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Enhancing Interactive Tabletop Workspaces with Tangible Contexts

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Abstract

In this paper, we introduce our concept of tangible contexts in the field of seamless interaction in shared workspaces between mobile devices and tabletop systems. We model the context as a relationship between a user, the user's mobile device and objects on the surface of an interactive tabletop system. The tabletop represents the public part of the context and the mobile device embodies the private part of the context in a tangible form. The mobile device's touchscreen provides an additional workspace, its gyroscopic sensors allow for detection of the device's orientation in the air and it can be used as multi-purpose tangible object on the tabletop's surface. Additionally, an interaction performed with a mobile device can be technically and conceptually linked to its owner. In particular, users can automatically authenticate interactions by using their own device. Therefore, by employing tangible contexts it is possible complementing public interaction on the tabletop with private interaction on the mobile device and providing an ownership metaphor of UI elements on an interactive surface.

1 Introduction

A manifold of application scenarios have two or more co-located users collaborate by using a computer system simultaneously. Interactive surfaces that are mounted on a table are well suited to provide an according workspace. Standing around or sitting at a table is a natural setting for collaboration. Interactive surfaces are able to support multi-touch and thus enable all users to interact with the computer system at the same time. Similarly, tangible user interfaces (UIs) where props, i.e. real objects that carry a certain semantic for the computer system, are put on the tabletop can be supported by today's interactive surfaces. Again, multiple users can interact with these props in parallel. Such interactive tabletops are becoming more mature and even commercial versions, for example the Microsoft Surface 2[1], are starting to be used in real-world applications.

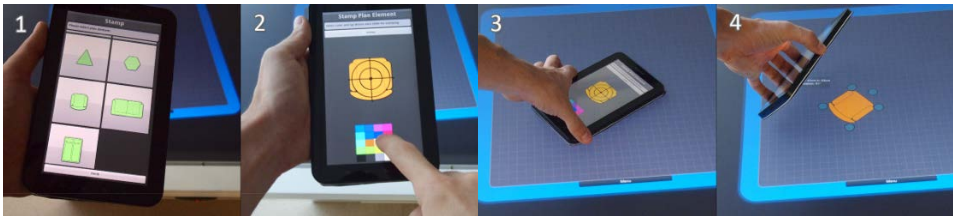

Figure 1: A user creates a new object on the mobile device and stamps it onto a workspace on the surface.

One potential drawback of interactive tabletops is that everything is public since all users can view the whole information displayed. No single user owns the workspace and is in charge – in contrast to a PC-based setting where all users can gather around the monitor but only one user controls keyboard and mouse. This may give rise to the need to complement the public workspace implemented by the interactive tabletop with private workspaces. For implementing these private workspaces, mobile devices are suited well since they are becoming affordable and popular; they support many interaction techniques (e.g. multi-touch or sensor-based interactions) and they are owned by an individual user, who often carries them along all day.

A key issue in the combination of mobile devices with tabletop surfaces is how to seamlessly support interaction between them (Fitzmaurice 1993), (Rekimoto 1998). In a straightforward approach (Echtler et al 2009) allow physically connecting a mobile device to a tabletop by putting the mobile device directly onto the surface and using it as an interactive tangible object. Providing individual and cooperative views among multi-users who are involved in a public space to support as well private as public interactions among multi-users (Lee et al 2011) is another important aspect. However, to build a coherent workspace, the private views on the mobile device and the according public view on the tabletop system need to be coupled closely to each other. There is still a need for concepts and solutions that are able to achieve this.

This paper contributes our concept of tangible contexts, in which we model the context as a seamless, shared workspace on the mobile device and the tabletop system. We introduce manipulation metaphors in which users interact with the tabletop system in a tangible way by using the mobile device as a multi-purpose tangible object in a continuous space ranging from the interactive surface to the hands of the user. In a tangible context, the mobile device provides an ownership metaphor for items on the tabletop surface, for example all UI elements (like images or notes) of a context can conceptually belong to the owner of a mobile device. Therefore, only owners of a context are allowed to use access-restricted controls on their mobile devices like deleting an item. Besides a discussion of our concepts, we report on

1 http://www.samsunglfd.com/product/feature.do?modelCd=SUR40

their usage in an example scenario, a room planner application, and review implementation as well as usability aspects based on a user test.

The paper is organized as follows. In the next section we review related work. Section 3 presents our tangible context concept and section 4 our tangible context manipulation metaphors. In section 5, we explain the implementation of our room planner application and in section 6 we discuss our evaluation results. Finally, section 7 concludes the paper and illustrates future work.

2 Related Work

Several research projects have investigated aspects of using handheld or moveable displays to extend and complement the capabilities of interactive surfaces. (Fitzmaurice 1993) introduced information spaces with spatially aware palmtop computers. A palmtop computer automatically recognizes its surrounding and shows adapted content. (Rekimoto 1998) contemplated employing hand-held computers as data-entry palettes for digital whiteboard systems as the Whiteboard’s large display renders conventional GUI design approaches inefficient. (Greenberg and Boyle 1998) analyzed the combination of personal mobile devices and shared public displays. Users can create notes in private or in small groups on their PDAs and publicize them on the shared display to discuss them with other users. (Myers et al 2004) focused on office and home applications as well as collaborative scenarios for shared workspaces. In terms of mobile devices in combination with tabletop systems, (Echtler and Klinker 2007) described an approach how to physically track mobile phones on interactive tabletops and proposed in (Echtler et al 2009) to employ this information to support casual interaction of users in board games on interactive tabletops. Users can join a board game by simply putting their mobile phone onto the tabletop system. (Olwal and Feiner 2009) described the use of handhelds for spatially aware and high-precision interaction with large displays like those in tabletop systems. Additionally to a physical tracking approach, they proposed using the handheld for a magic lens metaphor with high-precision controls, as the resolution of handheld displays is usually higher than those of large displays. Later, (Olwal 2009) discussed how surface interaction can be augmented with context-sensitive mobile devices. Additionally to the proposed magic lens metaphor and the precision controls, Olwal reminded that interacting with a mobile device identifies users and can be used for authenticated interaction. (Lee et al 2011) described a system for dual interaction between multi-displays and mobile devices. Their rendering system creates different outputs for mobile phones and collaborative displays and synchronizes interaction between different devices. (Dachselt and Buchholz 2009) described gestural interaction via throw and tilt of a mobile phone with other devices: By performing a throw-gesture, users can 'throw' contents from a mobile device on a big screen. By tilting the phone, users carry out interaction metaphors like mouse control or highlighting.

The mentioned research projects provide different, important aspects that need to be considered when designing interaction between mobile devices and public spaces or interactive surfaces. They, however, do not provide a holistic approach for seamless interaction between mobile devices and interactive surfaces.

3 Tangible Contexts

Interactive tabletop systems offer shared workspaces to multiple, co-located users. Such systems provide simultaneous interaction and can foster communication amongst users. However, the tabletop offers only one workspace for all users. A modification of the UI will be instantly publicly visible to all other users. It is not possible for users to prepare a solution individually before presenting the results to the public on the tabletop. Additionally, each user may manipulate all content on the tabletop.

Our concept of tangible context provides both: firstly, the possibility for each user to have a private workspace on their mobile device and secondly, an ownership metaphor for UI elements on the tabletop. A tangible context consists of UI elements on the tabletop and a UI on a mobile device. Each context belongs at least to one user but it can also have more than one owners. All UI elements on the table belong to at least one context and provide the public context, which all users can see and interact with. The UI on the mobile device however is the private context only accessible to its user. The private and the public context form a joint workspace. For instance, a user can connect the mobile device's UI to a UI element on the table by putting it on top of it. Therefore, the UI on the mobile device is spatially sensitive to the content on the tabletop. With tangible contexts multiple users can connect to the UI on the tabletop with their mobile devices. Instead of interacting directly with the public context on the tabletop, users can work in the same context independently and simultaneously on their mobile devices.

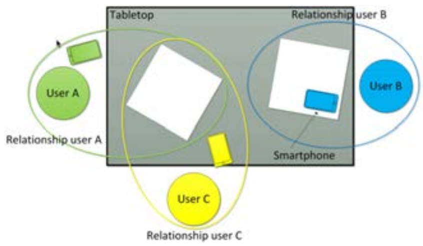

Figure 2: Two contexts: User A and C share a public context, while having their own tangible, private contexts on their mobile devices. User B owns a public and private context.

Figure 2 illustrates this concept: The tabletop shows two UI elements on the tabletop (represented by the white rectangles). The ovals represent a context. A context belongs at least to one user but can also be assigned to several users. The public contexts of user A and C share the same UI element on the tabletop, however each one has their own private context on their mobile device.

The private context on the mobile device comprises three components:

- **Controls** allow for manipulation of UI elements. Controls can be transformations like translation, rotation or scaling, configurations like changing the color or the type of an object or actions like deleting.
- **Access:** Usually, all content on the tabletop belongs to every user and every user can perform actions like deleting, adding or modifying content. However, with tangible contexts, access restrictions can be set and coupled to contexts. Actions with restricted access can only be performed in the private context on the mobile device.
- **Data** can be assigned to objects and is public or private. An object's public data like a description is visible to all users. In comparison to public data, private data is only accessible in the private context on the mobile device. For instance, while consulting a customer, an architect might present plans to a customer while holding back private information like pricing on the mobile device.

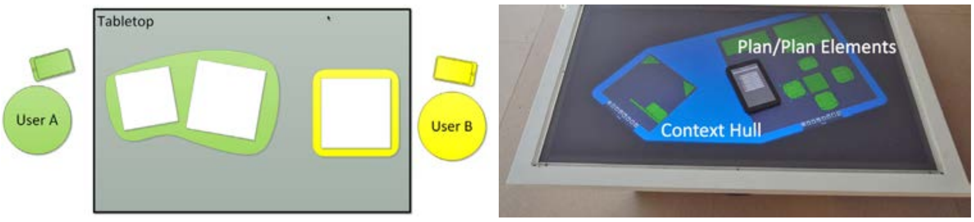

Figure 3: Visual grouping in convex hulls of UI elements on tabletop belonging to one context (left); actual room planner application (right). Each workspace has its own color that identifies the corresponding context.

To be able to illustrate and test our concept, we developed a room planner application that uses our tangible contexts (Figure 3, right). In the room planner, all UI elements that belong to the public context are visually arranged within a convex hull (Figure 3, left). According to the context to which the hull belongs, it has a certain background color. The hull contains different rooms and the rooms contain furniture (Figure 3, right). The private context on the mobile device's touchscreen shows different views relating to the current action that a user performs with it, e.g., in our room planner, when manipulating a chair in a room plan it presents related actions to the user (Figure 4).

Figure 4: The user puts the mobile device on a chair of a room plan in (2) and the UI presents related actions. In (3), the user presses the 'Focus' button to confirm the focusing and chooses in (4) to configure the object.

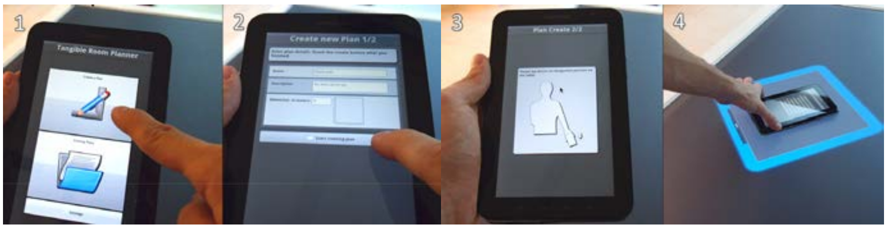

Figure 5: A user creates a new context on their mobile device (1), configures it (2), gets a hint to put mobile device onto the surface (3) and finally stamps it on the tabletop.

4 Tangible Context Manipulation Metaphors

Users control contexts in a tangible manner: In addition to direct touch interaction with the public context on the tabletop surface, interaction can be performed with the mobile device while holding it in the hand or by using it as a tangible object on the surface. In the following, we explain the different mobile device interaction metaphors with tangible contexts.

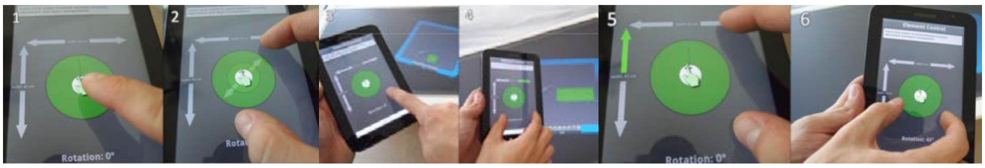

Figure 6 illustrates the precision controls on a 'focused' sofa. The precision control has two states: Accuracy adjustment and object manipulation that can be toggled by pressing the circle's center (1). In accuracy adjustment state, performing a pinch/scale gesture changes the control-display gain (CDG) and therefore the precision of a movement in the object manipulation state. The inner green circle indicates the CDG (2). (3), (4), (5) and (6) show the object manipulation state: drag, scale and rotate works with the usual pinch, scale, rotate and drag gestures.

At the heart of the tangible interaction stands 'focusing': By putting the mobile device on a UI element, the mobile device focuses it and shows the related controls in the UI of the private context on the mobile device (Figure 4). If the mobile device is part of the context, the private context UI on the device shows all actions. If not, the UI on the device shows only the public controls and data.

To initially create a new room plan or a new UI element within the room plan, users create it on their mobile device and stamp it onto the tabletop surface (

Figure 5). However, a user may only create a new UI element in a workspace on the tabletop that belongs to the same context as the mobile device.

As tabletops still do usually not offer the same touch-precision and display-resolution as most mobile devices (Olwal and Feiner 2009), a precision control on the phone allows for fine-grained adjustment of a focused UI element. Our precision control (illustrated in further detail in Figure 6) allows for fine-grained adjustment of UI elements.

The merge control allows comparing and merging different states of a UI element. Figure 7 presents a detailed illustration of the merge control. Therefore, different users can work in parallel in the private context on the same room plan and the results can be easily merged using the public context on the tabletop as soon as the work in the private contexts is finished.

Figure 7: The merge control allows for comparing and merging of plans on the mobile device: In (1), only the current room plan is visible on the tabletop. In (2), the user selects 'Show existing plans' and in (3) two existing plans are shown in a list on the device. Selecting the plans draws them in a comparison view on the tabletop in (4) and (5). Finally, in (6) the user has finished merging.

Usually changing the order of layers on an interactive surface can be pretty complicated, which is inherent to the two-dimensional nature of the surface. E.g., (Davidson and Han 2008) introduced special pressure-sensitive layering cues to provide ordering means via touch. Therefore, we introduce a layer control on the mobile device that allows for the ordering of different layers of a UI. E.g., in our room planner application the order of overlaying UI elements can be manipulated on the mobile device. The layer control uses the mobile device's gyroscopic sensor: After focusing a workspace, tilting the mobile device automatically shows the layering control. Figure 8 explains the layer control in further detail.

5 Implementation

As hardware, we used our self-built interactive tabletop system called 'TwinTable', which comprises a 1920 x 1080 pixel display (see Figure 3, right). Touch and fiducial detection on the TwinTable is performed by our own multi-touch and fiducial tracking application called Actracktive[2] that is based on reacTIVision (Kaltenbrunner 2009) and CCV[3]. For testing purposes, we used a Samsung Galaxy Tab GT-P1000[4] running Google Android 2.2[5] as a mobile device.

[2] http://code.google.com/p/actracktive

[3] http://ccv.nuigroup.com/

[4] http://www.samsung.com/ca/consumer/mobile/mobile-phones/tablets/GT-P1000ZKMBMC

[5] http://www.android.com/

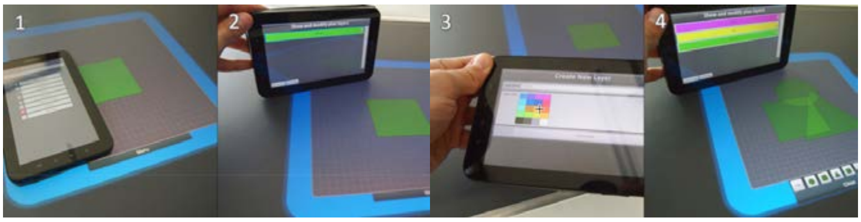

Figure 8: The layer control allows for rearranging superimposed layers. In (1), a user focuses the room plan with the mobile device. In (2), the device is tilted and the layer control opens. In (3), the user creates new layers that can be seen as semi transparent objects in (4). On the mobile device, the user may change their order.

We implemented the room planner with the Adobe Flash platform[6] for our tabletop system and for the mobile device. Both systems communicate with each other via BlazeDS[7]. Although there are more sophisticated approaches available like (Echtler et al 2009) or (Olwal & Feiner 2009), we initially decided to simulate mobile device detection on the tabletop surface by applying a reacTIVision fiducial marker to the mobile device.

6 Evaluation

We performed an initial evaluation of our manipulation concepts by performing a user test with 12 participants that we recruited from students of our faculty. All 12 participants had experience with touchscreen interaction but had so far no experience with direct touch and tangible interaction with tabletop systems.

We compared two interaction metaphors, namely the focusing of a UI element and the precision control each with two kinds of interaction versions. One version had to be performed with the mobile device, the other with direct touch only interaction. Therefore, we implemented the according touch metaphors. Each user performed both tasks in both versions in random order. To gather qualitative feedback, we interviewed participants after the user test. Additionally, to measure the user experience, participants filled out the User Experience Questionnaire (UEQ) by (Laugwitz et al 2006). The UEQ comprises five dimensions of user experience measured on bipolar 7-point Likert scales:

- Transparency (confusing / clearly arranged)
- Originality (conventional / inventive)
- Stimulation (uninteresting / interesting)
- Predictability (unpredictable / predictable)
- Efficiency (inefficient / efficient)

6 http://www.adobe.com/de/flashplatform/

7 http://opensource.adobe.com/wiki/display/blazeds/BlazeDS

Concerning the user experience dimensions, our hypothesis was that there are significant differences between…

- … precision and finger control (precision control significantly better).
- … mobile device and finger focusing (mobile device significantly better).

To evaluate the UEQ, we used Wilcoxon signed rank tests for each comparison. We could not find significant differences regarding the transparency, predictability and efficiency between the touch and the tangible context versions. We could however find significant differences for the stimulation and the originality for both tasks. The precision control is significantly more original ($p < 0.003$) and significantly more stimulating ($p < 0.022$) than the finger control. Mobile device focusing is significantly more original ($p < 0.002$) and significantly more stimulating ($p < 0.037$) than the finger focusing. Therefore, we assume that due to the novelty of the tangible contexts, the users find the tested interaction metaphors on the mobile device more original and more stimulating than their direct touch counterparts.

Amongst others, in the qualitative feedback, users told us that they find the mobile device focusing metaphor convenient. However, one person was concerned about laying a personal device onto the 'public' tabletop. Although they found the precision control on the mobile device slower than its direct touch counterpart, they found it more comfortable.

7 Conclusion and Future Work

Our work provides the concept of tangible contexts characterized by a relationship between a user, a workspace on a tabletop interface and the user's mobile device. Users employ their mobile device in a tangible way to interact with the tabletop. In a context, the mobile device represents the ownership of UI elements on the tabletop. Certain actions like deleting are only allowed for context owners. Additionally, we introduced tangible mobile device tabletop interaction metaphors. We implemented a room planner application as a proof of concept for the tangible context concept and to test manipulation metaphors. First evaluation results show that tangible contexts are more original and stimulating than direct touch only interfaces.

Today's ubiquitous mobile devices have the potential to complement public tabletop workspaces with a multitude of private workspaces. By using mobile devices, a simple access control mechanism is feasible employing our context concept. A mobile device's high-quality, high-precision touchscreen enhances touch-interaction with (still relatively low-resolution, low-precision) tabletop interfaces. A mobile device's sensors are useful for a multitude of interaction metaphors and it can be employed as multi-purpose tangible object directly on the tabletop's surface.

Tangible contexts with mobile devices and tabletop systems open up a cornucopia of interaction possibilities. There is still the need to explore those possibilities in future work. In addition, it is valuable to consider the question how the concept presented in this paper can be adapted in order to accommodate scenarios where users are not co-located.

Acknowledgements

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