Usage of Spatial Information for Selection of Co-located Devices

Roswitha Gostner, Enrico Rukzio, Hans Gellersen
Computing Department, Lancaster University, UK
{gostner, rukzio, hwg}@comp.lancs.ac.uk

ABSTRACT

Use of spatial information to support discovery of interaction opportunities has been widely demonstrated. In this paper, we focus on the use of spatial interfaces for identification and selection of devices a mobile user encounters in their immediate environment. We contribute an experimental evaluation of two spatial interface conditions in comparison with a non-spatial condition. The two spatial interface conditions are a device list ordered by distance and an iconic map of devices as seen from the user's perspective and the non-spatial condition is an alphabetical list. Our results show an overall user preference for the iconic map over the spatial and alphabetical list. However, there was no clear preference for the spatial interfaces over the non-spatial condition with respect to user satisfaction and mental load.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interface – *Graphical User Interface*. H.1.2 [**Models and Principles**]: User/Machine Systems – *Human Factors.*

General Terms

Design, Human Factors.

Keywords

Spatial reference, mobile devices, location information

1. INTRODUCTION

Among the core challenges in mobile computing is support for spontaneous interaction. The principal idea is to enable mobile users to associate their personal devices with devices encountered in their environment, in order to take advantage of serendipitous interaction opportunities [6]. Archetypal examples include use of a printer in an unknown environment, access to shared facilities in meeting rooms, and data exchange between mobile users.

Discovery mechanisms over wireless networks allow mobile devices to become aware of other devices available for interaction. However devices found on the network will be identified in network terms: a name and address geared toward their unique identification and localisation in the network as opposed to in the real world. For a mobile user it is not straightforward to match network names with reality. The problem, from the user's perspective, is how to identify and select a target device for interaction: if, through their mobile device, they find a device on the network, how can they identify it in the real world? And vice versa, if they physically encounter a device, how can they identify it to their device.

Use of spatial information has been widely considered for identification of devices and interaction opportunities in mobile and ubiquitous computing, from pioneering work on context-aware computing [8] to more recent work on models for proximity-based interaction [7]. It is generally held that the addition of basic geometric knowledge can greatly increase the shared understanding between user and system [2]. For example, Kortuem et al. have demonstrated how spatial references integrated in the mobile user interface can streamline access to other devices in co-located settings [4].

In this paper we contribute an experimental evaluation of the use of spatial information for selection of devices. The target scenario we investigate is interaction with co-located devices that a user encounters in their immediate environment, such as infrastructure devices and devices of other users they might encounter. Our study considers two different spatial user interfaces in comparison with an alphabetically sorted list of device names. The first of our spatial interfaces is a spatial list in which device names are sorted by distance, as common for instance in Bluetooth discovery. The second one is an iconic map visualising available devices in a world-in-miniature view, as proposed in related work on supporting spontaneous interaction in interactive spaces [1, 4].

2. EXPERIMENT

The aim of the experiment was to investigate whether spatial information provides added value to users when they search and select nearby devices. Previous work has highlighted the utility of spatial information for selection specifically when device names are not easily available, or ambiguous [4]. However in order to facilitate comparison of spatial interfaces with a non-spatial condition, we chose an experimental design in which all devices were labelled with their name.

We implemented two different types of spatial user interface: a spatial list (where items are listed according to the relative distance from the user, with closest on top) and an iconic map (an abstract map with basic information about the orientation and distance relative from the user). For comparison, we implemented an alphabetically sorted list as a non-spatial condition.

MobileHCI 2008, September 2–5, 2008, Amsterdam, the Netherlands.

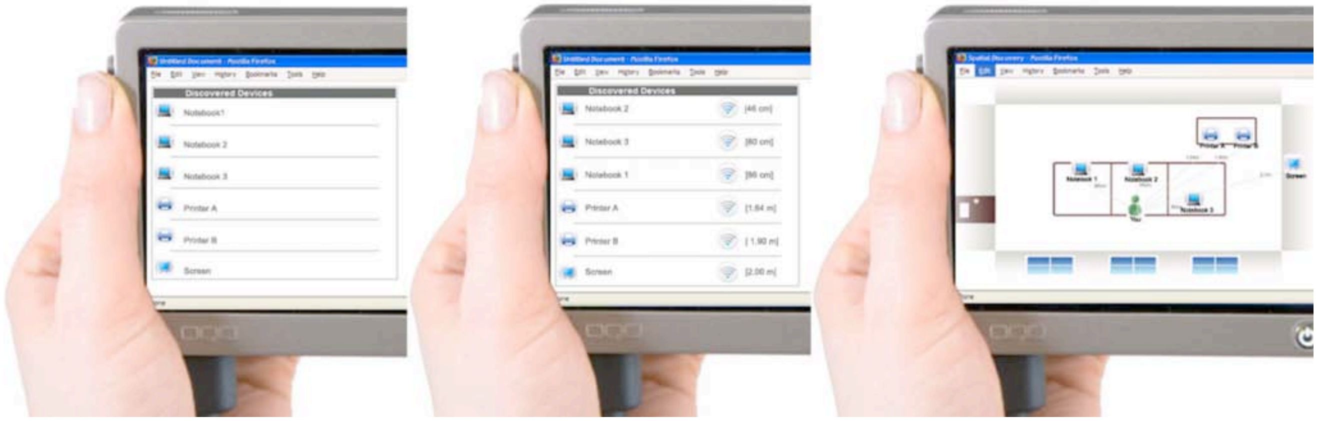

Figure 1. The three interfaces on the OQO, from left to right: a) Alphabetical List, b) Spatial List, c) Iconic Map.

We proposed the following hypothesis:

(H1) Users prefer interaction with spatial references; both the spatial list and the iconic map score better when compared with the alphabetical list.

(H2) The mental demand is lower using spatial references when compared with an alphabetical list.

2.1 Design

We chose a within-subject design with one independent variable. Spatial information has three levels: 1) no spatial information, 2) low spatial information (spatial list) and 3) high amount of spatial information (iconic map). The order of interface presentation and the target devices were randomised for each configuration using Latin squares. User satisfaction, mental load and ranking of the three interfaces were the primary dependent variables.

2.2 Apparatus

The computer running the experiment was an OQO model 01, with a 5" display and 800x480 pixel resolution. The three interfaces for the selection task were implemented with HTML and named as follows: a) Alphabetical List b) Spatial List and c) Iconic Map. The three interfaces are shown in Figure 1. We conducted the study in the department's library and used three notebooks, a projected screen and two printers to simulate a multifunctional meeting room, as illustrated in Figure 2. All devices were clearly labelled with their name to enable devices to be identified and selected without spatial hints.

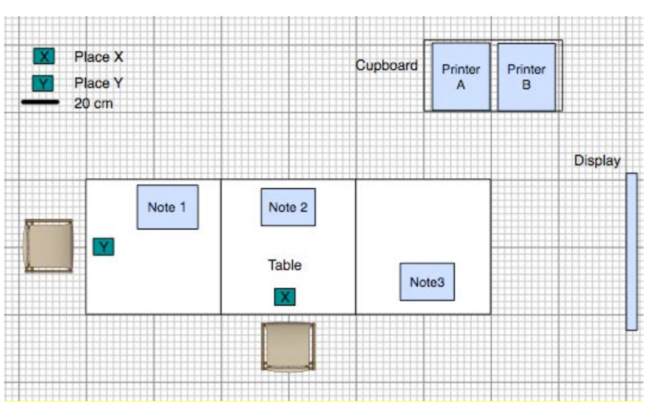

Figure 2. Device setup for participant sitting in place X; the place of notebook 1 and 2 are swapped as are printer A and B when participant moves to place Y.

2.3 Procedure

After familiarisation with the OQO handheld and its stylus interface, participants started the experiment in one of two predefined places, for example, place X or Y in Figure 2 (places were counterbalanced among subjects) and one interface configuration, for instance alphabetical list.

For the trial, the investigator touched one of the devices in the lab in order to show the participant which device (s)he should select. After seeing the target device and its location in the room, participants clicked on the start button of the application and saw an actual interface, such as the alphabetical list. The participant then had to choose the indicated target device by clicking either on the text or on the icon. The click closed the trial without feedback of correctness.

For each interface condition, a participant received six trials; the first two trials were warm-ups, followed by two in the first place and two more in the second place. With the re-location of the participant device locations were changed, as described in the caption of Figure 2. After all six trials, the participant filled out a questionnaire about satisfaction and mental load, see Figure 3. Question 1–9 are taken from the IBM computer usability satisfaction questionnaire [5] while question M1 – M3 are based on the NASA task load index [3].

This procedure was repeated for the two remaining interfaces: spatial list and iconic map. After trying all three configurations, the investigator interviewed the participants about demographic background, interface preference and finally whether they would find location information useful in two presented scenarios (connecting to a printer in unfamiliar surroundings at University and connecting to a projector in a meeting room).

2.4 Participants

9 male and 9 female participants took part in the study. The average age was M[1]=30.8 (SD=7.9), 88.8% were postgraduates from different departments, 5.6% were University employees and

[1] M = mean, SD= standard deviation

5.6% undergraduates. On average, they rated themselves with M=3.8 (SD=0.83) for their experience with computers and M=3.4 (SD=0.9) experience with mobile phones[2]. The results suggest that our participants were on average computer literate though not experts. 3 of the participants own a PDA and almost all participants (17) own a mobile phone.

3. RESULTS

We first present results on users satisfaction and mental load for the selection task, followed by ranking results and user comments.

3.1 Selection Task

Figure 3 shows the average scores in response to the questionnaire for the selection task. The spatial list received higher scores for the first nine questions (Q1–Q9), which indicates less satisfaction. The alphabetical list and the iconic interface received similar scores regarding user satisfaction.

Considering mental load, the alphabetical list and iconic interface received on average the same scores for all three questions (M1 – M3). Users found that mental demand (M1) and frustration level (M3) were higher for the spatial list than for the other interfaces. Performance (M2) was rated high for all three interfaces though participants felt slightly slower with the spatial list.

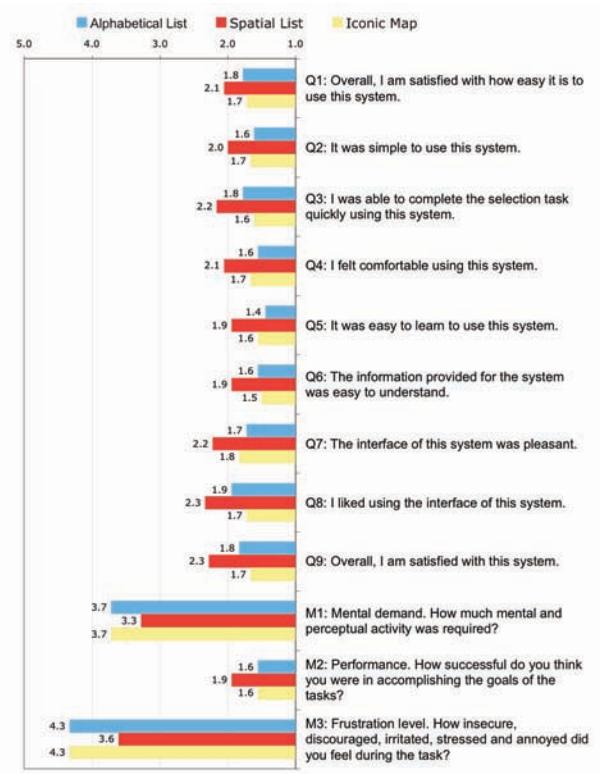

Figure 3. User satisfaction and mental load questionnaire; scale for Q1-Q9: 1="strongly agree" to 5="strongly disagree"; scale for M1-M3: 1="very high" to 5="very low".

3.2 Ranking Results

There was a significant association between the amount of spatial information and whether it would be ranked as the most preferred one to use $\chi^2(4)=14.67$, $p<0.01$. This seems to represent the fact that 2/3 of the participants chose the iconic map as the most preferred interface for the selection task, see Figure 4. We encouraged participants to comment on their choices. Reasons mentioned in favour for the iconic map were: "I know where the devices are" or "the map is the best" and "it is easier than the others". However, there were a few participants who had problems matching the room with the iconic interface and did not chose it as there favoured interface.

Only two participants ranked the spatial list highest; many participants commented that the spatial list's ordering system was confusing. Positive comments about the alphabetical list were: easy to memorize and logical (understandable) order system.

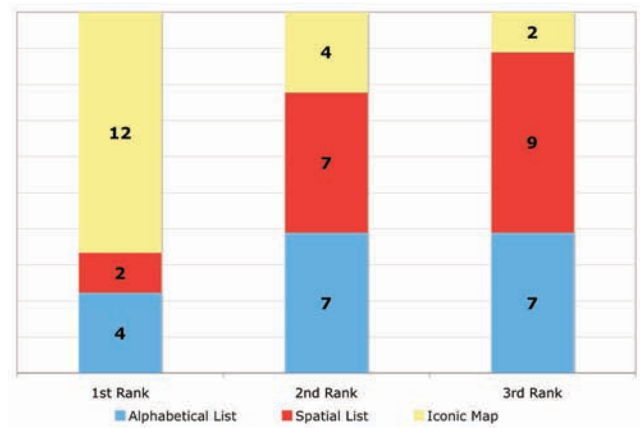

Figure 4. Ranking results for the three interfaces.

3.3 Utility of Location Information

In the interview we presented participants with two cases they might encounter at University: connecting spontaneously to a printer outside their office and connecting their computer to a projector in a meeting or lecture room.

For the printer scenario we asked the following questions: Have you tried to connect to a printer at University? What problem did you encounter? Do you think that location information would be useful? Two thirds of our participants had encountered a problem when connecting with a network printer at University. The University provides a list of all network printers but network name of the printer gives no information about the location of the printer. Participants complained about the fact that "you never know where you have printed something". When thinking of how location information would help, they mentioned that it would be useful if the printer would have location information (either descriptive such as building, floor and room name) or by having a map that shows the location of the printer (building, floor, room).

When asking about the same problem for connecting with a projector, fewer participants reported to have encountered problems. Many coped by either putting the presentation on a USB stick and using the local equipment or getting someone who knows how to use the equipment. Therefore, participants did not feel a need for location information in such a situation.

[2] Scale used: 1=none, 2=poor, 3=medium, 4=high, 5=expert

4. DISCUSSION

Our results indicate that participants did have difficulties with the spatial list, scoring on average worse than the two other interfaces. The satisfaction scores show no clear preference between iconic map and alphabetical list. These results do not support our first hypothesis, because alphabetical list received better scores than spatial list (and similar results to iconic map).

Looking at the interface ranking results, iconic map is clearly preferred above the two other interfaces. Participant's comments in the interview suggest that the additional spatial information of the iconic map supported the selection task. "I did not really check the text information," commented one of the participants after the trial. These results are clearly supporting our first hypothesis.

The results for the mental load show that participants felt a higher cognition load for spatial list because it has higher scores for the question M1 and M3 and lower scores for M2. On average, there was no difference between the scores for iconic map and alphabetic list. The results do not support our second hypothesis as spatial list and iconic map do not have better scores than alphabetical list. In fact, the spatial list appears to involve higher cognitive load for interaction than the non-spatial list. Participants could not make easily sense of the "logic" applied in the list.

We believe the poor results obtained for the spatial list condition are due to the fact that distances are all very similar in co-located device settings. The direction of the device (as seen from the perspective of the user) would appear to be much more significant than the distance for matching the interface to the real world. The spatial list requires a high degree of abstraction by the user, from the scene in front of them to the spatial information as captured in the interface. In contrast, the iconic map presents an immediate graphical representation of the situation around the user, which relays more information on the spatial topology of the devices present.

In our experiments, spatial interfaces did not perform better than the non-spatial alphabetical list. However, in order to enable use of an alphabetical list in the first place, we designed our experiment such that devices were labelled with their names. This effectively created a bias toward the non-spatial control condition, as the selection task did not depend on spatial hints for execution. Nonetheless, most of our participants ranked iconic map above the alphabetic list. In practice, device names are not as readily available to users as in our experiment, which means that the advantage of spatial interfaces would become more pronounced. The user feedback obtained confirms this: two thirds of the study participants had encountered problems of device identification, in particular in the context of printing.

5. CONCLUSION

This paper presents an experimental comparison of two spatial interfaces (spatial list and iconic map) and one non-spatial interface (alphabetic list) for the discovery and selection of nearby devices. The results provide clear evidence of users preferring the iconic map to the spatial and alphabetic list. The results are ambiguous when it comes to user satisfaction and mental load. Here the iconic map and alphabetic list perform equally, but both outperform the spatial list.

Considering these results, we might rethink the way nearby devices are currently visualised, for example, when selecting a nearby Bluetooth device, mobile phone, printer or laptop. Assuming the required localisation technology is available, then the provision of spatial information for device discovery and selection seems to provide added value to the user.

We are currently working on the next iteration of this study in which we will simulate a typical meeting scenario where files are exchanged among the participants. For this we plan to compare the use of spatial information with conventional methods of file exchange via USB stick, email or Skype.

ACKNOWLEDGEMENT

This work is supported by the INTERMEDIA NoE and the RELATE project, both funded by the European Commission.

6. REFERENCES

[1] Biehl J. T. and Bailey, B.P. 2004. ARIS: an interface for application relocation in an interactive space. In *Proc. of the 2004 Conference on Graphics interface* (London, Ontario, Canada, May 2004), 107-116.

[2] Brumitt, B., Krumm, J., Meyers B. and Shafer, S. 2000. Ubiquitous computing and the role of geometry. *IEEE Personal Communications*, pages 41–43, October 2000.

[3] Hart, S. G. and Staveland, L. E. 1988. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In Human Mental Workload (Amsterdam, North Holland, 1988) Press. 239-250.

[4] Kortuem, G., Kray, C. and Gellersen, H. 2005. Sensing and visualizing spatial relations of mobile devices. In *Proc. of the 18th Annual ACM Symposium on User interface Software and Technology* (Seattle, WA, USA, October 23 - 26, 2005). UIST '05. ACM Press, 93-102.

[5] Lewis, J. R. 1995. IBM computer usability satisfaction questionnaires: psychometric evaluation and instructions for use. Int. J. Hum.-Comput. Interact. 7, 1 (Jan. 1995), 57-78

[6] Newman, M. W., Sedivy, J. Z., Neuwirth, C. M., Edwards, W. K., Hong, J. I., Izadi, S., Marcelom, K. and Smith, T. F. 2002. Designing for serendipity: supporting end-user configuration of ubiquitous computing environments. *In Proceedings of the Conference on Designing interactive Systems: Processes, Practices, Methods, and Techniques* DIS '02. 147-156.

[7] Rekimoto, J., Ayatsuka, Y., Kohno, M., and Oba, H. 2003. Proximal Interactions: A Direct Manipulation Technique for Wireless Networking. In Proc. of Interact'2003, 511--518.

[8] Schilit, B. N., Adams, N. I., and Want, R. 1994. Context-aware computing applications. In *Proceedings of Workshop onMobile Computing Systems and Applications (WMCSA)*, pages 85–90, 1994. IEEE Computer Society.