Continuous Sonic Feedback from a Rolling Ball

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Balancing a ball along a tiltable track is a control metaphor for a variety of continuous control tasks. We designed the Ballancer experimental tangible interface to exploit such a metaphor. Direct, model-based sonification of the rolling ball improves the experience and effectiveness of the interaction.

Human interaction with the world is essentially continuous. Triggers are rare things in nature while, more often, we weigh forces, steer paths, and maintain equilibrium. For instance, consider the complex control actions that we seamlessly exert when riding a bicycle, including steering through curves and braking before hitting obstacles. Those tasks are inherently continuous and rely on a mixture of visual, kinesthetic, and auditory cues.

To achieve more natural human–machine communication, systems must support continuous interaction in interfaces. Tasks such as steering, aiming, or dragging require continuous control and continuous feedback. The latter can be acquired visually, kinesthetically, or auditorily, but in closing the control feedback loop the user must not have to repeatedly change the locus of attention.

If the locus is mainly visual, the haptic and auditory channels are suitable for providing nondistracting, informative feedback. In this respect, auditory displays provide the advantage of shareability with an audience, and they might give clues not directly available from other senses. In our physical, natural environments, human actions are generally always connected to continuous and instantaneous acoustic responses (rustling clothes, rubbing, scratching, and so on). In contrast, human–computer interaction is so far largely dominated by the visual channel, and auditory perception is rarely exploited in a depth that can adequately sense the omnipresence of continuous, reactive sonic feedback in natural surroundings.

An interesting arena for experimentation with sounds is that of embodied interfaces where meaning emerges as a by-product of interaction, often requiring peculiar control gestures.[1] As an example, we can make selection by tilting more effective if we combine it with force fields and either haptic or auditory feedback. Somewhat paradoxically, exaggerated effects in the employed sensory feedback, such as those used in cartoon animation, can reinforce the illusion of substance and, therefore, the overall degree of embodiment and sense of presence.[2]

GUIs are usually designed by using cartoon animation. As indicated by Gaver[3] and exploited in the Sounding Object European project,[4] sound models can also be “cartoonified” and used for feedback in human–computer interfaces. Sliding or friction sounds can accompany window dragging, and a sudden change of surface texture or friction coefficient can reveal an obstacle or underlying hidden object. Also, constraints such as pinning or snapping can be cartoonified either visually[2] or acoustically, for instance, by rendering the sounds of objects rolling in force fields.

Metaphoric rolling balls

Sonification aims at the acoustic representation of data, often by mapping the variables of interest onto sound signal properties. A less common but promising approach to conveying information through the acoustic channel is model-based sonification,[5] especially when supported by sound-friendly metaphors. We can view everyday sounds as the natural sonification of information about our environment, expressing attributes of events and processes that surround us. Human auditory perception is naturally adapted to extract the information transmitted through everyday sounds.

Therefore, one conceivable strategy of sonification would be to map an abstract system’s state onto an everyday sound scenario represented by a suitable model. This connection might be established in the form of an intuitively understood metaphor.

Many of the sounds that surround us in our familiar, everyday environments originate from contact of solid objects—such as hitting, rubbing, or scraping. The auditory recognition or estimation of ecological attributes such as material, size,

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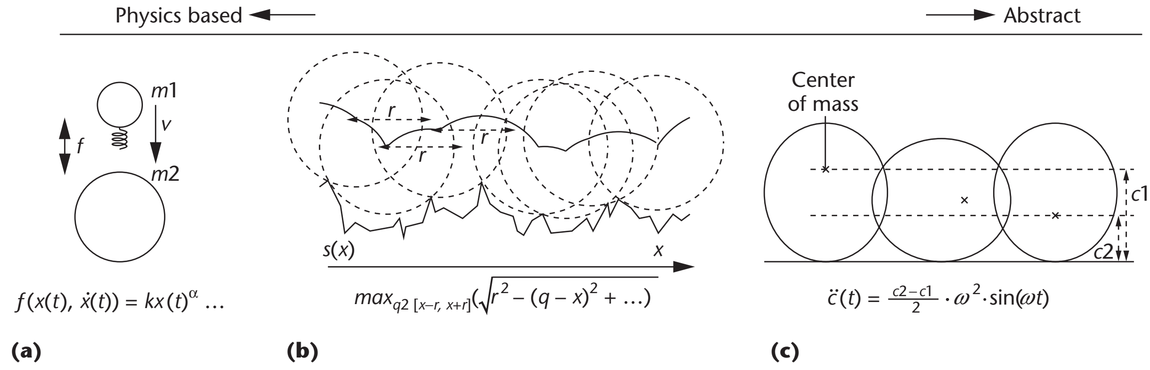

Figure 1. Schematic overview of the hybrid synthesis structure behind the sound model of rolling: (a) impact module, (b) rolling filter, and (c) macroscopic features.

or weight from such contact sounds is a common experience. Particularly informative within this large class are the sounds of rolling because these can convey information about direction or velocity of movement, as well as about the shape and surface textures of the contacting objects.[6] We developed a sound model for rolling interaction that enables the continuous control and immediate acoustic expression of the involved ecological parameters. The rolling model runs in real time in its complete control-feedback behavior and thus is well suited for interactive control tasks.

We embodied the model into a simple control metaphor of balancing a ball on a tiltable track. This system demonstrates the auditory support of continuous human–machine interaction and assesses the intuitive informative potential of rolling sounds. Users access the device through a physical representation of the balancing track, a 1-meter-long wooden stick, whose relevant position the system measures and processes. We have evaluated the complete, tangible audiovisual device, the Ballancer, in experiments that demonstrate how users spontaneously understand the metaphor, in both its sound and control aspects, and how they perceive and exploit the conveyed ecological information. An example video of the Ballancer in its configuration as a game of moving the virtual rolling ball into a target area can be found at http://csdl.computer.org/comp/mags/mu/2005/02/u2toc.htm.

Sound model of rolling

To achieve continuous reactivity and acoustic reflection of ecological attributes, a physics-based approach to sound synthesis is generally desirable. On the other hand, brute-force physical models tend to become highly complex in computation and control, especially for real-time implementation as part of a human–machine interface. Also, through the explicit consideration of known perceptual mechanisms, we can achieve a clearer, cartoon-like expression. We therefore realized our rolling model in a hybrid architecture with higher level structures. These structures account for perceptually important macroscopic phenomena and surround a central algorithm derived directly from a physical model of the elementary impact-like contact. We combine the lowest level, physics-based impact model and the higher level, perception-oriented structure through a connecting signal-processing algorithm—a "rolling filter" that reduces the rolling scenario's macroscopic geometry to the one dimension of the impact model (perpendicular to the global direction of the surface). We describe details of the rolling model elsewhere;[7] here, we only summarize some main points.

Figure 1 represents an overview of the architecture behind the rolling model on the basis of physical-mathematical descriptions on different levels of microscopic detail and of an increasing degree of abstraction (from left to right). In Figure 1a we model microscopic contact with a physics-based term of the perpendicular impact force. Figure 1b represents the connecting rolling filter that derives the resulting offset-constraint curve from a given surface. Figure 1c shows the explicit model of the global gravity force according to the simplified equation of energy and acceleration for a rolling object with asymmetries in shape and mass.

Rolling as continuous collision

In rolling scenarios, the mutual interaction force between the two objects in contact—the

Complementary Media

The video file showing an example of the Ballancer configured as a game is available at http://csdl.computer.org/comp/mags/mu/2005/02/u2toc.htm.

rolling body and the supporting plane—is basically that of an impact perpendicular to the local macroscopic surface of contact. Friction forces parallel to the surface are generally comparatively small (the main notion behind the invention of the wheel) and can be neglected in a first step of cartoonification. The sound model uses a physics-based model of impact interaction that has successfully generated sounds of hitting, bouncing, and breaking.[8,9] The impact algorithm derives from a physical model of the involved solid objects (modal synthesis) and of the occurring term of interaction force. At the same time, the physics-based algorithm already involves a degree of simplification and abstraction that implies efficient implementation and control—all quantities in the interaction term are 1D. In contrast to previous works on synthesis of contact sounds[10] that focus on the resonance and decay behavior of the interacting objects, our model of impact is reactive and dynamical: The approach produces complex transients that depend on the parameters of interaction (such as hardness) and the instantaneous states of the contacting objects. This dynamical quality is essential in situations of repeated, frequent, or sustained contact, as in the case of rolling.

Rolling as tracking and filtering surfaces

While an object is rolling on a plane, the point of contact moves along both the object surface and the plane. These tracked surface profiles are the source of the acoustic vibration in rolling: No sound would arise if a perfectly spherical object was rolling on a perfectly planar, smooth plane. If we restrict our view to the one dimension perpendicular to the plane, we see a time varying distance constraint between the rolling object and the plane, and this constraint can be translated into a time varying distance offset for the low-level impact model. However, the offset signal isn't simply the difference of the two surface profiles, since only certain peak points on both surfaces are possible points of contact. Figure 1b shows a sketch of the final offset signal derived from the surface profile. The actual movement of the rolling object differs from this idealized trajectory due to inertia and elasticity. It's exactly the consequences of these physical properties that the central impact model represents. We implemented the derivation of the described offset signal from a given surface profile as a nonlinear "rolling filter." Since a direct naive approach of calculating the offset curve would be too demanding in terms of computation, we have derived a special iterative algorithm for real-time performance.

Higher level modeling: Macroscopic characteristics

Of high perceptual importance are periodic patterns of timbre and intensity in typical rolling sounds. Although their timbre structure is difficult to classify, these periodic modulations appear as a strong perceptual cue of rolling—as opposed to, for example, sliding—and their frequency is particularly important for the perception of size and speed.[6]

However, instead of extending the strict physics-based approach of the impact model to the global 3D scenario of rolling, which would result in a highly complex and costly algorithm, we can trace back the remarked periodicities to macroscopic deviations of the rolling shape from a perfect sphere. As we roughly summarize in the following, macroscopic asymmetries lead to periodic modulations of the effective gravity force that can be explicitly inserted into our core model of impact interaction.

If a rolling object doesn't show perfect circular symmetry with respect to its center of mass, the height of the center of mass will vary during the movement (see Figure 1c). This varying height is related according to variations of the potential energy of the object in the gravity field, and this is reflected by variations of the effective force that holds down the rolling object. We can only determine the exact modulating terms of energy, forces, and velocities if we know the object's shape exactly.

However, if the goal is ecological expressiveness rather than simulation for its own sake, we might assume that the oscillating height of the center of mass $c(t)$ is approximately described by a sinusoid, and the effective additional force term between the rolling object and the plane is then proportional to the vertical acceleration:

$$\ddot{c}(t) = -(c2 - c1)/2 \cdot \omega^2 \cdot \sin(\omega t) \qquad (1)$$

We use such a sinusoidal force modulation term whose frequency is related to the transversal velocity and radius of the object. Equation 1 shows that the amplitude is proportional to the square of the angular velocity. The proportionality constant ($c1 - c2$) expresses an overall amount of deviation from perfect spherical symmetry.

Summing up, the hybrid synthesis architecture of the rolling model combines the advantages of physics-based modeling with those of rather abstract techniques. Due to the use of a dynamic physics-based algorithm that doesn't rely on prerecorded or predefined sound samples:

- generated sound is free of repetitions and reacts continuously and dynamically upon variations of the driving parameters such as position and velocity;
- there is no need to store, maintain, and process large banks of sound samples; and
- ecological attributes such as the size, mass, or shape of the rolling object, as well as the texture of the supporting surface, can be varied along a continuum and are directly reflected in the acoustic output.

By surrounding the central impact model with the cartoonification operated by higher level structures we can combine the aforementioned strengths of physics-based modeling with flexibility and efficiency in implementation, and a sharper elicited ecological impression.

Ballancer metaphor

The immersion of the sound model of rolling into a multimodal context in the Ballancer is strongly influenced by our experiences with a previous interactive device, the InvisiBall.

In that preliminary design, a virtual ball rolls on a deformable elastic surface. The user controls the deformation of the surface and thus the ball movement by pushing onto a physical representation, an elastic cloth on a rectangular frame. In the InvisiBall, the user can rely on three types of feedback:

- *Acoustic*: the sound model of the rolling ball
- *Haptic/kinesthetic*: the control of the ball's position by pressing the elastic membrane with a finger
- *Visual*: the graphical representation of the position of the ball on the computer monitor

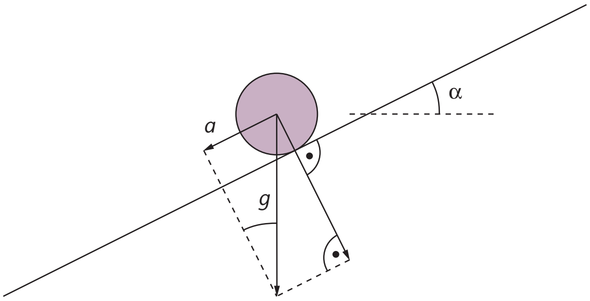

Figure 2. Scheme of a ball rolling on the tilted track. The gravity acceleration is split into two terms, parallel and perpendicular to the track, according to the track angle.

An accurate realization of the InvisiBall was difficult to achieve, demanding high accuracy in control gesture measurement and computation of the virtual ball's movement. Evaluation tests with different forms of sensory feedback revealed that subjects classified stimuli as more realistic if only acoustic or acoustic/visual feedback was used (that is, subjects were not directly controlling the interface).[9] This points out some difficulties in integrating control of gestures and haptics with multimodal feedback. Mismatch between different perceptual channels determines a disembodiment or, in other words, a decreased sense of presence.

Our experiences with InvisiBall led us to a simple metaphor for the Ballancer, that of balancing a ball on a tiltable track. The (virtual) ball is free to move along one axis over the length of the track, stopping or bouncing back when reaching the extremities. This familiar 1D metaphor offers a more direct coupling between the physical, the virtual, and the user's actions. Here, the acceleration of the ball along the length of the track, as shown in Figure 2, is directly related to the elevation angle. Possible vertical bounces of the ball or effects of rotation are neglected, and all the damping experienced by the ball is modeled by one term of friction force, proportional to the instantaneous velocity. The position x of the ball on the track is described by the following differential equation:

$$\ddot{x} = \sin(\alpha) \cdot g - k \cdot \dot{x} \qquad (2)$$

where $g = 9.8\ \mathrm{m/s^2}$ is the gravity acceleration, α is the track's tilt angle, and k is a damping factor.

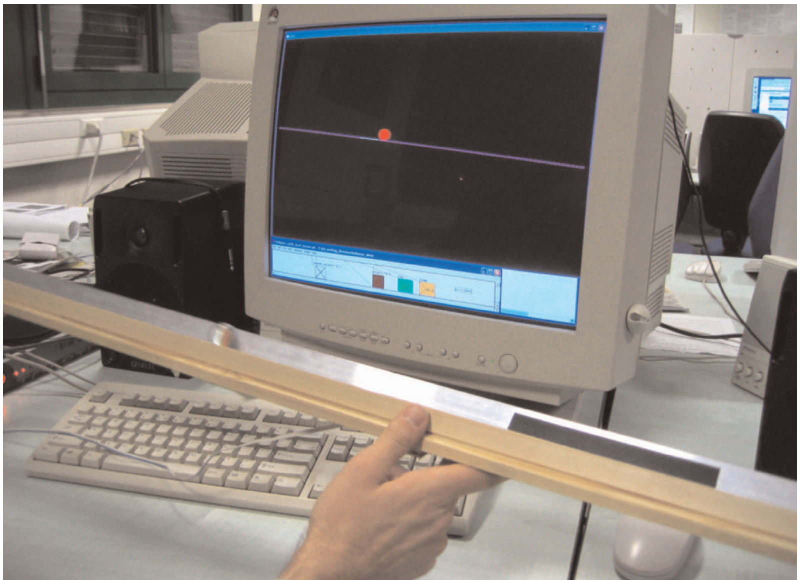

Figure 3. Ballancer with a glass marble rolling on its upper face's aluminum track.

The main points behind the choice of system metaphor follow:

- The simplicity of the idea supports a robust realization. The previous attempt of the InvisiBall taught us that a more complicated metaphor was only partially successful because of sensitivity to imperfections in the practical implementation.
- Working on the same general balancing notion, we could easily expand the system, for example, to a 2D plane.
- We can adapt the metaphor to a wide range of control tasks. The system can be seen as a simple representation of a controlled system that reacts with inertia.[11]
- Simplicity and generality are reached while the general principle, as well as the haptic control, are familiar from everyday experience. Therefore, a system like this should be easy for anyone to understand, even with little or no explanation or training.

Another strong advantage is that the physical, purely mechanical realization of the metaphor is straightforward. For instance, in our implementation the control track can also hold a real ball moving on its top surface (see Figure 3). In this way the virtual system can be directly compared to its mechanical pendant.

The complete software part of the tangible-audible interface runs with a low computational load on a standard PC. The sound component is realized with Pure Data (PD, see http://pd.iem.at/, a free software program that lets us combine predefined sound processing blocks and custom-made plug-ins using a graphical interface. Specific signal processing algorithms, which are discrete-time realizations of the impact, the modal resonators, and the rolling filter, are programmed in C language as PD plug-ins. The motion of the ball (see Equation 2) is also transferred into discrete time, but at a rate (in the range of 100 Hz) much lower than the audio sampling rate. The resulting calculation and the higher level structures of the rolling model are defined by means of the PD GUI. We implemented a schematic graphical representation of the balancing track and the rolling ball on the computer monitor (see Figure 3) in Graphics Environment for Multimedia (GEM, see http://gem.iem.at), an OpenGL extension for PD.

The Ballancer interface is physically controlled by holding and tilting the rolling track, a 1-m wooden bar, which can hold a small glass marble. Fixed to the rolling track is an accelerometer that measures acceleration in the direction of the track's length. This measured acceleration is the fraction of gravity in this direction, as described in Equation 2. We can thus calculate the tilt angle from the accelerometer output, again using the PD environment. The data transfer from the (analog) accelerometer to the software is established through a Kroonde (http://www.la-kitchen.fr) sensor wireless interface, connected to the computer via a UDP socket connection. Figure 3 depicts the whole system.

User performance

In general, through the use of expressive sound models of everyday scenarios (here, rolling) and of familiar sound-oriented control metaphors (balancing a ball), users can spontaneously understand the handling and nature of the system. We can thus improve the human–device interaction, reaching a deeper, intuitive, and natural quality.

To objectively assess our success in achieving these goals, we tested the Ballancer with subjects that had no previous knowledge or training with the device. Through questionnaires, we ascertained that subjects identified the modeled sound and the whole device in the intended way.

The second objective of the evaluation was to make sure that subjects could perceive and exploit

Table 1. Some subjects' answers to the question, What do you hear? after listening to a synthesized rolling sound.

Subject	Synthesized Rolling Sound Association
1	"Small metal ball rolling from right to left across some hard surface"
2	"Small, hard, like iron, ball, diameter about 2 cm, rolling on a smooth and hard surface"
3	"Hard ball, steel or glass, diameter about 3 cm, rolling on a hard, for example, marble surface"
4	"Steel ball rolling on a hard surface, diameter 1 to 1.5 cm"
5	"Rolling object"

the continuous information conveyed through the interface, especially through the sonic channel. We assessed this objective indirectly through a specific control task and by measurement of movements and performance in this task. Experiments and results are reported in detail in Rath's thesis.[11] Here, we only summarize the main findings.

Recognition of sound and metaphor

To examine if and which spontaneous association the rolling model's sound elicits, we asked subjects to identify short sound examples (generated by the model) played at the beginning of their testing session. We then conducted the same free-identification test with blindfolded subjects who were given access to the balancing track and asked to carefully move their arm up and down holding the track. After a free period of working with the device and hearing its sonic reaction to the movement, we asked these subjects to identify what they heard.

Later, we repeated the same test procedure, this time with a 2.5-cm diameter glass marble rolling on the track (replacing the virtual ball and synthesized sound and display). Blindfolded subjects listened to the sound of the small marble and again we asked what they heard. Finally, we gave the still-blindfolded subjects access to the track as before (that is, as in the virtual setting), followed by the same question.

Identification test results

Overall association of the synthetic sound with rolling was high in the identification test. For the synthesized sound example of a small ball rolling on a plain, smooth, hard surface until coming to a rest, 9 of the 10 subjects immediately described what they heard in terms of a scenario of a rolling object. Table 1 shows some answers.

The sound of the small glass marble rolling on the track in front of blindfolded subjects turned out to be more ambiguous to subjects than the synthesized sounds. While clearly hearing something moving in front of them, 4 of the 10 subjects perceived several (not just one) objects rolling on the track. One subject heard "something like a toy car," two others heard the object "inside a tube."

When controlling (blindfolded) the tangible-audible device with the synthesized sound feedback, all 10 subjects clearly described an object rolling from side to side, steered by the height of the held end. Eight of the 10 subjects even described the construction of a tiltable track or pipe.

The ambiguity in the (purely acoustic, blindfolded) perception of the mechanical scenario did not diminish when we gave subjects access to and control of the track. Also, subjects regularly estimated that the diameter of the real glass marble was much smaller, typically around 0.5 to 1 cm, than its de facto size of 3 cm. Subjects described the virtual ball's size as between 1 and 3 cm (compare to Table 1), much closer to the intended diameter of 2.5 cm.

Summarizing the results of the questions about the sounds and the tangible-audible device, we can state that the subjects intuitively understood the modeled metaphor. The combination of modeling everyday sounds and using a familiar control metaphor exhibits the advantage that virtually no explanation and learning are necessary. With our approach, users can immediately understand and react to transported information without being instructed, in contrast to systems that use abstract sounds and controls.[12] The identification of the scenario is even clearer for the tangible-audible interface than for the actual mechanical device that provides a physical realization of the metaphor. This demonstrates the effectiveness of the cartoonification approach to sound modeling: Although subjects perceive the device as fictitious, nevertheless it can quite reliably elicit an intended mental association, even more clearly than the real thing.

Table 2. Improvement through sound feedback of average times needed by subjects to perform the target-reaching task at various sizes.

Screen Size	Average Task Time with/without Sound (ms)	Difference (%)	Statistical Significance
Full	5,217/5,675	8.8	0.031
1/3	5,644/6,353	12.6	0.029
1/6	6,192/7,283	17.6	0.004
1/12	8,172/13,188	61.4	0.000

Performance measurement

The second part of the evaluation test addressed the question of whether users, besides identifying and appropriately using the sound model and control interface, actually perceive the dynamic ecological information contained in the sound and make use of this information. We asked subjects to perform a specific task, consisting of moving—by balancing and tilting the track—the virtual ball from a resting position at the left end of the track into a 15-cm-long mark slightly to the right of the center and stopping it. We had the subjects perform this task with various configurations of sensory feedback and recorded their movements. This indirect approach, as opposed to direct scaling or sorting experiments, has the advantage of revealing mechanisms of perception and action that are beyond subjects' awareness.

We asked the subjects to accomplish the task as fast as they could. Feedback about the position and velocity of the virtual ball during the trials was given acoustically through sound from the rolling model and/or visually on the computer screen, as a schematic representation of the ball on the track (see Figure 3). The target area was indicated in the graphical representation by a different color, and a rougher surface with a furrowed structure was used in the sound model. The graphical display, with the ball represented as a monochrome sphere on a line representing the track, and the target area marked by a different color, was realized in four different sizes: 1/3, 1/6, 1/12, all of the 19-inch computer screen. In the final stage, we asked subjects to solve the task without visual display, that is, with the auditory feedback only.

Performance task results

For all display sizes, the average time needed to perform the task improved significantly with the auditory feedback from the model, as Table 2 shows.[11] These performance improvements range from 9 percent for the largest to 60 percent for the smallest display.

By analyzing recorded user movements, we can attribute the improved performance to the different, more efficient behavior of acceleration and stopping the virtual ball before reaching the target area. The example trajectories in Figure 4 give an idea of the phenomenon. These systematic qualitative changes in control movement with sound feedback disprove that the performance improvement was due only to an additional notification through the change of sound when the ball enters the target area. If this had been the case, the continuous feedback might not be necessary, and any short notification signal would be sufficient.

We found no statistically significant influence of the task's order of presentation, with and without sound. This means that any possible learning effect that might be present after the short training phase is not strong enough to reach statistical significance. In other words, subjects adapt quickly to using the device as intended with the familiar metaphor and sound scenario.

We found interesting discrepancies between subjects' spontaneous, informal remarks and the experimental results. Some subjects were convinced that the solvability or easiness of the task did not clearly improve with sound for the largest displays, while their measured test performance showed an improvement. This contradiction points out the users' unawareness of the auditory-gesture control process that would hardly be assessable through conventional questionnaire-based experiments.

All subjects solved the task with purely auditory feedback, without display. This aspect is interesting, for example, for applications for the visually impaired and could surely be strengthened through the inclusion of state-of-the-art algorithms of spatialization.

Applications

Research has shown that continuous auditory feedback can enhance the somatosensory perception of the state of a manipulated object and even provide effective sensory substitution of haptic or visual feedback. We consider equilibrium tasks as possible areas of exploitation for this kind of feedback.

We can recast several complex tasks and interactions in terms of reaching or keeping an equilibrium point. As an example, we can reformulate selection by tilting[1] as a task of reaching one among several equilibrium points: A menu can be represented as a horizontal cylinder with a polygonal cross section; by rotating the cylinder about its axis the user selects different items and keeps one item as the corresponding face in equilibrium. Users need feedback to monitor deviations from the equilibrium point so that they can operate continuous adjustments to maintain the position. A virtual rolling ball could provide such feedback via a visual, auditory, or haptic display. Surface textures can help differentiate menu items.

By using anisotropic surface textures, we can extend the metaphor to 2D as we could try to estimate direction from auditory or haptic rolling patterns. In this way, we could also provide feedback for 2D selection by tilting, as required in devices such as the Hikari[1] or some other embodied user interfaces.

Even the action of steering a path within a corridor—as used in some experiments aimed at deriving predictive models in human–computer interaction[13]—can be thought of as trying to maintain equilibrium on the ideal middle line. According to some theories of perception and action, any task of steering or avoiding obstacles can be modeled in differential form as

$$\ddot{\theta} = k(\theta - \theta_0) - b\dot{\theta} \qquad (3)$$

which resembles the equation of a damped spring with natural rest length of θ_0.[14] In activities such as bicycle riding the variable θ is the instantaneous heading. Equation 3

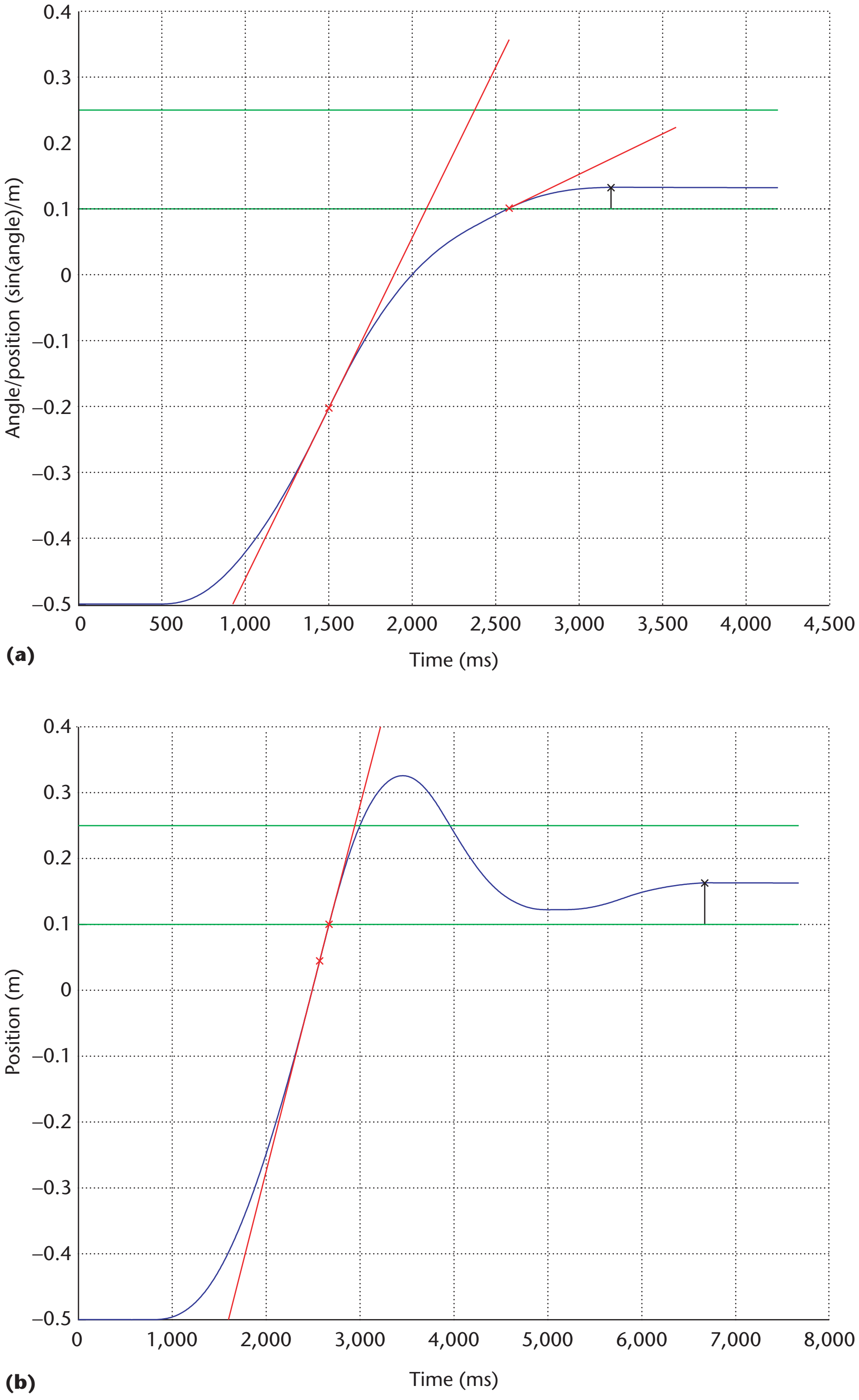

Figure 4. Movement trajectories of the controlled virtual ball position (from the center) over time (a) with and (b) without sonic feedback. On average, the ball reaches maximum velocity earlier and enters the target area (inside the green marks) with slower velocity when the controlling subject receives auditory feedback. The average difference of these indicators of optimized acceleration and stopping with sound is statistically relevant for all display sizes.

can be readily converted into Equation 2 describing a tilt-and-roll situation, and its representative of the target-aiming task used for the evaluation of the Ballancer.

Therefore, the metaphor of the rolling ball is potentially useful for a variety of tasks (steering, aiming, avoiding obstacles) that are common in everyday life as well as in human–computer interfaces. Video games and virtual environments provide the most obvious application arena, but even tasks such as navigation of menu hierarchies might be recast to exploit such a metaphor.

Final thoughts

We advocate the use of continuous auditory feedback in embodied interfaces. Physics-based sound models can afford immediate and accurate grasping of everyday phenomena such as rolling, which can be used as a metaphor in a variety of interaction tasks.

In many cases, a degree of cartoonification has to be applied to sound models to make them sharper and less ambiguous. Researchers are using cartoon sound models in new interfaces, and investigating their effectiveness in multimodal contexts. Experiences such as those reported in this article indicate that both the illusion of substance and the performance in continuous interaction tasks can be improved by carefully designed sound models. **MM**

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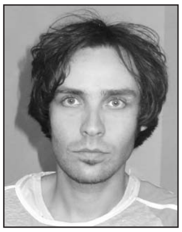

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2005 Editorial Calendar

January/February: Emerging Technologies*

This issue covers the Siggraph 2004 Emerging Technologies exhibit, where the graphics community demonstrates innovative approaches to interactivity in robotics, graphics, music, audio, displays, haptics, sensors, gaming, the Web, AI, visualization, collaborative environments, and entertainment.

*Bonus CD-ROM of demos included with this issue.

March/April: State-of-the-Art Graphics

This issue covers an array state-of-the-art computer graphics, including new developments in VR, visualization, and novel applications. The broad range of topics highlights the usefulness of computer graphics.

May/June: Smart Depiction for Visual Communication

Smart depiction systems are computer algorithms and interfaces that embody principles and techniques from graphic design, visual art, perceptual psychology, and cognitive science. This special issue presents such systems that hold the potential for significantly reducing the time and effort required to generate rich and effective visual content.

July/August: Applications of Large Displays

The emergence of large displays holds the promise of basking us in rich and dynamic visual landscapes of information, art, and entertainment. How will our viewing and interaction experiences change when large displays are introduced in our workplace, home, and commercial settings? This special issue will serve to collect and focus the efforts of researchers and practitioners on the frontier of designing large displays.

September/October: Computer Graphics in Education

Graphics educators are cultivating the next generation of developers. However, hardware and software barriers to entry have shrunk, and people from nongraphics areas have begun adopting the technology. This special issue will highlight approaches from inside computer graphics education and uses from outside the field in domain-specific education.

November/December: Moving Mixed Reality into the Real World

As computing and sensing technologies become faster, smaller, and less expensive, researchers and designers are applying mixed reality technology to real problems in real environments, This special issue will present a broad range of issues faced by designers as they move state-of-the-art technology beyond the laboratory.

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