Laptap: Laptop Computer as a Musical Instrument using Audio Feedback

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ABSTRACT

Laptap is a laptop-based, real-time sound synthesis/control system for music and multimedia performance. The system produces unique sounds by positive audio feedback between the on-board microphone and the speaker of a laptop computer. Users can make a variety of sounds by touching the laptop computer in several different ways, and control their timbre with the gestures of the other hand above the microphone and the speaker to manipulate the characteristics of the acoustic feedback path. We introduce the basic concept of this audio feedback system, describe its features for sound generation and manipulation, and discuss the result of an experimental performance. Finally we suggest some relevant research topics that might follow in the future.

Keywords

Laptop music, laptop computer, audio feedback, hand gesture, gestural control, musical mapping, audio visualization, musical notation

1. INTRODUCTION

Audio feedback, also known as the Larsen effect, is a positive feedback of sound between an audio input and an audio output: when a sound signal to a microphone is amplified and used to drive a loudspeaker, the amplified sound returns to the same microphone and is endlessly re-amplified.

Although audio feedback may cause uncomfortable ringing noise (often described as squealing, screeching, howling, etc.) which has to be avoided in ordinary situations, there have been several practical applications using audio feedback in various musical genre. For example, many guitarists in the pop/rock music scene employed controlled feedback to artistic advantage; here, a microphone was conceptually replaced by the pickup of an electric guitar.

While much less common, use of audio feedback is also found in electroacoustic music. An example is *Pendulum Music* (1968) by Reich, which involved suspended microphones and speakers that created phasing feedback sounds [1]. More recently, Scipio introduced the *Audible EcoSystemics n.2*, an interactive electronic music composed only with Larsen tones [2].

Latest examples of musical instruments with audio feedback include Waters' Virtual/Physical Feedback, where players perform with a variety of hybrid instruments such as the metatrumpet and the feedback flute [3]. Overholt et al. presented actuated musical instruments which use electromagnetic actuators to make it possible to have more detailed control on audio feedback [4]. In [5], Kim et al. documented a novel way of physical pipe organ using audio feedback. The system generates resonant sounds by amplification at the feedback frequency of the pipe without any physical air blows.

In this paper, we introduce *Laptap*, a real-time sound synthesis/control system based on a laptop computer platform. Instead of using any virtual oscillator, the system utilizes positive audio feedback loop between its built-in microphone and speaker. Various hand gestures of the performer, such as hitting, tapping, scratching, rubbing, keyboard-typing, and/or covering, can make sound and control its timbre in real-time, which contributes to the expressiveness and the performativity of this "instrument". For on-stage performance, sound from the Laptap can be captured by an external microphone, played through the PA system and visualized on a large screen for the audience.

We describe the design and implementation of the system and discuss its potential as a new laptop-based instrument for music and multimedia performance.

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2. SYSTEM DESIGN

Figure 1 illustrates the overall structure of Laptap system. The performer plays the laptop "instrument" to generate sound through audio feedback. Sounds are captured by external microphones, not using the built-in headphone port, and transmitted to the PA system for listening. As for the video output, performing action and laptop's display are visualized on a large-screen as well for the audience.

2.1 Laptop Computer

At the core of Laptap is a laptop computer with on-board microphone and speakers. This serves as not only the sound source (i.e., audio feedback between its microphone and speakers) but also the user interface to detect various hand gestures). In addition, the laptop can capture the performer's hand gesture by camera and generate real-time visualizations out of its sound, both of which can be displayed for the performer and the audience. Table 1 summarizes information on the laptop used.

2.2 Audio Feedback

In order to construct an audio feedback loop in audio software, the input signal from the microphone should be transferred to the speaker (in case of Max/MSP, the output of an `adc~` object must be connected to the input of a `dac~` object). Here, optional components can be inserted between them for more advanced signal processing, as will be briefly discussed in section 3.2

Figure 1: System for laptop music performance.

Table 1: Specification of the laptop computer and software used for Laptap.

Hardware	MacBook Pro Retina 15"
CPU	2.6GHz Intel Core i7
RAM	8GB 1600 MHz DDR3
Operating System	OS X 10.8.2
Video Programming	Processing
Audio Programming	Max/MSP 6

In addition, the feedback loop must be completed in the analog world by feeding the speaker output to the microphone. Figure 2 shows the positions of the speakers and the microphone of the laptop used; on the left side of the keyboard the microphone is adjacent to the speaker, making it highly easy and convenient for the performer to generate speaker-microphone audio feedback with simple "covering" hand gestures (details on hand gestures to control the sound will be covered in section 3.1). This becomes the fundamental source of the sound of Laptap.

(a) (b)

Figure 2: Position of the speakers and the microphone on MacBook Pro Retina. Two speakers are located on both ends of the laptop (a), while the microphone is only on the lefthand side (b).

2.3 Real-time Audiovisual Display

For the performer, Laptap features a Max/MSP patch that displays basic information (e.g., frequency/pitch, waveform and spectrogram) on the sound that is currently generated. The patch also features some optional controls on selected signal processing algorithms (e.g., adjusting the amount of delay time) to manipulate the timbre, as shown in figure 3.

In order to make the laptop sound output audible to the audience, two microphones are placed over the speakers (each on a side) during performance. Signals from the microphones can be optionally mixed, filtered, and amplified through an audio mixer, amplified, and then played through loudspeakers. At the same time, music-making gestures (e.g., touching laptop, controlling DSP parameter values, making different handshapes) of the performer can be displayed on a large screen for the audience. This can be accompanied by real-time visualization of the sound from the performance.

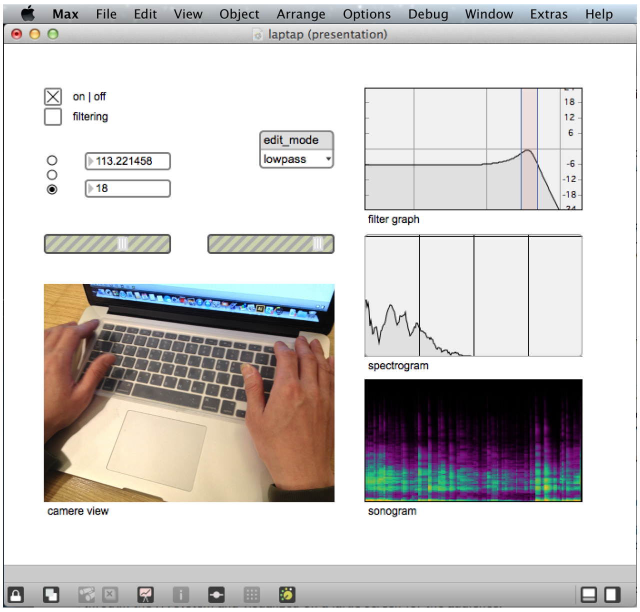


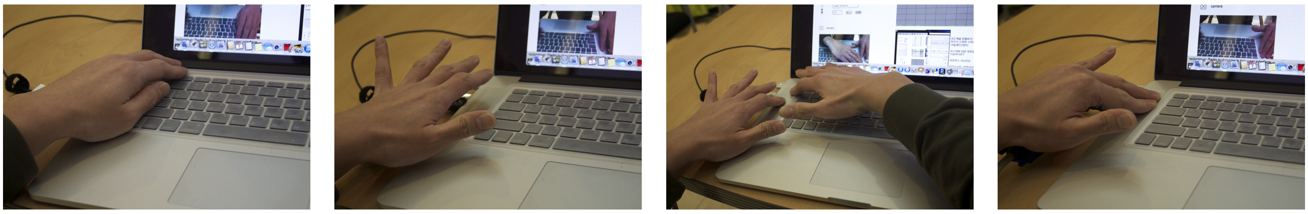
Figure 3: Screenshot of laptop display (a Max/MSP patch) for the performer.

3. SOUND CONTROL

For a musical instrument and a performing device, it is important to have a distinguishable awareness for the audience in terms of audio and video [7]. In this context, we focused on the expressiveness and the performativity of our musical interface by direct manipulation with hand gestures. The music-making procedure (i.e., "playing" the laptop as a musical instrument with various gestures) can also be presented to the audience visually. Video excerpt of a test performance is available at `http://youtu.be/GmnU-Fpgb8g`.

3.1 Feedback Control and Hand Gestures

In order to control the sonic attributes of audio feedback, researchers and artists have used several methods. As one of the simplest (and most common) examples, it can be achieved by changing the distance between a microphone



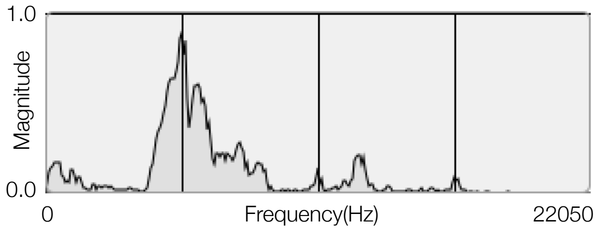
(a) (b) (c) (d)

Figure 4: Examples of handshapes (e.g., cupping (a) and fingering (b)) and gestures (e.g., tapping (c) and rubbing (d)) to control feedback and manipulate timbre.

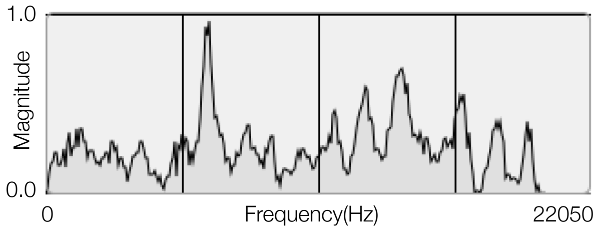
and a speaker [8]. However, since it is practically impossible to change the fixed positions of the microphone and the speaker on a laptop computer, we presented some alternatives for controlling of audio feedback.

Firstly, by applying different "handshapes" above the (left) speaker and the microphone, we were able to interfere the feedback loop and produce unique sounds. Also, certain gestures such as tapping, rubbing, and scratching the surface of the laptop introduced new "excitations" to the feedback loop, making the sound more complex. Figure 4 shows examples of different handshapes and gestures that result in different timbres. Two spectra depicted in figure 5 show significant differences in timbre caused by different handshapes, implying that the performer can change the sound of Laptap significantly with dexterous hand movements.

In fact, this idea of gesture-based user interface for a musical instrument is similar to the case of Theremin [9, 10].



(a)



(b)

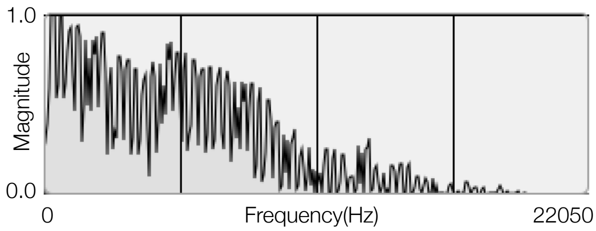
Figure 5: Magnitude spectra generated by different handshapes: cupping (a) and fingering (b).

3.2 Delay and Additional DSP

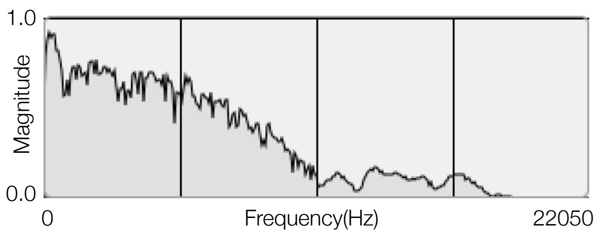
The amount of "artificial" time delay – controlled in Max/MSP – can also be considered as a parameter to emulate the change in the physical length of the audio feedback loop. Figure 6 shows the variation in spectrum introduced by changes in time delay.

It is noteworthy that, as the time delay gets shorter, pitch of the resulting sound becomes higher accordingly. When the time delay is longer than 50 ms, the "roughness" phenomenon occurs, resulting in unrecognizable pitch with cyclic beats.

Other DSP routines can be added, if required. We tested a biquad filter as an additional means for the performer to control timbre, mostly by adjusting the signal level at the resonance frequency of audio feedback. An external audio mixer may also be used to help the performer control the sound faster and more effectively in a live performance.



(a)



(b)

Figure 6: Magnitude spectra generated by different time delays: 3ms (a) and 20ms (b).

4. VISUAL DISPLAY

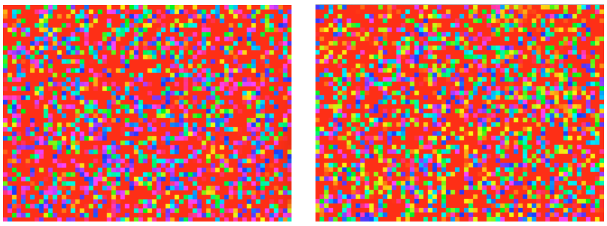
As Stuart mentioned in [11], use of laptop instruments in performance may cause various negative responses from the audience who must undergo a strange experience; he pointed out the loss of theatrical spectacle and the lack of performativity, which happens as a result of the lack of gesture and communicative information from the performer. As the term "laptop music" implies, visual cues of this genre are usually not enough to let the audience correlate what they see and what they hear.

For this reason, our visual design was aimed at exposing the performer's gesture to the audience as much as possible, thereby providing more information on the contents of the performance for more immersive experience. We can share more of the music-making procedure with the audience by showing the performer's laptop display on the large screen.

Also, considering the physical structure of a laptop and the way we produce sound, there is a high possibility that the display panel will obstruct the audience's field of vision and make the performer's hand gestures hidden and invisible. In order to solve this problem, we used an external webcam to capture the performer's action over the laptop, which was shown on the main screen so that the audience could visually appreciate the performance.

In addition, sound visualization in our performance provided another channel for communication. Examples are shown in figure 7. Here, sounds from the instrument are converted into pixels, and the RGB color values of each pixel are determined by the result of spectral analysis of the sound.

Any sound visualization for Laptap will be designed to provide the audience with not only theatrical spectacle and visual amusement but also graphical notation of the "music" played.



(a) (b)

Figure 7: Examples of sound visualization: sound generated by cupping gesture (a) and fingering gesture (b).

5. CONCLUSION

This paper presented a new approach for musical performance using audio feedback on laptop computer. Though there have been several applications to utilize this phenomenon in electronic music, our system uniquely focuses on the direct manipulation of the acoustic field using performer's hand shape and gesture. We must admit that there exists a limitation of the built-in microphone, which has a fixed frequency response already, thus it is hard to boost up the low frequency fundamentals to produce a rich sound. Despite this drawback, we believe this will be gradually developed sooner or later by using digital filters and new DSP technology.

When it comes to designing a musical instrument, it is important to consider every aspect that influences on the expressiveness. As Arfib et al. also mentioned, designers of digital musical instrument should take into account the expressiveness for the performer [14]. In our case, the laptop instrument was given mixed characteristics of two different aspects: physical (e.g., the sound producing mechanism and the interface) and virtual (the digital filtering and time delay function) so as to get more abondant expressiveness.

As for the controllability, both of performer's hands harmonically collaborated to obtain several musical functionalities. Due to the position of the built-in microphone, the left hand gestures which initiate sound tend to be more complex than those of the right hand. We categorized gestures into different kinds and found out the individual gesture showed different type of spectrogram. Though the left hand movement controls excitation and timbre modification, and the right hand movement controls volume and duration, the sound properties can be varied when the interaction of both hands works lively and organically.

Visual information presented to the performer was designed to give a primary feedback when the s/he inputs gestures to the instrument. By seeing the sound wave and spectrogram in real-time, the player can predict the feedback transition somehow, which helps to produce sounds the user wants. In regards to the auditory visualization for this performance, especially the notation idea, we may need to develop its practical adaption and evaluation tool. At the moment, by using a specific hand gesture, it is possible to generate a certain sound and write down a graphical notation, but the opposite application (i.e., to figure out its original gesture from the written notation) is less robust. If we can interpret the relationship between audio signal and visual image at will, the usefulness of this research would possibly cover several everyday life domains beyond music and art.

In addition to the current application, we would like to improve our music-making method in future work. Our next step will be to concentrate on the precise control of audio feedback, interaction between performers (with or without network communication), and the use of multiple microphones. Another future work will involve the evaluation so that it would value and measure the performativity of this gestural controller as a musical interface.

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