CozyMaps: Real-time Collaboration on a Shared Map with Multiple Displays

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ABSTRACT
With the use of several tablet devices and a shared large display, CozyMaps is a multi-display system that supports real-time collocated collaboration on a shared map. This paper builds on existing works and introduces rich user interactions by proposing awareness, notification, and view sharing techniques, to enable seamless information sharing and integration in map-based applications. Based on our exploratory study, we demonstrated that participants are satisfied with these new proposed interactions. We found that view sharing techniques should be location-focused rather than user-focused. Our results provide implications for the design of interactive techniques in collaborative multi-display map systems.

Author Keywords
Collaboration; Share large display; Multi-touch tablets, Viewport; Overview+Detail; Workspace awareness

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces—evaluation/methodology, input devices and strategies, interaction styles.

INTRODUCTION
Effective collaboration has become increasingly important for map-based information sharing and decision-making; especially in multiple displays environments such as in meeting rooms, or in living rooms, where tablets, laptops and large displays are commonly used. Map-based application is one of the most popular applications in our daily life. The effectiveness and benefits of using more than one display for collaborating and sharing of location-based information, such as geographic data analysis, have already been confirmed [9]. Other applications sharing similar interaction requirements and characteristics, such as managing disaster recovery, or search and rescue operations planning, may also benefit. Information can be shared on the geographical map where commanders can get an overview of the whole situation, while controllers can look into the specific area of interest. Planned routes and activities can be visualized and combined with real-time data provided from the field.

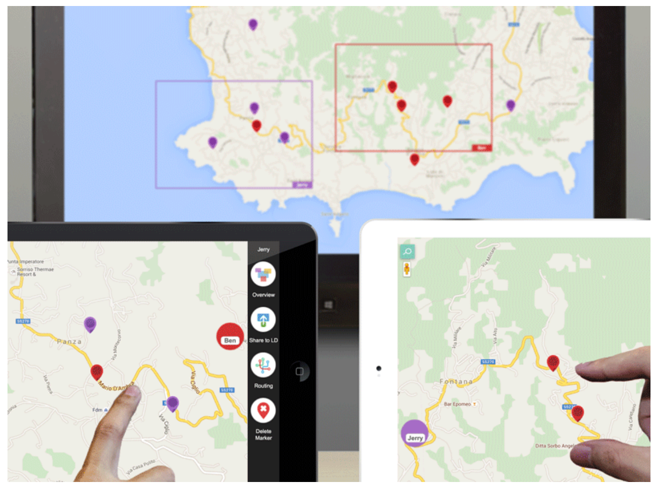

Figure 1. A shared large display showing an overview of a shared map, and tablet views from two users.

In these scenarios, supporting and enhancing real-time information sharing and integration of information between the whole team is a key factor to success [3, 4]. However, existing map-based systems are not primarily designed for these collaborative tasks in multiple display settings. In this paper, by utilizing existing works on workspace awareness [7] and viewport navigation on large displays [2], we propose CozyMaps, a multi-display collaborative map environment with several tablet devices and a shared large display. We design and implement new user interactions for *tablet-tablet* and *tablet-large display* interactions.

Interactions are designed to provide awareness, notification, and view sharing capabilities to the users. We conducted an exploratory study to gauge users' initial reaction from using CozyMaps. Results demonstrated that participants were satisfied with using the system for a collaborative task. We also found that when designing view sharing features for map-based applications, one should consider the need to focus on information being shared (e.g. a location) rather than on the collaborators' viewports, in order to facilitate shared information exploration and integration. Findings from our exploratory study can lead to improving the design of collaborative multi-display map systems.

RELATED WORKS

Existing map-based applications are designed for solo work and thus making teamwork for exploring maps a tedious and expensive process [7]. A significant body of related works and studies [2, 6, 8, 9] have focused on collaborative map exploration, where visual output is distributed across displays. A simple solution may involve multiple users working together with their private displays on a shared map resource, such as online maps. To enhance these map-based search tasks, Ens et al. [6] explored how multiple co-located mobile phones work collaboratively in a map-based application. Their results highlighted the importance of workspace awareness, such as who's who in a work environment, physical and social cues. Rashid et al. [8] investigated how different configurations of input and output across displays affect performance, and found that a mobile device-controlled large display configuration performs best in the map-based search task.

CozyMaps' multi-display configuration comprises of tablet devices and a large shared display, in order to support real-time collocated collaboration with a shared map. To our knowledge, there are few similar works sharing the same goal as CozyMaps. Projector phone [9] is a working prototype of mobile phones with integrated pico projectors, but it lacks enough interactions among phones and large display. VisPorter [3] is a complicated visual analytics system using the multiple display and device configuration. However, the interactions that VisPorter provides are inadequate to facilitate map-based search tasks. The question of how we can enrich user interactions in order to provide awareness, notification and view sharing techniques for map-based applications still remain unsolved.

COZYMAPS SYSTEM

CozyMaps is an interactive map-based system that runs on web browsers. The configuration of CozyMaps is akin to a tree hierarchy with a shared large display as root, and several personal tablets as nodes. The large display serves as the overview, while the tablets serve as exploration and communication tool for the users. They are able to perform both independent and dependent tasks on the tablets while sharing data through the shared large display. All actions are synchronized in real time on all displays. An overview of the CozyMaps system is shown in Figure 1.

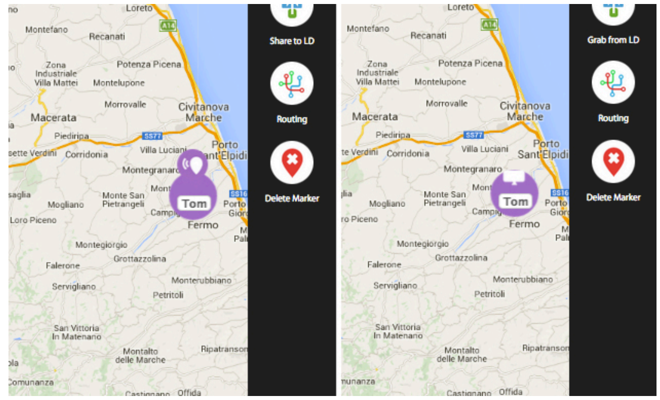

Figure 2. The circle located on the edge of the tablet represents the direction of Tom relative to the current user (towards the right). The maker broadcast icon above the circle represents a maker sharing notification from Tom (left). The screen icon means Tom is sharing his view to the large display (right).

To provide a conducive collaborative environment, we set the following design goals for our system:

- Enable seamless map-based information sharing and integration on a single shared map;
- Enable spatial and activity awareness;
- Enable improved communication through view sharing and notifications.

Design rationales are as follows: awareness of other member's spatial position as well as their behaviors allows better performance in collaborative activities [7]; data sharing enables users to easily share individual information and results; the real-time and seamless information transition among workspaces is a key factor to group brainstorming and decision-making. Combining all of the above, our system will be able to facilitate the process of real-time collaborative map-based tasks. We proposed two groups of interaction techniques based on these rationales.

Tablet-Tablet Interaction

Group members can access the map and all location-based information through web browsers on their tablets. CozyMaps maintains basic manipulations on map-based tasks such as panning, zooming, pin markers, and routing.

Spatial Awareness: An outer rectangular frame, with a name label at the corner, is created for each user to represent his "*viewport"* (the area of the map that they are currently viewing on their device). Two viewports can be seen on the large display in figure 1. Each viewport is assigned a different color to represent each individual. All viewports are visible on all other tablets so that all users are aware of each other's view and position on the map. Users' touch points are also transmitted to everyone. In order to provide location awareness of collaborators even when their viewports do not intersect with the current user's view, we designed and proposed the use of "*head circles*" - small circles that resides at the edge of the individual's tablet view. The head circles are drawn using the corresponding colors and name labels of the collaborators. When two users' views move away from each other with no overlap, the head circles are automatically generated along the edges of the map view. They are positioned in real-time to indicate the relative position of other users on the map (figure 2).

Activity Awareness: When a user manipulates her markers (add, edit, and delete) on her map view, others can also see these markers being updated on their own map view in real-time. User's can notify other users of a particular marker by long pressing on it. This will make the marker bounce on the spot for a few seconds and others can see an icon notification with the same bouncing animation (figure 2-left). The animation indicates that the user is trying to notify everyone else about one of her markers. By simply tapping on the head circle (with the animated notification), others can change their view to that of the notifying user.

View sharing and following: When user A taps on user B's head circle, A will be brought to the same view as B. We call this the "*preview*" mode. At this time, a new option will appear on the toolbar to allow user A to follow user B's view. In this "*following*" mode, the follower (A) can see everything that B can see, but A has no control over the content in that view, but has two other options: 1) return back to her original view; 2) stop following and investigate the new location.

Collaborative routing: In addition, each member is able to easily create routes by tapping markers in sequence. A route is created when two markers are tapped one after another. The routes are visualized with the corresponding user's color and rendered on all members' tablets in real-time.

Tablet-Large Display Interaction

Overview+Detail is an information visualization technique for viewing large workspaces, where an overview and a detailed view are displayed simultaneously in separate presentation spaces [5]. In our system, besides using tablets to execute individual tasks on a detailed view, group members can also contribute and share information to the shared large display and follow the entire collaboration session from an overview perspective.

Overview Awareness: As a shared space, the large display presents an overview. Group members' viewports are presented as colored rectangles on the map. Their touch points and markers are also reflected. To ensure activity awareness, the large display also shows animated markers as well, when activated to jump. Compared to the limited space on the tablets, the large display provides a more convenient way for collaboration, especially effective for collaborative routing since group members can work on routing strategies from an overview perspective.

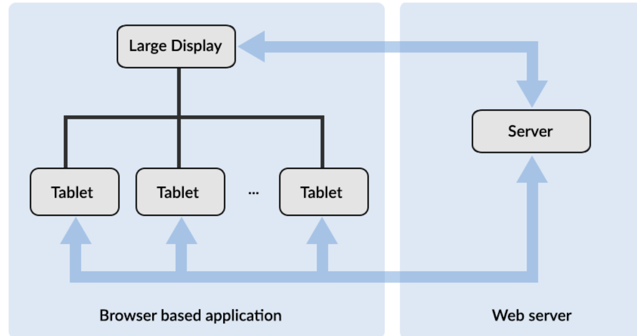

Figure 3. System diagram of our implementation.

Smart Overview: In addition to visualizing basic results and information of each group member on the large display, the overview will resize its bounds automatically based on all members' positions on the map. The system recalculates its view by traversing all members' locations and their view sizes, and then seamlessly performs panning and transition between zoom levels on the map, so that all members' viewport are always visible.

Share to Large Display: In order to support group discussion in such a collaborative environment, at any time, users are free to share their view to the shared large display. The large display's view will then have exactly the same view as the user who shared it. At the same time, a "*sharing notification*" will appear on everyone's tablet, on the head circle of user who shared it (figure 2-right). At this point, users can just look up at the shared large display to see what is being shared. Alternatively, they can easily tap the head circle with the notification, and preview the same view on their own tablet. The view sharer can withdraw sharing her view at any time.

Implementation

CozyMaps is implemented as a browser base application, making it device-agnostic. The system is built on node.js, socket.io, and Google Maps API. On the tablets (clients), a web browser is used to connect to our web server. Similarly, the view on the large display is driven by another web browser, with a specialized view that is different to the clients. The clients capture touch events or button press events and, together with viewport location, they are all pushed to the server. The server keeps track of all user view positions and states, and processes all events such as changes in the views, touch activities, or notifications. The results are then broadcasted back to the client devices that need to receive the particular update in real-time, as well as the large display. The client devices display the updates where necessary. The map tiles are fetched separately by each individual browser directly from the map provider.

EXPLORATORY STUDY

We conducted an exploratory study to gauge the initial reaction from users using our system. We investigated the usefulness, strengths and weaknesses of our system in a

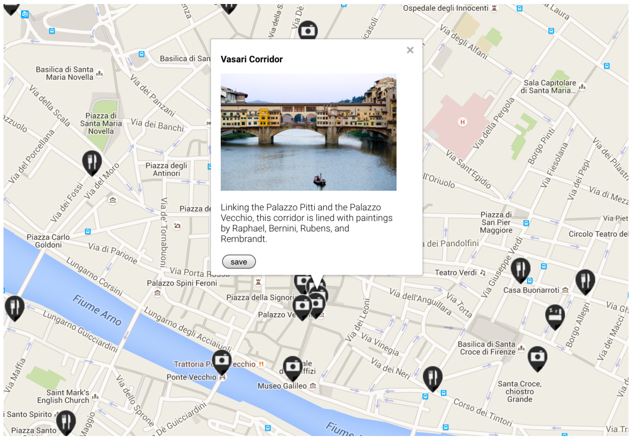

Figure 4. Pre-populated markers showing attractions, restaurants, and hotels information, photos and ratings.

map-based trip-planning task. Trip planning is a common task where people discuss among the group and make collaborative decisions on the shared map. Based on the previous work by Ashikaga et al. [1] who only considered bookmarking on maps, our study also focuses on the routing process in a trip planning task. Collaborative route planning involves discovering places of interests (POIs), pin or add markers, sharing their discovery, gathering information, and finally create an agreed route, which requires intense collaboration and communication. The route creation process is also a collaborative task in itself since multiple users can contribute different segments of the route.

Twelve volunteers (4 female) ranging from 19-43 years old (26.8 average) from our organization participated in the study. Seven had technical background, while the others did not. In groups of three, they were asked to plan a 2 day 1 night trip to the city of Milan, Italy. To complete the task, the group had to discuss among themselves the trip details, and were asked to produce a route linking all the attractions, hotels, and restaurants that they would like to visit during their trip. We measured the number of interactions for each of our features and the duration that they spent in each mode. They also completed a post-study questionnaire that captured the usefulness of the features, ease of learning, and satisfaction ratings in 7-point Likert scales, as well as other open-ended questions.

Apparatus and procedure

Using three Apple tablet devices at a resolution of 2048 × 1536 pixels, and a 65” TV at 1920 × 1080 pixels. Each tablet devices and the TV were using Chrome browsers connected to our own server, which was running from a laptop.

In the same room, groups of three volunteers were initially given a 30-minute tutorial of the system, and practiced the various features and modes that the system provides, using another city. At pre-determined cities on the map, pre-

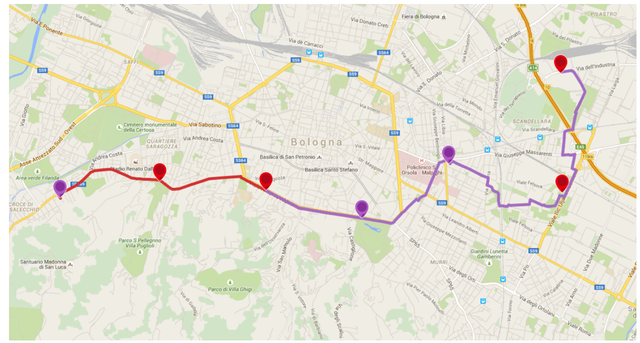

Figure 5. Participants completed the task by collaboratively creating a route.

defined markers were created to represent different attractions, hotels and restaurants. They were also pre-populated with photos, text descriptions, and ratings (figure 4). This frees them from the need to search outside of our app for places of interest. We pre-defined 20 attractions, 15 restaurants, and 10 hotels in Milan. In the experimental task, participants were asked to plan a trip and produce a final route itinerary within 45 minutes (figure 5).

FINDINGS AND DISCUSSIONS

From the 7-point Likert scale in our post-study questionnaire, participants found CozyMaps to be useful (mean of 5.3 out of 7). Most of them agreed that CozyMaps was fun to use (5.3/7), and helps them be more effective (5.1/7).

The mean usefulness ratings of each feature by participants are shown in figure 6. The features that had the highest usefulness ratings were creating marker sharing notifications (6.3/7) and receiving marker notifications (6.2/7). Users seemed more interested in sharing something that they have found interesting, rather than constantly knowing what others are seeing at any given time. That is, there are more interest in marker sharing activities compared to view sharing activities. This is further categorized by a comment from user 11 that “*I was too concentrated on finding relevant materials and not concerned about other members’ exploration*”. Collaborative route planning was rated highly as well (6.2 out of 7), while users spent 12.8% of the time doing that (figure 7), and received positive feedback overall.

Upon further investigation, we recorded a total of 216 marker sharing notifications, however, only 15 times when users actually switched to preview other users view. This may be attributed to the fact that when one user’s view was intersecting with another’s view, they could see the notified markers directly or they preferred to do simple panning themselves (rather than using the preview feature). Participants tended to stay in their own view where they are exploring, rather than dramatically switching to others’ view. One possible reason behind this phenomenon is that switching views could lead to increased cognitive load and frequent switching is a tedious process. In addition, users

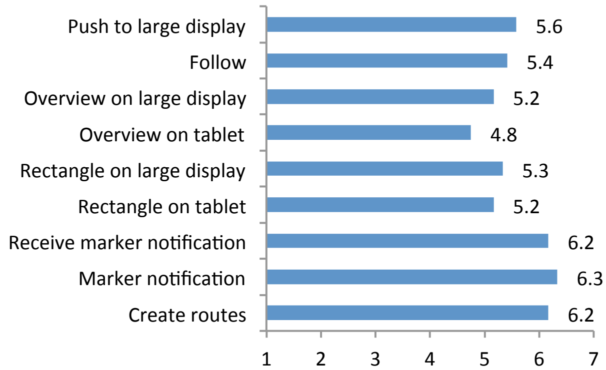

Figure 6. Mean ratings from a 7-point Likert scale questionnaire. It asked whether users agree with the usefulness of the various features. (1-strongly disagree to 7-strongly agree.)

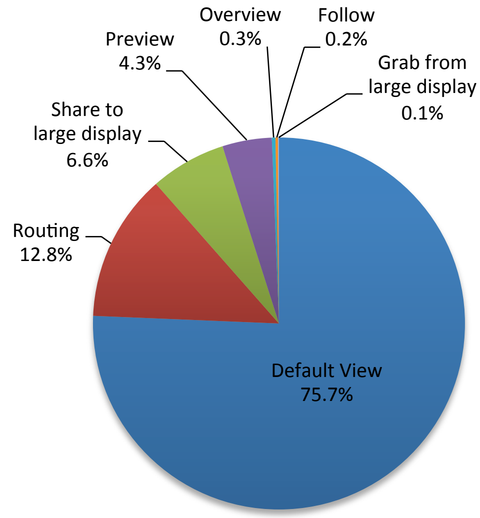

Figure 7. Mean percentage of time in each mode for all users.

may be more interested in where the notified markers are, and consider these markers in the context of their own exploration, rather than switching to other users' view directly, where they might be disoriented momentarily.

One inference that we may draw from this is that spatial and activity awareness should serve more for expanding and enriching the user's exploration and to help understand others' findings in relation to the user. Rather than previewing another user's view, the preview feature should allow users to preview the marker location, and perhaps in relation to the user's current location. When designing the preview feature for map-based search applications, one should also consider the distance among viewports. When viewports are close enough, smooth transition along the path from one viewport to the other may be easier to follow, rather than direct switching. In addition, to reduce cognitive load, sharing to large display may be a more effective alternative than asking other members to preview.

Figure 7 shows the mean usage percentages of each mode for all users. As can be seen, the mode that participants used most is the default mode, which is the detailed view.

Participants tended to explore on their own tablets displays and regard the large display as an overview. The spatial and activity awareness enables users to focus on exploration and reduces the number of view switching, which can be a cognition-consuming process. As expected, the usefulness of the large display came from the ability for it to show information on the users' periphery. By default it shows users an overview, which reduces the need for users to switch to overview on their tablet device. Therefore, the usage percentages for switching to overview is only 0.3% (4 out of the 12 users used it only once). In addition, people found the overview on large display to be more useful (5.2/7) as compared to overview on the tablet device (4.8/7). Related to this was that there were 16 occurrences of sharing to the large display, but only 2 occurrences of reciprocal pulling from the large display. This result gave us more evidences that the large display is more for displaying information, rather than regarded as another active workspace. It may be worth investigating additional information that could be presented on such displays.

Finally, three users found their views on the tablet to be "too cluttered." Together with the previous insight where views should be more location-focused rather than user-focused, it may be worth investigating if the rectangle representations of viewports are worth keeping on all tablet displays (leaving them on the large display).

Summary

In summary, from our exploratory study, we found interesting insights for the design of collaborative map-based interface on multi-displays:

- Users have a tendency to share more than they receive
- View sharing techniques should be designed carefully to avoid big jumps and reduce cognitive load
- View sharing techniques should focus more on the location of the shared object rather than the location of the user that is sharing
- The large display is more for displaying information and overview, rather than regarded as another active workspace
- Viewport representation should be carefully designed to avoid visual overload on the tablet

CONCLUSION

CozyMaps has shown many attributes that support collaboration through spatial and activities awareness, view sharing, and notification techniques on a shared map in a multi-display setting. It expands on previous work by utilizing a plurality of features that occur across a multitude of varied devices. Through our exploratory study, we found spatial and activity awareness should be designed to serve for expanding and enriching individual exploration in map-based applications. Previewing may be designed carefully to avoid the effect of interference. Awareness tools such as rectangular viewports representation may cause clutter on tablets, but may be useful to be shown on a large display at the peripheral. These hypotheses will need to be investigated further to ascertain their true effect in more controlled experiments.

ACKNOWLEDGEMENT

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