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Body Panning – A Movement-based Navigation Technique for Large Interactive Surfaces

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ABSTRACT
In this note we introduce Body Panning, a novel interaction technique for horizontal panning on interactive surfaces. Based on an established sensory hardware setup, we implemented a robust body tracking system for a large-scaled tabletop. On this basis a user can pan through a spatial user interface by adjusting her position at the table. As a natural form of interaction, this technique is convenient and applicable to many existing use cases and applications, as we will present in this note. Besides, we expected to see positive effects on the user's navigational and spatial memory performance. We conducted an experiment between a common touch panning and a body panning interface to find out about differences in these performances. For the body panning condition, we observed an increased spatial memory performance and an invariant navigation performance. We present and discuss these results focusing on application domains for the body panning technique.

Author Keywords
Body Movement; Panning; Tabletop; Interactive Surface; Spatial Memory; User Study; Spatial User Interfaces

ACM Classification Keywords
H.5 m [Information interfaces and presentation]: Miscellaneous

INTRODUCTION
Recently, the development of large-scale tabletop interfaces has increasingly addressed heterogeneous usage domains, such as design, sensemaking, planning, and information exploration tasks. Such tabletop user interfaces often implement a panning navigation style, whenever only a limited amount of physical display space is available for navigating a larger virtual canvas of spatially distributed information [4]. Mapping and planning applications which show vast amounts of visual data are one example for such panning UIs. Furthermore, they have become common for home screen navigation on interactive surfaces (e.g. Windows 8, iOS, or Android home screens). For panning navigation on interactive surfaces touch is mostly used as a substitute for mouse interaction. A large body of research has revealed some insights on the effects that this shift from mouse to touch input has on the users' navigation [3][4][7]. For example, the shift to touch interaction is often considered as an enrichment of the users' perception. Hence, touch interaction can be seen as a first step to regain natural interaction. However, upcoming research fields like Spatial Interaction and Proxemics focus on how the entire body could be a used as an interaction device. In the context of such research, we present a utilization of the user's body for a very fine-grained interaction technique: by allowing users to pan through the interface through the movement of their body.

BODY PANNING AS AN INTERACTION TECHNIQUE
The basic idea of the Body Panning (BP) technique derived from the fact that users are not bound to specific locations during the interaction with large-scale tabletops and interactive walls. They are free to move around and therefore their body positions might be used as an additional input modality during interaction with the system. One example for utilizing the body orientation and position cues for interaction was presented by Vogel and Balakrishnan [11]. Here, the body position was used to control the position of a 1D cursor on a vertical display.

For the development of body-centered interaction techniques it is necessary to detect the user's position. We equipped a state of the art multi-touch tabletop with an established user-tracking system that provides data on the user's location and movement through an array of proximity sensors, which are arranged around the table [6].

Figure 1. Body Panning

Based on this technical basis we implemented the BP technique that allows a user to pan horizontally through a spatial user interface by adjusting her position at the table (Figure 1). Here, a virtual canvas of the spatial UI covers three times the physical display size of the table. Depending on the user's position at the table the corresponding position covering one-third of the entire virtual canvas is shown. When the user adjusts her position at the table, the canvas continuously pans to the new corresponding position.

For the BP implementation we utilized the long sides of the table. Each side is equipped with 32 proximity sensors which are located underneath the tabletop display (Figure 2). The sensors are distributed over a length of 143cm and can detect a larger body in the vicinity of a maximum of 70 cm. The distribution of 32 sensors at each side of the table leads to an accuracy resolution of 4.46 cm for tracking a body.

Figure 2. Tracking System

Technically the proximity sensors provide a binary array, where 1 represents a body presence in front of the sensor and 0 stands for the opposite. This array is transformed into position data by means of a simple algorithm. In order to calculate the position of the user's body the algorithm determines the mean position of all covered sensors. This produces a set of about 70-100 pan steps depending on the size and shape of the body. For the reason that the system responds sensitively to changes of the body position, which lead to unwanted landscape movement, an additional Kalman filter [5] was utilized for the position calculation. Also the graphical interface is performing some interpolations with animations between the absolute positions to ensure a more comfortable panning.

Based on a pretest with 10 participants, we defined the maximum virtual canvas size which still allows a convenient body panning navigation. The results show that the tracking resolution allows an acceptable panning accuracy for a virtual canvas size of three times the physical display space. Since our tabletop is equipped with a 65" Full HD display, the virtual canvas has a resolution of 5760x1080 pixels.

In summary this technical implementation leads to a continuous panning interaction. Each position of the user's body at the table is directly mapped to the corresponding relative position on the virtual canvas.

Usage Domains

BP is an interaction technique which is suitable for a number of heterogeneous use cases or usage scenarios. We divided those into two groups: scenarios where the *hands are occupied* and those with what we call *dense touch object aggregation*.

Hand occupation appears in interfaces where the hands are needed for other tasks or devices. For instance interaction with surfaces is often combined with complementary devices such as tablets or physical lenses. Here, the complementary devices are spatial-aware and can augment the main surface with additional information or layers. There are a lot of examples for this device constellation. Fitzmaurice showed with his Chameleon prototype how a palmtop unit could be used for displaying information layers above maps and library shelves [2]. Spindler et al. uses physical paper lenses for studying multi-layer interaction above tabletops [9]. Wallace et al. used a tablet-tabletop combination for sensemaking [12]. The application of BP to these interfaces would allow a panning navigation on the main surface whereby the hands could be exclusively used for other tasks on the complementary devices.

Interfaces with *dense touch object aggregation* can be found in different application domains. For instance, music programs and virtual mixing boards often consist of dense aggregated touch controls for music production. Furthermore, tabletops are often used for exploration of spatially distributed digital artifact collections (e.g. photos and videos) by scaling and rotating touch sensitive objects [8]. Manipulation and selection of vast amounts of objects can also be found in planning and mapping scenarios. For these interfaces panning is often implemented through 'dragging' object-free spaces of the canvas. Since cluttered objects often restrict these spaces heavily, BP could be a suitable alternative navigation technique since users are no longer required to find and acquire object-free areas. This is especially useful in densely populated spaces.

Beside these groups of applications BP can be beneficial for other applications that are specifically designed for this interaction technique. For example, applying BP for public displays (e.g. museums) would provide users a novel way of information exploration (e.g. a timeline visualization or panorama images).

RELATED WORK

The most common used panning technique on interactive surfaces is tap-and-drag touch panning. Due to the fact that touch is used as a substitute for mouse interaction, research has focused on a comparison of mouse and touch panning. Studies of selection tasks on a tabletop found that task completion was faster with touch and the error rate was comparable to the mouse [7]. Furthermore, replacing the mouse with touch might have strong effects that go far beyond speed and accuracy of target acquisition. They suggest that other design considerations, such as spatial memory, should play a role and further investigations into such qualities are needed [3][7]. Spatial memory could be understood as a cognitive process in which a mental representation of space is developed in the human's mind

[1]. In HCI, studies of spatial memory are often focused on the visuo-spatial metaphors on the screen and how they affect the user [4]. We are only aware of two studies which focus on the impact of input methods on spatial memory. Tan et al. compared mouse vs. touch input for a memorization task in which users had to memorize objects by dragging them into given locations. For touch input they reported a significant improvement of accuracy for the locations to be remembered [10]. Jetter et al. also observed that touch interaction for a panning-only user interface on tabletops leads to better spatial memory as well as better navigation performance in comparison to mouse interaction [4].

EXPERIMENT

We conducted an experiment to compare the impact of body panning vs. touch panning on a horizontal panning UI that resembled a virtual canvas with different kind of objects (Figure 3).

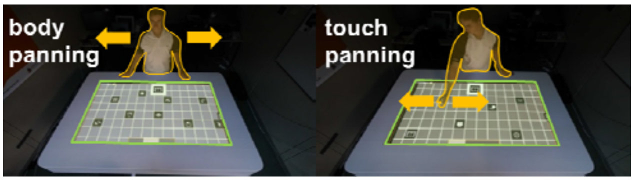

Figure 3. Body panning and touch panning condition

The general hypothesis was that body panning (BP) instead of touch panning (TP) would result in better *navigation performance*. Furthermore the experiment should investigate if body panning shows positive effects on the user's *spatial memory*.

We used a 65" horizontal interactive tabletop (182cm*120cm) with a resolution of 1920x1080pixels and an IR frame for touch recognition. For touch panning we used a 1 to 1 mapping, which means that the distance moved with the finger is the exact translation on the virtual canvas. For body panning we used the described technical implementation.

NAVIGATION AND SPATIAL MEMORY EXPERIMENT

In our experiment, 49 participants took part, who we randomly assigned to two different conditions (Body Panning vs. Touch Panning) in a between subjects design (n(BP): 24, n(TP): 25). Also, gender distribution was nearly equal in both groups. Accordingly, for statistical analysis, we used an Independent Samples t-Test. All participants were recruited from the campus of our university. Participants ranged in age from 21 to 28 years and were paid 7 EUR in compensation for their time.

In the experiment, we used a locate & drag task to measure performance. The canvas featured a multitude of potential target locations with different symbols. The target item had to be placed on the correct target location by drag&drop.

The experiment consisted of two tasks which were executed sequentially by the participants. The first task of the experiment embraced a simple placement task. This task was used to measure the navigation performance. The virtual canvas showed a 42 by 8 grid for orientation. It contained 24 possible target locations (Figure 4). These target locations were specified by different symbols of similar size and color and were distributed over the entire virtual canvas. Participants were presented a target item showing a specific symbol on it. The participants' task was to find the target location which corresponds to this target item. They then had to drag and drop it to the designated target location. To ensure that the target item was always in arm's reach in both conditions it was always presented in front of the participant and followed her as she moved on the long side of the table. To reach the target locations participants always had to pan through the virtual canvas. The target locations did not change their positions during the experiment. Participants had to place 6 symbolic items after another for each block. Each block was repeated 8 times to increase the development of an accurate mental model.

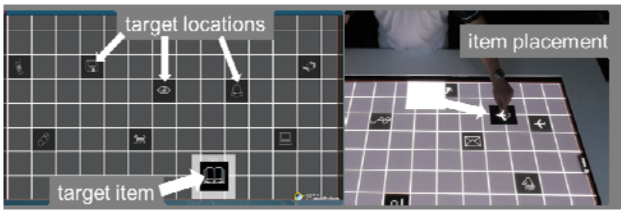

Figure 4. Placing objects task (E1)

In the second task of the experiment we focused on the spatial memory performance. We asked the participants to reproduce the memorized target location configuration in a reproduction task. In order to do so, the participants were shown an empty grid on which they had to place the 6 items. Those items were the same as in the previous placement task and where given in the exact same order. For one item after another, they were challenged to put the item at the exact location in the grid (according to the initial position from the proceeding placement task).

This spatial memory task design was motivated through the studies of Tan [10] and Jetter [4] who also used a grid and a reproduction task. We didn't use a Fitts' style selection task because it does not provide insights into how the techniques perform for the arguably more demanding dragging actions. Furthermore, the application of simple selection tasks does not help to directly address our hypothesis concerning spatial memory and navigation.

Results

To determine the navigation performance of the placement task for the conditions (BP vs. TP), we measured each time between the placements of items. With body panning the mean was 6.79 sec. (SD = 1.25) and not significantly smaller than the mean with the touch condition of 7.27 sec.

(SD = 1.65) with $t(45) = 1.148$; $p > 0.05$. Hence, participants with the BP condition did not have a significantly better navigation performance than the participants with the TP condition.

Jetter et al. define spatial memory "as the users' mental representation of the virtual canvas" [4] which could be measured by analyzing the accuracy of memorization. Therefore we measured during the reproduction task the accuracy of item placement calculating the Euclidean distance between the memorized and the correct locations of the items. The comparison of these results of this spatial memory task shows a better spatial memory performance for the BP condition. For the BP the mean error in pixel was 401 (SD = 125) in the touch panning condition the mean was 608 (SD = 300). This difference is statistically significant with $t(32) = 3.179$; $p < 0.05$. Hence, BP has a beneficial impact on spatial memory performance.

DISCUSSION

Based on the results of the experiment we may conclude that body panning (6.79 sec) is not inferior in navigation performance to touch panning (7.27 sec) for a simple placement task. However, our tracking hardware implementation has a rather low resolution, which makes it more difficult for users to predict and control the panning. A higher tracking resolution e.g. by enhancing the number of sensors could therefore have a positive impact on the navigation performance.

The results of the spatial memory task showed a significantly better performance for body panning. Therefore, it seems plausible that an UI's input modality and its proprioceptive and kinesthetic feedback have an effect on users' spatial memory as Jetter et al. already proposed [4].

Overall it is important to mention that the participants acquired the body panning technique quite fast. They quickly understood that approaching an item result in an ongoing movement of the virtual canvas. However, in some cases, participants had issues with overshooting, specifically at the beginning of the experiment. We could see these issues diminish over the course of the experiment as participants got convenient with the sensitivity of the body tracking.

CONCLUSION & FUTURE WORK

In this note we introduced Body Panning, a novel interaction technique for horizontal panning on interactive surfaces. The most interesting study result is the positive effect of BP on the user's spatial memory. This effect may have an impact on the design of future applications since this effect supports e.g. the recalling of visual landmarks and their spatial relation and therefore an effective and efficient navigation. In our future research we will take a deeper look on this positive effect by focusing on learning tasks of spatial arranged information (e.g. timeline visualizations).

As touch panning is a software-based and body panning is a hardware-based technique it might be beneficial to combine these techniques. For instance, body panning for coarse grained and touch panning for fine grained navigation. Furthermore, the body panning approach is at the moment designed for single user interaction but we think that it could as well support certain multi-user scenarios which we will address in our future research.

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