“Multi-toe” interaction with a high-resolution multi-touch floor

Konstantin Kaefer
konstantin.kaefer@student.hpi.uni-potsdam.de

Dorian Kanitz
dorian.kanitz@student.hpi.uni-potsdam.de

René Meusel
rene.meusel@student.hpi.uni-potsdam.de

Caroline Fetzer
caroline.fetzer@student.hpi.uni-potsdam.de

Thomas Augsten
thomas.augsten@student.hpi.uni-potsdam.de

Thomas Stoff
thomas.stoff@student.hpi.uni-potsdam.de

Christian Holz
christian.holz@hpi.uni-potsdam.de

Patrick Baudisch
patrick.baudisch@hpi.uni-potsdam.de

Hasso Plattner Institute
Potsdam, Germany

CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.

Abstract
In this paper, we propose extending interactive floors by integrating recent high-resolution multi-touch technology. The resulting systems combine the interactive capabilities and precision of a tabletop computer with the size, form factor, and spirit of a Ubicomp environment. We discuss the resulting research questions and design challenges.

Keywords
Interactive Floor, Touch interaction, Input Gestures

ACM Classification Keywords
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces: *Input devices and strategies*

Introduction
The combination of projection and cameras has allowed interaction designers to create simple interactive floors.

In this paper, we propose extending interactive floors by integrating recent high-resolution multi-touch technology. This allows for a new class of systems that can recognize users based on their shoes, can distinguish foot postures and determine the state of individual toes, track users’ head positions based on the weight distribution across their feet, and allow users to interact while standing, sitting, kneeling, and lying.

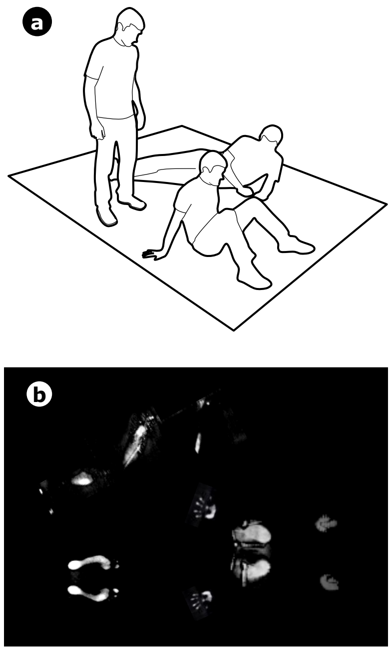

Figure 1: (a) Three postures and (b) the "body prints" they produce on an FTIR floor.

The resulting systems combine the interactive capabilities and precision of a tabletop computer with the size, form factor, and spirit of a Ubicomp environment (e.g., *easyLiving*[2]). Unlike smart homes and ambient floors, the proposed floors allow users to interact intentionally and with precision, thereby enabling applications that were traditionally only possible on systems that were operated *using hand*s, such as desktops or tabletops.

The technological transfer from tabletop to floor, however, brings up new challenges. While hands can touch, hover, and reach buttons outside the interactive surface, feet need to carry their owner's weight at all times. This makes the ergonomics requirements of floors very different from tables. It also requires new interaction techniques that allow distinguishing intentional action from standing and walking. In this paper, we discuss a selection of these challenges typically in direct comparison between tables and floors.

1) Standing, Sitting, and Lying

When interacting with tabletop systems, users sit along the sides. In exceptional cases, they might stand, but that makes hardly any difference from the table's perspective.

On multi-touch floors this is different. While the obvious posture is to stand, they may also be lying, sitting, kneeling, or crouching. Seen from below, each posture produces a different characteristic pattern (Figure 1a). The "body prints" can be analyzed as discussed in [8].

Each posture affords its own characteristic display area (dashed outlines in Figure 2). Input areas, i.e., floor areas users can reach using their hands or feet, are not necessarily collocated with the output area.

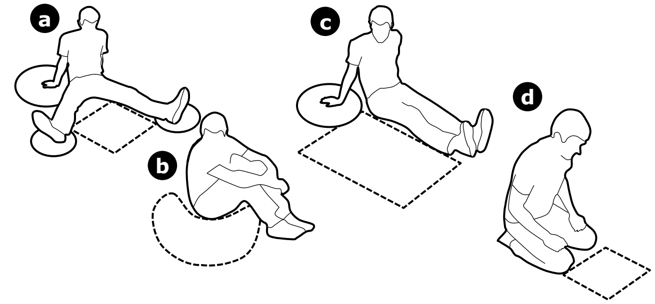

Figure 2: Four different sitting positions and the display areas (dashed) and interaction areas (solid outlines) they afford.

Head tracking

Unlike tabletops, floors bear the user's complete weight at all times. Analysis of the pressure distribution[4] over the user's feet allows locating the user's center of gravity (Figure 3). This input can be used to approximate the user's head position, e.g., to enable fish tank VR.

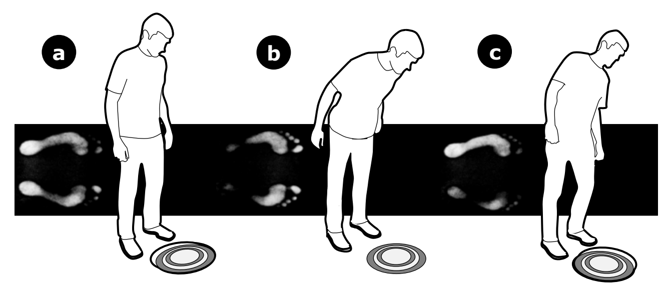

Figure 3: Moving the head around causes the user's weight to shift, which yields a different pressure distribution on the floor. Here the floor renders the perspective of an object accordingly.

2) Identify Users

On tabletop systems, it is hard to identify users based on their hands since most fingertips look similar. Without the use of an overhead camera [10], even features such as hand lengths are hard to extract, because fingers are typically flexed.

Feet, in contrast, often touch the floor in their entirety or we can reconstruct the entire imprint by combining a series of camera images. Foot prints allow distinguishing users to a certain extent based on features, such as length and width of foot and height of the instep. Recognition is simplified further if users are wearing shoes; here characteristic sole pattern help distinguish users (Figure 4a). Maintaining user profiles with sole patterns allows identifying users across sessions (Figure 4b). Other postures allow for other features to be used for identification, such as shape of back pockets in Figure 1.

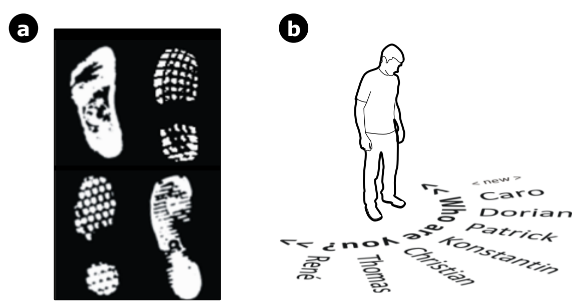

Figure 4: (a) Many shoes feature unique sole pattern that make them easy to recognize from below. (b) When the floor sees a pair of soles for the first time, it asks for identification.

Unlike tabletops, where fingers can "disappear" for extended periods of time when users lift their hands, gravity assures that a floor captures at least some part of a user's body at all times. Even when users jump, the pressure distribution before take-off allows the floor to estimate the direction of the jump.

3) The Gravity Problem

All touch-sensitive devices suffer from inadvertent touch, even though to different extent. Touch-based tablet computers (e.g., SMART *Sympodium*) offer a "palm reject" function to prevent a palm resting on the screen from interfering with pen input. Tabletops suffer from a similar problem when the user rests an elbow on the tracked area.

On touch sensitive floors, gravity forces users to touch the surface at basically all times. Thus, the floor needs to distinguish intentional action from standing and walking. In addition, stationary menus are often a long walk away, suggesting the need for a mechanism for popping-up a local context menu (see also *location-independent UI* [9]).

Touch-insensitive areas allow users to walk without interfering. However, they clash with applications where every pixel is interactive, such as painting programs. Here a mode switching mechanism is required.

Approach 1: Modal. A distinctive gesture to switch into a command mode. Jumping seems well suited, as it hardly occurs unintentionally (Figure 5c and d).

Approach 2: Non-modal. Foot gestures, such as stomping can be used to trigger actions. Fast walking or tip toeing allow passing an area without interacting (Figure 5a and b).

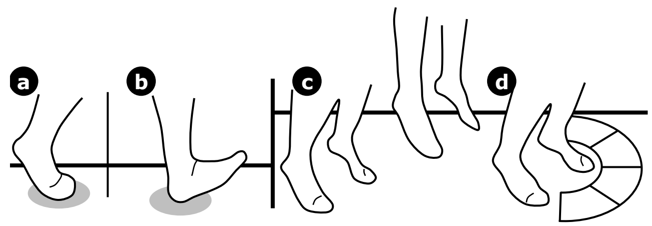

Figure 5: (a) Ball of the foot interacts, (b) heel to secondary-click, (c) and (d) jumping enters “command” mode.

4) Widgets and ergonomics

Many interaction techniques on tables involve users temporarily lifting their hands. These techniques need to be redesigned when adapting them to floors.

Buttons

Pilot studies showed that users tend to tap a button with one foot instead of stepping on it, most likely because tapping resembles tapping with a finger on tabletops. Tapping offers the following benefits:
(1) Users are familiar with tapping from using physical buttons. (2) Tapping allows users to stand back, keeping interface elements clearly visible in front of them. (3) Users stay in the same position, making it easy to stay oriented. (4) Lifting the foot after tapping reveals the interface element, allowing it to show visual feedback.

Unfortunately, on a floor tapping is subject to ergonomic limitations: Having to stand on one leg is tiring and potentially instable. Especially targets that are further away are hard to acquire (Figure 6c).

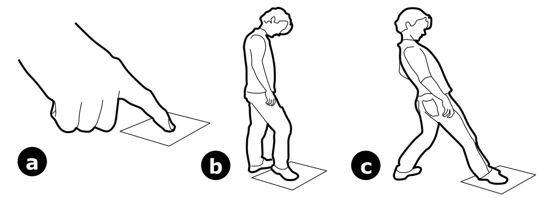

Figure 6: (a) Tapping on a tabletop vs. (b) on a floor. On the floor, tapping requires users to extend their leg forward.
(c) The further away users tap, the further they need to lean backwards to keep balance.

We have therefore started to explore interaction techniques that allow users to use their feet alternatingly, just like normal walking.

Keyboard

The following Figures illustrate the concept of alternating foot use. To avoid tapping, the user in Figure 7 uses feet alternatingly. Certain letter combinations, however, cause users to tangle their feet.

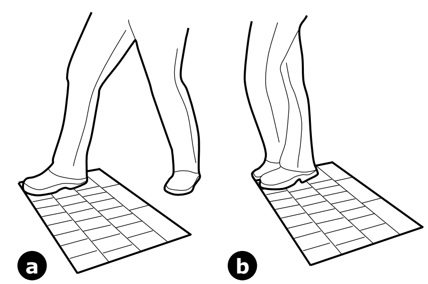

Figure 7: This naïve version of an onscreen keyboard causes users to tangle their feet when accessing certain letter combinations.

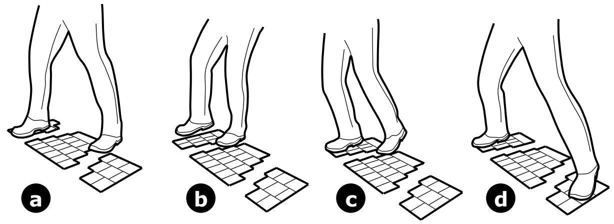

Figure 8: The split-keyboard allows users to use feet alternatingly by offering a “dead zone”.

To simplify alternation of feet, the keyboard design in Figure 8 is split into three pieces; this allows users to step into one of the “dead zones” with the unused foot in order to maintain the rhythm.

Unfortunately, the split keyboard gives up on other qualities of the tapping keyboard: When users stand on the upper rows, keys located behind them are hard to see. The keyboard design in Figure 9 addresses this. It moves with the user and places itself in front of the next active foot.

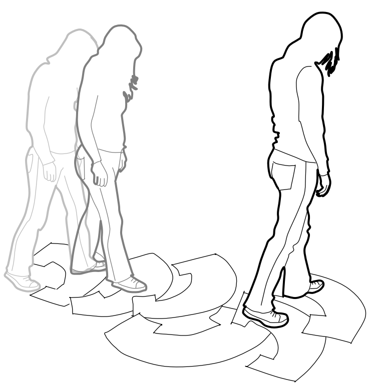

Figure 9: Users move forward, avoiding the sometimes abrupt directional changes of previous two designs.

Rotating, zooming, and bi-manual/bi-pedal

On tabletops, multi-finger or bi-manual gestures are common, e.g., when rotating or zooming an image. These gestures do not transfer to floors because users cannot move both feet at the same time unless they jump. Novel foot-compatible gestures are needed. To find out which gestures might be most intuitive, we conducted a paper prototyping session, inviting participants to demonstrate how they would perform the most common tabletop manipulations using their feet. Figure 10 shows a selection of results for image rotation.

Figure 10: Five participants of a paper prototyping session demonstrate how they would rotate a picture on a floor:
(a) Building up rotation inertia by swinging arms.
(b) Extinguishing a cigarette. (c) Dragging a corner.
(d) Tapping and sliding in a circle. (e) Flicking the corner.

About the Project

Figure 11a shows the current building status of our $8m^2$, back-projected interactive floor. It will use a single 10 megapixel projector and a single 12 megapixel camera.

All photographs in this paper were taken with a smaller prototype (Figure 11c). It uses the same stack-up of the final full-scale design, supporting Frustrated Total Internal Reflection [4] and Diffused Illumination (Figure 11a).

Figure 11: (a) Back-projection design of the floor. (b) Samples of the glass pane. (c) The prototype we use to explore the materials for the final design.

Figure 12: The construction site earlier this year.

Conclusions

In this papers, we have taken a first look at the high-resolution multi-touch floors. We have discussed the resulting research questions and design challenges.

Acknowledgements

Gerald Morrison for his input and compliant surface, Sebastian Boring, Florian Echtler, Peter Brandl, Christian Mueller-Tomfelde, Johannes Luderschmidt, Raphael Wimmer, Frank Priester and Timm Krohn.

References

[1] Bianchi-Berthouze N., Cairns P.,Cox A.,Jennett C.,Kim W. On posture as a modality for expressing and recognizing emotions. *BCS-HCI'06*.

[2] Brumitt B., Meyers B., Krumm J., Kern A., Shafer S. EasyLiving: Technologies for Intelligent Environments. *HUC'00*, pp. 12-27.

[3] Cao, X., Wilson, A., Balakrishnan, R., Hinckley, K., and Hudson, S. ShapeTouch: Leveraging Contact Shape on Interactive Surfaces. *Tabletop'08*.

[4] Davidson, P., Han, J. Extending 2D object arrangement with pressure-sensitive layering cues. *UIST 2008*, pp. 87-90.

[5] Dietz, P. and Leigh, D. DiamondTouch: a multi-user touch technology. *UIST'01*, pp. 219-226.

[6] Grønbæk, K., Iversen, O.S., Kortbek, K.J., Nielsen, K.R., Aagaard, L. iGameFloor - a Platform for Co-Located Collaborative Games. *ACM'07*, pp. 64-71.

[7] Grossman T., Hinckley K., Baudisch P., Agrawala M., Balakrishnan R. Hover widgets: using the tracking state to extend the capabilities of pen-operated devices. *CHI'06*, pp. 861-870.

[8] Mota, S. Picard, R. Automated Posture Analysis for detecting Learner's Interest Level. *CVPR HCI'03*.

[9] Pier, K. and Landay, J. Issues for Location-Independent Interfaces. 1992.

[10] Schmidt, D. and Gellerson, H. Show Your Hands: A Vision-Based Approach to. User Identification for Interactive Surfaces. *TableTop'09*.

[11] Wobbrock, J. O., Morris, M. R., Wilson, A. User-Defined Gestures for Surface Computing. *CHI'09.*

[12] Yoruk E., u Konukogl E.,Sankur B.,Darbon J. Shape-based hand recognition. Image Processing. *IEEE Trans Image Process'06*, pp. 1803-1815.