Devices as Interactive Physical Containers: The Shoogle System

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Abstract
Shoogle is a novel interface for sensing data within a mobile device, such as presence and properties of text messages or remaining resources. It is based around active exploration: devices are shaken, revealing the contents rattling around "inside". Vibrotactile display and realistic impact sonification create a compelling system. Inertial sensing is used for completely eyes-free, single-handed interaction. Prototypes run on both PDA's and on standard mobile phones with a wireless sensor pack.

Keywords
Audio, vibrotactile, accelerometer, multimodal, mobile

ACM Classification Keywords
H.5.2 User Interfaces: Haptic I/O; H.5.2 User Interfaces: Interaction Styles; H.5.2 User Interfaces: Auditory (non-speech) feedback

Introduction
Users of mobile devices are continuously bombarded with alerts and notifications; waiting voice mail messages, incoming SMS messages, low battery alarms etc. This disrupts the tasks they are otherwise engaged in and can often be socially unacceptable. We propose an

alternative interaction style, where the user *excites* information from the device and then *negotiates* with the system, in a continuous, closed-loop interaction. This work applies this concept to the display of the internal state of mobile devices: sonifying and haptically rendering the contents of inboxes, the state of battery life, or remaining memory. Feedback is tightly coupled to the input. In contrast to static display approaches, this *active perception* approach takes advantage of people's expectations about the evolution of physical systems. This avoids disturbing the user unnecessarily and potentiates richer, more informative feedback. Users know what motions they have applied and interpret the display in that specific context. The Shoogle interface uses inertial sensing for natural motion sensing without external moving parts; the user just shakes, tilts or wobbles the device to stimulate the auditory and vibrotactile feedback. This can either be explicit, or can occur as part of a user's background motion; walking, running, standing up or other everyday motions.

Status and Audience

Shoogle is still in the research prototype phase, although the implementation as it stands is already close to what would be required for commercial deployment. It is intended to demonstrate the power of the model-based interaction technique for multimodal mobile devices. The ideas outlined here are intended to provide motivation and concrete tools for constructing compelling, real-time interactions with mobile devices.

Background

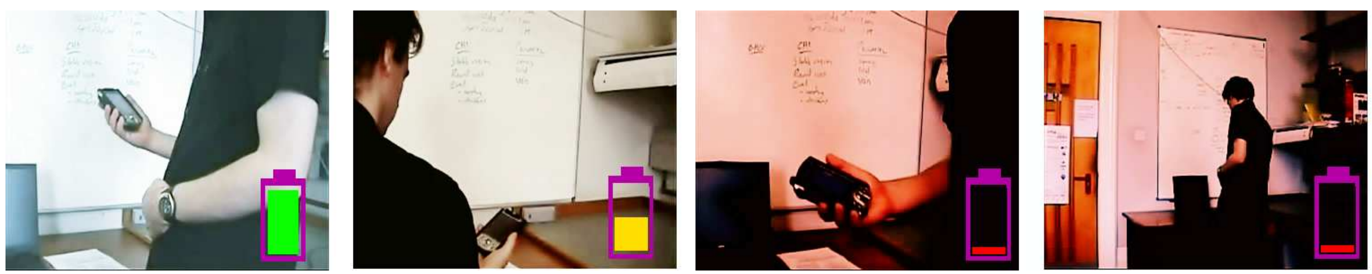
Realistic synthesis of vibrotactile and audio sensations is key to building eyes-free interfaces. The model-driven approach is a fruitful design method for creating plausible and interpretable multimodal feedback without extensive *ad hoc* design. Yao and Hayward [12], for example, created a convincing sensation of a ball rolling down a hollow tube using an audio and vibrotactile display. A similar sonification of the physical motion of a ball along a beam is described in detail in [8]; subjects were able to percieve the motion ball from the sonification alone. Granular approaches to realistic natural sound generation were explored in [6], where contact events sensed from a contact microphone underneath a bed of pebbles drove a sample-based granular synthesis engine.

Scenarios of Use

The following scenarios illustrate how a device augmented with these capabilities could be used in everyday tasks, while remaining eyes-free and without interrupting the user.

Message Box. The user reaches into a drawer, and shakes the device, without removing or looking at it. The contents of an SMS inbox are transformed into virtual “message balls”. As the user shakes, impacts are heard and felt as these balls bounce around.

Keys in a pocket*.* The user carries the phone in a pocket while walking. Motion from the gait of the user is sensed by the accelerometers. As messages arrive, objects begin jangling around in the user’s pocket, in a manner similar to loose change or keys.



Liquid battery life. The user shakes the device to gain a sense of its “fullness”. When the battery is full, the sensation is like that of a full bucket of water sloshing around. As the battery drains, shaking the device sounds like a few droplets splashing, until finally all power evaporates. This is similar to the virtual maracas approach for resource sensing suggested by Fernstrom in [1].

System Description

Complete working prototypes of Shoogle have been implemented on both PDA and standard mobile phone platforms. There are three important components of Shoogle: the sensing hardware, to transform motion into measurable signals; the dynamics model, to simulate the motion of the virtual objects; and the display, which reveals the state of those objects.

Inertial Sensing

Figure 1. The MESH inertial sensing platform.

The initial prototype of Shoogle was implemented on the iPaq 5550 device (see Figure 1), using the MESH [4] device for inertial sensing and on-board vibrotactile display.

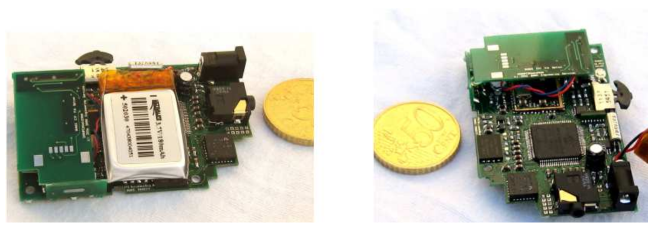


Figure 2. The SHAKE inertial sensor, with a 50 cent (Euro) piece for size comparison.

Shoogle has also been implemented on standard mobile phone hardware (Nokia Series 60 phones). This uses the custom-built Bluetooth SHAKE (Sensing Hardware Accessory for Kinesthetic Expression) inertial sensor pack for sensing (Figure 2). Mobile phones which already incorporate accelerometers (like the the Nokia 5500 and Samsung SCH-S310) would require no additional hardware.

Dynamics

The Shoogle metaphor involves a number of spherical balls rattling around in a rectangular box whose physical dimensions appear to be the same as the device. The box is assumed to be two-dimensional, the vertical component being ignored. The measured accelerations are used directly in an Euler integration model. Nonlinear frictional damping (a stiction model with different static and moving coefficients) is applied. As each ball is generated (e.g. as a message arrives), it is anchored to a randomly-allocated position within the box by a Hooke-law spring (see Figure 3).

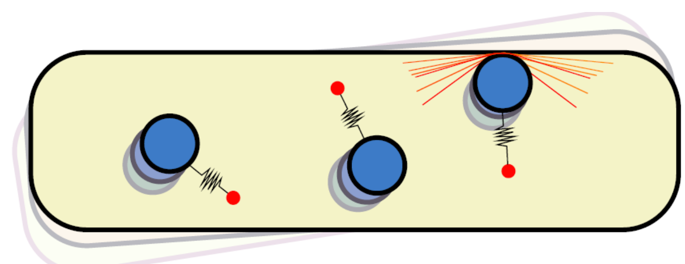


Figure 3. Simulated balls bounce around. Impacts generate audio and vibrotactile feedback.

Collision Detection

Feedback events are generated when the balls collide with the walls of the device "box". Inter-ball collisions are not tested. Wall collisions are inelastic, transferring some kinetic energy to the wall, and the remainder to rebound. Users can also tap the device (detected via capacitive sensing), at which the balls bounce upwards. They rain back down in the order they were created, giving a structured overview of the contents.

Audio and Vibrotactile Display

The presentation of timely haptic responses greatly improves the sensation of a true object bouncing around within the device over an audio-only display. As Kuchenbecker et al [5] describe, event-based playback of high-frequency waveforms can greatly enhance the sensation of stiffness in force-feedback applications. In mobile scenarios, where kinaesthetic feedback is impractical, event-triggered vibration patterns can produce realistic impressions of contacts when the masses involved are sufficiently small.

Generation

The vibrotactile waveforms are enveloped sine waves, with center frequency at 250Hz (both the resonant frequency of the transducer, and the peak sensitivity of the skin receptors involved in vibrotactile perception). The waves have a very rapid linear attack, and an exponential decay. To enhance the sensations, the internal eccentric motor of the iPaq is used in combination with the high-frequency vibrator. High-frequency vibrations are sent to the smaller vibrator, with heavy, slow impacts also being routed to the motor-driven actuator.

Audio Feedback

The impact of the balls on the virtual box produces sound related to the physics of the collisions. Although ideally these sounds would be generated by a physical model (such as the general contact sound engine given by van den Doel et al [10]), the limited computational power of many mobile devices -- which lack efficient floating point units -- makes this currently impractical. Shoogle instead employs a sample-based technique. This gives a high degree of realism, but comes at the cost of significant effort in creating a sample library, and limited flexibility. A number of impact sounds (8--16) are pre-recorded for a particular impact ``class'' (wood on glass, for example). On impact, a random sound from within this class is selected and mixed into the output stream. Shoogle currently has eighteen impact types, including candy rattling in jars, keys jangling and water sloshing in bottles. These provide a wide range of natural and distinguishable timbres. Humans are adept at inferring the physical properties of materials from the sound of their physical interaction, and the realistic nature of the generated sounds makes the nature of the impact immediately obvious.

Audio Transformations

The audio is transformed based on the properties of each particular collision. The intensity of the impact sound is proportional to the kinetic energy of the impact, while the pitch of the sample is related to the size of the impacting object. For the SMS scenario, the class of impact sound is linked to the content or the meta-data of the message represented. In the prototype, messages are tagged according to sender group (work, friends, family, unknown, etc.) Messages could also be automatically classified with a language model (e.g. as in [7]) and the various styles or languages used could be mapped to different simulated materials.

Conclusions

The Shoogle prototypes illustrate how model-based interaction can be brought into practical mobile interfaces. The resulting interface is based around *active sensing*, letting the user drive the interaction. The result is a rich multimodal display that can be used without any visual attention whatsoever, taking advantage of user's familiarity with the dynamics of processes in the physical world to present information in a natural and non-irritating manner. The SHAKE sensor allows realistic inertial sensing prototypes to be rapidly implemented on mobile phones, with plausible form factors and all of the accumulated data a real phone carries. The ideas can be extended to include multimodal selection, extending the interaction from excitation to true negotiation. Although these prototypes only scratch the surface of the potential this interaction style offers, even in its current state the system is compelling. Of the several dozen people who have experimented with Shoogle, all have found it captivating and intuitive. Enormous scope exists to build sophisticated, model-driven interfaces upon this foundation, linking content and context to the physical properties of simulated systems, and the rich feedback which is a natural consequence of their behaviour.

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