Users' quest for an optimized representation of a multi-device space

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ABSTRACT

A plethora of reaching techniques, intended for moving objects between locations distant to the user, have recently been proposed and tested. One of the most promising techniques is the Radar View. Up till now, the focus has been mostly on how a user can interact efficiently with a given radar map, not on how these maps are created and maintained. It is for instance unclear whether or not users would appreciate the possibility of adapting such radar maps to particular tasks and personal preferences. In this paper we address this question by means of a prolonged user study with the Sketch Radar prototype. The study demonstrates that users do indeed modify the default maps in order to improve interactions for particular tasks. It also provides insights into how and why the default physical map is modified.

Categories and Subject Descriptors

H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous.

General Terms

Design, Human Factors, Performance.

Keywords

Interaction techniques, map, spatial, reaching, large-display systems, multi-display systems.

1. INTRODUCTION

Thanks to the rapidly reducing cost of display and network technologies, situations in which many different devices with heterogeneous display sizes interact together are becoming commonplace. Often these environments present a mixture of personal devices such as Personal Digital Assistants (PDAs), tablet and laptop PCs, and shared devices such as large displays. In a device-cluttered space, such as the one shown in Figure 1 (left), the tasks of identifying a particular device and facilitating the transfer of objects from one device to another, also referred to as multi-device (display) reaching, becomes frequent. Therefore, alternative techniques for performing such interactions have lately received a fair share of attention.

A number of interaction techniques have been developed that aim at intuitive and efficient reaching between different devices. The recent study by Nacenta et al. [7] suggests that Radar View might be a very efficient technique for multi-device reaching. Map-based techniques such as Radar View [7] have the potential to support intuitive system identification and interaction without necessarily requiring physical proximity to the system they interact with (although they might profit from it). The success of map-based techniques relies on being able to associate a physical device with its representation on the map. In this paper, we report on a user study that explores whether or not users appreciate the possibility of adapting such radar maps to particular tasks and personal preferences. Or, in other words, if users are given freedom to modify the Radar View representation, will they strive to optimize this representation? If so, which criteria do they use to motivate changes?

The study was done using the Sketch Radar prototype [1]. With it, a user is able to control how and what information is presented on the map at any time. The users are free to adjust the map to make it fit better to a particular task or to their preference. We strived for a natural setting where people would be engaged in an activity over an extended period of time. We also wanted our participants to focus on the activity supported by the tool rather than on the interface with the tool itself. Therefore, we created a user study in the form of a game.

2. RELATED WORK

The Radar technique uses a reduced representation (a map) of the surrounding environment. When the pen touches an object, such as a file, the map appears. The user can place the object at a desired location by moving the pen to that target location. Radar View is hence similar to the World in Miniature [9], but in two dimensions. Users do not need to physically move to access a remote system, but the required precision of their actions increases when more devices need to be represented within a radar map of fixed size and resolution.

A recent study [7] has experimentally compared several multi-display reaching techniques. Radar View was found to be faster than the other techniques and was also subjectively preferred. The success of map-based techniques such as Radar View [7] relies on being able to associate a physical device with its representation on the map. Or in other words Radar Views support Stimulus-Response Compatibility (SRC). SRC was introduced in 1953 by Fitts et al [6]. It was shown that the speed and accuracy of responding is dependent on how compatible stimuli and response are. Duncan [5] has studied spatial SRC and found that when spatially distributed stimuli (lights) and responses (buttons) have a compatible arrangement subjects were able to respond faster than when the arrangement was incompatible. However the effect of SRC is unclear when more complex tasks need to be solved. It was also shown that the spatial organization of displays allows efficient access to them, in the sense that it outperforms existing tree- or list-based approaches (such as File explorer or Favorites in Internet explorer) [8].

The only known example of a system that uses the radar metaphor and that addresses how physical devices can be arranged on a map is ARIS [3, 4]. ARIS uses an iconic map of a space as part of an interface for performing application relocation and input redirection. The differences with the Sketch Radar technique that was used in this experiment are the following. First, Sketch Radar aims at supporting a different task, i.e. placing and retrieving files, not relocating applications. Second, Sketch Radar is not limited to devices that have screens, but can include other devices such as printers. Third, because Sketch Radar does not necessarily rely on a physical layout, such as the devices in a single room, it allows combining distant devices in a single map. The nature of the tasks and spaces in ARIS implies that the flexibility in map layout offered by Sketch Radar is not required.

3. User study

A preliminary pilot study showed that some users adjust the default physical map when told that they will be required to repeat prescribed tasks. The goal of this study was to determine whether such behavior is also observed in a natural setting where people are engaged in an activity over an extended period of time. In order to make our users focus on the activity supported by the tool rather than on the interface or the tool itself, the setting for the user study consisted of a game.

Our main research question can be formulated as follows:
Given the freedom to modify the Radar View representation in real time, will users strive to optimize this representation? If so, which criteria will be used to motivate changes (nature of the task, prior knowledge of the environment, spatial location, etc.)?

Ultimately the study would also allow answering the second question:
How much and in which way does the nature of the task performed in a multi-device environment affect the map representation, if at all?

In order to improve validity of the study and reduce the effect of different playing strategies that participants might employ during the game, the study was divided into two parts. The first part consisted of several controlled sessions in which participants performed preset tasks. The second part was an unconstrained gaming situation.

3.1 Game and task description

Feeding Boris is a tamagochi-like game and was inspired by the Feeding Youshi game presented in [2]. The main goal of the game was to feed a virtual cat called Boris. Boris is continuously traveling between different computers to find a "safe" hiding place. Depending on the players' actions Boris becomes hungry or unhappy, which in turn determines his most likely hiding place.

The computers that play a part in the game are not directly

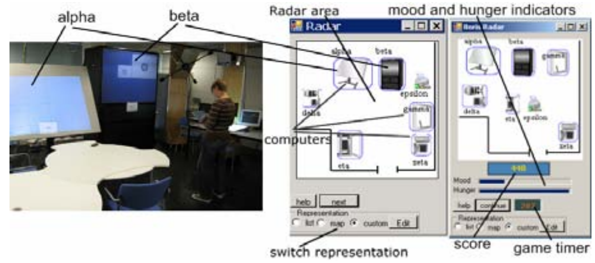

Figure 1. Environment used in the "Feeding the cat" experiment (left), Sketch Radar main window with the room plan (center) and Sketch Radar in game mode (right).

accessible, they only provide visual information (i.e., only the displayed output of the computers is available). For example the player can find out where the cat is by either exploring computers one-level-at-a-time through Boris Radar or by physically moving around to check the screens of the computers. However, to feed the cat the player needs to use Boris Radar.

A TabletPC with the Sketch Radar prototype (Figure 1) software was used to access and explore the different computers, to gather food and to feed Boris. Additionally, using the Sketch Radar editing capabilities users were able to control how and what information was presented on the map during the experiment.

In order to examine the effect of the specific task both Boris's movements and the meal locations were non-random. For example, Boris would only hide on 3 of the 10 computers, and specific kinds of food would only appear on specific computers. During the first part of the study participants were receiving different hints (for example "Boris usually hides on computers with large screens." or "Boris has found a new hiding place in computer Theta."

The test started in a single room which contained multiple devices that the participant needed to interact with: two PCs with their displays switched on (Zeta and Delta), one PC with the display switched off (Eta), one tabletop display (Gamma), one printer (Epsilon) and two wall displays (Alpha and Beta) (Figure 1). All devices were clearly labeled with their respective names. During the course of the study two new rooms were introduced, each room contained a single PC with a display (Theta and Kappa).

The experiment was conducted with 7 participants (2 females and 5 males) between the ages of 23 and 35. All participants had previous experience with graphical user interfaces, but not with Sketch Radar. The environment where the study took place was familiar to all participants. The participants were tested individually. The experiment consisted of three parts: tutorial, controlled sessions, and free form game.

In the first part participants performed multiple training tasks with the Sketch Radar application on the TabletPC, following a map building tutorial. The duration of this first part varied across participants from 30-60 minutes.

The second part lasted for three days and included one 20-40 minute session per day. On the first day participants received the TabletPC with a preloaded physical map of the first room. All systems were presented equally on the map (in terms of geometrical size) in a position that closely corresponded to their actual physical position within the room. The participants were also positioned inside the same room. Their task consisted of feeding the cat with specific food. During the experiment two more rooms with one computer in each were introduced.

The third part of the experiment was the actual game. It also lasted for three days (with 15-30 minutes playing sessions every day). Users started from the maps and knowledge that they had acquired from the second part of the experiment. Users were free to choose where they wanted to be physically, but all of them chose to play the game from within the first room (which contained most of the systems). The goal of the game was to acquire as many points as possible by feeding Boris, in a given time. Participants were aware of the fact that the one who collected the maximum score would get a prize.

3.2 Results

The evaluation showed that users indeed changed the layout of the map to make it more suitable for the particular task that they needed to perform. Most of the participants (5/7) only adjusted the map before and after test sessions, but not during the session itself. By the end of the experiment all participants had created their own representation, only 2 participants used the preset physical map during the first part of the experiment, but changed it after the first game session. All other participants switched to their own representation after the first session of the first part.

There are some more specific observations that were made during the experiment:

1) Physical location provides strong external cues, while custom-made representations which are often based on internal cues that might be forgotten or changed, need repetitive usage to be remembered. Between sessions some participants (3/7) had forgotten about acquired patterns of cat and food behavior. Therefore their own representation created during a previous session did not make sense to them anymore, and even caused confusion.

2) In the post interview where participants were asked to describe computers that shared the same task-related property, the description usually relied on properties provided in the game hints (6), names (3), look (2) or/and location on the map (2). For example if the provided hint stated that “Boris is hiding on computers with large displays”, the most common answer on the question: “Where does Boris usually hide?”, would be “Large computers Alpha, Beta, and Gamma”.

3) If to the known group of computers (for example “Large computers where Boris hides”) a new computer is added (“This is a new computer Boris also can hide here”), even without giving it any specific properties, it will acquire the properties of the group. So first time it will be referred as a “new one”, and after that it will usually be referred together with the rest of the group so “Large computers Alpha, Beta, Gamma, and Theta [new computer]”. This new computer Theta that is actually physically small is placed in the group of “large computers” which no longer corresponds to the physical size but more to the fact that Boris can be found on them. Therefore “large computers” evolves from being a property of the computer to becoming a label. This was observed with 4 out of 7 participants.

5) When placed in a separate room, where participants could not see the screens of the devices, only one participant moved from a physical to a purely task-oriented map. Others commented that if from the beginning they would not be able to see devices and content of their screens it might be quite possible that they would adjust the map more drastically.

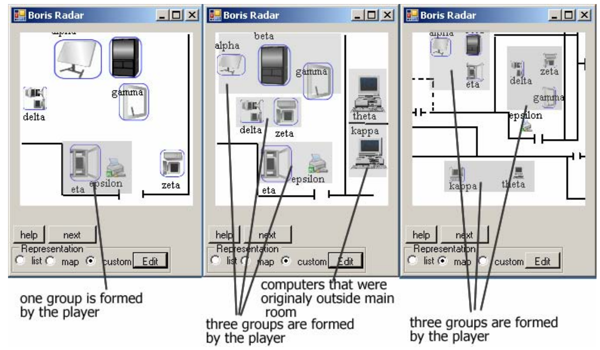

Figure 2. Different levels of modification. The map is moderately distorted, with one user-defined group (computers that have only one hiding place and one type of food) (left); the map is strongly distorted with fouruser-defined groups (center); the custom map is completely distorted (right).

6) Four common steps in the evolution of custom-made maps could be identified:

1. The physical maps are only slightly distorted. The icons that represent those devices are slightly resized and repositioned to make movements shorter. No specific grouping is made. (5/7)
2. The map is moderately distorted (Figure 2). Some grouping is made. For example, computers where food appears more often are grouped together. However participants try to maintain as much as possible a correspondence to physical location. (5/7)
3. The map is strongly distorted (Figure 2). Only the computers that have screens and that are located in the first room retain a position that correlates strongly with the actual physical location. Computers that do not have screens are positioned freely based on different properties. Computers that were originally outside of the first room were positioned freely, although still kept outside of the room boundaries. (6/7)
4. The map is completely distorted (Figure 2). Computers are grouped based on certain properties, no correspondence with physical location. However some order-based spatial relationships between computers are retained (such as this computer is to the left, right or in front of that computer). (4/7)

7) During the experiment, all devices with screens were constantly displaying information about their status. The same information was available through the SketchRadar, but in order to obtain this information, participants needed to go through several steps. We observed that during the game participants very often instead of exploring the device representation on the TabletPC were first checking the content of surrounding displays, locating the cat or needed type of food and only then accessed the food or cat through the TabletPC. They would only start to look for the cat through the TabletPC if it was not visible on any of the screens. We believe that is why most of the participants did change the map but also tried to partly keep some references to the physical location of devices.

The speed with which this transformation occurred varied between participants (Figure 3). Some participants skipped steps in between. Two participants immediately after the first session created custom-made representations that were moderately distorted. One participant moved back to the physical map used it for two consequent sessions and then jumped to the strongly distorted representation (Level 3).

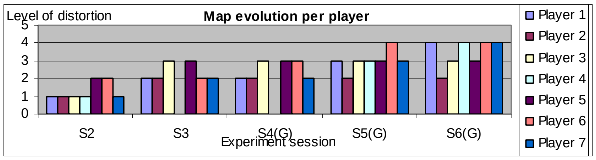

Figure 3. Level of map distortion on every session, for every player (during first session all players used the physical map).

8) While creating their own representation participants only adjusted location (7/7) and size (6/7). Other features of the Map Builder, such as sketching or adding text, were not used. Several participants commented that they were thinking of adding some labels, but none of them actually did.

9) Participants usually grouped computers based on the kind of food they provide, the amount of clicks needed to reach a specific kind of food (7/7), how often the computers are visited by Boris (6/7), if the computers have a screen or not (7/7), and if the computer is located inside or outside of the room (7/7).

10) In addition to grouping, some participants reduced the distances between computers to improve movement time, and some changed (usually increased) the size of computers to more efficiently use empty space.

Figure 3 illustrates how the map evolved during the course of the experiment. After the first 4 sessions, 3 out of the 7 participants reached a stable representation that they no longer modified. The post questionnaire revealed that the main reason for avoiding additional changes was that these users felt they had already experienced the representation extensively, and that any change to this established representation could cause confusion and therefore reduce performance in the game.

Based on these results we can formulate an answer to the first research question. During prolonged usage of a modifiable Radar View representation, users do strive to optimize the representation based on the task and personal preferences. The nature of the task is the main criterion for motivating the change; other less important criteria are the location of devices, the amount of available space, the visibility of devices, and the type of devices.

It's however still unclear if the new representation is more efficient than a physical location-based representation. It also remains difficult to derive how exactly and why tasks affected the change. The study also did not address mobility which is an important aspect that might influence the perception of the map and behavior of users, especially if the representation of the environment does not anymore match physical locations. Different approaches might be used to solve this issue, for example, the mobile device can be represented on the map as another static device, or the system can automatically position the device based on its distances from other devices represented on the map (for example, the mobile device can be shown next to the static device that is currently closest).

3.3 Design guidelines

Based on the results of the study we can formulate the following guidelines for building reaching interaction techniques that use a map-like representation:

- If the number of computers is small and they all have observable screens and interaction occurs only inside the represented area, a simple physical mapping such as the iconic map in ARIS system [4] is the best representation.
- If the interaction occurs outside of an environment, even in case when the environment is known to the users, it is wise to use a representation that allows better task-oriented interaction. However the mapping should be very clear to the users so they can easily remember it.
- In mixed environments a tool that allows some adjustments of the map has been proven to be useful.
- In situations where available space is limited, the exact spatial locations of devices can be sacrificed in favor of looser, order-based, relations.

4. Conclusions

One of the most promising reaching techniques is Radar View. We performed a user study that explored whether or not users appreciate the possibility of adapting radar maps to particular tasks and personal preferences and if so, which criteria are used to motivate these changes. A modified version of the Sketch Radar prototype, which provides an easy and quick way to manage maps of available devices, was used in the experiment.

The study confirmed that users indeed modify the map for different reasons, namely to more clearly represent the type or visibility of individual computers, and to clarify task-related relationships between computers. Since no explicit performance measures were gathered within the experiment, it remains undecided whether or not user-defined representations are more efficient than representations that agree closely with physical locations.

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