Cross-Device Interaction

Definition, Taxonomy and Applications

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***Abstract*—This contribution proposes a definition and taxonomy of the often used term cross-device interaction. Despite of technical progress, systems and interfaces that integrate into the environment are still the subject of intensive research. We still live in a world where devices reside in the foreground and present themselves and their interaction capabilities to the user. At the same time, computing devices become an integral part of our environment, be it in the form of public displays or mobile computers. Furthermore, the number of devices a user owns or has access to is increasing. Humans interacting consciously with multiple devices can be seen as an intermediate stage towards ambient environments or ubiquitous computing. The term cross-device interaction (XDI) is often used to refer to the underlying interaction paradigm in such environments. Unfortunately, the term still lacks consistent and concise definitions. This can be a problem as different authors use the term XDI with divergent meanings within a wide variety of application contexts. To mitigate this problem, we propose a taxonomy and give a user-, space- and interaction-centric definition for XDI. Additionally, we make use of this taxonomy to classify XDI-scenarios found in the literature and the concepts of XDI they exhibit.**

Keywords-human computer interaction; computer interfaces; context awareness; collaborative work; ambient computing.

I. INTRODUCTION

Although we are still far away from the all-embracing vision of ubiquitous computing, the future as discussed by Weiser [22], Norman [14] and others slowly finds its way into the world. However, computers still do not *"weave themselves into the fabric of everyday life until they are indistinguishable from it"* [22], but they are getting smaller and are potentially hidden within other technologies or environments. However, unlike described in the visions, in most cases they are still perceived as electronic, computer-driven devices that need to be configured, networked and used in some peculiar way. The actual state we are in has been described by Weiser as Phase I of ubiquitous computing. It is a phase, which is said to be *"unlikely to achieve optimal invisibility, but is a start down the radical direction, for computer science, away from attention on the machine and back on the person and his or her life in the world of work, play, and home"* [21].

Information Appliances as described by Norman [14] have been with us for some time now and their number is increasing. Today, many people own more than one device. Besides traditional computers like desktop PCs or notebooks, they use computers for home entertainment, powerful smartphones and other mobile devices like tablet PCs as well as special-purpose devices like music-players or e-book readers. Computer devices even enter their clothes and bodies as biomedical or special purpose communication devices. As the number of devices grows, so does the need to exchange information and mediate interaction between them. People increasingly express their frustration about the lack of integration between devices and see the need for network standardization and connectivity [20]. While some of the technical interconnectivity problems have already been tackled by different industrial groups like Digital Living Network Alliance (DLNA) [3], others are still open. Of particular interest are changing patterns of use.

Computers are used today in more varying contexts than ever before, ranging from highly structured work to more ad-hoc use of independent, simple tools. They are used in work settings as well as for leisure activities. Computers are, in addition to serving as tools, means of communication and interaction. Some of them just emerge as media in the strongest sense, bridging into rich application worlds. When it comes to information and entertainment usage, the general purpose computer in many cases has been replaced or at least augmented by specific computing devices. Movies are watched and books are read via special computer devices like Blue-ray players or e-book readers, or computers act as cloud devices for public as well as personal media content.

If users control more than one computer, they have to look into issues of whether and how different devices should be and can be connected. This also involves the technical realization of high-speed, high-bandwidth interconnections, but even more so questions of usage patterns, user requirements and user behavior.

Naturally, different devices have different capabilities. Mobile phones for example have computing and storage power that exceeds recent personal computers. They are often considered as very personal items and are always available. Not only are contacts, private photos or calendars being stored, but smartphones also give access to a variety of services. Moreover, as a result of improved wireless interconnectivity, smartphones are often connected to the

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Internet permanently, making them a premier point of access to data stored in the cloud or being used as IO-devices to interact with other systems. As they can be carried around and identified uniquely, they may even serve as tokens indicating the location and even the identity of the user. A wide variety of location-based services has been suggested and many of them have been implemented [8]. The underlying assumption is that the location of the user is an important part of the user's context.

Not only mobile phones but all devices should be able to connect to each other as all devices have their advantages and disadvantages compared to other devices, e.g., with respect to display size and resolution, presentation capabilities or input modalities. Cross-device interaction (XDI) may help to overcome these obstacles through interconnection and seamless integration of different devices in a predefined or ad-hoc manner.

This contribution is structured as follows: first, we will discuss our understanding of XDI and the relation of XDI to current computing paradigms. From this analysis, we derive a definition for XDI and propose a taxonomy to classify different XDI scenarios. Then, we relate examples of XDI in the literature to this definition and discuss how they fit into our understanding of XDI and the taxonomy.

II. Cross-Device Interaction

In environments where humans interact with multiple devices, the term cross-device interaction (XDI) has often been used to describe the underlying interaction paradigm but without a proper definition. This can be problematic as there is no consistency in how the term XDI is used by different authors and in varying application contexts. For example, it is used to describe different forms of interaction with multiple devices [5, 9, 13, 15, 16] or menu navigation [24] up to simple synchronization of history between multiple devices [1, 18, 19]. Even within the areas of those examples, the use of the term differs severely. Therefore, we propose a more structured definition of XDI.

In most cases, when we deal with computers, we are quite aware of the devices that we interact with. A common approach for interaction is Direct Manipulation, where input and output processing meets in a close and consistent regulation loop [7, 17]. Gesture-based approaches, e.g., interacting in front of public or shared displays [12] or using multitouch devices, try to close the gap between input and output.

However, there are certain situations where users can take advantage of non-direct interaction, e.g., if output devices are spatially separated from users or do not offer interfaces between each other, it is hard to interact with them at all. Users can get handicapped by devices if they are not familiar with the input modalities. Also, handling private data can be problematic, if the interaction device is publicly accessible. Not all devices are capable of displaying every type of media like audio, images, videos, 2D- or 3D-objects and thus the information sometimes has to be visualized by specialized devices. In all these examples, it can be helpful or even necessary to interact with other devices available in the spatial context, which are enabled for certain media or certain kinds of interaction modalities. These are typical situations where XDI is required.

In the following, we will clarify the term cross-device interaction in order to give a better understanding of the concept and to prevent misunderstandings.

A. *Devices*

XDI takes place between devices. It is important to explain our use of the term in order to be able to limit the scope of XDI. Generally, we have three classes of devices: input-, output- and mixed-devices.

Input devices take any form of user input in order to pass control signals onto application systems for further processing or execution. Depending on the device modality, there are different subclasses to refer to. We are talking of mainly visual, sensor, auditory and haptic input devices. Visual input devices consist for example of person-, gesture-, or eye-trackers and pointer-based input. Sensor input devices also track users, but with a multitude of different sensors, despite the mentioned ones. Auditory input devices react to auditive input and haptic devices react to grasp or touch input, e.g. tangibles or touchscreens. Input devices provide the communication interface to computers and act as controllers. Here, the actions of a user are passed on to the computer, processed in applications and the result is usually passed on to output devices. The user either interacts directly with the input device itself, e.g., with mouse, keyboard and touch-input or from a distance, e.g., with trackers or speech-input.

Output devices render and present any kind of information. The output itself can take place in any form that human senses are able to perceive. This ranges from visual to haptic or auditory feedback that the user is able to interpret and can also be multimodal. Common output devices are displays, printers or sound systems but they can also create physical movements such as motors or vibrators or distribute materials like water [2] or even odors.

Mixed devices incorporate both input as well as output, within one device. Combined with processing units, they can act as stand-alone devices. Touch-screens, especially multitouch tables, smartphones or tablet PCs for example belong to the class of mixed devices. Although personal computers consist of different input and output hardware like mice, keyboards, monitors or sound systems they are often perceived as one coherent integrated sensomotorical system by their users.

Apart from this classification, devices can be of different nature to the user. Here, we especially consider the ownership and access of devices.

The *ownership of devices* will be an important factor for XDI settings as it has an impact on the content and the collaboration potential of a particular setting. We see three basic situations:

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- *Personal:* Devices that belong to a specific user and are configured and used only by him or her can be seen as *personal devices*. They are potentially carried along and can then be used as a unique token to access user specific settings and content. Another important aspect of personal devices is that owners are usually quite familiar with the handling and the specific interaction techniques of their device. For this reason it may be beneficial to incorporate well handled personal devices in the design of interaction scenarios instead of unfamiliar ones.

- *Group:* If the person belongs to a group or explicitly invites others to share the device, we will call them *group devices*, whereas groups may have different meanings, e.g., memberships or ad-hoc pairing.

- *Open:* When devices can be used by anyone who can access the space, we will call them *open devices*. Those devices do not have a specific owner.

The *access to devices* is depending on the location and the context in which devices are used within XDI. We distinguish between three forms of use of devices:

- *Private:* If a device is controlled by and displays for exactly one person, we will call this private access. This person is the only one interacting with them and his or her actions and information cannot be observed directly by others.

- *Public:* If a device displays for more than one person, but is still controlled by only one person, we speak of public access. However, observers other than the owner will not be able take direct influence into the actions or to the information displayed.

- *Shared:* The third option includes several people who take part in the interaction through a certain device. If at least two persons have access to and control the same device, we speak of shared access.

B. Interaction

The question arises how interaction in XDI scenarios differs from other kinds of interaction with multiple devices. In order to delimit XDI from other forms of interaction, some rules must be provided. We extracted distinctive features of scenarios proposed in different research papers. Then we examined these features from an HCI perspective with regard to the following aspects. How do humans interact with devices within each scenario, e.g., whether a device is touched or just looked at? What kind of relation do devices establish between each other, e.g., input, output, distributed interfaces?

For a typical XDI scenario, we assume that a user directly and consciously uses an input device to manipulate content on some output device. This stands in contrast to systems in ambient environments that may track users and get implicit feedback from them. With XDI input and output take place on different devices, independent of being mixed devices or separated input and output devices.

When we speak of XDI, we presume that a user indirectly interacts with an output device. He or she uses input devices within his or her reach in order to control output devices. We will not use the term XDI when input and output take place on the same device (mixed device). A desktop computer system with mouse and display for example could be seen as a simple form of XDI, because a peripheral input device is used to manipulate a separate output device. A tablet PC in contradiction has no periphery and utilizes direct manipulation right on the display, which also functions as output device. Thus, we only focus on scenarios where input and output devices are from a user's perspective separate from each other.

Within XDI, input is closely connected with output. That means that commands executed over an XDI system will create an immediate and explicit response and the user is able to perceive feedback to the action on the target systems without noticeable delay (cf. Direct Manipulation). This does not necessarily apply to the output time characteristics of the controlled media itself, which can be delayed, e.g., when rendering takes longer.

C. Crossing and Distance

Devices and interaction are closely linked with each other. The interaction within XDI happens across all kind of input, output and mixed devices and not only on some specific device itself. This involves devices like tablets, PCs, smartphones, TVs, presentation computers or even smart items or objects. As our interaction criteria show, XDI is a kind of *proxemic interaction* between devices where users are located inside some well-defined or user perceived activity space. Within this space, users may connect and use devices with different capabilities in order to utilize features for varied presentation, handling or manipulation of information. The response to input is linked with visible, audible or otherwise perceptible output. Therefore, input and output devices have to be situated in such a way that the user can perceive the results of the action immediately. We do not distinguish between rooms, but between activity spaces, e.g., because the disposition of devices and furniture inside rooms determines activity spaces. It is important to point out the interaction and user-centered focus of XDI. Therefore, XDI is bound to explicit sensomotoric feedback, e.g., applications with feedback on a functional or application level are not in the scope of XDI.

III. XDI AND KNOWN COMPUTING PARADIGMS

Many researchers have been concentrating on computing paradigms like ambient computing, ubiquitous computing, pervasive computing and cloud computing. Several aspects of those paradigms are influencing XDI. In the following, we will discuss relations between XDI and these current computing paradigms.

A. Ambient Computing.

Within ambient computing, the environment observes and tracks the users and their actions with the help of sensors and reacts either explicitly but mostly implicitly like anticipated by the users (or the developers). As in the vision of ubiquitous computing, computers are integrated in the environment and reside in the background, even more so, they do not show up at all as they are not meant for direct interaction. XDI can benefit from ambient computing from being more aware of the activities of its users and devices. It can be helpful to know about the context of a user, which is relevant for information retrieval or to know about his or her environment. This allows, for example, that devices in reach can be located or information to be linked to previous activities. Here again, XDI requires explicit interaction with devices and also explicit response of systems.

B. Ubiquitous Computing.

The vision of ubiquitous computing, as already discussed, includes the omnipresent availability of computers that are preferably not distinguishable from everyday objects. In conjunction with ubiquitous computing, Weiser talked about "calm technology", where technology resides in the periphery, playing a non-dominating role in a user's life [23]. The general availability of devices and computing power is important for XDI, but here, the perception of devices plays a major role. As outlined before, we are still in Weiser's Phase I of ubiquitous computing, and within our XDI settings people consciously use devices that are in their main focus in order to control remote devices.

C. Pervasive Computing.

Pervasive computing is often used in conjunction with or even synonymous for ubiquitous computing, although it is not the same. Pervasive computing deals with the connectivity and interfacing of participating devices within a network. This is basically a technical point of view [10]. Pervasive computing provides a technological background of seamless network infrastructures, which is important for XDI, while XDI itself is concerned about the interaction of humans with their devices.

D. Cloud Computing.

"Cloud Computing refers to both the applications delivered as services over the Internet and the hardware and system software in the datacenters that provide those services" [4]. Cloud computing provides data consistency among different devices and the users gain flexibility as they are able to access their data anytime from different locations. This also supports unplanned activities, e.g. in *ad-hoc situations* [1]. XDI also benefits from an omnipresent availability of data. Handling multiple devices needs access and consistency of information distributed among all participating devices. What cloud computing does not cover, is the interaction of users with multiple devices. XDI has its focus on interaction with information, whereas cloud computing defines storage, accessibility and data services.

As can be seen, XDI references all of these computing paradigms. It can be seen as a method to access information and interact with endpoints in each paradigm. Furthermore, XDI may be a way to create additional personal interfaces for environments that would normally rely on implicit interaction only. This could help users to reach a better understanding of their surrounding environments.

IV. A Taxonomy for Cross-Device Interaction

Our research helped to identify important distinguishing features that delimit XDI from other forms of interaction with multiple devices. In the following, we summarize our understanding of XDI as outlined in this paper by presenting a definition and a taxonomy for classifying different scenarios of XDI. Our definition of XDI is based on this proposition of a discriminatory subset of distinguishing features as mandatory criteria.

- *Direct Interaction with Input Devices:* The interaction with an input device in order to manipulate content on output devices.
- *Mediated Interaction:* The use of an input device in order to control separate output devices.
- *Perception of Output Devices:* Devices have to be within an activity space of a user that connects multiple devices within an area of perception.
- *Immediate and explicit Feedback:* Users get an immediate explicit response on their commands and are able to see and regulate feedback to the action on the target systems without noticeable delay.

Resulting of our research and reflection above, we define XDI as follows:

> *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, there are various possible scenarios of XDI.

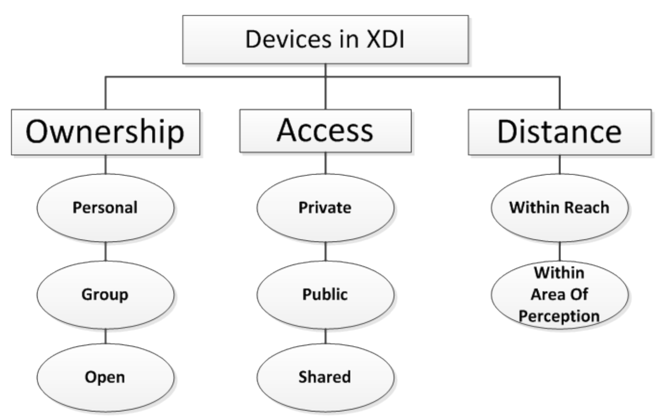

Figure 1. Taxonomy for XDI devices

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To address more detailed characteristics we present a first taxonomy that focuses on attributes of devices: ownership, access and distance (Figure 1). These attributes can be used for further characterization of XDI scenarios.

V. XDI IN THE LITERATURE

After we defined XDI and provided some further refining criteria and parameters in the preceding section, this section will present related work in the field of XDI. The term XDI has often been used in conjunction with many kinds of communicating devices, while the form of interaction has not always been stated clearly [6]. Some work also uses the term XDI, but is difficult to categorize. We outline some approaches that give more detailed information about certain XDI approaches within the field of private and public spaces, ad-hoc situations, control of multiple devices, task continuity and web-history and classify them in terms of our understanding of XDI. This serves to test the robustness of our definition and clarify the boundary to other concepts.

A. Case 1

Schmidt et al. [15] introduce XDI as a solution to several problems when using mobiles and multitouch tables. They identify some issues in connection with the use of multitouch-tables and propose six input attributes for interaction as solutions. Thereby, they target the six problems concerning data transfer, personalization, user interface composition, authentication, localized, private feedback and input expressiveness. Their approaches are based on the identification of mobile phones, some combined with touch-input. Within their scenarios, they fulfill the given mandatory criteria for XDI. There are at least two devices involved, as the interaction always takes place between mobile phones and multitouch tables. The interaction of the user and the system feedback are explicit and immediate and the user is always in line-of-sight with the output device. Their scenarios are good examples for XDI within private, public and shared spaces as well as using personal and group devices. Personal devices are used as secure input devices for public displays. For example, passwords can be entered by selecting the password field on a multitouch-table with a mobile phone, typing the password concealed from others into the designated field on the mobile and transferring it back to the multitouch.

B. Case 2

A system that utilizes Personal Digital Assistants (PDA) to control applications running on other computer systems is realized in the Pebbles project by Myers et al. [13]. One of the applications implemented within Pebbles is the SlideShow Commander. With the SlideShow Commander, one can control PowerPoint presentations given with desktop or laptop computers from one's own PDA. One can not only move forward and backward in the presentation, but also scribble on slides images presented on the PDA, while annotations are shown on the presentation for the audience. Another interaction opportunity is given by the fact that the user can switch between different applications on the presentation device from his handheld computer. In principle, it is possible to use SlideShow Commander in collaborative settings, where different members of the audience take turn in controlling the application or share annotations. This setting also inherits all mandatory criteria for XDI. One device is used to control a presentation platform that is nearby and visible to the user, whereas the given feedback reacts immediately to the users input.

C. Case 3

Among the interesting topics in the field of XDI are ad-hoc situations. Depending on the situation, XDI can either happen within a static environment with fixed devices or ad-hoc, when people meet coincidentally in unknown environments or like to connect personal devices such as mobile phones with devices in these environments. Devices form new constellations when brought together that influence how they are used. Gellersen et al. [5] observe situations with interaction across devices where *"spontaneous interaction enables users to associate their personal devices with devices encountered in their environment"*. They want to facilitate remote interaction with unknown devices, public displays as well as data exchange between mobile devices. Their RELATE interaction model supports the discovery of devices and services within sight in the near environment and proposes the connection of mobiles with those devices. A major topic they discuss is the identification and discovery of participating devices within the immediate environment of a user. In our sense, their work is located in the field of XDI insofar as their design supports the use of mobile devices in ad-hoc situations in order to control other nearby devices with the help of direct manipulation techniques, e.g., pick-and-drop for transferring objects between computer or eSquirt *"a point and click technique for metaphorical squirting of data from one device onto another"*. Unfortunately, they do not give hints about the responsiveness of output devices.

D. Case 4

Another example for XDI is discussed by Kimman et al. [9]. They discuss a design-study for a remote control, which can also be seen as residing within the field of XDI. The remote is used to manipulate multiple different output devices in order to reduce the number of input devices. They use explicit input to control spatially separated devices. This is a borderline case in terms of our classification as it is not quite clear whether the output devices are within area of perception and give immediate feedback.

E. Case 5

Approaches where several devices are coupled to present one input and output area, as done by Schmitz et al. [16] for mobile phones, are difficult to interpret and classify. From a technical point of view their system shows a kind of XDI. Multiple devices can connect in ad-hoc situations and one device can be used to manipulate content seen on another in real-time. Seen from an HCI point of view, the intention of using multiple devices in order to build one large mixed device eliminates the use for XDI as there is only one logical device left to communicate with. If anything, this system has to be categorized as a borderline case of XDI.

F. Case 6

Yin and Zhai initiate an instant messaging communication to display menu choices during phone conversations with an interactive voice response (IVR) system [24]. Their work is interesting for XDI insofar, as they interact directly with a mobile phone to navigate through a menu displayed on a remote computer. Their interaction also causes immediate and explicit feedback. The proposed system is a good example of XDI, although the user controls a remote system (IVR). The important aspect here is that the feedback is perceivable on a nearby device, the user's PC.

G. Case 7

There is also other work that seems to be located in the field of XDI, but does not meet our definition. Studies of Sohn et al. from Nokia Research [1, 18, 19], for example, show research in the field of continuous workspaces or web-migration. They deal with access to information at different locations with different devices. Users are enabled to browse web pages with one device and proceed with their work later on another device, based on their web-history. While there is communication between devices involved, important criteria for XDI are missing. The distance between user and output device as well as the response time to the user's interaction does not matter in their case. It is possible to use a device and pick up the work later at any time, any place on another device. Here, devices are not used to control other devices, but to synchronize information between them.

H. Case 8

Marquardt et al. [11] explore cross-device interaction in a setting of co-located users interacting collaboratively across handheld devices and using those with wall-mounted displays. Their research focuses on interaction techniques that leverage the spatial relationship between people that are interacting with each other as well as proxemics of devices used in their application. The presented interaction techniques aim to ease manipulation of digital information across nearby federated devices and thereby meet our definition of XDI on a general level. There is a slight difference in the basic setting that incorporates collaborating users. From our point of view, this is not a limitation but rather a broader understanding of XDI. At this moment we consider scenarios starting on a personal input device, ending on another nearby output device, independent of any other user at this endpoint. There may be other users and they are affecting XDI but only as an influence and not as a protagonist in such interaction scenarios.

These eight cases delivered an insight into the broad understanding of cross-device interaction that motivated us to clarify and refine the term.

VI. Conclusion and Further Work

So far, the term cross-device interaction (XDI) has been used quite often, but a clear and consistent definition is still lacking. In this paper, we have proposed a basic definition for XDI. Our taxonomy contributes to delimit the realm of XDI by introducing the dimensions of ownership and access. Our work furthermore allows classifying or constructing different scenarios within this scope in a user- and interaction-centered manner. We exemplify our approach by examining eight cases of potential XDI use found in the literature. We have shown that our taxonomy is widely and practically applicable. However, some special cases that could not be classified properly have shown that there is still potential to further refine the definition and taxonomy.

In our own work, we make use of this definition to guide our investigation of novel ways to make use of the increasing availability of computing devices. For example, we have developed a system for location-centric access and control of presentation systems with the help of personal mobile devices. We have furthermore developed an electronic whiteboard application for collaborative work in shared activity spaces. Work is ongoing of accessing this whiteboard with personal mobile devices as well. Last but not least, we have introduced frameworks for contextualized computer systems as well as media delivery and manipulation on a wide range of devices, from personal mobile devices to open public displays. We refrained from describing these systems in detail since our focus in this contribution has been set on the taxonomy and definition.

In the future, we will further investigate different scenarios of use in the context of cross-device interaction. We expect our definition to evolve to take both the empirical evaluation of our own research systems as well as new literature into account. Our hope is that the taxonomy proposed will help to clarify the research questions involved and to distinguish XDI as a field of research that is distinct, but has close connections to other HCI research areas.

References

[1] E. Bales, T. Sohn, and V. Setlur, "Planning, Apps, and the High-end Smartphone: Exploring the landscape of modern cross-device reaccess," Pervasive Computing, 2011, pp. 1–18.

[2] Bit.Fall: http://sphericalrobots.org/, retrieved: Feb., 2013.

[3] Digital Living Network Alliance: http://www.dlna.org/, retrieved: Aug, 2012.

[4] A. Fox and R. Griffith. Above the clouds: A Berkeley view of cloud computing. University of California, Berkeley, 2009.

[5] H. Gellersen, et al. "Supporting device discovery and spontaneous interaction with spatial references," Personal and Ubiquitous Computing, Jul. 2008, pp. 255–264.

[6] F. Geyer and H. Reiterer, "A cross-device spatial workspace supporting artifact-mediated collaboration in interaction design," Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems - CHI EA, 2010, pp. 3787-3792.

[7] E. Hutchins, J. Holland, and D. Norman, "Direct Manipulation Interfaces," User Centered System Design. ed. D. Norman and S. Draper, Lawrence Erlbaum Associates, 1986, pp. 87–124.

[8] I. Junglas, "On the usefulness and ease of use of location-based services: insights into the information system

innovator’s dilemma," International Journal of Mobile Communications, vol. 5, issue 4, 2007, pp. 389–408.

[9] F. Kimman, H. Weda, E. van den Hoven, T. de Zeeuw, and S. Luitjens, "Spinning in control," Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction - TEI '11, New York, New York, USA, 2011, pp. 189-192.

[10] A. Kofod-Petersen, "A Case-Based Approach to Realising Ambient Intelligence among Agents," Norwegian University of Science and Technology, 2007.

[11] N. Marquardt, K. Hinckley, and S. Greenberg, "Cross-device interaction via micro-mobility and f-formations," Proceedings of the 25th annual ACM symposium on User interface software and technology - UIST, 2012, pp. 13-22.

[12] J. Müller, R. Walter, G. Bailly, M. Nischt, and F. Alt, "Looking glass," Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI, New York, New York, USA, 2012, pp. 297-306.

[13] B. Myers, "Using handhelds and PCs together," Communications of the ACM, vol. 44, issue 11, Nov. 2001, pp. 34–41.

[14] D. Norman, "The Invisible Computer: Why Good Products Can Fail, the Personal Computer Is So Complex, and Information Appliances Are the Solution," MIT Press, 1998.

[15] D. Schmidt, J. Seifert, E. Rukzio, and H. Gellersen "A cross-device interaction style for mobiles and surfaces," Proceedings of the Designing Interactive Systems Conference on - DIS, 2012, pp. 318-327.

[16] A. Schmitz and M. Li, "Ad-Hoc Multi-Displays for Mobile Interactive Applications," Eurographics 2010-Areas. vol. 29, issue 2, 2010, pp. 45–52.

[17] B. Shneiderman, "Direct manipulation: A step beyond programming languages," ACM SIGSOC Bulletin, vol. 08, 1981.

[18] T. Sohn, K. Mori, and V. Setlur, "Enabling cross-device interaction with web history," Proceedings of the 28th of the international conference extended abstracts on Human factors in computing systems - CHI EA, 2010, pp. 3883-3888.

[19] T. Sohn et al., "Myngle: unifying and filtering web content for unplanned access between multiple personal devices," Proceedings of the 13th international conference on Ubiquitous computing - UbiComp, New York, New York, USA, 2011, pp. 257–266.

[20] C. Sørensen and D. Gibson, "Ubiquitous visions and opaque realities: professionals talking about mobile technologies," Info. vol. 6, issue 3, 2004, pp. 188–196.

[21] M. Weiser, "Some computer science issues in ubiquitous computing," Communications of the ACM, 1993.

[22] M. Weiser, "The computer for the 21 st century," ACM SIGMOBILE Mobile Computing and Communications Review. vol. 3, issue 3, Jul. 1991, pp. 3–11.

[23] M. Weiser and J. Brown, "The coming age of calm technology," Xerox PARC, 1996, pp. 1–17.

[24] M. Yin and S. Zhai, "Dial and see," Proceedings of the 18th annual ACM symposium on User interface software and technology - UIST, New York, New York, USA, 2005, pp. 187-190.