Exploring New On-Body Input & Output Modalities for Mobile Computing

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Abstract
The predominant use of mobile computing today involves eyes-busy and hands-busy user interfaces. Applications such as game playing, map browsing, and others require the user to attend to the screen of his or her device and interact with it directly via touch, speech, or multi-touch gestures. A second, and currently somewhat less common, use case involves eyes-free and hands-free interaction. This scenario is most common in situations such as driving, when a user typically provides input to the system in the form of speech-based commands, and output from the system is in the form of speech and non-speech audio feedback. We propose the use of interfaces that focus on eyes-free use of the mobile phone, driven by lightweight input microinteractions and non-visual output feedback via a collection of on-body devices.

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General Terms
Design, Human Factors.

Introduction
Researchers have been working on eyes-free and hands-free interactions for "natural user interfaces" for years [2]. However, there are still opportunities to explore new approaches to appropriate the unutilized bandwidth of the human body and mobile devices to overcome some of the limitations of current interactions, considering social appropriateness, privacy, and cognitive load. The next step in realizing a vision of always-available computing is through the development of new hardware and techniques to expand the input and output space of on-body and mobile interactions.

The primary interface for mobile and wearable computing, including cellphones and novel devices such as Google Glass, is characterized by a highly visual output. Most applications require the user to attend to the screen of his or her device and interact with it directly via touch, speech, or multi-touch gestures. A second case involves eyes-free and hands-free interaction. While this style of interface is predominantly used in driving situations, it can also be used outside of driving situations: via an earphone/microphone combination, the mobile device can remain in the user's pocket while he or she interacts with it via speech input and speech/non-speech audio output.

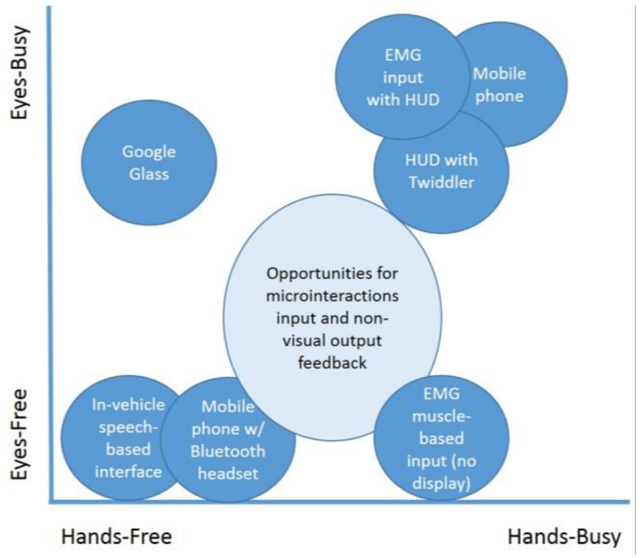

Figure 1. Current design space for mobile computing considering hands-free/hands-busy and eyes-free/eyes-busy interactions. The proposed approach of spatialized audio information coupled with microinteractions and non-visual output is highlighted in the center.

These usage modalities represent important points in the design space of mobile user interfaces. The first is appropriate for highly focused tasks (game playing, browsing) in which the use of the device is the user's primary goal and the user attends directly to the device. The second is appropriate when the need for low distraction is paramount, in which the user must focus on keeping hands on the wheel and eyes on the road. We argue, however, that these two endpoints do not represent the sum total of interaction possibilities for mobile computing interfaces (see Figure 1). In particular, there are middle ground situations in which neither of these usage modalities may be appropriate. When finding your way around a strange city, for instance, users may wish to keep their mobile devices in their pockets, whether due to safety and security reasons, or simply to attend to their surroundings; this means that interfaces that require eyes-busy interactions may not be appropriate. Likewise, while speech interfaces may be appropriate in an automobile setting, they may be less appropriate in other situations, whether due to a desire for privacy around others, a lack of responsiveness in noisy environments, or when speech may be socially awkward, such as in a quiet environment.

We propose a new interface approach for mobile computing, which allows for eyes-free use of the mobile phone, but without the need for spoken voice commands to the system. Our interface approach relies on a rich form of audio presentation in which sound sources (and thus information) are spatialized to appear to come from locations in the real world, coupled with lightweight microinteractions provided to the system via a collection of worn, on-body input devices.

Microinteraction Gestures

Microinteractions [1] are simple input gestures that can be performed without looking, and with tightly integrated feedback. They are also inherently more discreet than speech, as they do not require spoken commands [3]. Microinteractions also typically describe interactions that allow for a certain task to be completed within 4 seconds or less.

Future opportunities for my work in this input space suggest the exploration and combination of sensing on multiple parts of the body to provide richer and more robust input. The current project I am proposing is the combination of head- and neck-based input events (humming, head tilting, and teeth clacking) detected using multimodal sensing, including a body surface microphone and a modified headset. I am also interested in exploring other sensing technologies typically used in the engineering field, such as strain sensors and bone conduction microphones, which in concert could enable new input interfaces that are adaptive and responsive to the user's context.

A key advantage of this style of on-body gestural input is that it takes advantage of proprioception [6, 7], the sense of where one's body is in space, meaning that the devices can be used with low sensory, physical, or cognitive load. One can "find" the input device and actuate it without having to look for it or search for it.

Spatialized Audio Information Interfaces

Spatialized audio rendering systems have been explored and proposed for immersion in virtual environments [5]. Systems are optimized for rendering a sufficient number of dynamically moving sound sources in multi-speaker environments using off-the-shelf audio hardware. In our case, coupling the movement of the human body (e.g. head rotation, direction the body is facing) and the user's location within a mobile setting, audio information can be presented dynamically based on contextual and geographic cues. In order to accomplish a spatialized audio interface for a mobile user, we are exploring the use of magnetometers, gyroscopes, accelerometers, and additional sensing embedded in a headset. Sensors must be built into a headset rather than a handset, so that head orientation (rather than just phone orientation) is detected. Sensors could also potentially be used for recognition of basic head gestures (brief head nod for confirmation; brief head shake for rejection). We are interested in exploring menu navigation and other forms of content delivery on a mobile device via this type of audio interface [4], further extending previous work in the space of wearable audio computing [8].

Applications

There are a number of challenge areas in the field of wearable computing: power, networking, privacy, and novel interfaces [9]. Our proposed style of low-distraction, low bandwidth, and socially appropriate integrated I/O modalities have not been heavily explored in mobile computing. While our focus in this current project is in the use of spatialized audio with upper body triggers as input, we believe this approach to mobile computing focusing on non-visual output and microinteraction input has potential for a broad range of applications, from new forms of gaming to increased productivity at work. We believe that the input interaction techniques we develop also have potential when coupled with Google Glass and other mobile computing devices. For example, microinteraction gestures would allow a user to provide a range of commands to Glass-style interfaces without spoken input, and may increase social acceptability of such devices.

Project Status

We are in the very early stages of prototyping the proposed modified headset and neck-based hardware, and we've begun exploring the use of various different sensors for input detection. We plan to build both the electronic circuitry and physical casings for all wearable devices. Gabriel Reyes, a computer science Ph.D. student with dual degrees in electrical engineering, is leading the efforts as part of his early Ph.D. research work. The work will be supported by the GVU Prototyping Lab, a facility on the Georgia Tech campus, which provides a wide range of physical prototyping equipment, including CNC routers, 3D printers, vacuuform machines, circuit mills, and more. We will then evaluate these devices in specific sample scenario applications that are yet to be decided upon.

Objective for Attending the Doctoral School

My interest in attending the Doctoral School at UbiComp/ISWC 2013 is to receive feedback on the current direction of my early PhD work, facilitate developing research questions, and gather advice from other researchers in the UbiComp/ISWC communities. My goal is to lay the groundwork for new low-distraction, low bandwidth, and socially appropriate application modalities for mobile computing.

Biographical Sketch

Gabriel Reyes is a second year Ph.D. student in computer science and human-computer interaction at Georgia Tech's School of Interactive Computing. He holds B.S. and M.S. degrees in electrical engineering and has broad research interests in ubiquitous computing, user interfaces, and human-computer interaction. Specifically, he is interested in enabling a world of always-available computing (when desired) by leveraging novel hardware for on-body and mobile input and output. He joined the Ph.D. program in fall 2011 and tentatively plans to graduate in spring 2016.

Dr. W. Keith Edwards is a Professor of Interactive Computing at the Georgia Tech College of Computing and the Director of the GVU Center. His research interests focus on rethinking various aspects of computing infrastructure to enable new types of experiences and, conversely, understanding how current computing infrastructures too often "show through" in the user experience.

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