Dynamic Knobs: Shape Change as a Means of Interaction on a Mobile Phone

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Abstract
In this paper, we introduce the change of a mobile phone's hardware shape as a means of tactile interaction.

The alteration of shape is implemented in a hardware prototype using a *dynamic knob* as an interaction device for the user. The knob alters the phone's shape according to different events and states, like incoming calls, new voice mail, or missed calls. Therefore, the user can explore the phone's status by touching it – ambiently, even through the pocket. Initial user testing showed that this form of tactile interaction was easy to understand and handy to interact with, also for unexperienced users.

Keywords
Force feedback, mobile phone, notification systems, shape change, tangible interfaces

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces - Input devices and strategies

Introduction
The predominant feedback channels of mobile phones are visual display, sound and vibration. Visual display

requires the user to look at his phone; Sound and vibration only occur at the very time of an event - all together, these circumstances often lure users into *frequent checking* of their phones for missed calls, new text messages, etc.. We imagined that a *permanent, ambient status display* could be a solution in that case.

During a call, when holding the phone next to the ear, the interaction with the device is very limited: The phone's screen (due to the compact shape of mobile phones) is held next to the ear, along with the keypad. While some phones offer buttons on their *sides*, interacting with them usually does not go beyond changing the speaker volume. Out of dissatisfaction with that, we sought a richer way of *on-the-ear-interaction.*

Out of these observations, we envisioned that - similar to the concept of force feedback - *shape feedback* might be valuable in the situations mentioned above.

Related Work

Several explorations have been undertaken in the field of shape change and tactile interaction design to date.

Shape change has been investigated as a means of status display before, yet seldom over the state of a concept or an experimental prototype - often due to the lack of a technical solution. It has been proposed to physically display the amount of data stored on a USB stick [1], yet without a technical solution at hand.

The flexibility and the dynamics of tactile surface output through a *matrix of extending elements*, as initially demonstrated by Horev [2], are compelling - however, also their integration into mobile devices has yet to be explored.

Explorations of this field that have already taken place in the mobile phone context investigated the field of *tactile telecommunication*. “ComTouch”, as proposed by Chang et al. [3] instantiates a first prototype of this aspect. Our prototype could work as a platform for tactile telecommunication as well, communicating touch and pressure through *remote deformation*.

The human fingertip is a high-resolution sensory organ, and so tactile sensations need to be designed carefully. Development kits for force feedback are commercially available [4], which points to the potential of tactile and proprioceptive user interfaces. Other tactile feedback systems have been proposed, stretching the touching finger's skin [5] or employing momentum-based actuators [6] - however, all of these do only implement notification at the time of an event.

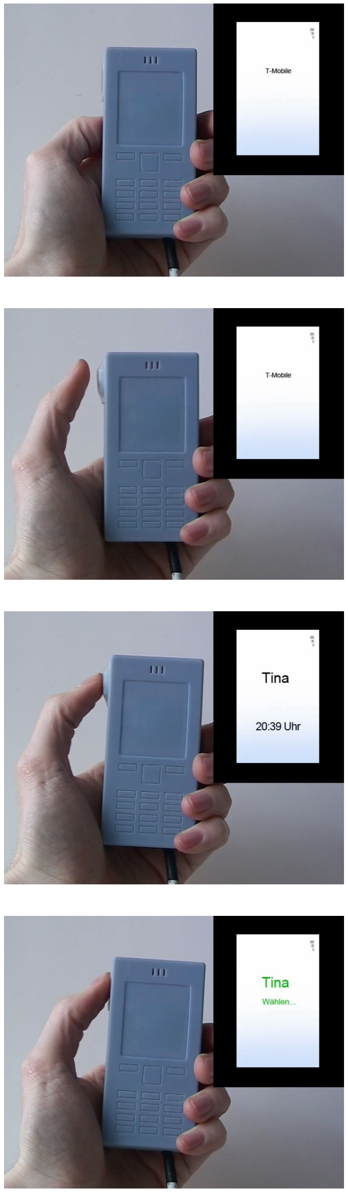

Fig. 1: Final prototype, consisting of mobile-phone shaped box and an external screen interface

Implementation

To realize shape feedback on a mobile device, several factors had to be taken into consideration: The mechanism had to be powerful enough to withstand a thumb-press, and at the same time power-efficient, so that energy would only be used while changing the shape, and while maintaining it - the device should be able to *lock* into a shape if necessary.

For this project, we limited the shape change to a small extension on one of the phone's sides, so it would be possible to feel the change through a pocket, and also to manipulate it while holding it next to the ear.

To move this *dynamic knob*, we used a servo motor [7] with a high-aspect mechanical transmission system. Even without power connection, the system would be very stiff (due to the gear aspect ratio of the transmission system), while quick movements could still be realized, at a high spatial resolution. It was clear that we also needed to measure how strong the finger was pushing the knob: It should be possible to let the knob react to touching, pushing, and holding. A thin (< .5 mm), force-sensitive resistor, placed on top of the knob, allowed us to measure the thumb pressure at a sufficiently high resolution.

The final prototype (Fig. 1) is a handheld device. As depicted, it has the dynamic knob in its top left corner, so it can be operated with either a thumb or index finger, depending on which hand it is held in. The motor and the sensor are both operated by the Arduino Board [8], while all data processing is done on a nearby computer. The computer is connected to the Arduino through a USB connection and operates a simple GUI based on PureData [9].

Application Scenarios

To visualize possible use cases of the proposed system, we present two application scenarios, one depicting the strengths of a *permanent status notification through shape change*, and one showing a possible application for *on-the-ear-interaction*.

Application Scenario 1: Missed Call

In this scenario (Fig. 2), *each* missed call is represented through a knob that comes out of the side of the phone. This allows the user to check the phone for missed events without looking at it. The check is done through a quick grasp, which is possible even through the pocket. At the same time, however, it is possible to ignore the change if necessary - the notification is ambient.

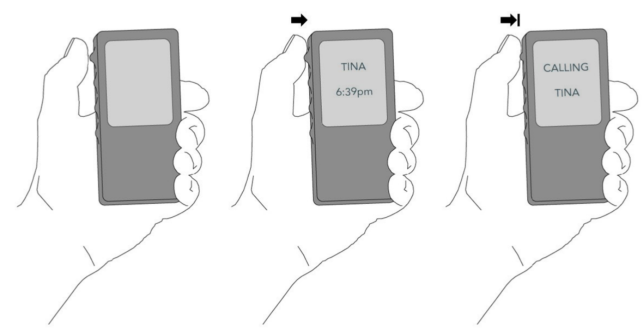

Fig. 2: Checking for missed calls through feeling the extensions on the phone's side

The knob also works as the interface for accessing information about the missed event and for responding to it. In this scenario, touching the knob displays the name of the caller.

Fig. 3: On-the-ear-interaction, listening to a voice mail message

This functionality enables the user to quickly check the list of persons who have called, by simply touching each knob, one after the other. Pressing the knob back inside the phone makes it disappear; holding it for 3 more seconds dials the number. This simple interaction principle also allows starting a conference call, simply by pressing multiple knobs at once (It should be noted, however, our prototype contained only one dynamic knob).

Application Scenario 2: Voice Mail
In this application (Fig. 3), the extension of the knob represents the length of a voice mail message. Through the knob, the user can control the playback of the message. This is, opposed to the current scheme of *"Press 4 to go to the next message. Press 7 to rewind. Press 8 to delete"* an action that can be performed comfortably while holding the phone next to the ear.

The following interactions are possible on our prototype:

Pushing the knob plays the message. The principle is based on the idea of "squeezing" the message out of the phone; as in this case, the behavior of the knob is similar to a spring, offering a decent counterforce. The physical length of the button is mapped to the length of the message.

Pushing the knob harder activates „fast forward". This principle offers a convenient way to search a specific point in the message, or to skip parts of it.

Holding the knob with little force pauses playback. If the user is interrupted while listening to the message, he can pause playback immediately.

Releasing the knob rewinds the message. This is an intuitive way to have the caller „repeat" a phone number you are just writing down.

Holding the button at the end of the message will dial the caller's number. To call back the person who left the message, the knob needs to be held a bit longer. The phone will then dial the number automatically.

Initial User Testing

We conducted a user test with a small group of volunteer users (2f, 4m, Ø32.2yrs). The users were of various experience levels, reaching from casual mobile phone users to professional user interface designers, and we conducted interviews with them in which they were able to try out the prototype.

The first set of tasks the users were assigned was implemented using the *experimental mode* of the software we created for the prototype, which allowed the simulation of different button types.

We simulated different patterns (a photo camera trigger, a spring, etc.) and the users described them coherently afterwards, including comments like *"This feels like 'action completed successfully'."* (as for the camera trigger), *"This feels like a critical button, it is not supposed to be pushed by accident."* (for a button that reacted only to strong pushes) and *"This button seems to cause some kind of internal processing that takes some time."* (for a button that remained in the phone for three seconds and then popped out again).

Problems surfaced when we set the threshold level of the force sensor too high: The users were unsure if the device was not working, and anxious that they would break the prototype. The users were also unsure if they would accidentally push the knob in their pocket.

Afterwards, we presented the application scenarios to the users. They were appealed by the approach, and they intuitively understood how to check for missed calls, and how to navigate in the voice message, having tried out the interaction for only a few seconds.

All of them were able to learn and perform the possible interactions of the *Missed Call* scenario (*"check for missed call", "check caller id"*, *"call back"*).

They were also able to safely navigate within the voicemail message while holding the prototype next to their ear, including tasks like *"Listen to the phone number mentioned in this voice message, then listen to it again to note the number down with your other hand, then fast-forward to the end of the message.*".

While this required some initial exploration of the necessary pressure, the users instantly understood how the knob acted like a spring and "followed" their finger.

Discussion

The users were able to intuitively pick up the interaction principles, regardless of what was simulated on the knob, and whether they used it through their pocket, in their hand or held next to their ear.

The user comments made clear that our tactile sense is well-trained to associate sensations with known objects (*"This feels like a camera trigger, ..."*) and so with underlying principles (*"... so I guess I just have to press it briefly and wait for the affirmative clicking."*).

Even though our test group was small, these results foreshadow a promising new interaction principle for users of all skill levels.

Conclusion and Outlook

The proposed system has demonstrated its strengths. Now, a long-term study could generate valuable insight into how *shape feedback* is indeed helpful to avoid over-frequent checking of the phone, and acquire statistically sound data about the usability of shape-based *on-the-ear-interaction*.

As simplicity and usability are becoming prevalent selling points for many target groups in the mobile phone market, we encourage the development of easy and intuitive patterns, and a "tactile language" within the user interface. The proposed principle offers unique, simple user experiences that can be grasped in an instant.

Acknowledgments

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