Natural User Interfaces in Mobile Phone Interaction

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Abstract
User interfaces for mobile devices move away from mainly button- and menu-based interaction styles and towards more direct techniques, involving rich sensory input and output. The recently proposed concept of Natural User Interfaces (NUIs) provides a way to structure the discussion about these developments. We examine how two-sided and around-device interaction, gestural input, and shape- and weight-based output can be used to create NUIs for mobile devices. We discuss the applicability of NUI properties in the context of mobile interaction.

Keywords
Natural user interfaces, physical interaction, mobile interaction, mobile devices, mobile phones

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation: User Interfaces—*Input devices and strategies, interaction styles, haptic I/O*

Introduction
In mobile device interaction, a trend can be observed, away from button-based and indirect, menu-driven UIs and towards direct, unmediated and responsive interfaces. For instance, such developments are present

Figure 1 Shape-based display of digital contents in mobile phones; Prototype from the *Shape-Changing Mobiles*

in the adoption of advanced input techniques (such as multi-touch) in recent mobile devices. Additionally, these devices provide rich and responsive feedback (e.g. by suggesting physicality in the UI). This indicates that the development trend of current and future mobile interfaces is moving into the direction of Natural User Interfaces (NUIs).

In this paper, we examine how two-sided and around-device interaction, gestural input, and shape- and weight-based output can be used to create NUIs for mobile devices. For each of these techniques we will discuss which properties are useful for the implementation of NUIs and how they fit into the general NUI paradigm.

Mobile User Interfaces from a NUI Perspective

NUIs have been referred to as a potential next step in the evolution of user interfaces. In a talk at UX Week 2008 Dennis Wixon [1] gives a historical analysis of UI paradigms and thereby characterizes NUIs by comparing them to command line and graphical user interfaces. According to him, NUIs are primarily based on intuitive and unmediated interactions with UI objects. These interactions are suggested by the affordances that these objects and the given context provide. Wixon defines a number of principles, including *performance aesthetics* (pleasure from interacting, not from task accomplishment), *scaffolding* (stepwise exposure of the system), and *contextual environments* (the environment suggests possible actions). The “super principles” include the *social* dimension of NUIs (utility in multi-user settings), *seamlessness* (through similarities between physical and virtual interactions), and *spatiality* (leveraging spatial memory through movements and zooming).

In mobile technology, we see a shift away from predominantly utilitarian notion of interaction towards more playful and socially relevant forms, which makes the principles of NUIs relevant for mobile user interfaces. They provide a useful perspective for the analysis of mobile interface phenomena. The NUI paradigm highlights non-technical aspects, such as social and aesthetic qualities of interactions. This is of particular relevance because mobile interactions are often performed in social contexts. Mobile interactions can thus at least partially be understood as a form of self-expression. Aspects like the joy of doing, the pleasure of interaction, and the emphasis on the contextual become more important than in traditional user interfaces.

Another paradigm that is helpful for explaining current mobile interfaces is Reality-Based Interaction (RBI) [2]. The RBI framework is based on the dimensions of naïve physics, body awareness and skills, environment awareness and skills, and social awareness and skills.

In the following, we will further analyze current mobile user interfaces using the basic principles of NUIs put forward by Wixon: *object-driven, evocative, fast-few, contextual, intuition*.

Object-Driven

Object-driven interfaces for mobile devices are still in an early state of development. Mobile UIs continue to be modeled mainly on the WIMP paradigm. Recent examples of object-driven interfaces include the photo browser and the map navigation interfaces on the

Figure 2 Two-dimensional weight-shift-based haptic display; *Weight-Shifting Mobiles* prototype.

iPhone. For interaction, they use multi-touch and the affordances provided by the photos or the map canvas, respectively (i.e. pinch to zoom, drag to scroll). There are still many opportunities available to make mobile UIs more object-driven. Many of the typical data items on modern mobile phones, such as media files (images, video, audio files), communication data (emails, short messages, contact data, calendars) and also more abstract functions (search requests, etc.) can benefit from the addition of affordances for direct interaction.

Evocative

Current mobile phone UIs are becoming more visually polished and employ more sophisticated visual feedback than the UIs of mobile phones that were marketed as recently as 2-3 years ago. The success of recent mobile phones such as the iPhone or phones running the Android platform show that mobile phone users appreciate a visually well-designed UI that provides responsive and aesthetically pleasing feedback for the users' actions. This significant progress in mobile phone interfaces has led to increased market shares for manufacturers focusing on user experience.

Recently, we proposed a shape-based display of digital contents in mobile devices [3]. Through alteration of the device's geometrical properties (Figure 1), such a display can be used to physically display abstract properties, or guide users — e.g. in a navigation scenario — towards external points of interest. Such styles of output are inherently evocative: The device encourages users to directly interact with digital content.

Fast, but few

The *Fast Few* paradigm is especially important for mobile UIs. Mobile applications usually help the user perform a single specific task and the mobile UI needs to be engineered to support this task in the most efficient and direct way. As the user is sometimes focusing on a secondary task (i.e. walking in the public, catching a train) the user must not be overwhelmed with functionality but rather guided towards accomplishing the goal of his task. Current mobile UIs have shown some very positive development in the last 2-3 years. For example, setting up the connection to an email account used to be a relatively complicated process on older mobile devices.

Mobile device displays are a particular example of the "Fast, but few" principle. Due to their small size, mobile displays are often limited in the amount of information they are able to show at a given time, and thus in the bandwidth of data they are able to convey. On the other hand, they are usually easily understandable, and very intuitive. As an example, the recently proposed *Weight-Shifting Mobiles* [4] project investigates the mass-based display of digital content: A moving weight on the device's inside (Figure 2) is used to augment GUI operations and also, similar to the previously mentioned shape-based variant, to give directional cues as a "tactile compass."

Context-Sensitive

Mobile devices are predestined to support contextual applications. A large variety of sensors are already installed on current devices, such as cameras, 3D acceleration sensors, magnetic field sensors, ambient light sensors and also location sensors through GPS, cell tower IDs and Wi-Fi access point location

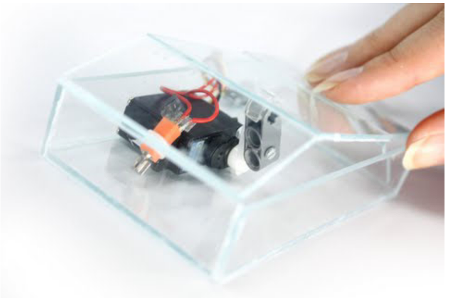

Figure 3 Life-like actuation in mobile phones; *Ambient Life* prototype.

databases. The availability of this ubiquitous location information has spawned a variety of new application classes, such as pervasive mobile games or mobile “AR” applications, such as Layar, that overlay the device's camera viewfinder image with geo-referenced information items.

Still, the sensing capabilities of mobile phones could be improved. For example, integrating 3D time-of-flight cameras into the mobile device could enable the sensing of the immediate surroundings by the mobile device. Depth sensing could not only improve object recognition, for example in applications such as Google Goggles [5], but also further improve around-device interaction [6], which can be used for the detection of hand postures or gestures.

Intuition
Mobile devices have made progress towards implementing "intuitive" behavior in the UI. An example for this is implied physicality.

Although the expressivity of input for mobile user interfaces has improved with the advent of multi-touch, the overall expressivity of mobile user interfaces is still constrained due to the small device size.

Intuitiveness can be especially helpful in mobile interactions: Such devices are usually tightly integrated with our everyday lives, and so they operate on the borderline of information and annoyance. A recent research activity in this area is the “Ambient Life” [7] project: Here, life-like behavior is simulated on a mobile device by augmenting it with physical breath and pulse (Figure 3). The device communicates through its pulse and breathing: either a “calm” state (which stands for no missed calls, no new text messages, and a sufficient amount of remaining battery life) or an “excited” state (representing the phone’s need for attention, e.g. because of a missed call).

Furthermore, we are currently exploring several techniques aimed at improving expressivity and increasing the intuitiveness of mobile interface technologies. In the following sections of this paper we discuss gesture-based interaction, two-sided interaction with pressure input and also around-device interaction.

Mobile Interaction Techniques Supporting NUIs
There are several interaction techniques that can be used to implement NUIs in mobile devices.

Gesture-Based Interaction
Mobile devices can recognize gestures performed by the user by using 3D acceleration sensors [8] or by analyzing images provided by the device's camera [9]. Gestures can range from simply changing the device's orientation to complex 3D movements as known from the Nintendo Wii.

Gestures are an important form of intuitive interaction. Gestures are used frequently in daily life and input through (well-chosen) gestures can feel natural, for instance when arm swings are used for mobile device authentication [10]. Gestures are also potentially useful for interacting with external devices and in combination with other modalities [11].

Two-Sided Pressure-Sensing Input
Early work on two-sided input was presented by Baudisch [12]. Two-sided input is an intuitive extension

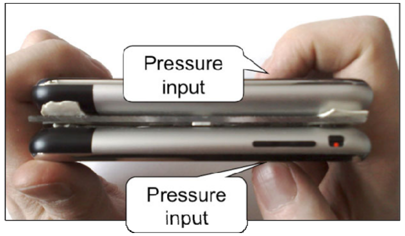

Figure 4 The iPhone Sandwich allows two-sided multi-touch interaction with pressure sensing.

Figure 5 This map viewer makes use of the high degrees of local control afforded by the combination of pressure and rear-of-device interaction

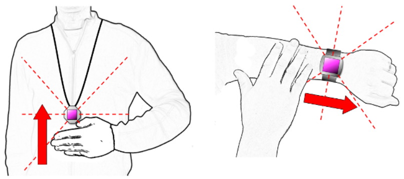

Figure 6 Around Device Interaction with very small devices using coarse hand gestures.

of mobile UIs if feedback is appropriate. In our iPhone Sandwich [13], we have expanded on this technique by adding pressure sensors between the two devices (Figure 4). Studies conducted by us have shown that pressure input with a handheld device shows similar performance compared to pressure input on devices placed on a hard surface [14]. Dual-sided pressure-based multi-touch input has the benefit of adding a high local input dimensionality to mobile user interfaces (Figure 5). This can, for example, be used for complex 3D object manipulation or widgets featuring a high degree of local input expressivity [13,15].

Around-Device Interaction
Equipping devices with proximity sensors or even time-of-flight depth cams enables them to sense the proximal space. This allows for Around-Device-Interaction (ADI) [6], where hand gesture tracking provides coarse but fast interaction. ADI expands an application's input context into the space around the device, thus the device doesn't necessarily need to be held in the user's hand for interaction. This is useful for devices with very small screens, for example digital jewelry (Figure 6) for which occlusion can become a major obstacle for direct touch input — here ADI seems to be a more natural way of interacting with the device.

Physical Output
The presented research endeavors — shape-based, weight-based, and aliveness-based displays — are still on a proof-of-concept level. However, they provide a perspective on how physical interaction could be designed in the future, once technology has advanced sufficiently. We inherently interact naturally with physical entities in our surroundings — basing our interactions with the digital world on the same principles, and transferring them into our physical world, may provide fruitful ground for interactions that are increasingly natural.

Conclusion
We conducted a review of current trends in mobile UI development and have shown how developers are incorporating an increasing amount of NUI concepts into their applications. A NUI-centric point of view highlights a number of aspects of mobile interfaces that deserve particular attention.

We presented several novel mobile interaction techniques stemming from current research, both for input and for output. We believe that the NUI paradigm is worth considering for mobile interaction. While it provides a good basis for structuring the discussion, more work needs to be done to extend it to a complete framework. It will be exciting to see further research in this area.

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