Design Solutions for Cross-Device Interaction Issues

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Abstract— This paper shows occurring issues and existing design solutions in the field of cross-device interaction. Despite an ever-growing access to different devices, the interaction between them in the proximity is still cumbersome and hence an interesting subject for research. First, nearby devices have to be discovered to establish a connection, which is not only a question of technology but also a question of interface and interaction design. Then possible intentions for interacting with other devices have to be identified to provide adequate interaction options. In this context, the different types of devices and the access to them have to be considered since this affects how a device can be used and which purposes result from this. Aside from data transfer, other things need to be taken into account like the visualization and customization of shared data.

Index Terms—Cross-device interaction, XDI, Multi-surface environments, Multi-device user interfaces, Collaborative computing

1 Introduction

With an increasing number of different devices the necessity to exchange data between them is also increasing. By interconnecting them, the individual advantages of each device could be exploited and collaborative work with digital objects can be made feasible. But interaction between multiple devices is currently still cumbersome due to the lack of appropriately implemented design solutions. With this paper, I intend to give an overview of emerging issues and existing design solutions concerning this subject. First the term cross-device interaction is being clarified, then I show based on examples in literature how specific intentions for interaction between devices are handled and which advantages and disadvantages those solutions include.

2 Definition

The term cross-device interaction is first defined by Scharf et al. [9]:

> *Cross-device interaction (XDI) is the type of interaction, where human users interact with multiple separate input and output devices, where input devices will be used to manipulate content on output devices within a perceived interaction space with immediate and explicit feedback.*

Within this definition, several possible scenarios have to be considered: The ownership of a device can be personal, group or open and the access to it respectively private, shared or public. The distance is accordingly to this definition within reach or within area of perception.

3 Discovery of interaction opportunities

To access other devices spontaneously, it is necessary that the devices become aware of the presence and capability of other nearby devices without tedious human administration. Literature about pervasive computing [1] describes the technical background of possible discovery systems like wireless infrastructures and direct peer-to-peer channels. Thus, the devices can be identified with their network properties, but still cannot map the real world. To help users understand which network entities correspond to which physical entity, the positions of the nearby devices have to be determined and an interface for the identification has to be provided. Based on a peer-to-peer system for relative positioning of devices [4], spatial references can be visualized dynamically using the compass metaphor [2, 6, 12]. The *Relate Gateways* interface shows available nearby devices around the edges of the screen according to location. Matching colours that reinforce when approaching emphasize the connectivity between displays. Marquardt et al. [6, 7] as well show *dynamic notifications about device presence and location* but also take non-verbal communication into account. The distance to other people and the relative body orientation to each other are taken as an indication of their social relationship and the kind of task that has to be performed. If another device is known, the distance can also be larger to establish a connection. Depending on whether the task is collaborative, competitive or co-present but individual, adequate interaction possibilities can be found. Though, the disadvantage of this suggestion is that a static environment, i.e. a room with installed cameras and radio modules, is needed which is not favourable for spontaneous interaction. The *HuddleLamp* [8] however is also applicable in ad-hoc situations. The idea is to track the position of mobile devices and hands on a table with a RGB camera in a portable desk lamp. That way no additional software needs to be installed and the tracking of the hands opens up new interaction possibilities. Interaction with immobile devices is excluded, though. Schmidt et al. [10] use the *PhoneTouch* technique which associates the identity of a mobile phone with the position of the touch on a shared interactive display. Thus, personalized interaction is possible without additional hardware. This concept is the most versatile since it is applicable on every other touch-sensitive surface, whereby the other concepts mostly confine themselves on just a few forms of interaction i.e. for example interaction only between personal mobile devices. Connections can also be established explicitly by pointing to another device [11] or by performing synchronous gestures [5].

4 Actual interaction across devices

Once connected, the user needs to know how an intended action can be performed. I identified three main purposes which have to be considered when thinking about XDI. Obviously it should be possible to transfer data between different devices taking into account that sensitive data should be treated personally. Then the shared data should be suitably visualized and associations should be easy recognizable. Multi-user applications on a shared or public surface benefit also from individual feedback and from a personalization of the presented data and toolbars, since every user has different needs.

4.1 Data transfer and privacy

The transfer of data is a main issue for XDI and is closely linked to privacy concerns. On the one hand, the transfer should be intuitive. On the other hand, data not meant for sharing should be protected.

4.1.1 Data transfer

Data consistency among different devices is covered by cloud computing. But what is not covered is the interaction of the user with the device. A popular design technique are *Portals* that are shown along the shared screen edge of two slates where content can be dragged through. Marquardt et al. [7] offer moreover a possibility to just copy content by tilting the tablet more than 10 degrees. This is a common

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behaviour when sharing content alongside another person and is therefore acknowledged as easy-to-use. But the distinction between transferring and just copying content turned out to be confusing in their evaluation. By tilting the tablet more than 70 degrees towards a target, a temporary copy of the screen can be created. The target can either be one other person, a group of people or a digital whiteboard. Thus, this concept provides many forms of transfer with a various number of devices. When the position of fingers and devices on a table are being tracked, a simple flick gesture can be applied to push data across the table [8]. An alternative is to pick up a digital object at one screen and to transport it with the hand to another one, which probably makes the user feel like using just one device. A similar technique is to use the personal mobile phone as finger or stylus to pick up content [10]. However, this usage of the mobile might worry the users in terms of damaging their personal device which would impede the workflow.

4.1.2 Data privacy

When it comes to sharing personal information, the privacy is a main issue for users. No one wants to reveal for example a password for authentication on a shared or public display. For this purpose Schmidt et al. [10] propose to use the phone itself like a key to authorize access or to enter a password unobserved in the personal device and then transfer it. Accidentally sharing of data is neither desirable. Marquardt's approaches [6, 7] are only suitable for some situations when loose sharing is beneficial such as when you are at home or in small-group meeting places. Otherwise, unintentional actions are likely even when interaction possibilities presented to the user are limited to the nearest devices. The *proximity-dependent progressive reveal* is useful when working in small groups. The user can control the amount of shared information he wants to show on a shared display by changing the distance to the display.

4.2 Data visualization

A reasonable visualization for shared data is not only important for usability but also for an effective digital teamwork. The data has to be usefully organized so that it is readily comprehensible. Then the user interface should be readily accessible for everyone. And the screen should be scalable for large visual representations.

4.2.1 Data organisation

When related objects are split across multiple displays it is essential to make the user understand which objects are linked. Cords with different colours can be used to make associations visible [12]. But also with only one display the spatial visualization of data is important. Physical and digital objects e.g. drawings and videos are mostly archived separately and unstructured in digital repositories which make it hard to draw connections between them in individual or collaborative reflection e.g. in design process. Geyer et al. [3] identified the need to properly arrange them and consider the metaphor of a virtual pin board which can be synchronized across devices. It also has integrated zooming techniques so that every member has an individual view on the data.

4.2.2 User interface placement

An individual view is also helpful for toolbars and command menus since on large shared surfaces it may be difficult for every user to have access. A personal phone can for example be used like a palette, but instead of colours, one can select commands which then are executed with the next phone-touch on the surface [10]. By tracking the position and orientation of the devices, the *HuddleLamp* [8] enables the user with *Spatially-aware Menus and Modes* to adapt the mode of a mobile device by moving or rotating it. Changing the orientation from landscape to portrait reveals a menu where tools for the entire group of nearby devices can be modified. A mode for note taking is activated when a device is approaching a user.

4.2.3 Screen expandability

Large-scale displays are useful when presenting large visual information, but are also expensive and immobile. Therefore it would be nice if multiple mobile devices could be federated to one large screen. When people's orientation in space is tracked, devices just need to be held together and a simple pinch-to-zoom gesture has to be executed so that the content expands across devices [7]. A large interaction area can also be created with the *Huddle Navigation* [8]. The *Peephole Navigation* transforms the table into a large display and the device into a metaphorical peephole through which one can view the content.

4.3 Personalization

When working together in multi-user-environments not every team member has the same needs and abilities at the same time. Therefore it is important to provide the possibility to personalize shared information and to get individual private feedback.

4.3.1 Data and user interface adaption

Personalizing content means for example to translate it. But since this might disturb other users who would like to read it in the already displayed language, not the whole text should be translated. With *PhoneLenses* [10] content can be adapted in a small area of view on a surface when one touches it. The finger touch is automatically associated to the phone's user and in this case to his language preferences. Customizing a command interface is possible with *PhoneFaçades* with which a user can pick commands onto his personal device and assort them manually.

4.3.2 Private feedback

When it comes to recognizing if an input was effective, affirmative or negative feedback is essential, without disturbing parallel users. Schmidt et al. [10] suggest a solution for individual audio and visual feedback. With plugged in headphones the *PhoneSpeaker* technique enables audio feedback. And with the *PhoneZone* technique a private space is created across phone and surface for visual feedback.

5 Conclusion

In summary it can be said, that the possibilities for XDI depend strongly on the given conditions and on the kinds of devices that are involved. To cover as many areas of application as possible, ad-hoc use is favourable where no additional hardware is needed. The *PhoneTouch* technique can probably be used in most cases *(see table 1)* but as mentioned above the workflow is perhaps not that smooth. Future development could examine for one thing how the benefits from the different design solutions could be put together so that every issue is covered with diverse interaction possibilities, and for another thing how the use differs depending on situation and users.

Table 1. Summarizing comparison of Marquardt's [7], Rädle's [8] and Schmidt's [10] design solutions. ★= Diverse interaction possibilities, ✯= Issue somehow covered, ☆= No interaction possible.

Comparison criterions		[7]	[8]	[10]
Conditions	Ad-hoc use possible		✓	✓
	No additional hardware needed			✓
	Interaction with immobile devices possible	✓		✓
Input attributes	Surface touch location	✓	✓	✓
	Hand location		✓	
	Device or user location and 2D orientation	✓	✓	✓
	Device 3D orientation	✓		✓
	Device identifier			✓
Issues	Data transfer	★	✯	✯
	Data privacy	✯	✯	★
	Data organisation	☆	☆	☆
	User interface placement	☆	★	★
	Screen expandability	✯	★	☆
	Personalization	☆	☆	★

References

[1] W. K. Edwards. Supporting device discovery and spontaneous interaction with spatial references. *Pervasive Computing*, 5(2):70–77, 2006.

[2] H. Gellersen, C. Fischer, D. Guinard, R. Gostner, G. Kortuem, C. Kray, E. Rukzio, and S. Streng. Supporting device discovery and spontaneous interaction with spatial references. *Personal Ubiquitous Comput.*, 13(4):255–264, May 2009.

[3] F. Geyer and H. Reiterer. A cross-device spatial workspace supporting artifact-mediated collaboration in interaction design. In *CHI '10 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '10, pages 3787–3792, New York, NY, USA, 2010. ACM.

[4] M. Hazas, C. Kray, H. Gellersen, H. Agbota, G. Kortuem, and A. Krohn. A relative positioning system for co-located mobile devices. In *Proceedings of the 3rd International Conference on Mobile Systems, Applications, and Services*, MobiSys '05, pages 177–190, New York, NY, USA, 2005. ACM.

[5] K. Hinckley. Synchronous gestures for multiple persons and computers. In *Proceedings of the 16th Annual ACM Symposium on User Interface Software and Technology*, UIST '03, pages 149–158, New York, NY, USA, 2003. ACM.

[6] N. Marquardt, T. Ballendat, S. Boring, S. Greenberg, and K. Hinckley. Gradual engagement: Facilitating information exchange between digital devices as a function of proximity. In *Proceedings of the 2012 ACM International Conference on Interactive Tabletops and Surfaces*, ITS '12, pages 31–40, New York, NY, USA, 2012. ACM.

[7] N. Marquardt, K. Hinckley, and S. Greenberg. Cross-device interaction via micro-mobility and f-formations. In *Proceedings of the 25th Annual ACM Symposium on User Interface Software and Technology*, UIST '12, pages 13–22, New York, NY, USA, 2012. ACM.

[8] R. Rädle, H.-C. Jetter, N. Marquardt, H. Reiterer, and Y. Rogers. Huddlelamp: Spatially-aware mobile displays for ad-hoc around-the-table collaboration. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces*, ITS '14, pages 45–54, New York, NY, USA, 2014. ACM.

[9] F. Scharf, C. Wolters, and M. Herczeg. Cross-device interaction: Definition, taxonomy and applications. In *AMBIENT 2013: The Third International Conference on Ambient Computing, Applications, Services and Technologies*, pages 35–40. IARIA, 2013.

[10] D. Schmidt, J. Seifert, E. Rukzio, and H. Gellersen. A cross-device interaction style for mobiles and surfaces. In *Proceedings of the Designing Interactive Systems Conference*, DIS '12, pages 318–327, New York, NY, USA, 2012. ACM.

[11] C. Swindells, K. M. Inkpen, J. C. Dill, and M. Tory. That one there! pointing to establish device identity. In *UIST '02: Proceedings of the 15th annual ACM symposium on User interface software and technology*, pages 151–160, New York, NY, USA, 2002. ACM.

[12] D. Wigdor, C. Shen, C. Forlines, and R. Balakrishnan. Table-centric interactive spaces for real-time collaboration. In *Proceedings of the Working Conference on Advanced Visual Interfaces*, AVI '06, pages 103–107, New York, NY, USA, 2006. ACM.