Sound Bounce: Physical Metaphors in Designing Mobile Music Performance

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ABSTRACT
The use of metaphor has a prominent role in HCI, both as a device to help users understand unfamiliar technologies, and as a tool to guide the design process. Creators of new computer-based instruments face similar design challenges as those in HCI. In the course of creating a new piece for Mobile Phone Orchestra we propose the metaphor of *a sound as a ball* and explore the interactions and sound mappings it suggests. These lead to the design of a gesture-controlled instrument that allows players to “bounce” sounds, “throw” them to other players, and compete in a game to “knock out” others’ sounds. We composed the piece *SoundBounce* based on these interactions, and note that audiences seem to find performances of the piece accessible and engaging, perhaps due to the visibility of the metaphor.

Keywords
Mobile music, design, metaphor, performance, gameplay.

1. INTRODUCTION
Designers and composers of computer-based musical interactions are faced with a great number of choices and opportunities. Computer hardware affords numerous input capabilities such as mice, keyboards, accelerometers, and touch screens, and software allows us to map these to sound generating processes in ways that are not constrained by physics or material considerations in the way that acoustic instruments are. Furthermore, performance practices in technology-mediated music are not standardized. The composer must design not only the instruments, including the actions by which they are performed and the resulting sounds, but also the interactions between conductor, performers, and score, all the while taking into account how these affect the audience’s understanding of the performance.

The Stanford Mobile Phone Orchestra (MoPhO) is a performing ensemble in which small hand-held computing devices such as iPhones and iPod Touches are used as musical instruments [3, 11]. Composers write custom software applications to enable the musical interactions they desire, and in this process confront the aforementioned design challenges.

Researchers and designers in human-computer interaction (HCI) often use metaphor to help users quickly gain an intuitive understanding of a device’s operation, as well as to guide the process of designing new interactions [1].

This paper describes the role of metaphor in HCI design, and its use in the creation and performance of the piece *SoundBounce*, for MoPhO. We used the metaphor of *a sound as a ball* to explore possible interactions, to create the soundbounce instrument and its sound control mappings, and to structure the performance of the piece. The paper concludes with an evaluating the expressive capabilities of the instrument and the success of its performance from the audience’s perspective.

2. METAPHOR IN DESIGN

2.1 History
A metaphor is a figure of speech or a literary device in which one object is described as if it were another. The use of metaphor in human computer interaction has a long and rich history, as described in detail by Blackwell [1]. Often an entity on the computer, such as a file directory, is visually represented as a physical object, a folder in the case of the desktop metaphor, and the operations on this entity are described as the physical actions typically performed on the object, e.g. opening, adding and removing documents.

The metaphor allows the user to understand abstract or complicated operations of the computer in terms of physical objects or interactions with which they are already familiar. A metaphor may refer to a physical reality, or to a common cultural understanding (what Fels calls *literature* [4]). The work of Lakoff and Johnson suggests that all abstract understanding occurs through metaphors that reference our embodied spatial experience [9,10].

The desktop metaphor is probably the most well-known application of metaphor in HCI, but other examples include navigation metaphors in file and web browsing, cockpit metaphors (a sub-class of navigation) in games and in discussions of technologically-augmented power [1], and cave metaphors in virtual reality.

A metaphor can be used not only to structure a user’s experience but also to guide the design process. Fels describes the use of metaphor in designing new musical instruments in general and its application to four unique instruments [4]. In Verplank’s Framework for Interaction Design, which is used in a course on music interaction design at Stanford [5], metaphor is used during brainstorming and design to create meanings for both designer and the user.

2.2 The Bouncing Ball

Typically a new design does not emerge fully-formed in a flash of inspiration. Rather through exploration and prototyping an initial insight may lead to subsequent discoveries and refinements.

SoundBounce began with the desire to create a gesture-controlled instrument that enabled interesting interactions between performers. The idea of a "bounce" gesture came from holding an iPod Touch in hand and playfully exploring movement possibilities. Unlike the Wiimote, which one tends to hold with the thumb side of the hand up, the iPod is typically held with the screen up. The flatness of the screen suggests a paddle, and an upward flick of the wrist creates a motion as if one were bouncing a ball upward (Fig. 1). The idea of bouncing a sound led to the metaphor of *a sound as a ball*. Bouncing a ball then becomes the act of "playing with a sound" and "keeping it going." We will discuss in section 3.1 how this metaphor led to a particular sound synthesis and mapping.

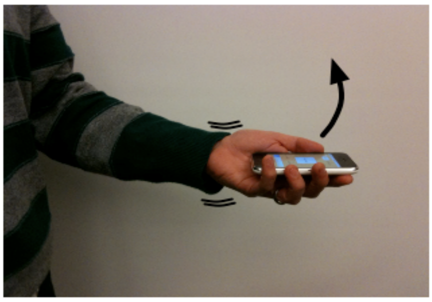

Figure 1: Holding the iPhone suggests a "hit" gesture

Notice that this metaphor makes us think of a sound not as the result of some process, but as a distinct object, separate from other sounds, amenable to manipulation, and able to be transferred from one person to another. Blackwell points out that a metaphor frames not just the interaction between a user and the computer, but also how the designer sees the user. The metaphor of *a sound as a ball* frames the performer as someone playing with a ball. When more than one player is present this leads naturally to the interaction of passing a sound from one performer to another. Thus we added to the possible interactions the ability to take aim at another performer and throw a sound to them.

Figure 2: Throwing a sound

It is only a small step from passing a ball around to playing a ball game. As one possible mode of interaction between players we created a game using only the actions of bouncing and throwing sounds. Players attempt to knock out others players' sounds by throwing their own sound at them. Details are given in section 3.2.

3. FROM METAPHOR TO MUSIC

3.1 Metaphor-Based Mappings

In computer-based instruments the mapping from physical movement to sound generation has been decoupled from physical necessity, giving the designer a staggering number of options. Luckily we can use our metaphor to structure not only the interactions with the instrument and between performers, but also the sounds that these interactions create.

In the sound bounce instrument the ball is not just a metaphor. It is implemented in code as a virtual bouncing ball object with its own simulated physics. When a player makes a hitting gesture an upward velocity is imparted onto this virtual ball which then rises and falls ballistically under the acceleration of constant gravity. The movement of the ball is sonified, creating an instrument that maps gesture to sound via a simulated physics.

The sound of the ball is created with frequency modulation (FM) synthesis, where a single carrier oscillator's audio-rate frequency is modulated by the output of a slower modulation oscillator. In order to choose a mapping from the virtual ball's behavior to synthesis parameter we can again refer to metaphor.

People often employ spatial and movement metaphors when discussing music and its effects [7]. We say that a melody "rises", "falls", or "comes to rest. One common association is between spatial height and melodic pitch height. In the sound bounce instrument the height of the virtual ball controls both the frequency of the carrier oscillator and the amplitude of the modulating oscillator. This leads to a sound that rises in pitch and gets spectrally brighter as the ball rises, thus taking advantage of these metaphorical associations.

Some occurrences suggest discrete sonic events. A sharp impact sound occurs whenever a performer bounces a ball. If the player fails to hit the ball before it falls below a certain height the ball is dropped, triggering a crashing sound and making the ball unavailable to further interaction

A performer can take aim by holding the iPhone horizontal and pointing it at another player. This triggers two short pitched sounds which are not metaphorically motivated. Rather they are designed to allow the performers to hear whom they are aiming at and who is aiming at them. The first sound is played by performer's own instrument at a pitch associated with the person aimed at. The second occurs a fraction of a second later on the instrument of the person aimed at, at a pitch associated with the person aiming. These sounds create an audible link between the players and become part of the soundscape of the piece.

Once a performer has taken aim they can pass their sound to another player by making an over-handed throwing gesture (Fig 2). The sound of a throw is similar to a bounce in that the virtual ball is launched upwards. However the sound gradually cross-fades from the thrower's instrument to the receiver's, creating the illusion of a moving sonic object.

3.2 The Game

The last section of the *SoundBounce* piece is structured as a game. The soundscape of the game is designed so that all actions and changes of state have audible correlates, allowing both players and audience to perceive what is happening without any explicit visual information.

When a player's ball is knocked out by another player's throw, the targeted player's instrument plays a loud clanging sound. The targeted player then loses health, thereby coming closer to dying. This change of state is conveyed by the addition of a noisy distortion to all of the player's sounds. As the player loses more health the distortion gets progressively greater. This can be seen as a metaphorical association of clear sounds with good health and distortion with poor health. Once a player dies they can no longer make sound and are ejected from the game.

In autumn of 2009 *SoundBounce* was modified for performance by the Stanford Mobile Phone Orchestra, and the sound bounce iPhone application was developed. All details presented in this paper pertain to the MoPhO version of the piece.

SoundBounce for MoPhO was premiered on December 3, 2009 at the Center for Computer Research in Music and Acoustics (CCRMA) at Stanford University. The five performers stood in a circle facing each other in the center of the performance space, with audience members both surrounding and within this circle. Sound was projected from powered speakers mounted on gloves worn by the performers. The structure of the piece was based on the three principle interactions: bouncing, throwing, and game play.

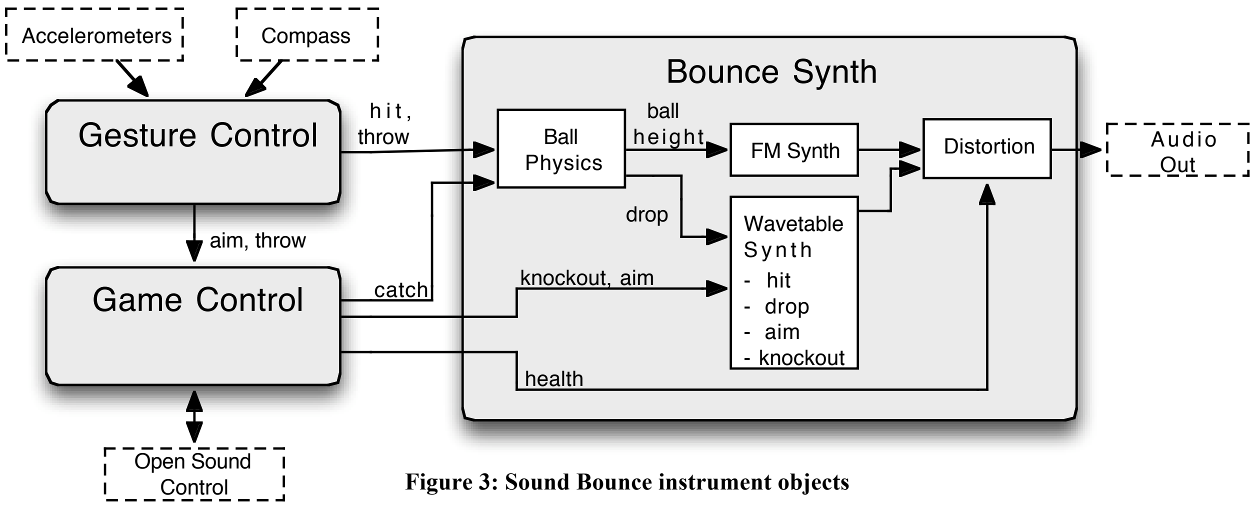

Figure 3: Sound Bounce instrument objects

3.3 Implementation

The sound bounce instrument is implemented as an iPhone3.0 application, and uses the MoMu API [2] for audio output, accelerometer and compass data, and network communication using Open Sound Control (OSC). All computation, including gesture detection and sound synthesis, is performed by this application.

The code is structured into three objects. Gesture Control uses information from the iPhone's accelerometers and compass to detect when the user performs a hit, throw, or aim gesture. The Bounce Synth object computes the virtual ball physics and performs all sound processing. Hit and throw messages from Gesture Control are used to impart velocity to the virtual ball whose height is used to control the FM synthesizer. Bounce Synth also contains a wavetable synth which plays the sounds associated with the hit, ball drop, aim, and knockout events. Audio from the FM and wavetable synths is passed through a distortion which adds noise based on the performer's game health. The Game Control object keeps track of all game states, and sends and receives OSC messages for aiming, throwing, and receiving sounds.

3.4 Performance History

SoundBounce was originally created as a piece for the Stanford Laptop Orchestra (Slork) in the spring of 2009. Performers were seated at laptop stations, and made gestures with iPod touches. We used the iPhoneOS application TouchOSC [6] to send accelerometer data from the iPods to laptop computers via OSC. Gesture detection was performed on the laptop by a Max/MSP patch that then sent OSC messages to a ChucK program, also on the laptop, for sound synthesis. The premiere performance on June 4, 2009 was composed and coordinated by Luke Dahl, Diana Siwiak, Leah Reid, and Lauchlan Casey.

Before the piece begins performers check that sound and networking are working properly by aiming at each other and listening to the pitched aim sounds. This creates a polyphonic texture akin to the sound of an orchestra warming up. The piece begins with each performer in turn generating a new sound, bouncing it a few times, and letting it drop. All performers then bounce their sounds in synchrony and suddenly let them drop. In the second section players throw a sound from one player to the next, first in a circle, and then in more complex patterns with multiple sounds at once. The piece ends with the game, during which the soundscape becomes progressively more distorted as players lose health, and then sparser as players drop out. When the duel between the last two remaining players is resolved, the winner performs a few victory bounces and the piece ends. A video of this performance can be seen at `http://ccrma.stanford.edu/~lukedahl/soundbounce/`

4. REFLECTIONS

4.1 Expressivity and Visibility

Since design is an iterative process, it can be useful to reflect on the instrument we designed and the music we composed for it. We can measure an instrument's expressivity in a number of ways. Does it allow for a wide range of sonic possibilities? Does it enable precise control of subtle variations in sound? According to these metrics the sound bounce instrument is not especially expressive. Performers can choose how high to bounce a ball and can be somewhat expressive in choosing the timing of their gestures, but the sonic palette of ball-controlled FM synthesis and pre-recorded triggered sounds is rather limited. These limits may be a function of the metaphor:

bouncing a ball is not expressive in the way we associate with musical instruments.

Fels claims that expressivity is a function of *transparency* – that is, whether the mapping from action to sound is understandable by both the performer and the audience – and that transparency is improved through the use of metaphor [4]. Indeed, the metaphor used in *SoundBounce* helps performers quickly understand the instrument and makes it easy to communicate about the structure of the piece, e.g. "Let's go to the passing-the-ball-around section." More importantly, the use of metaphor allows the audience to understand both the relationship between a performer's gesture and the resultant sound, and the interactions occurring between performers. In other words, Metaphor increases what Klemmer calls *visibility* [8].

Bouncing a ball may not be expressive, but it is playful. Rather than enabling individual expressivity, performing *SoundBounce* brings out a sort of group expressivity. Players use a number of non-verbal cues such as body orientation and eye contact to communicate intentions during performance, and these non-audible actions become part of the performance. During the December 2009 MoPhO performance the audience seemed to pick up on these signals, responding with sympathetic vocalizations when a throw mistakenly went to the wrong recipient. The game section of the piece allows for the most diversity of behaviors, with impromptu alliances being made and broken during the course of the game. Again, the audience became more engaged as the rules of the game became apparent and the competition intensified, signaling so through laughs and vocalizations.

4.2 Aesthetics

We use the verb "play" to describe both what we do with a musical instrument and what we do in a game. However it is unclear whether the use of gameplay in a musical performance leads to an aesthetic and musical experience by the audience. Do they perceive the performance as music or as art, or do they watch the performance in the same way they might regard a sports event?

Using a metaphor in an artistic endeavor comes with the danger that the result may be overly simplistic. It is possible that our rather straightforward application of a metaphor imposes too much structure on the audience's experience, leaving too little room for the active interpretation and multiplicity of understandings that good art allows.

5. CONCLUSION

Future work on *SoundBounce* might proceed in two different directions. We can explore the metaphor further in order to enrich the possible interactions with the instrument. For example what would it mean to catch a sound from the environment, or to intercept or steal someone else's sound? How might the metaphor help us modify the instrument, interactions, and composition to work for a large number of performers? Or we could use the instruments and interaction possibilities defined so far in new compositions whose structure is less restricted by metaphor and thus open to more diverse interpretations.

In summary, following the lead of HCI, we have used a physically based metaphor, *a sound as a ball*, to explore possible performer-instrument and performer-performer interactions. This led to the design of an instrument and a musical piece, *SoundBounce*, whose sound mappings and structure are informed by the same metaphor. Upon reflection we found that the resulting instrument, while not being expressive on its own, elicits interactions that are understandable and engaging to an audience.

6. ACKNOWLEDGMENTS

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We hope that this paper will inspire other researchers in technology-mediated music interactions to reflect on and publish their own design processes.

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