Weight-Shifting Mobiles: One-Dimensional Gravitational Displays in Mobile Phones

Fabian Hemmert, Susann Hamann, Matthias Löwe, Anne Wohlauf, Gesche Joost
Deutsche Telekom Laboratories
Ernst-Reuter-Platz 7,
10587 Berlin, Germany
{fabian.hemmert, susann.hamann, matthias.loewe, anne.wohlauf, gesche.joost}@telekom.de

ABSTRACT
In this paper, we present a novel actuation system for mobile phones: An actuated center of gravity. We present a number of applications, including *interactive feedback*, *notification* and the usage of the system as an *ambient display*. We present the results of an initial user study, in which the users were asked to estimate the position of the device's center of gravity. The results indicated that weight-shift is suitable to support mobile interactions.

ACM Classification: H5.2 [Information interfaces and presentation]: User Interfaces. – Haptic I/O.

General terms: Design, Human Factors

Keywords: center of gravity, weight-shift, mobile phone, tactile actuation, feedback, notification, ambient display.

INTRODUCTION
Mobile interaction design has, in the past years, advanced to an active area of research. Here, a particular circumstance that has to be dealt with is that interacting with a device while on the go is often equipped with only limited audiovisual resources – one's audiovisual attention is often required by other tasks, such as walking, driving, or interacting with other people. As a previous study by Oulasvirta et al. has indicated, interaction on the go often occurs in 'bursts' [5]. It appears therefore to be worthwhile to investigate *permanent non-visual* displays for usage in mobile interaction design.

BACKGROUND
Tactile mobile interaction design is an active research field. In this paper, we will focus on strategies of mobile actuation that *permanently* change the physical properties of the device.

Shape-Changing Surfaces
One category of permanent tactile displays is that utilizing a shape-change of the device. Work in this area has been conducted by O'Modhrain et al. [3] and Hemmert et al. [2]. These can be used without visual contact, even though they rely on specific *tactile attention*.

Fig. 1: Prototype. Sony-Ericsson W880i mobile phone, mounted on weight-actuated box.

Temperature Displays
Temperature-based displays, on the other hand, are ambiently readable. Work in this area has, for instance, been conducted by Ottensmeyer et al. [4], and, more recently, by Wettach et al. [7]. While this is a promising area of actuation, users seem to be mostly unable to sense *absolute* values. Furthermore, temperature displays operate, compared to other display techniques, rather slow.

Ungrounded Force Displays
Recently, ungrounded force-based displays have been proposed by Amemiya [1], and also in the GyroCube project [6]. The advantage of these is their directedness; however the actuation occurs in *bursts*, which might result in a 'jumpy' feeling of the device. Scheibe et al. [7] have explored a weight-shift based system for usage in virtual reality contexts, but an integration of weight-shift based actation into a mobile phone has not been proposed to date.

PROTOTYPE
Our prototype consists of a box, in which a servo motor with an additional weight moves around its axis (Fig. 1). The motor is connected to a nearby microcontroller, which is connected to a PC. Through a Bluetooth connection, the PC communicates with a mobile phone, which is mounted on top of the 'weight actuated' box. The empty box, measuring 130x60x40mm, weighs 40g, the motor, including the weight, weighs 63g, the phone weighs 70g.

UIST'09, October 4–7, 2009, Victoria, BC, Canada.

APPLICATIONS

As the proposed weight-actuation is achieved through a servo motor, it is possible to react in a timely manner to user interactions. It would therefore be possible to add *interactive feedback* to the user's actions on the phone through a moving center of gravity in the device. We implemented a photo viewer on the phone, which featured a weight-augmented list of photographs: The more off-screen elements are on a side, the more the center of gravity moves to that side. Besides being given direct feedback while interacting with the device, users might also receive *notification* over a longer period of time through a moving weight inside the device. We implemented a simulated file download; as the download progresses, the weight moves from the top of the device to its bottom. The subtleness of changes in the gravitational properties of the device might also qualify this style of display as an *ambient display*. We implemented a battery status display: The weight, moved to the top of the phone, symbolizes a full battery; when moved to the device's bottom, it indicates a nearing empty state.

USER STUDY

In an initial user study, we assessed how precise users were able to determine the device's *absolute* center of gravity.

Users and Task

12 users (5f, 7m, Ø 25.2 yrs., all right-handed) participated in our study. Each was allowed to use their preferred hand for holding a mobile phone. After a training session, in which they were demonstrated different positions of the device's center of gravity, every user, wearing headphones, engaged in 9 trials, each of which was structured as follows: They were asked to place the weight-actuated box (without the phone) on the table in front of them. Through a nearby computer, the weight in the phone was then moved to one of 9 pseudo-randomized target positions. The user was then instructed to pick up the phone and estimate its center of weight, and mark it at an original-sized picture of the weight-actuated box.

Results

The mean estimation error from the user's estimation of the weight's position to its actual position was 26.84mm (SD=23.35mm). As for time on task and error rate, we did not find any effects of trial number or weight position. In 88.5% of the trials, users were able to determine whether the weight had moved upwards or downwards (χ^2 (1, N=96) = 57.04, $p_{1\text{-tailed}}$=.000), since they lastly held it in hand. Estimating the center of gravity, some users placed the phone on their fingertips, while others moved it over one finger, to see when it would flip. Most users moved the device around, in order to get a feeling for how it would respond to movement.

DISCUSSION

The findings we made in the user tests suggest that gravitational displays as we proposed them are a valuable addition to mobile phone interaction. Users were able to estimate the position of the phone's actuated center of gravity at accuracies sufficient for many applications. More importantly, they were able to get a good feeling for the relative tendency of weight change – a circumstance that should be studied in more depth in the future.

CONCLUSION

We have introduced a new actuation system for mobile devices. It seems suitable for a variety of applications, longing from direct interaction feedback to ambient displays. It draws on sensorimotor skills which have rarely been explored as a means of interaction before.

FUTURE WORK

In future iterations of this work, we will investigate two-dimensional gravitational displays, and study in-depth how different factors influence the perception of the weight (e.g. how the device is held in hand, the contrast of the device's weight and the movable weight, and movement patterns).

REFERENCES

1. Amemiya, T., Ando, H. and Maeda, T. Lead-me interface for a pulling sensation from hand-held devices. *ACM Trans. Appl. Percept.*, *5* (3). 1-17.
2. Hemmert, F., Joost, G., Knörig, A. and Wettach, R., Dynamic knobs: shape change as a means of interaction on a mobile phone. In *CHI '08: CHI '08 Extended Abstracts on Human Factors in Comp. Sys.*, (2008), ACM, 2309-2314.
3. O'Modhrain, S. Touch and Go --- Designing Haptic Feedback for a Hand-Held Mobile Device. *BT Technology Journal*, *22* (4). 139-145.
4. Ottensmeyer, M. and Salisbury, J.K., Hot and Cold Running VR: Adding Thermal Stimuli to the Haptic Experience. In *Proceedings of The Second PHANToM User's Group Workshop, October 1997*, (1997).
5. Oulasvirta, A., Tamminen, S., Roto, V. and Kuorelahti, J., Interaction in 4-second bursts: the fragmented nature of attentional resources in mobile HCI. In *CHI '05: Proc. of the SIGCHI Conf. on Human Factors in Computing Systems*, (2005), ACM Press, 919-928.
6. Sakai, M., Fukui, Y. and Nakamura, N., Effective Output Patterns for Torque Display 'GyroCube'. In *Online Proc. of the 13th Int. Conf. on Artificial Reality and Telexistence, December 3-5, 2003, Keio University, Tokyo, Japan.*, (2003).
7. Scheibe, R., Schneider, H., Hochstrate, J., Froehlich, B., Haptic Feedback Through Weight Shifting. In *IEEE VR Workshop New Directions in 3D User Interfaces*, Bonn, (2005).
8. Wettach, R., Behrens, C., Danielsson, A. and Ness, T., A thermal information display for mobile applications. in *MobileHCI '07: Proc. of the 9th int. conf. on Human Computer Interaction with Mobile Devices and Services*, (Singapore, 2007), ACM, 182-185.