MESH: Supporting Mobile Multi-modal Interfaces

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ABSTRACT
Handheld devices possess limited input and output functionality when compared with desktop computers. However, many mobile interfaces are simply adaptations of desktop GUIs, and not designed specifically with this reduced capacity for communication in mind. Multi-modal interfaces may serve to redress this discrepancy. In particular we suggest that input in the form of motion and output in the form of vibration is a powerful combination. We describe MESH, a novel expansion for iPaq handheld computers featuring such functionality and a number of application domains that we exploring to showcase how its capabilities can be employed.

KEYWORDS: Mobile, motion sensing, vibrotactile display

INTRODUCTION
Handheld devices, in the form of mobile phones and PDAs, are rapidly evolving into powerful and sophisticated tools. Arguably, raw computational power is no longer the limiting factor constraining their functionality. A more fundamentally challenging and significant problem lies in creating interfaces that enable their capabilities to be easily accessed. Output on these devices comes in the form of small graphical screens and limited audio and vibrotactile cues; input from a touch screen or a relatively small number of buttons. Metaphors for control, especially in the case of PDAs, are typically drawn from desktop GUIs, despite the greatly reduced input/output capacities possessed by these devices. This discrepancy has led to a sense that the development of new interaction techniques specifically designed for mobile scenarios is urgently required [2].

Using the movement of the handheld device itself as input has been proposed by a number of authors [e.g 4, 5]. However, one significant drawback to this idea is inherent tradeoff between the richness of the movements used and the ability to gain instantaneous feedback as to their effects. Essentially, significantly moving the device precludes delivering visual feedback as to the state of the operation being conducted – the screen cannot be seen. This has led to authors studying particular forms of motion where the display is likely to remain in view throughout. Examples include tilting the device by 5 or 10 degrees as a mechanism to control scrolling in lists or 2D canvases [5], mapping device orientation to screen image orientation [4], and detecting simultaneous impacts to make associations between two devices [3]. One possible solution to this problem is to use non-visual feedback to support movement based interactions. In particular we suggest that vibrotactile feedback is well suited to this role as it is, by its very nature, discreet and (through the already established physical connection to the hand) possesses considerable immunity to environmental noise.

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Figure 1. MESH hardware shown next to an iPaq running a simple tilt-driven maze game

To this end, we describe MESH, a custom slim-line backpack for the iPaq series of handheld computers featuring a range of novel movement sensing input and vibrotactile output functionality.

MESH
MESH is illustrated in Figure 1. Its primary movement sensing capabilities are based on six Degree of Freedom (DOF) inertial measurement in the form of orthogonally mounted MEMS accelerometers and gyroscopes. The bandwidth for both these systems is 40Hz, the range for the accelerometers extends to 2G, and the gyroscopes to +/-350 degrees/second. This functionality is supplemented with a 3 DOF magnetometer, allowing the evaluation of compass heading to within 9 degrees, and a GPS unit. We anticipate that this rich combination of sensors will support the development of a broad range of applications and enable us to investigate these from a robust perspective of sensor fusion. MESH also supports a sophisticated vibrotactile output system. The electrical design supports three separate vibrotactile displays, although the mechanical design currently contains only one, housed within the main body of the hardware and delivering vibrations to the entire handheld device. We are in the process of investigating the ergonomics of situating mechanically isolated displays on either side of the PDA. Given the full-handed grasp

typically used when holding these devices, we anticipate this would enable us to display separate vibrotactile effects to the fingers and thumb pad.

The main vibrotactile display is a transducer, a modified VBW32 [1], originally developed as an aid for hearing impaired people. It resonates at 250Hz, the frequency at which human vibrotactile sensitivity peaks, and has a dynamic range of 54 dB. Samples are delivered to this actuator at 2000Hz, allowing the display of a range of crisp popping and clicking sensations as well as spectrum of continuous buzzes.

Given the potential demands of this high sample rate, MESH provides three mechanisms for the host iPaq to deliver vibrations. Firstly, they can be sent directly over the expansion bay connector. Secondly, we take advantage of the inclusion of an audio channel in this connector to allow the iPaq to use its hardware supported sound playback systems to drive the vibrotactile display. Finally, MESH supports a simple resource management system. It enables the iPaq to upload vibrotactile samples to the MESH hardware, and then play them back by issuing short commands. 16 samples of 250ms duration are supported, as is on-the-fly modification of properties such as amplitude and phase. This allows the delivery of high bandwidth vibrotactile samples with negligible processor load.

APPLICATIONS

The novel functionality provided by MESH is widely applicable; our explorations in a number of domains are briefly described below and illustrated in Figure 2.

Gesture recognition: MESH can support new forms of gesture recognition. Combining movement-sensing functionality with a high-fidelity vibrotactile display enables the presentation of continuous feedback during the performance of a gesture, changing the interaction from an open loop system, to one that is closed. This enables gesture performance, typically a complex but discreet interaction in which the outcome is only revealed upon completion of the motion, to become an interactive process, which the user can monitor and correct as it is taking place.

Information navigation: Navigating information using tilt has attracted attention from a number of other authors [5], but the inclusion of a high-fidelity vibrotactile display opens out a much broader range of interactions. By relying on the haptic display (rather than the graphical one) to provide feedback, we can build interactions based on a wider range of motions. Furthermore, we can begin to look at developing interfaces that require a minimum of visual attention; interactive systems that demand your gaze only when there is something interesting displayed on screen.

Communication: Communication through touch, in the form of interpersonal interactions such as handshakes and hugs, is an essential part of human life. By combining movement sensing and vibrotactile output, MESH provides a new platform on which we can experiment with virtual haptic communication. Squeezing, shaking or tapping a

Figure 2. Sample applications on MESH hardware

device could trigger related patterns of vibration in a connected device, allowing us to explore the design of meaningful and expressive digitally mediated haptic communication.

Video: Mobile devices are increasing becoming targeted as media display devices allowing users to watch videos, either captured by the devices themselves or delivered over high-bandwidth networks. Given the atrophied nature of the mobile viewing scenario, we believe vibrotactile feedback has the potential to substantially enhance the viewing experience – allowing users to feel aspects of the media as well as see and hear them.

Gaming: Games are a well-established market for mobile devices, and one in which additional input and output functionality has traditionally been rapidly adopted. There is significant potential for both the creation of tilt-driven games, and for games that feature rich and compelling vibrotactile feedback.

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