Permulin: Collaboration on Interactive Surfaces with Personal In- and Output

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Abstract
Interactive tables are well suited for co-located collaboration. Most prior research assumed users to share the same overall display output; a key challenge was the appropriate partitioning of screen real estate, assembling the right information "at the users' fingertips" through simultaneous input. A different approach is followed in recent multi-view display environments: they offer personal output for each team member, yet risk to dissolve the team due to the lack of a common visual focus. Our approach combines both lines of thought, guided by the question: "What if the visible output and simultaneous input was *partly* shared and *partly* private?" We present *Permulin* as a concrete corresponding implementation, based on a set of novel interaction concepts that support fluid transitions between individual and group activities, coordination of group activities, and concurrent, distraction-free in-place manipulation. Study results indicate that users are able to focus on individual work on the whole surface without notable mutual interference, while at the same time establishing a strong sense of collaboration.

Author Keywords
Tabletops; multi-view display; personalized multitouch

ACM Classification Keywords
H5.2. User interfaces: Graphical user interfaces (GUI), Input devices and strategies, Interaction styles.

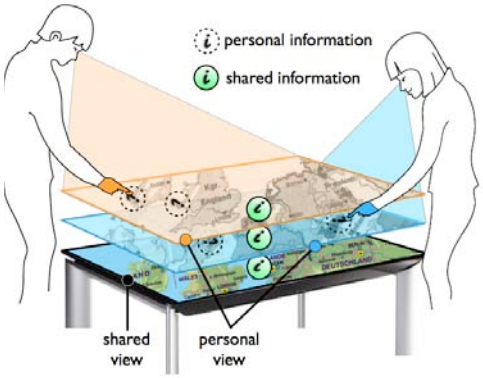

Figure 1. Permulin: personal views oriented towards user, visible only for her; shared view visible for both.

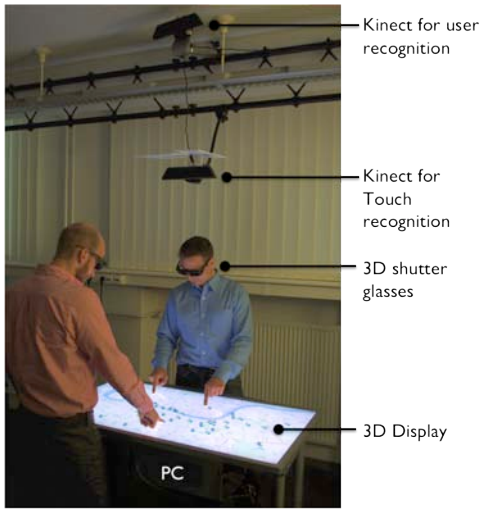

Figure 2. Permulin overview

General Terms

Human Factors

Introduction

Alice and Bob plan a day out, sightseeing in Manhattan. Along the way, they want to visit famous cafés and restaurants. They gather around a digital tabletop, where they collaboratively use a digital map to plan their trip. They divide some of the tasks at hand: Alice agrees to look for sights while Bob focuses on cafés and restaurants; when they are both done, they share their findings. In between, Alice shortly checks her private email for the address of their hotel to make sure the selected locations are nearby.

The above scenario reveals two key requirements for co-located collaboration on interactive surfaces [3]: *(a) simultaneous interaction* with the shared surface and *(b) mixed-focus collaboration* i.e. frequent transition between group and individual work. Prior work has enabled *simultaneous interaction* through personal input [2, 8]. However, this creates potential for access conflicts on a shared surface, such as 'global conflicts' (one user clears the screen while others are still working) or 'whole-element conflicts' (access to a particular interface element is disputed) [7]. In turn, this requires collaborators to coordinate their interactions through e.g. partitioning the surface into dedicated areas, where elements are only accessible by either everybody (shared space) or the owner (private space) [7]. This partitioning is also used to support *mixed-focus collaboration* [10], whilst it constrains each user in both interaction and screen space.

To overcome screen space limitations, Caretta [12] investigated the usage of secondary small devices for private interaction. However, this requires the users to switch their attention between the surface and the secondary device. As an alternative, multi-view displays [4, 6] provide personal output to each collaborator. Lumisight [6] is a tabletop system with four rear projectors and special projection films; it provides personal output for up to four users, rendered depending on the projection direction. Most recently, PiVOT [4] enabled personal view overlays depending on the user's viewing angle. While these systems provide personal output, they do not allow for simultaneous personal input in overlapping personal areas.

Our contribution is three-fold, which reflects the remainder of this work in progress: (1) we contribute *Permulin*, a novel interactive surface concept enabling users to utilize the *entire* horizontal surface for *personal in- and output* simultaneously (cf. Fig. 1). Permulin is particularly well suited for mixed-focus collaboration: users share some in- and output, while they can use the en-tire surface for personal interaction without distracting each other. (2) We introduce a set of novel interaction techniques which support (a) short- and long-term transition between individual and group work, (b) coordination of group activities among collaborators and (c) distraction-free in-place manipulation. (3) Results from an explorative user study indicate that users perceive and use Permulin fundamentally different than traditional tabletops: Permulin affords being used as a personal device during individual work, while serving as a highly cooperative device during group work.

Permulin: Concept and Implementation

Permulin is centred on the idea of providing both *personal* and *shared* in- and output (views) for collaborating users. The concept of personal-vs-shared *views* is to be distinguished from that of personal-vs-

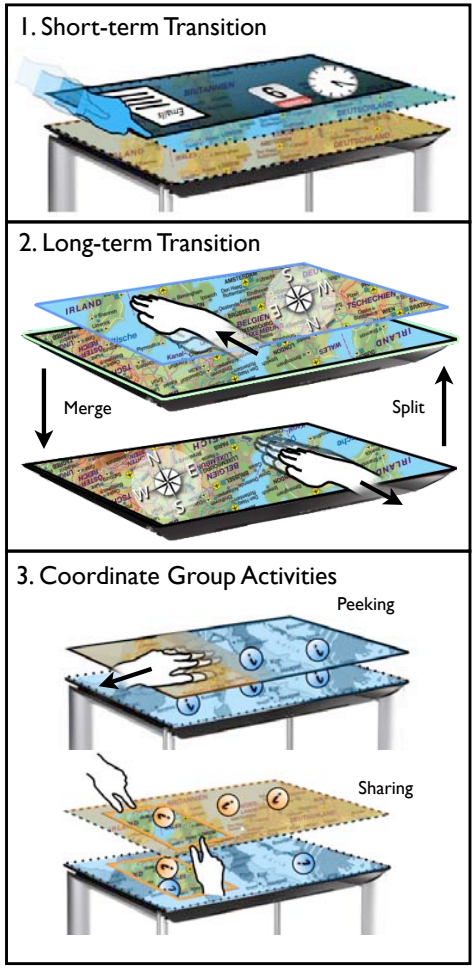

Figure 3. Interaction techniques for parallel collaboration with Permulin

shared *information*. Personal information is only visible in a user's personal view. Shared information, however, can be output and manipulated either in a shared view or in personal views (cf. Fig. 1).

The current setup of Permulin utilizes a 52" Philips 3D TV mounted on a table frame (cf. Fig. 2). Through active shutter glasses equipped with a so-called "two-player mode" [1], each user is able to see her personal view simultaneously on the entire screen. The number of parallel users is limited by the TVs refresh rate [13] (120 Hz, i.e. two users in our case). The TV emits polarized light, matching the polarization of the glasses. Thus, viewing is only possible from the longer side of the TV. We therefore added a diffusion film to the screen: a Kimoto 100 SXE foil. This depolarizes the light and enables a 360° personal view.

User tracking and touch recognition are enabled through two Kinect cameras (cf. Fig. 2). The higher mounted Kinect is used for user tracking the lower one detects touches using dSensingNI [5]. Data from both sensors contribute to the support of personalized input.

Interaction Techniques

Below we present interaction techniques that support mixed-focus collaboration with Permulin. They are also demonstrated in the video accompanying this paper.

Short-Term Transition

Permulin enables each user to quickly access personal information on the *entire* surface without occupying valuable display space, in contrast existing techniques occupy available display space for doing so [10] or impose a fixed viewing angle on the user [4]. Figure 3.1 illustrates the technique: the personal area is visible in the personal view. Its size can be adjusted by vertical dragging. It is visualized on top of all other views. As an example, the system provides a set of standard widgets such as an email inbox, personal notes and a calendar. Personal content can be shared by simply dragging it out of the personal area.

Long-term Transition

Permulin supports 'long-term transition' between individual and group work through split and merge interactions as follows.

Split: This technique enables users to work individually, utilizing the *entire* surface for both in- and output and not only a small fraction [10]. Shared information, e.g., a map, can then be manipulated independently in parallel. Figure 3.2 (bottom) shows the concept: a user places her hand flat on the surface and moves it toward her. This splits the workspace virtually, presenting a personally oriented view of it to each user. The split interaction is visually supported through a user-colored border around the personal view. From here on, all manipulations are mapped to the personal view. Permulin solves hereby afore mentioned global conflict, by allowing users to occupy the whole screen for own use and interaction (here the full-screen map). In contrast this is not possible with normal tabletops, because so far they have tried to either duplicate an element or divide the screen. Both approaches however lead to a limitation of screen and interaction space.

Merge: With this technique, split personal views are merged back into a common shared view. Figure 3.2

[1] See http://www.philips.co.uk/c/televisions/33092/cat/#!/dual-view (last checked: Jan 9, 2013).

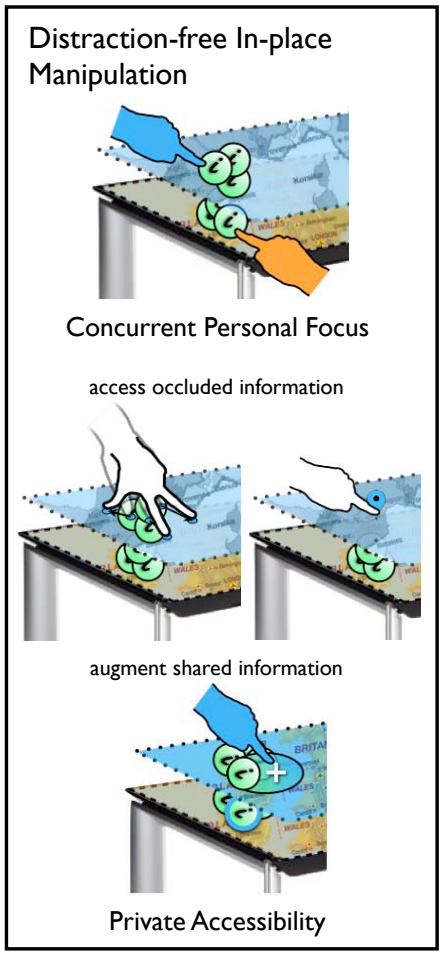

Figure 4. Interaction techniques for parallel collaboration with Permulin

(top) illustrates the technique: a user places her hand flat on the screen and moves the hand away from herself. In order to avoid screen clutter and confusion, personally added content remains privately visible first. Each user can then share personal content with others as described in the following.

Coordinate Group Activities
Permulin provides additional means to users for coordinating their group activities through sharing and peeking techniques. This enables collaborators to synchronize their working states.

Sharing: We distinguish between temporal and permanent sharing. *Temporal* sharing allows a user to quickly share a part of her personal view with other users. Figure 3.3 (bottom) illustrates the technique: a user utilizes a pinch gesture with both of her hands simultaneously, thereby framing a shared viewing area wherein others can see her personal information. Additionally, others see their own personal information in this area as well. Personal information (e.g. points of interest on a map) can then be shared *permanently* at any time by double tapping onto it.

Peeking: This technique allows a user to take a quick look at another user's personal view (inspired by [1]). Users can hereby peek *without* distracting other collaborators. Figure 3.3 (top) shows the technique: a user can privately peek at the personal view of her collaborator with a horizontal three-finger flick gesture.

Distraction-free In-place Manipulation
Parallel manipulation is prone to global and whole-element access conflicts between users: they cannot interact with elements without interfering with each other. As opposed to prior work which focused on duplicating conflicted elements [7], Permulin enables in-place manipulation of shared resources without distracting users from one another by providing concurrent personal focus and private accessibility techniques.

Concurrent Personal Focus: This technique allows users to concurrently maintain their personal focus on specific interface elements within their personal view, without occluding each other. Figure 4 (top) illustrates this: to enforce a personal focus on a specific element, a user touches and holds the element. If multiple users perform this technique in place, each of them sees 'their' element concurrently in focus.

Private Accessibility: Users are able to access digitally occluded, shared information on the personal view. To achieve this, occluding content is temporarily hidden (cf. Fig. 4 mid): spreading out three fingers across a pile of elements brings personal elements to the fore, while hiding the others. Since this is visualized in a user's personal view, others can continue working without being distracted. The reverse action, a three-finger squeeze, brings elements back.

In Permulin, shared information can be augmented with personal information *without* occupying screen space on the shared view: additional information is visualized in the personal view. Figure 4 (buttom) illustrates this: an additional button is visualized near shared content, only visible in the personal view.

Evaluation and Discussion

We conducted an explorative user study with 5 groups of 2 volunteer participants each (3f, 7m; avg. 26

years). The participants were recruited using a snow-ball-sampling technique. Two groups, (P1, P2) and (P3, P4), consisted of close friends; (P5, P6) were friends from work and two groups, (P7, P8) and (P9, P10), were strangers. We chose a within-subject design and each group session lasted about 2.5 hours (think-aloud protocol, video-taped, interaction logs and semi-structured interviews after each task). We were interested in observing *(a) the overall experience*, *(b) mutual interference between users,* and *(c) collaboration.*

As a main theme for the tasks, we adopted the scenario from the introduction: the participants were asked to collaboratively plan a trip using a shared digital map. In total, we had 5 tasks. First, participants had to search for interesting places in a city of their choice: once without (T1) and once with (T2) the ability to split and merge views. Next, they started with split views in pre-defined cities and were asked to coordinate their planning activities (T3). Afterwards, they had to fulfill planning tasks, described on virtual post-it notes in their personal information area (T4). Last, they had to freely plan a city trip, again of their choice (T5).

For each task, the participants were given a short introduction and time for familiarizing with the system until they felt confident. After each session we transcribed the data, selected salient quotes and coded them using an open coding approach. Next, we present the results.

Perceived Sense of Possession — "Yours and Mine"
Regarding *(a) experience*, Permulin was well received by all participants. They particularly liked the way in which it supports mixed-focus collaboration. This is underlined by their strong sense of possession when interacting with Permulin: they described the surface as "*my* territory" (P5), "*my* virtual space" (P2) and "*my* map, and you [P8] have *your* own map" (P7). Throughout the study, they stressed that Permulin helps to focus on individual tasks; as P3 put it: "I don't have to wait, I can just do my own things […] and the system helps me to focus on them".

However, the two distinct personal views and therefore the subdivision between "yours and mine" on the surface let us observe two phenomena: first, it evoked privacy concerns. For instance P3 feared that P4 might just "discover some private activity, while peeking into my view". And second, the participants were uncertain about the other user's view on the surface, even for shared information, which was distinctively visualized as such; they commented, "I didn't realize that you could see that [the map in T4]" (P10). This identifies a lack of shared awareness, which is contradictory to prevailing assumptions that a shared reference point to foster shared understandings on multi-view displays [11] is enough. We therefore argue that these do not hold for multi-view displays *with* personal input.

Physical Interference
As to *(b) non-interference*, we often observed both participants to interact 'close to each other' in all groups. Surprisingly, this did not lead to any notable physical interference. The participants stated that they "faded out the other participant's fingers" (P1) and that "fingers are not problematic, I didn't realize them" (P9). These comments are in line with our observations that participants used nearly the whole surface for interaction, even when they had to interact near each other. This is further backed by a very interesting mismatch between our interaction logs (cf. Fig. 5) and the participants' perception: The logs show that almost

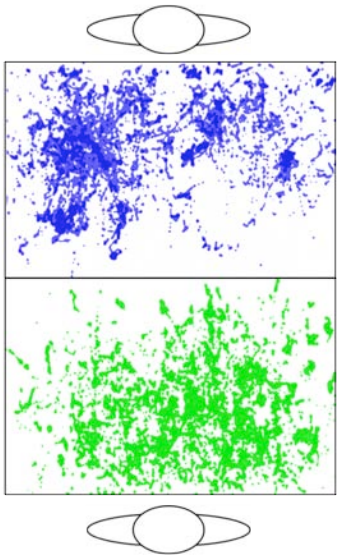

Figure 5. Accumulated interaction logs across all participants for T2 and T5 (same setting). Participants used the entire surface for interaction (the darker the color, the more touches).

the entire surface had been used for interaction, while the participants felt they had interacted only in their proximity. We consider this as a strong indicator that boundaries between territories [9] on the surface blur or even dissolve when switching from group to individual work (and vice versa) – an important advantage of our approach over split-screens.

Perceived Sense of Collaboration

Regarding *(c) collaboration,* the participants liked the ability to coordinate their activities in-place using one unique surface for mixed-focus collaboration. They often used the sharing technique to let the other user know about their activities, e.g. what they had found on the map. P7 commented: "it's easy to synchronize different views […]; it's just there, in front of you". Although the participants were often involved in separate personal views throughout the tasks, they had a strong feeling of cooperation: "it was always about cooperative work" (P5, P6) and "although we worked individually, we still worked together" (P3, P4). Additionally, we observed that participants preferred to split their views long-term, particularly in tasks 2 and 5.

Conclusion

We contributed Permulin, a novel interactive surface concept. It goes beyond prior work by enabling users to utilize the *entire* horizontal surface for *personal in- and output* simultaneously. We introduced a set of novel interaction techniques enabling fluid mixed-focus collaboration.

We assess the results of our explorative study as very promising: the overall user *experience* was that of a personal device during individual work and that of a highly cooperative device during group work. The entire screen real estate was used by both collaborators during individual work without any notable mutual *interference*. *Collaboration* was perceived to be always readily available.

Future work concerns two areas: (1) *further studies* are needed in order to understand issues of privacy, territorialities and space usage in more detail; (2) *additional interaction concepts* are required in order to further improve shared awareness. Finally, the studies with two participants were appropriate for initial findings and for our current setup, but support for larger teams remains an important issue to address in the future [13].

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