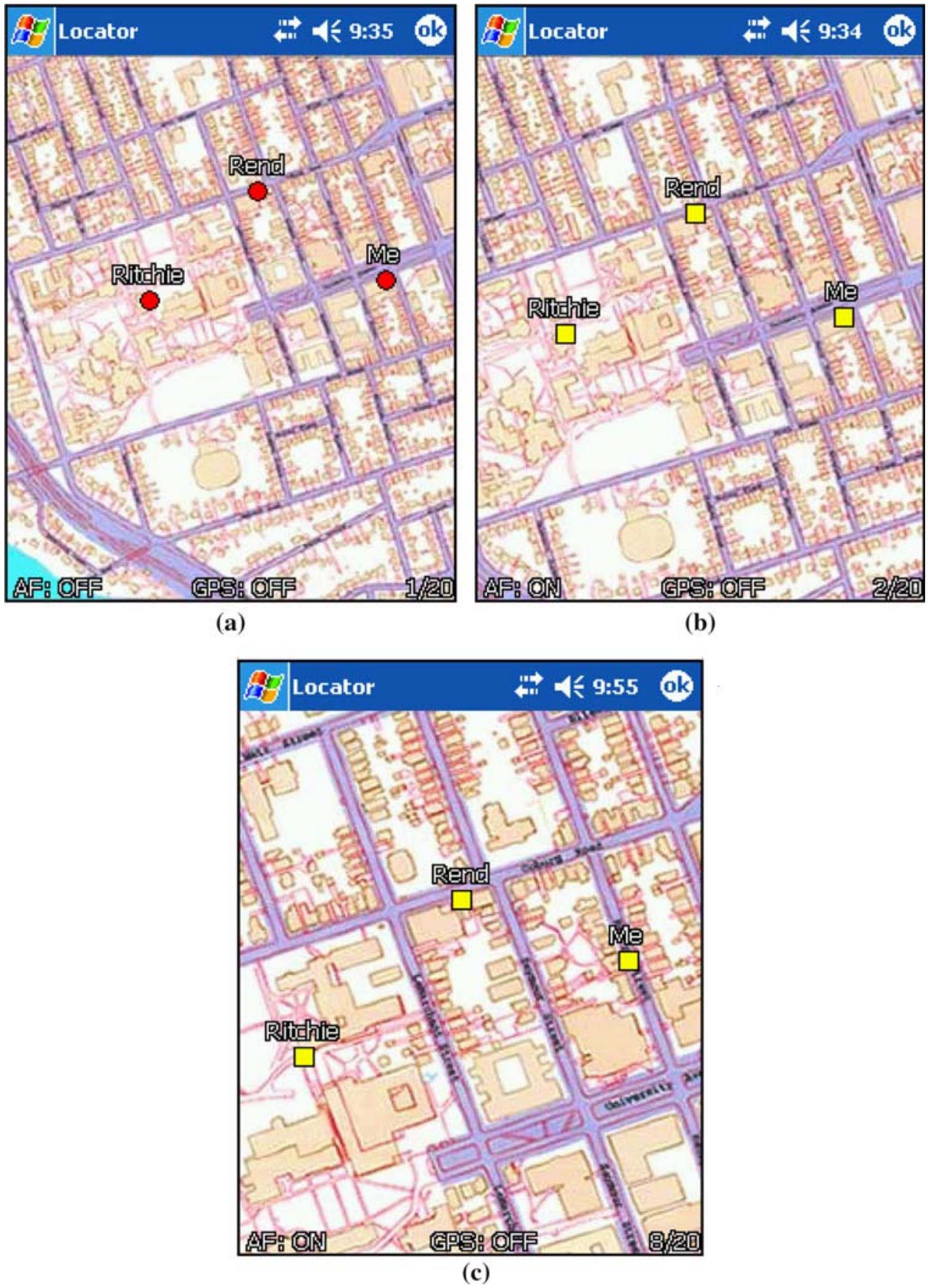

Fig. 2 The location-aware map application used in study 2 (autofocus). In **a** the participant ('Me'), their partner ('Ritchie') and the rendezvous ('Rend') are initially not selected as focus locations. The participant selects all three locations (**b**) as focus locations. As the proximity between the 3 locations change (**c**), autofocus zooms and pans the map appropriately

the display. In the case of one focus location, the map will be positioned such that the location is centered in the screen. In the case of multiple focus locations, the map will be positioned such that all the locations are visible on the map in the display at an appropriate zoom level, ensuring a buffer between the locations and the screens' edge. Ensuring locations are not on the very edge of the display will ensure users can easily view the map details surrounding the location. When the position of a focus location changes, such as when the proximity between a participant and the rendezvous decreases or increases, autofocus will refine the map view, panning and zooming respectively. For example, in Fig. 2, the participant ('Me') has selected (via directly touching the location markers on the display) that her location, the location of her partner ('Ritchie') and the rendezvous ('Rend') are focus locations. The small squares bellow the location nametag (Fig. 2b) indicates that the location is now a focus location. As the participant and their partner progress closer to the rendezvous, the distance between them will decrease. Autofocus will identify that the distance between the focus locations is changing and will actively refine the map view by zooming and panning the map (Fig. 2b, c). At all times, autofocus will ensure that the map is positioned and at the appropriate zoom level such that all the focus locations are visible; in this example that means the location of the participant, their partner and the rendezvous.

The hardware (HP IPAQ h4155 Pocket PC) and software for the autofocus study is identical to that used in the observation study (see Study 1). We modified the map application to integrate the functionality of autofocus. Additionally, we refined the zoom interaction of our application based on the offline comments of study 1 participants. Participants indicated that the on screen zoom widgets were difficult to select while moving. To address this concern, we replaced the screen widgets with the respective up and down functionality of the HP IPAQ's hardware directional pad. Additionally, we replaced our wizard-of-oz technique for positioning participants with a Bluetooth GPS.

4.2 Autofocus study design

Our investigation of autofocus involved two experimental conditions: *mandatory* and *choice*.

- *Mandatory condition.* In this condition, we required participants to use the map application with autofocus active at all times. Even with autofocus active, participants were instructed that they could still pan and zoom the map manually when needed. When a pan or zoom was registered by the application, autofocus would become inactive for sort period of time (5 s). We did this to ensure participants would not be continuously fighting the automation when they needed to perform a manual pan or zoom. After 5 s of inactivity, autofocus would resume, repositioning the map to its previous view. We recorded all manual interaction with the application in this condition to identify instances of information need that autofocus could not accommodate.
- *Choice condition.* In this condition, we gave participants the option to toggle autofocus on and off during the experiment. They were not required to use it as in the mandatory condition. Additionally, we provided participants in this condition with training on the day prior to the study. This training day served two purposes: (1) it expose participants to autofocus and the application features to reduce the novelty effect; and (2) it gave participants significant exposure to autofocus so that they could make an informed decision when given the choice to use it or not. On the training day, we required participants to complete six rendezvous scenarios, three with autofocus on and three with autofocus off. No questionnaires were given and no data was collected.

Participants for both conditions completed four rendezvous scenarios, in the same order. The rendezvous scenarios (as in study 1) were specifically tailored to a university environment: (scenario 1 and 2) meeting at a previously agreed location; and (scenario 3 and 4) at a spontaneous rendezvous. The scenarios were adapted from the similar scenarios in study 1. We again scripted the movement of the participant's partner and used a research assistant to reduce variability between participants.

4.3 Participants and setting

Twenty-one participants took part in study 2. Twelve completed the mandatory condition (6 male and 6 female) and 9 completed the choice condition (5 male and 4 female). All were daily computer users, with varying mobile device experience. The study took place during the winter of 2006, on the Dalhousie University campus. Again, participants were recruited from the active university community to ensure they were familiar with the environment.

4.4 Procedure, data collection and analysis

Participants in the choice condition completed training on the day prior to the study. We introduced them to the software and autofocus. Then, as previously mentioned we required participants to complete six rendezvous scenarios, three with autofocus on and three without autofocus. No questionnaires were given.

On the day of the study, the procedure for participants in both conditions was exactly the same. To start, we required the participants to complete a background questionnaire. We then briefed them about the nature of the study and the type of tasks they would be required to complete. Participants were informed they would be performing four different rendezvous scenarios where they would have to meet up with a partner. The participant was then introduced to their partner (the scripted assistant) who then proceeded to his starting location for the first scenario. As in study 1, participants were not instructed that their partner was a research assistant, but were led to believe he was another participant.

We then gave the participants an introduction to the mobile device, the location-aware map application and autofocus. We asked them to explore the application until they were comfortable with autofocus and the application's features. We informed participants in the mandatory condition that for each scenario autofocus would remain on continually. Participants in the choice condition were given the option to start with autofocus on or off and explained that they could turn it on or off during the study as they pleased. To start each scenario, we read a script to the participant explaining the rendezvous scenario. We then gave them the application and asked them to proceed. After each scenario, a post-scenario semi-structured interview was conducted. We conducted a concluding semi-structured interview after each participant completed all 4 scenarios.

Similar to study 1, the map application kept data logs of each participant's interactions with the application. Post-study, we harvested the log file for each participant and created a step-by-step visual reconstruction of the participant's mobile device screen. This data allowed us to identify both map interactions (i.e. transition between detail levels and screen positioning) and what information the participant chose to have displayed on the screen (i.e. their personal location, the partner's location or the rendezvous location). Post-session interviews provided a qualitative perspective of the participant's map usage and perceptions across scenarios. We analysed the transcripts from all interviews and used them to justify specific actions and trends observed in the data logs.

5 Results

Perceived usefulness of autofocus. In the post session questionnaires, we asked participants to rate the usefulness of automating the zoom, pan, and location visibility features of autofocus on a 5 point Likert scale. Participants (11/12) in the mandatory condition strongly agreed that having the application automatically zoom and pan was useful ($M = 4.92$, SD = 0.29). Additionally, the participants in the mandatory condition (10/12) strongly agreed that it was useful to have the application maintain the on screen visibility of their location and the location of their partner and rendezvous ($M = 4.83$, SD = 0.39). Participants (8/9) in the choice condition strongly agreed that having the application automatically zoom and pan was useful ($M = 4.78$, SD = 0.67). Additionally, all of the participants in the choice condition (9/9) either agreed or strongly agreed that it was useful to have the application maintain the on screen visibility of their location and the location of their partner and rendezvous ($M = 4.55$, SD = 0.53). One participant (P2) found the automation process undesirable and chose not to use autofocus.

Zoom and pan interactions. It is important to note that even though participants perceived autofocus as useful, there were numerous instances when participants manually interacted with the map. The number of interactions and the type of interaction (e.g. zoom-in/out and panning) varied across all four scenarios.

Mandatory condition: As shown in Fig. 3, the majority of participants (10/12) exhibited additional pan or zoom interactions ($M = 17.0$, SD = 32.71). The number of interactions varied significantly based on gender, with females performing significantly more interactions ($M = 52.0$, SD = 31.6) than their male counterparts ($M = 9.8$, SD = 16.9), $t(7) = -2.88$, $p < 0.05$).

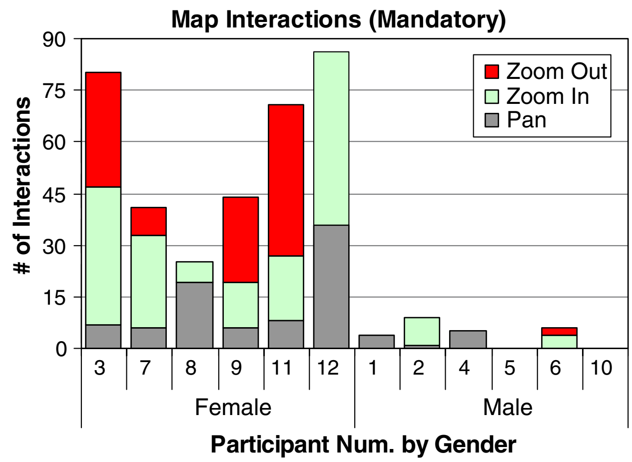

Fig. 3 The total number of interactions and the type of interaction performed by each participant in the mandatory condition (separated by gender) for study 2 (autofocus)

Choice condition: All of the participants (except P2) relied on autofocus; usage varied between 85 and 99% of the scenario completion time. Even when relying on autofocus, all participants (9/9) exhibited additional pan or zoom interactions ($M = 23.0$, SD = 59.8), see Fig. 4. Participant P6 was atypical, exhibiting interactions more than four times the standard deviation above the mean. As a result, this participant's interactions were removed as an outlier in the interaction analysis. The number of interactions varied by gender but not significantly ($t(6) = -1.54$, $p = 0.174$) We note again that prior to starting the first scenario, choice condition participants were given the option to start the map application with autofocus on or off.

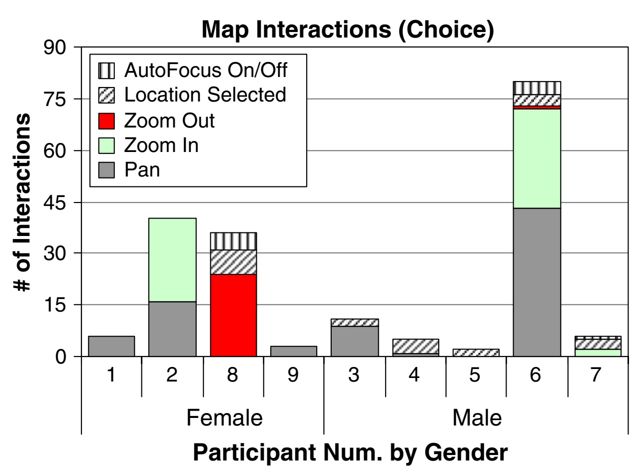

Fig. 4 The total number of interactions and the type of interaction performed by each participant in the choice condition (separated by gender) for study 2 (autofocus)

Given the training day, we believe participants had enough experience with autofocus to make an informed choice. Two thirds of the participants (6/9) chose to start the first scenario with autofocus on. Two chose to start the first scenario with autofocus off but turned it on almost immediately at the start of the first scenario. The majority of participants (8/9) used autofocus when given the choice and continued to use it almost constantly throughout all 4 scenarios.

5.1 Discussion of usage

Participants' usage of autofocus and their questionnaire feedback unsurprisingly confirm that automation was perceived as useful given the observations from study 1. However, even with the automation, participants still exhibited a large number of manual zoom and pan interactions. This is evidence that although useful, autofocus did not always support the participants' information need. Automating the zoom and pan map functionality for a rendezvous application is more dynamic and nuanced than originally envisioned. In this section, we discuss our findings.

Usefulness. The majority of participants (19/21) indicated that autofocus was useful during their rendezvous. As expected, participants commented that autofocus reduced their need to interact with the device. The automation process was particularly useful considering their partner's location was constantly changing:

> (P3-A) "Given that she was moving and not static [autofocus] was very helpful to be able to track her down."

The usefulness of autofocus was confirmed not only by the positive questionnaire responses but also by the majority of participants in the choice condition who chose to start with autofocus active (6/9) or who turned it on almost immediately after selecting their focus locations (2/9). The 8 participants who turned autofocus on left it on almost constantly during the entire study session.

Customizing the focus. The majority of participants in the choice condition, who used autofocus, set the location of themself, their partner and the rendezvous (if applicable for the scenario) as focus locations. However, we observed instances where four participants chose a subset of the available locations. In scenario 1 and 2, two of the participants turned the focus on their partner's location off. As a result, autofocus ignored the partner and focused the map on their personal location and the rendezvous; instantly providing the participant with a more detailed view of the map region between their personal location and the rendezvous. In scenario 3 and 4, a participant removed focus from his location. As a result, autofocus ignored the participant's location, centering the display on the location of their partner and zoomed the map to the highest level of detail. This provided the participant with a detailed map view of the location around their partner that follows their partner as she moves. Similarly, 1 participant at the start of scenario 2 used autofocus as a quick and efficient way to zoom the map to the highest level of detail on the location of their partner; removing focus from their personal location and the rendezvous, leaving only the location of their partner with focus. Responding to this change, autofocus zoomed the map to the highest level of detail, centering the location of their partner in the display. The need for detail was only temporary, and the participant changed their focus back to its pervious state, returning focus on their personal location and the rendezvous. These participants leveraged the focus feature of autofocus to perform a lengthy sequence of zoom and pan interaction immediately, using 1 or 2 interactions and maintained this view with no further interactions.

Interacting with the autofocus. Participants in both the mandatory and choice conditions interacted with the device on numerous occasion while autofocus was active. The interactions were not frequent, but they were purposeful. At times, autofocus did not perform as the participant needed or did not provide the information they required. In these instances, participants would zoom or pan the map, in an attempt to gather additional information as to better understand the map and the locations within the information space. The automation process, seemingly an obvious implementation to some, did not fully address the individual needs of the participants. It is these needs that we discuss and highlight in this section.

At the start of a scenario, the distance between the participants, their partner, and rendezvous (if applicable) is large. As a result, autofocus would position the map at a zoom level, such that all the initial focus locations were visible. However, when zoomed out, it was difficult to discern finer map details such as street names; the distinguishing features on buildings; pedestrian paths; and the ally-ways that define the physical separation between buildings. Participants commented that they sometimes needed to interact with the application to briefly zoom in to the map to read a street name, locate a path or identify a building and then allowed autofocus to resume:

> (P2-A) "I [zoomed in] at first to see street name, but found it was easier to just let the system auto-update."

One participant commented that while the map was zoomed out, it was difficult for him to infer the direction he was heading. This is because (1) our location markers were designed to be direction neutral and (2) a small amount of movement while zoomed out translated into an indistinguishable change in the location marker on the display. Only while zoomed into the map were small movements noticeable.

> (P4-A) "[I zoomed] at the beginning to judge my direction."

As a scenario progressed successfully, the distance between the participants, their partner and the rendezvous point (if applicable) decreased. Autofocus would then pan and zoom the map, increasing the zoom level appropriately. When the zoom level increased, greater region specific details became available. However, as the zoom level of a region between focus locations increased, the outside area around a focus location became increasingly constrained. Buildings and streets that were once visible were cut off with each successive zooms. One participant commented that there was a landmark she used to orient herself that was no longer visible because of the automatic zoom and pan. As a result, she would periodically pan the map to view the landmark to help her reorient.

> (P1-C) "[I] didn't have proper bearings at first. I always use [an easily identifiable landmark on campus] as my 'home base'. So I panned to find it, then went from there."

Similarly, participants expressed the need to pan and zoom the map to better understand the structures and buildings surrounding their personal location, the location of their partner or the rendezvous point. Through zoom and pan, the full outline of a once visible building would become cut-off by the edge of the display space. It was difficult for some people to identify a building that was not labeled without being able to view the full outline of the building.

> (P8-A) "[I panned the map] just a couple of times to get a better idea of the buildings my partner was near."

Participants also found that while zoomed into the map, autofocus limited their ability to look ahead. If they wanted to see the name of the street they were approaching or were parallel to, they would have to pan or zoom out to view it.

> (P1-A) "Had to pan a few times because the triangulation of the three points [personal, partner and rendezvous] cropped off the road I was following."

One of the participants did not use autofocus for the entire session. However, she did manually pan (6 instances) and zoom (24 instances) the map. She indicated that the focus feature was too restrictive and that she wanted to maintain a zoom level much less than what autofocus was providing. For her, the automation process did not address her needs, and she found it easier to perform the tasks herself.

> (P2-C) "[Autofocus] didn't always show me what I wanted and I felt more secure doing it myself."

Her refusal to use autofocus highlights the fact that simple variables such as the buffer distance between a location and the edge of the display was important enough to render the automation unusable. Without fully understanding the influences of these variables even the most sophisticated automation can be useless in the mind of a user.

5.2 Gender difference in the number of interactions

Although examination of gender differences was not a focus of this paper, research has shown that men and women exhibit different navigation strategies [28, 29]. We found a significant gender difference for the number of interactions in the mandatory condition. We also observed a similar (non-significant) trend in the choice condition. Further investigation with an appropriate sample size is required to validate these results. We suspect that the difference in the number of interactions exhibited by women and men may be related to the sexual dimorphism in topographic and navigation strategies [28, 29]. Sandstrom et al. [29] found that when navigating a virtual environment female performance was significantly affected when landmark cues were unreliable, whereas male performance was not affected. Dabbs et al. [28] report similar findings, indicating females rely significantly on landmarks for their navigation strategies. Participant comments generally suggested that the reason for zoom and pan interactions was an attempt to better understand the relationship between their location and their partner's location with the environment. As commented previously, the act of zooming would frequently cut off buildings or streets that were previously visible. As a result, implementation details such as the buffer between the focus locations and the screen border may significantly impact the usefulness of map automation for women. Additional research is required to further investigate this issue.

5.3 Design considerations for future automation

It is evident from our results that our implemented automation, autofocus, is useful, but that the automation process is not as naïve as we originally conceived given the results of study 1. Study 2 highlighted the fact that navigational aids and personalization are significant considerations for the automation process.

Consider the environment. The automation process needs to not only take into consideration the location of the user and their partner(s), but it also needs to consider the environment itself. Our results show that distinguishing features such as landmarks, buildings and streets are important to users. An application should identify the outline of buildings and street intersections that straddle the edge of the screen and position the map such that the buildings and intersections are completely visible on the display. Additionally, the direction and orientation of a user is important for providing the ability to "look ahead". An application can exploit a user's orientation and direction to position the map such that a larger region ahead of the user is displayed. In doing so, the user can gain a greater understanding of the region they are progressing towards. If the user's location is too close to the edge of the screen, they will not have the appropriate information to make future navigation decisions.

The ability to define unique landmarks. Users should be able to define unique landmarks that help them navigate. Users as a whole may be generally familiar with an environment, but an individual users' familiarity with particular features and buildings within the environment will vary. Users should be able to define landmarks based on their experience and familiarity with the environment. In doing so, we will be able to better address a broader range of navigation strategies.

Visualize off-screen locations and landmarks. Landmarks and other personal static location are important to our mapping of the physical and virtual worlds. Research by Sandstrom et al. [29] and Dabbs et al. [28] have shown this to be particularly true for females. Additionally, given a larger, more realistic scenario, it is possible that more than two people are trying to rendezvous. In such a case, it may be that everyone is of interest, but only the closest person is of particular focus. If a location of interest (i.e. a landmark) lies within the map boundary defined by a user's focus locations, then we can simply highlight the location to enhance its visibility. However, the problem lies in how to provide a visual awareness of location outside the map boundary defined by a user's focus locations. If we define these as focus locations, we could lose the benefit of the automated pan and zoom as the user's proximity between focus locations change. Rather, these locations should not be presented on screen, but augmented with a visualization to provide the user with an awareness of the location. Techniques such as Halos [24] or City lights [25] could be used to provide off-screen awareness and could be modified with excentric labeling [30] to identify the location. We believe that using such a technique will facilitate the purpose of landmarks for navigation (and other interesting locations), but not limit the usability of any automation technique.

6 Conclusion and future work

It is evident from the participants' usage of autofocus and their comments that automation is useful, but that our implementation did not facilitate all their information needs. Our implementation of autofocus was intentionally simple; it maintained the visibility of locations of interest by manipulating the zoom level and position of the map based on the locations' relative proximity to one another. Autofocus' simplicity allowed us to identify many unique instances of information need. Specifically, automation must support how users navigate and the map based information they require to successfully navigate.

Our results suggest that the visibility of key landmarks can help facilitate navigations. Prominent landmarks could be flagged by the system, or users could define custom landmarks as focus locations. Additionally, we need to consider the importance of landmarks, buildings and structures surrounding our focus area because of their importance for how we navigate. Rather than positioning the map such that a structure is only partially visible on the screen, the automation could identify the outline of the structure and position the map so it is completely visible. Our findings will benefit future location-aware map applications, influencing the design of more robust, clever automations to facilitate rendezvousing.

In future work, we plan to study the validity of our proposed improvements to insure they appropriately address the needs of users. In addition, it is often the case that rendezvous' occur with more than one person; thus, it is important that we consider how to address a greater number of participants.

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