A Demonstration of Sonar-based User Presence Detection

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Abstract
We demonstrate a technique to determine presence and attention levels of computer users. This technique relies on ultrasonic sonar using hardware that already exists on commodity laptop computers and other electronic devices. It leverages the fact that human bodies have a different effect on sound waves than air and other objects. A full discussion of related work, our experimental validation, and conclusions can be found in the accompanying paper [1].

Keywords
Sonar, presence, attention, user study, ultrasonics

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): Miscellaneous.; D.4.m Operating Systems: Miscellaneous.

Introduction
In ubiquitous computing systems, it is often advantageous for distributed electronic devices to sense the presence and attention of humans, even when they are not directly interacting with the devices. This ability allows such a system to provide services to human users only when appropriate. In traditional desktop computing, attention information is also useful;

it is already used by Operating System (OS) power management systems to save energy by deactivating the display when the keyboard and mouse are inactive. Security systems prevent unauthorized access by logging out or locking a user's session after a timeout period. In both of these cases, the OS must know whether a user is present and *attentive*, i.e., using the computer system, or whether the user is absent. In this demonstration, we show that these two user states are reflected by very different sonar responses.

Active Sonar

Audio in the 15 to 25 kilohertz range can be produced and recorded by a laptop computer but is inaudible to most adults; these frequencies are called *ultrasonic*.

Sonar systems emit sound "pings" and listen for the resulting echoes. Based on the characteristics of the echoes, a rough map of the surrounding physical space can be derived. The omnidirectional (unfocused) and relatively insensitive microphones and speakers built into most laptops are not ideal for building a precise sonar system. However, our expectations for the sonar system are modest; we only need information about the user's attention state, not a detailed map of the room. Our sonar system emits a continuous 20 kilohertz sine wave and records the resulting echoes using a microphone.

We hypothesize that the echo intensities will vary more if a user is present. We assume that human users are the only nearby moving objects and that users' motions will be reflected by changes in echo intensity.

To detect user presence we look for changes in the echo's intensity. To calculate an estimate of the echo intensity, we use a frequency-band filtering approach. We assume that all of the sound energy recorded in the 20 kilohertz band represents sonar echoes; our measurements confirm that ambient noise in that frequency-band was negligible. We use Bartlett's method (with 10 non-overlapping rectangular windows and a 1024-point Fast Fourier Transform) to estimate the recording's power spectrum; in each of the ten windows, the amplitude of the Fourier coefficient nearest 20 kilohertz was squared to get an energy value and then averaged with the other nine values. As is common in audio measurement, we scaled down the results with a base-10 logarithm.

In this demonstration, we use a simple characterization of the echo's variance that we call *echo delta*, Δ_e. This is calculated by first breaking each recording into a sequence of 100 millisecond windows. The echo intensity is calculated for each of these by Bartlett's method, as described above; this gives us an echo intensity sequence $e_1 \ldots e_N$. The echo delta Δ_e is just the average of absolute differences in that sequence:

$$\Delta_e(e_1 \ldots e_N) \equiv \frac{1}{N} \sum_{i=1}^{N-1} |e_{i+1} - e_i|$$

Echo delta characterizes echo variances on the time scale of a 100 millisecond window.

References

[1] S. P. Tarzia, R. P. Dick, P. A. Dinda, and G. Memik. Sonar-based measurement of user presence and attention. In *Proc. UbiComp '09*, 2009.