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Turn it, Pour it, Twist it: A Model for Designing Mobile Device-Based Interactions

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ABSTRACT
Interaction designers for mobile phones mainly focus on displays but have only little knowledge about sensor characteristics. Beside multitouch input, mobile devices provide versatile possibilities to interact in a physical, device-based manner due to their built-in hardware. Even though such interactions may provide many advantages in everyday life, they have limited visibility in interaction design. Interaction designers are seldom experts in gesture and pattern recognition and even prototypical implementations of simple mobile-based interactions need advanced technical knowledge. Hence, the potential for designing mobile device-based interactions is often not fully exploited. To contribute to a common knowledge of mobile device-based interactions, this paper proposes *Mobile Spaces*. This model aims at supporting designers of mobile applications to broaden their view on interaction possibilities with one or more collocated devices which go beyond the screen. We discuss the applicability of *Mobile Spaces* by means of several examples from research.

Author Keywords
Collocated interaction; design model; mobile devices; gestures; device-based interaction; interaction design.

ACM Classification Keywords
H.5.2. User Interfaces: Interaction styles (e.g., commands, menus, forms, direct manipulation)

INTRODUCTION
Mobile devices, especially smartphones, have become an indispensable part of our everyday life. Current devices innately provide numerous sensors, such as accelerometer, orientation or light sensors. These built-in sensors offer a wide range of interaction possibilities beside conventional multitouch interaction. For example, by shaking the device users are enabled to send feedback to Google Maps[1] about missing points of interest and roads or wrong locations and map information. So-called device-based interactions with mobile phones can support users in various everyday situations. During situations like meetings people can easily mute incoming calls or message alerts by turning over their device[2]. By performing a throw movement in the direction of a distant screen, meeting participants can transfer and show presentation files [3]. Further, collocated group work often includes merging different content. Figuratively pouring content from one device to another aims at avoiding digital disruptions during collaborative activities [8]. In general, mobile device-based interaction techniques provide possibilities (1) to interact unobtrusively and discreetly as possible, (2) to interact with distant interfaces, (3) to enable quick access to device functions, and (4) to facilitate collocated multi-user tasks [11]. With these use cases, we observe a paradigm-shift from display-focused to casual device-based interactions with mobile phones. Although there are numerous examples from research and practice, mobile device-based interaction techniques still have a limited visibility in interaction design. As device-based interactions use built-in sensors, mobile app designers should have some knowledge about the interaction possibilities using these sensors. However, most mobile designers only have little idea about the design space of interaction techniques based on device sensors [1, 7]. With this work, we want to frame the design space of mobile device-based interaction techniques. We propose *Mobile Spaces* as a model for interaction designers to use it as conceptual framework when designing mobile interactions regardless the variety of device classes, e.g. smartphones, tablets, smart watches or glasses. The core contribution of this work is to support designers of mobile applications in understanding mobile device-based interaction techniques. As smartphones are still most widespread in everyday life, our work firstly focuses on that class of mobile devices but is not limited to them. After giving an overview of literature, the paper introduces the model itself. We discuss its applicability by means of several examples and conclude with our future work.

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RELATED WORK
Prior work has focused on mobile interactions based on built-in sensors from different perspectives. A lot of research

[1] https://www.youtube.com/watch?v=eskT6TyFyHg

[2] https://www.samsung.com/ca/support/mobile-devices/what-are-the-advanced-features-available-on-my-galaxy-note8/

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proposes concrete solutions for specific interaction tasks (e.g. [3, 8–10, 12, 13, 15, 16], classifies mobile interaction as taxonomies (e.g. [2, 19]) or investigates social acceptability of mobile gestures (e.g. [18]). Each of these works provide own definitions to describe their approaches and thereby highlight different aspects of mobile interaction. Ashbrook and Starner [1] emphasize the temporal aspect and define *mobile microinteractions* as interactions with a device that take less than four seconds to initiate and complete. Lucero et al. propose several mobile solutions for collocated collaborative scenarios, e.g. [13, 15, 16]. They propose the concept of shared-multiuser mobile phone use introducing the term *social and spatial interactions* [14]. Other researchers concentrate on individual usage scenarios instead collaboration [2, 12, 18, 19]. Whereas Chong et al. [2] propose the term *guidance-based* interaction techniques where users act in the real world instead of using the screens in order to connect multiple mobile devices, Scoditti et al. [19] focus on interaction techniques which only base on accelerometer sensors (*accelerometer-based interactions*). Broader views are proposed by Leigh et al. [12], who describe single-device interactions where smartphones act as a physical interface (*tangible interaction for smartphones*), and Rico et al. [18], who define interactions that involve touching or moving mobile devices directly as *device-based gestures*. Although these approaches address mobile interactions where built-in sensors and physicality are centered, they show a wide range depending on their perspective. By introducing our model, we combine these different concepts to gain a condensed definition for mobile device-based interaction techniques.

Research on models related to designing mobile device-based interactions range from tangible to mobile user interfaces. Some models focus on linking specific interactions and gestures to device functions (e.g. [4]), which is important for realizing and testing ideas. However, for supporting the ideation phase of interaction design, it is crucial to look at interactions from a user experience perspective. Hornecker and Buur [6] created a framework for analyzing and designing tangible interaction that focuses on the user experience and the interweaving of physical and social aspects of interaction. The framework consists of four themes: tangible manipulation, spatial interaction, embodied facilitation, and expressive representation. As the framework characterizes tangible interaction in a broad view, it has to be specified for interactions with mobile devices because of technical and form constraints. The Social and Spatial Interactions (SSI) platform proposed by Lucero et al. [14] specifies social and spatial experiences to mobile phones. They name four principles and aim at designing mobile interactions for a shared-multiuser experience. These principles emphasize tangibility and spatiality as well as social and multimodal aspects to support collaboration but lack personal use cases and further technical aspects. The framework of Lundgren et al. [17] describes beside a social and spatial also a technological and temporal perspective. The four perspectives aim at designing applications as a whole and therefore describe face-to-face interactions between collaborators instead of physical properties of the devices themselves. The presented research either proposes single- or multi-user experiences with and without mobile devices. Our model proposes a combined view on mobile device-based interactions and thereby comprises different aspects during interaction design.

THE *MOBILE SPACES* MODEL

Our approach *Mobile Spaces* aims at guiding mobile designers in conceiving device-based interactions. As we have shown in the related work section, there is a lack of a common understanding of these interaction techniques. To address the different perspectives on mobile device-based interaction techniques, we summarize such tangible and sensor-based mobile usage as: interaction techniques for *personal and shared usage* of mobile devices where devices act as *physical* interfaces without using the screen content directly but utilize *simple gestures* to facilitate their usage and enhance their application.

Based on previous works, we created *Mobile Spaces* (see Figure 1), a model for designers of mobile applications to get them aware of and to help designing device-based interaction techniques. It consists of four components that are not mutually exclusive, but interrelated: representational, tangible, spatial and technological. They are framed by individual and collaborative usage scenarios.

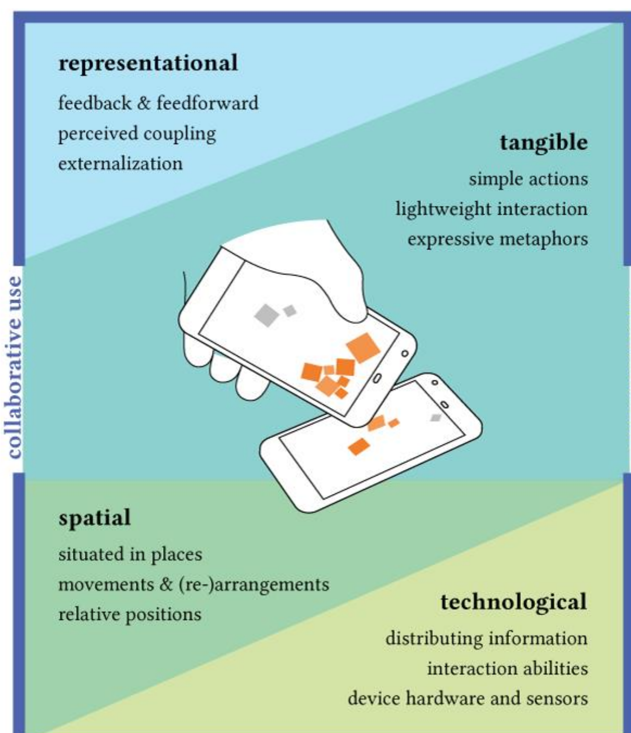

Figure 1. *Mobile Spaces* comprises relevant characteristics of mobile device-based interactions. The components address designing user experience (*representational* and *tangible*, blue), information that is relevant to understand interaction performance (*tangible* and *spatial*, turquoise) as well as information relevant for implementation (*spatial* and *technological*, green).

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Individual and/or Collaborative Use. The frame illustrates the major interaction use: individually or collaboratively. Depending on the scenario, users either use their personal mobile devices individually or share their devices to interact collaboratively in collocated situations.

Representational. Multimodal feedback provides information about the devices' status, e.g. about gesture detection or the devices' coupling in case of multiple devices. Feedforward mechanisms provide constant updates on how a gesture could be further executed, which is important to help users performing interactions. Moreover, the physical state represents the virtual state of the device to others (externalization), e.g. facing down the phone mutes incoming calls.

Tangible. The component of tangibility refers to the direct manipulation of the device. Mobile device-based interactions cover simple actions that users know from everyday life. They are lightweight, because they require little time and effort to perform. Expressive metaphors (e.g. pouring, throwing, sorting) support understanding and learning interactions.

Spatial. Spatiality is an inherited characteristic by interacting physically. The mobile devices are situated in real space (e.g. on a table or held in a hand) and can depend on their relative positions to each other. Dynamic movements or static arrangements of one or more devices can be determined.

Technological. For realizing device-based interactions, built-in device sensors are included and combined to detect movements, proxemics and localization. The hardware also influences the device's interaction abilities, e.g. an integrated fingerprint sensor enables additional input mechanisms. Moreover, designers have to consider how information is distributed and if it is available to all devices at any time or not and which technology is responsible for distribution (Wi-Fi, Bluetooth vs. an active internet connection).

The model components are classified according to application focus (see Figure 1). The upper part (*representational* and *tangible*, blue) focuses on designing user experience, the lower part (*spatial* and *technological*, green) relates to information for developing device-based interactions. The overlapping area (*tangible* and *spatial*, turquoise) labels information that is important for users to understand how to perform an interaction. The information should be considered, e.g. during designing onboarding tutorials [5].

DISCUSSION

To illustrate the applicability of *Mobile Spaces*, this section discusses three different smartphone-focused examples from research in more detail (see Figure 2): *Tilt to Vote* [10], *Order to Rate* [9] and *Pour to Compose* [8].

Tilt to Vote is used for accepting or rejecting content of any kind. If users tilt their device along the y-axis, they reject. If they tilt their device along the x-axis, they accept content (*spatial*). Tilting for accepting or rejecting is inspired by the metaphor of nodding and shaking the head (*tangible*). To realize the tilt movement for interacting, motion sensors like

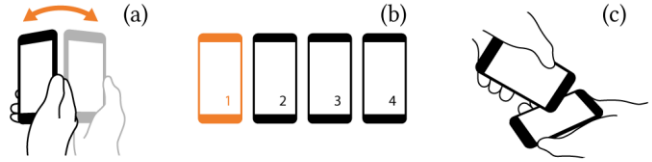

Figure 2. Characteristic examples for mobile device-based interaction techniques: (a) Tilt to Vote [10], (b) Order to Rate [9], and (c) Pour to Compose [8].

accelerometer and gyroscope are required (*technological*). If tilting is recognized, the user gets feedback via vibration and a visual note on the device display (*representational*). The authors describe an individual use in a collaborative context.

Order to Rate is intended to support collaborative tasks, where users have to compare and rate different content on their mobile phones. Each device displays and represents a suggestion and while discussing collaborators arrange the devices and therefore the suggestions in a horizontal line (*spatial*). The interaction is due to the metaphor of a descending order, inspired by paper sorting (*tangible*). Visual feedback is given showing the actual rating result and is updated automatically. In doing so, users are able to perceive the coupling (*representational*). The involved devices are permanently connected via Wi-Fi Direct; Bluetooth allows estimating the approximate distances for determining the rating order (*technological*).

Pour to Compose was designed for sharing and merging content from one device to another. The interaction can be performed between two or more devices. In order to share or merge content, one device needs to be tilted above another device as shown in Figure 2 (c) (*spatial*). The underlying metaphor is to pour water from a bottle into a glass (*tangible*). The proximity sensor recognizes the upper device while the gyroscope of the upper device identifies the movement as pouring (*technological*). Device feedback is given to the user through vibrations as well as visually through the appearing content (*representational*).

As the examples cover a broad spectrum of mobile device-based interaction techniques, we demonstrated that the model can be used for analyzing existing interaction techniques. We further plan to investigate the impact for ideating device-based interactions with several mobile applications.

CONCLUSION AND FUTURE WORK

This work presented *Mobile Spaces*, a model for mobile device-based interaction techniques. *Mobile Spaces* addresses interaction designers of mobile applications to broaden their view and make them aware of the design space provided by the built-in sensors. We also proposed a definition to contribute to a common understanding of these interaction techniques. With a discussion of representative examples, we demonstrated its applicability in a first step to smartphones. Although the model covers a broad range of mobile device-based interactions for supporting ideation, we plan to complement our model with a toolbox for facilitating construction. Moreover, we aim at using *Mobile Spaces* to enhance

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several applications with mobile device-based techniques instead of common multitouch interactions. In doing so, we contribute to an easier and less screen-focused usage of mobile devices, where mobile interaction is more convenient.

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