echobo : A Mobile Music Instrument Designed for Audience To Play

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ABSTRACT
This work aims to create a musical performance for large-scale audience participation using mobile phones as musical instruments. Utilizing ubiquitous smartphones, we attempted to facilitate audience engagement with networked phones as musical instruments. Drawing lessons learnt from previous works of mobile music, audience participation practices, and networked instrument design, we developed *echobo*. Audience members download the app, play the instrument instantly, interact with other audience members, and contribute to the music via sound generated on their mobile phones. Surveys of participants indicated that it was easy to play and that participants felt connected to the music and other musicians.

Keywords
mobile music, audience participation, networked instrument

1. INTRODUCTION
By encouraging participatory gestures from audiences, such as singing along, clapping to the beat or waving arms, musicians can effectively engage audiences with their music. The goal of our work is to achieve such engagement by letting audiences participate directly in a musical performance. In our proposed performance format, audiences play a networked musical instrument, generating sound from their personal mobile devices.

There have been a number of musical works written to facilitate large-scale audience participation in musical performances, with and without digital technologies. Upon reviewing a series of audience participation works in musical contexts, we proposed five criteria for a successful participatory experience (see [16] for more detail): i) to make participation easy (accessibility); ii) to collect gestures from the audience and turn them into a single musical composition (musical security); iii) to drive audiences to start participation without reservation (initiation); iv) to motivate people to participate and sustain the interest (attraction); and v) to provide a clear relationship between their gestures and outcome in music (transparency). To achieve these, we developed a mobile music application, named *echobo*, so that audience members can download the app at a concert, learn the instrument instantly, and perform a composition. *echobo* is a blend of two words, *echo*, which represents the state of being empathized with others, and *chobo* (초보), which means the first step or a novice in Korean. As part of this work, the authors presented a six-minute composition for *echobo* and clarinet, twice in a classroom setting for the purpose of evaluation and once in a public performance.

While there much prior artistic work and research in audience participation in a computer music context, there are very few examples where large audiences are able to participate as performers and play musical instruments. To the best of our knowledge, this is the first attempt to develop a large-scale audience participation environment that allows audiences to play musical instruments and generate sound from their mobile phones.

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2. USE OF MOBILE PHONES IN COMPUTER MUSIC
Many have suggested that *Dialtones (A Telesymphony)* by Golan Levin [17] is the first work that incorporated mobile phones in a music performance. The piece showed the potential of the mobile phone as a new interface in computer music. *Pocket Gamelan* is another noteworthy work of early mobile music [25]. It used the mobility (lightweightness and network capability) of devices to create a flying sound source.

Mobile music researchers initially focused on the audio synthesis capability on the mobile platform [5, 12] and then on the interaction potential of its embedded sensors [6, 7, 24, 28]. More recently, many researchers have sought to turn smartphones into self-contained musical instruments in various forms [30, 33] and created a new form of ensemble solely with mobile devices [19, 31].

We found six distinct trends in the use of mobile phones in computer music: ubiquity, sound synthesis, mobility, interactivity, social interaction, and mobile composition. Table 1 lists several well-known works of mobile music and indicates the relation of each work to these six trends of mobile music. As seen from the table, *Dialtones (A Telesymphony)* is the only work that has utilized the ubiquity of mobile phones. Many other works are somewhat motivated by the ubiquity of mobile devices, but ubiquity is not a precondition of their design. We believe that a music performance with hundreds of mobile phones is relatively unexplored area. Given the current state of the art, it is now practical to add audience interaction to the scope of a work such as *Dialtones (A Telesymphony)*.

3. AUDIENCE PARTICIPATION AT A MUSIC PERFORMANCE
There is a definite separation between audiences and performers in a traditional musical concert. However, musicians and composers often try to blur this line by making audiences involved in the performance. This happens in a wide variety of genres from experimental to popular music.

3.1 Audience Participation in Mobile Music
Although *Dialtones*(*A Telesymphony*) is the first use of audience mobile phones in large-scale music performance, researchers who have studied audience participation note that it

is not audience participation due to their passive roles [8, 18, 20]. McAllister et al. utilized PDAs to capture and transmit the graphic gestures of participants, sampled from the audience, for a music improvisation [18]. *Net_Dérive* by Tanaka [29] was an audiovisual installation in a gallery where the location of three participants were deployed as materials for visualization and sonification of the installation. Although these were pioneering works of audience participation using mobile phones, the participation was limited to a few selected people and did not fully take advantage of ubiquity of mobile phones, e.g. mobile phones with the specific application installed were provided to three to four audience members.

Sello let audiences use their own mobile phones to participate in his piece, *isms* [26], using text messages that audience members send to a designated phone number for the music score and video projection. More recently, the Stanford Mobile Phone Orchestra held their annual concert with the theme of audience participation [20]. For each piece, the audience could participate in the performance using their mobile phones. In *Converge 2.0* [21], the audience was encouraged to submit audio-visual material prior to the concert. The submitted materials were then used as sonic and visual objects at the actual performance. *Madder Libs* also used video snippets that people submitted to trigger rhythmic audiovisual events in a grid controller. In *TweetDreams*, Twitter tweets containing certain hashtags were sonified and visualized with their textual content so audiences could trigger audiovisual events in real time at the performance venue [3].

There has been a series of efforts to develop programmable mobile interfaces, which are often useful in audience participation works. In *Moori* [15], participants could send text messages in response to guided questions by the performer using the OSC controller application *MrMr* [1] and then the messages were visualized on screen and spoken with text to speech (TTS) software. *massMobile* is an audience participation framework that facilitates rapid development and enables plug-and-play setup on mobile web platform [34]. In [23], the audience used *Control,* the OSC controller app, to participate in the composition as they control different musical parameters in response to conductor's gestures.

In these works, audiences could effectively participate in the performance only if they had mobile phones (or smartphones). However, the action of participation in these pieces is far from playing a musical instrument, rather close to influencing music indirectly or triggering some acoustic events that musicians pre-defined. If these works were applied to Table 1, all would be associated with the trends of ubiquity and mobility but not the others. Therein lies one of our motivations: to provide a musical instrument to the audience so that their acts of participation become more musically expressive.

3.2 Types of Audience Participation

As mentioned earlier, we propose five criteria for a successful participatory musical performance: accessibility, musical security, initiation, attraction, and transparency. Here we suggest three methods to classify participatory musical works in order to understand how each mode necessitates different strategies to meet these criteria. In addition to the suggested methods, spatial and temporal dimensions of audience participation were suggested in [21].

3.2.1 Role of Audience: Composer vs. Performer vs. Audiovisual Objects

In Jean Hasse's *Moths*[13], audience was instructed to whistle along to a conductor's gestures and a graphical score. The role of the audience in this piece was to play music as a performer, and the whistling of the audience was the only sound of the performance. In popular music, audiences also often participate by making sounds directly such as singing, clapping, or stomping feet (e.g. *We will rock you* by Queen).

Other works let audiences shape the music rather than play the music, more like composers than performers. The author's (Freeman) previous works fall into this category, where the outcome of participation is a real-time music notation [9, 11]. In *Glimmer*, audiences use light sticks to influence the composition indirectly, rather than to generate sound directly, in order to make the audience comfortable in participating without any musical background (accessibility). This type of participation requires one or more intermediate steps, and the mediation helps to structure the diversity of audience input and to make the resulting music cohere (musical security).

Especially in works with mobile phones, there have been cases where the role of audience is neither a performer nor a composer. For example, in *TweetDreams* and *Moori*, even though the audience triggers audiovisual events in the music, the intention of their actions is textual communication with musicians and other audience members, rather than musical expression. In a paper on *TweetDreams*, the author states that "audience members do not play the instrument in the sense of directly controlling what sounds are made [3]." This type of audience participation is an effective way in which performers can securely shape the audience's inputs as they desire (musical security) and motivate the audience to participate with social interaction elements (attraction). And a visual projection can help to identify their participation and achieve transparency of participation (transparency).

3.2.2 Collective vs. Individual vs. Selective

In a popular music concert, each audience member can participate in music by singing along or clapping and can differentiate individual participation from the collective musical result. In *TweetDreams* or *Moori*, likewise, single act of participation is linked to single event in music, which is easy to identify with textual contents on screen (tweets, messages, username). In these examples, individual outcomes of participation guarantee transparency of participation.

Table 1 Frequently cited works of mobile music and associated trends

	Ubiquity	Sound Synthesis	Mobility	Interactivity	Social Interaction	Mobile Composition
Dialtones	X					
PDa/ MobileSTK		X				
Pocket Gamelan		X	X			
Malleable Mobile Music			X	X		
CaMus/ShaMus		X	X	X		
Ocarina		X	X	X	X	
ZoozBeat		X	X	X	X	X
Mobile Phone Orchestra		X	X	X	X	X

Another common approach is to collect acts of participation and average them to influence the music. In Duffy's *the Critic's Choice*, the audience participates in the composition by casting a vote on the possible ending of music [4]. In Baird's *No Clergy*, the audience submits values of parameters for algorithmic composition software via a web browser so that music notation can be generated based on the average value [2]. Collective application of participatory acts is less transparent for audiences than the case of individual participation, especially when decisions of individual audience members differ from the aggregated result of whole audience. Furthermore, we have found that aggregating group interaction can make the resulting music less varied, because averaging all participation can cancel out the contrasting ideas of different audience members [9].

Lastly, a musician who leads the audience participation can take a selective approach. In *Piano Etudes* [10], the pianist selects one piece out of submissions from the public in advance to the concert. In [23], eight participants among many possible participants were selected to control the music parameters, and the nature of waiting to be selected was part of their motivation. In this mode of selective participation, the outcome of participation is more transparent than the case where the whole audience can participate, since each individual has more influence on the music. In addition, the selection process for participants enables musicians to pick more motivated participants (e.g. volunteers) and to reduce risk by making the participation smaller scale.

3.2.3 Sound Source: Audience vs. Stage

Another distinction can be made based on the sound source from which the acoustic outcome of participation is generated. The sound source can be the audience themselves, musicians' instruments or speakers on stage. When sound comes from the audience, the role of each participant is close to an acoustic instrument player because the sound is coming from where they perform. The location of the sound source matters if it comes from the audience. It means that they have direct control over their sound to differentiate from other people (transparency). *Moths* and the clapping / stomping examples from popular music fall into this category.

In contrast, the notion of a "stage" best represents the cases where the outcome of audience participation comes from instruments or main speakers on stage. For most of the audience participation works we reviewed in this paper, except *Moths*, the acoustic outcome of audience participation comes from stage.

3.3 Audience Participation Using Mobile Phones as Musical Instruments.

As one might have noticed, there is a clear separation between audience participation works in computer music and non-computer music contexts. The works in non-computer music contexts (e.g. *Moths*, clapping/singing examples from popular music) took an approach of having each individual audience member as a performer (*Performer/Individual/Audience type*), while audience participation works from computer music rather let audiences influence the music through intermediate steps. Our novel contribution is in following this particular mode of audience participation within the context of an electroacoustic performance: audience members participate as individual musicians and generate sound from their seats using mobile phones as musical instruments. We do realize that we cannot create a completely '*individual*' type of participation and that there exists a '*selective'* process simply because participants must own a compatible smartphone.

4. DESIGN PRINCPLES

4.1 Networked Music Instrument

The goal of this research is to create a participatory musical performance that connects audiences to the performance by letting them play musical instruments on their mobile phones. Obviously, providing a musical instrument (e.g. violin) to audience members does not guarantee a successful performance due to the variety of musical backgrounds audience members will have. Therefore, it is essential to design the instrument to be easy and interesting to play and to provide a composed piece to audience. To ensure the performance is accessible to audience members and that they are able to perform successfully, we adapt the concept of a networked collaborative instrument in developing the mobile application.

Among the many types of multi-user instruments, we chose the networked instrument for which musicians have distributed roles in a global sequence of generating sound. *The Squeezables* exemplifies this type of approach, where each performer controls different parameters (melody/ timbre/level/rhythm) of music [32]. Another influence on our work is *Pazellian* [22], a distributed interactive music application using harmonic constraints. In this application, there exist three different types of roles to control music: Performer, Conductor, or Maestro. The conductor-role user can control the high level aspects of the music such as volume, tempo and, notably, the harmony of the music at the moment. The performers can choose a voice (instrumentation) of the music and perform in real-time by moving an indicator in a two-dimensional space (pitch-volume) using a mouse. The system automatically adjusts the pitch selected by performer users according to the harmony of the music, which is concurrently controlled by the conductor user.

The harmonic constraint model of *Pazellian* is borrowed for this work so that the application will delegate a high-level musical decision to a musician/conductor (or a master musician) and let the audience/performers (or audience musicians) improvise under this constraint. With this model in mind, we developed a mobile music application for iOS devices, named *echobo* The following section will cover design details of *echobo*.

4.2 Performance Concept

echobo provides two types of instruments: one for the master musician and one for the audience. The master musician controls the high-level musical structure (chord progression) but does not make any sound. Then the harmonic constraint that the master musician defines is transferred to the audience's mobile phones to determine the harmonic content (scale) of the instrument. The audience can play the instrument note by note and generate sounds in a harmonically controlled manner. The constraint (the selected chord) is transmitted over any available mobile network (e.g. 3G, 4G, or WiFi). See Figure 1 for a visual representation of the performance structure.

The audience's instrument is a simplified key instrument with eight keys (See Figure 3); the pitches for each key change based on the chord selected by the master musician. (They are always in a major or minor scale. For example, if the master musician selects C Major, eight keys in a major scale with a root note of C will appear on audience's interface. If the master musician then changes the chord to E minor, the existing keys in C Major will fade out and a new set of keys in the E minor scale will appear.) The master musician's interface is projected in performance so that audiences can anticipate the timing of key changes.

By having limited keys based on the chord progression sequence, any possible sound generated by audiences will be in

a scale that the master musician controls. This application structure, in which the master musician controls the pitch space while the audience generates sound, challenges the master musician on stage to take the responsibility to move the music through a harmonic structure over time. In the meantime, the audience still takes ownership of the musical instruments by generating sound within the limited harmonic possibilities.

In performance, an additional musician performs on an acoustic instrument (Figure 1), providing melodic material for the composition while the audience creates the harmonic backdrop. Having this acoustic musician not only improves the musical results, but also helps the audience connect to the music through collaborating with the musician.

4.3 Master Musician's Interface

To perform a piece, the master musician has to create a room and share the name of the room with the audience so they can join. The graphical user interface to create/join a room exists both in the master interface and the audience interface.

Once the master musician creates a room, a graphical interface to create and navigate a space of chord progressions is presented. The design of the interface directly draws from the author's previous work. (See [27] for more detail). The interface represents chords as colored squares (or "blocks"") and a piece of music as a set of blocks which resembles a crossword puzzle (Figure 2B). The master musician instantiates a block with the plus sign button on the bottom left (Figure 2A). Then, the master musician associates the block with a base note of the chord (e.g. C, D, E) and a chord type (e.g. major, minor, major 7, etc.) by traversing the scrolling menu and selecting the combination of interest. Finally, the chord block can be placed anywhere on the screen with a drag and drop gesture using the grab buttons (two blue hand icons in Figure 2A). While adding blocks provides a base for the musical structure, the position of the cursor (the white square outline in Figure 2B) determines the temporal progression of chord. The cursor can move only one block unit in four directions (up, down, left and right) with each step. The buttons for moving the cursor in four directions are placed on the four sides of the screen. In addition, the master musician can send pre-typed text messages (such as "play long tones", "play densely" or "tremolo") to the audience to coordinate the specific texture of the sound (see Figure 3A for an example of textual message). This visual interface is intuitive for the master musician to use and for the audience to understand when they see it projected in performance. It helps create a transparency in the relationship between the master musician and audience musicians, to build the audience's expectation of upcoming chords based on the topology of the blocks, and to facilitate audience engagement via sharing musical structure.

4.4 Audience Musicians' Instrument

In general, it is a virtue in developing a new musical instrument to offer *low entry fee with no ceiling on virtuosity* [35]. In contrast, the goal of *echobo* is not to help a user develop virtuosity in this one-time use instrument but to engage them in the performance while it takes place. Therefore, audience members need not to have full freedom of expressivity close to a traditional acoustic instrument. In fact, we deliberately avoid a wide range of expressivity and virtuosity, which might make the music sound out of control and ultimately discourage participation. It was a natural choice to implement a keyboard-like instrument (See Figure 3) due to its familiarity and easy initial learning curve [14].

The key instrument generates an electronic piano sound from the internal speakers of a mobile phone. It includes an octave of pitches (within the scale constraint) and the ability to control

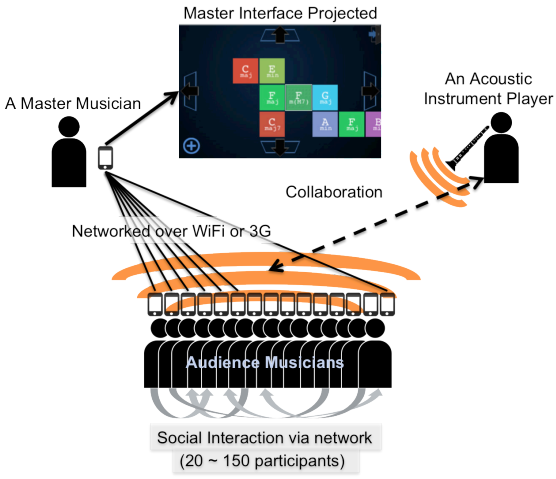

Figure 1 Performance Concept Diagram

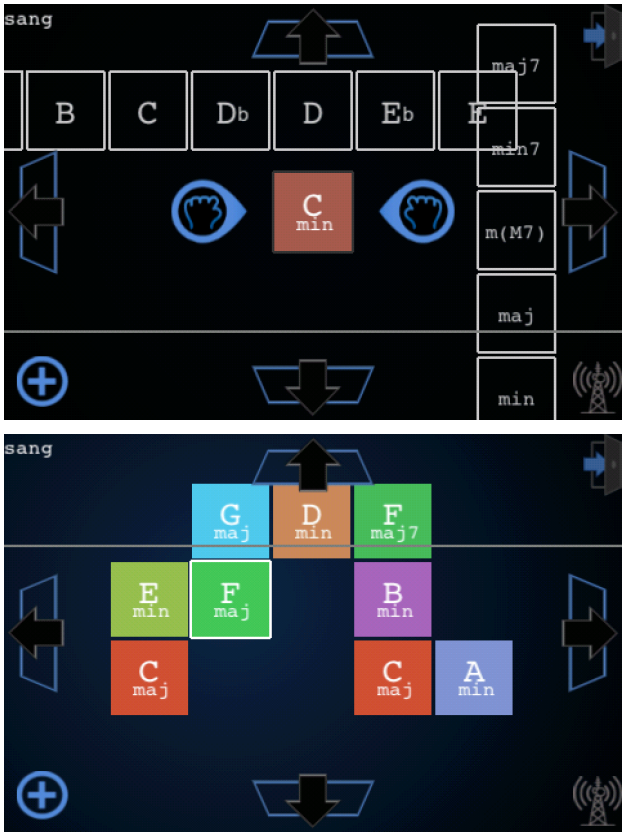

Figure 2A (upper) Chord selection in the master musician's interface. 2B (lower) Placing chord blocks to create a chord sequence. The currently selected chord is F major (by placing the white cursor on the block). The four arrows on each side move the cursor within the block structure. The horizontal bar is a time clock synchronized with the audience musicians.

duration, polyphony and amplitude modulation (or tremolo). When a number of audience members play this key instrument at the same time, the aggregated sound results in a dense and stochastic combination of the notes in the scale and can be employed as a background harmonic texture. Since no rhythmic guidelines are given, the sound is defined by each audience member's musical decisions and it is hard to predict how each individual will play the keys. When the whole audience produces sound, it can create a granular texture, rhythmically

chaotic, but harmonically in tune with the chord. Additionally, the texture of the sounds can vary based on the number of participants and the degree of collaboration among audience members, which can be orchestrated by pre-typed textual messages.

While the instrument can create effective musical textures this way, it can quickly become boring for audience members to participate. To sustain their interest in the participation and the instrument, we implemented a pattern-broadcasting function. To broadcast a pattern to other audience members, one can first record a pattern by pressing the antenna button on the top right. Once it is recorded, the pattern is visualized as a series of falling squares (notes) on mobile phones of the person who created it as well as two other randomly-selected audience members (See Figure 3B). When audience members see the falling squares, they can press each square as it falls in the outlined squares under each key (just as in rhythm games such as Guitar Hero). If the patterns is followed correctly, it is then broadcasted to two more audience members, eventually spreading virally through the audience. As one pattern can be spread exponentially over cycles, it is theoretically possible for the whole audience to eventually play one pattern synchronously, creating a very different texture to the free rhythmic improvisation. The social dynamics of being a pattern broadcaster or a follower also have implicit rewards. One might like to develop a pattern that is easy and interesting at the same time so that the rest of audience is more likely to follow. On the other hand, those who follow a pattern have the pleasure of making music in sync with others.

5. CONCLUSION AND DISCUSSION

We presented three *echobo* performances in spring 2012 (see Figure 4). See [16] for more detail on the implementation, the composition, the rehearsal process, the performance setup, the survey questions and the evaluation results.

In surveys administered after the performance, audience members indicated that they found the participation very easy and felt connected to the music and other musicians (the clarinet player, other audience members, and the master musician). A large percentage of the audience was able to actively participate in the piece and contribute to the music by playing the instrument. Survey results also indicate that audience members found the performance to be musically satisfying. In addition, our introduction of the system to the audience (through a verbal introduction, demonstration and quasi-rehearsal) worked effectively to make participants comfortable in participating. The application, within the six minute long performance, successfully motivated participants and sustained their interest by offering a controlled space for musical expression and facilitating social interaction among audience members. From both survey comments and informal feedback, it seems that the audience liked the novel musical experience and would like to participate in it again.

Interestingly, survey results indicated that the audience felt more connected to the clarinet player than other audience members and the master musician. Many participants commented that they felt that the master musician limited their musical expressivity by "taking away" keys too often. In addition, interactions among the audience were not as effective as desired despite the high rate of broadcasting patterns. It seemed that playing in sync with the randomly selected participants was not clear enough to make them feel a sense of collaboration due to the limited volume of mobile phones and the arbitrary locations of those selected. With respect to this weakness, some participants suggested that they would like to have visual feedback on who (or how many) were following the pattern.

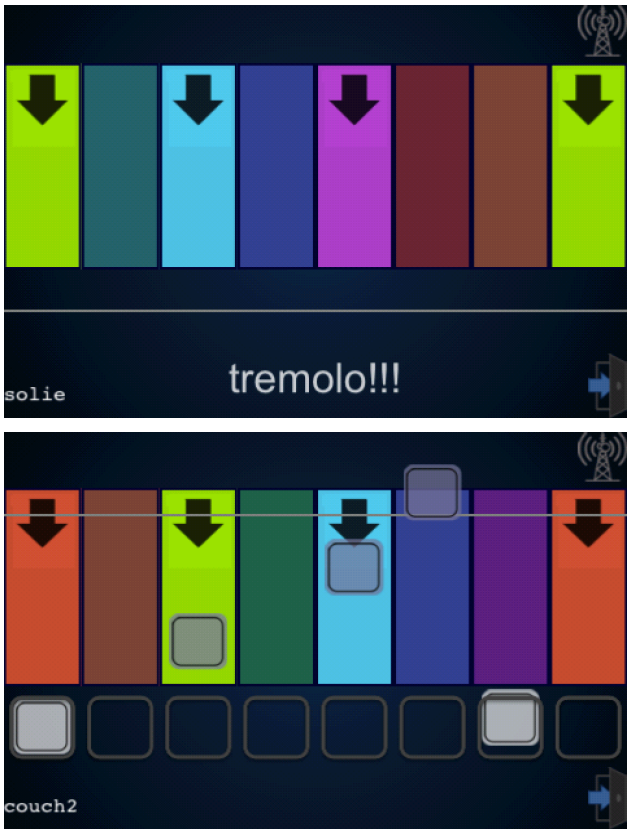

Figure 3A (upper) Key instrument is in F major. Keys of the selected chord are marked with a black arrow. Audience is instructed to play keys with black arrows more than others. 3B (lower) a pattern broadcasted is displayed as a set of notes coming from the top.

Figure 4 *echobo* performance footage[1]. A total of 105 participants joined the performance.

For future work, we wish to extend the application for more general musical styles in terms of its mapping and sounds. While keeping the key concept – a master musician restricting the musical expressivity of each audience member – we can make both the sound synthesis and mapping parts (chord-scale) of the application programmable so that an artist can personalize the musical instrument depending on the composition.

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[1] Performance video available at http://sangwonlee.com/works/echobo/

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