1. This paper proposed a mechanism to support interaction between performers and audience in a music performance.
2. It utilizes DTMF sounds to send data from performers to audience.
3. It is difficulty to recognize the low volume USC emitted by iPhones, among the high volume sounds.
4. It assumes iPhone users do not have Internet access, which is unreasonable.

Cryptone: Interaction between Performers and Audiences With Inaudible DTMF Sounds

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Abstract

We developed a system called Cryptone which enables interaction between performers and audience at venues for music performances. Sound IDs consisting of high frequency DTMF are used to communicate with each other. Cryptone is easy to use in sound performances, and can enhance experiences for music entertainment. The system is implemented on an iPhone, therefore applications are freely obtained via the AppStore.

Keywords: interaction, music entertainment, sound ID

1 Introduction

Interactive presentation methods have become common in the arts and so called media arts. However, in the field of music, old-fashioned methods still remain and innovation of interactive mechanisms has not progressed. The way of enjoying music has been changed from CDs to downloading, and even further, people oriented to live performance venues. In these circumstances, we think that novel changes would be needed in music experiences.

We aim to improve experiences on music enterrainment by introducing interactive methods. These methods will bring evolution into traditional implicit interaction in venues, such as applause, dancing or gestures, similar as what happened in media arts. Our goal is to bring forth new ways of enjoying music and new experiences for people by introducing interactive technologies into music.

For this purpose, we created an organization called NxPC.Lab [NxPC.Lab]. In NxPC.Lab, we are working towards the research and development of interactive methods that enable new representations and new experiences in music entertainment, and we also organize music events called NxPC.LIVE. Through these activities, we are discussing interactions among performers and audiences, as well as venues and audiences, on the internet, and then develop the system to carry out better experiences in the venue of music [Toma 2011], [Shirai 2011], [Shimizu 2012].

Cryptone is a system that archives an interactive environment for the performers and the audience. By using the mechanism of communication with sound, we have realized an interactive system suitable for music venues without interfering with the music performance that is important in the venue. Sounds are very easy to use for music venues and musicians. Our methods can be adopted easily to the PA system of each venue, and be included into songs for musicians.

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In addition, this system can only be realized with an iPhone/iPod Touch, the application of the work available through the official application store, AppStore, for free. The visuals on the iPhones of the audience members will change according to the music, and by shaking the iPhones, the responses will appear to the venue for the audience and the performers. These interactions of the performers and the audience will achieve immersion feeling at the venue and sharing of feeling among audiences.

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2 Related Works

"Interactive Live" by Susumu Hirasawa has been famous since 1994 as an attempt of interaction with the performer and the audience in the field of music entertainment [Hirasawa]. This series of live performances has utilized their visual expression and reaction of audiences to control the scenario of live performance. In recent years, the "SYNK" project (2010) by Riche Hawtin (aka Plastikman) is also acclaimed [Plastikman]. "SYNK" is released as an iPhone application via the AppStore, and with this application the audience can control sound and the LED lighting on the stage, can watch live camera images from the view point of the DJ, and can also communicate via a chat system. Aphex Twin, at an event in 2010, introduced an interactive visual system during his performance [Aphex Twin]. The live visuals of the audience were projected onto the screen at the venue, and the faces of the audience were exchanged with Aphex Twin's face, which is his trademark. The teamLabBall by Team Lab Inc. is a system to enrich the experience at a venue [TeamLab]. At the venue, the audience can play with the light balls, which have built-in full color LEDs and sensors. The color of the ball will change by tossing it, and will also synchronize with other balls.

These attempts to introduce mechanisms that have interactivity into the venue of musical experiences have been particularly active in recent years. Although the attempt of SYNK is similar to our approach, we will achieve interactions between the artists and the audience in real time, and no special communication methods are necessary. We will just use sound for communication.

For communication methods utilizing sound, INFOSOUND by the YAMAHA Corporation [INFOSOUND] and acoustic OFDM [Matsuoka 2008] can be given as examples. INFOSOUND utilizes the direct sequence spread spectrum (DSSS) method for high frequency sound to define acoustic IDs. The acoustic OFDM is the technology of applying the orthogonal frequency-division multiplexing (OFDM) method to audible sound with a transmission data of approximately 1kbpm. Both works differ from our system they cannot encode data ~~of data cannot~~ with a smartphone by itself, and the process of encoding is not open to users. Therefore our approach does not have many technological advantages compared to other methods. The merit of our approach is distinguished from those other methods by its suitable-ness and ease of employment for artists and audiences.

3 Communication Using High Frequency Sound

3.1 Ultra Sound Communication (USC)

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We developed a method of communication by using DTMF (Dual Tone Multiple Frequency) with high frequency sound, which we call Ultra Sound Communication (USC). USC is the method of defining sound IDs by using the DTMF method with sounds from 17000Hz to 20000Hz.

In general, humans can hear sounds from 20Hz to 20000Hz, but it is said that people over 20 years old cannot hear sounds over 16000Hz. In addition, these sound wave lengths are not actively used in music. Therefore we think that there are not many people aware of sound IDs with USC in music venues, and malfunctions does not occur frequently in music.

3.2 Verification on iPhones

We examined the frequency range of the sound used in USC, and the available range can be recognized and can playback with built-in loudspeaker for iPhone4, iPhone3GS, iPod Touch (4th generation), iPad, and iPad2. We investigated the upper limit frequency of the sound that can be recognized by a built-in microphone with FFT analysis of sine wave sound that was gradually increased from 20Hz.

As a result, we confirmed that they can recognize up to 22050Hz, and also confirmed that they can playback up to 20000Hz, which is the specification on Apple's catalogue. We decided from these results that the frequency of DTMF for USC uses from 17000Hz to 20000Hz, the range needed to ensure sufficient bandwidth.

3.3 Configuration of the DTMF for the USC

DTMF is a traditional method defining sound IDs by playing two frequencies simultaneously, the commonly used method for telephone tones (ITU Q.24). We applied this method to high frequency sounds. We divide the frequency from 17000Hz to 20000Hz by 500Hz steps, with table 1 showing DTMF frequency for USC.

Table 1 Configuration of Tones and IDs

	19,000Hz	19,500Hz	20,000Hz
17,000Hz	1	2	3
17,500Hz	4	5	6
18,000Hz	7	8	9
18,500Hz	10	11	12

3.4 Applications of USC

USC originally developed for near field communication method for data exchange between iPhones. We created several artworks as examples of near field communication between iPhones. USC also can be used for a broadcast when sound is amplified and played back with large loudspeakers. The USC can easily broadcast IDs with popular PA systems (amplifiers and loudspeakers) in venues without any special equipment. In addition, IDs can be recognized with microphones, the ones built-in on iPhones or those inside PA systems. Also, musicians can easily generate USC sound with music software, and can incorporate it into their music. We believe that these features signify the possibility of a highly versatile communication method in music.

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4 Cryptone

We created an artwork called Cryptone, which enables interaction between performers and audiences by using USC as a broadcast method. We demonstrated Cryptone several times in our events, and during these events it has been improved and extended.

4.1 Cryptone Version 1.0

On 2nd November 2011 at Club METRO in Kyoto, we demonstrated Cryptone at NxPC.LIVE Vol.10. At this event, with the cooperation of Softpad [Softpad] - a co-organizer of the event and the artist unit playing electronica music - we used Cryptone in their live performance. The application of Cryptone was published at AppStore in advance, so visitors can install it for free.

When the application starts, the screen appeared like the left side of figure 1. On this screen, event information, artist details, and a timetable can be seen. By selecting the Cryptone icon, Cryptone starts and shows a screen like the right side of figure 1.

Figure 1 Screens of Cryptone

On this screen, a visual of the artist's name and cubes, which change according to the movement of the iPhone, are displayed. These screen graphics have 12 patterns for each type and will vary according to sound IDs of USC. For example, there are screens displaying sine wave graphics, screens whose frequency spectrum responds to the music, and so on (shown in figure 2).

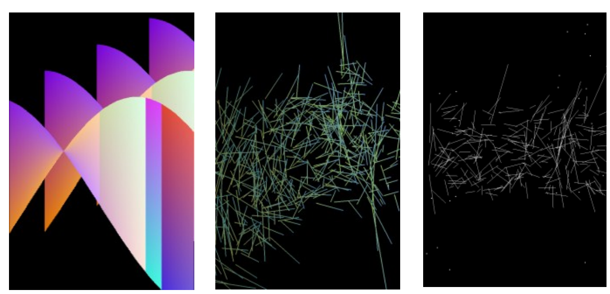
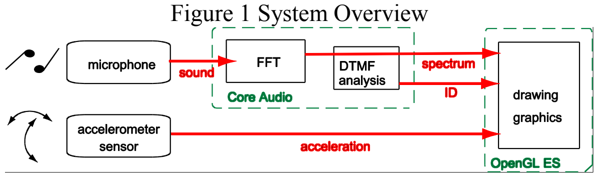


Figure 2 Examples of Screens

4.2 Overview of the System

The overview system of Cryptone is as displayed in figure 3. Sound that is inputted from the microphone is analyzed by FFT, and then compared with the appropriate DTMF of the USC to determine an ID. The visual to display on the screen is selected according to the ID. The graphics vary with the results of FFT and accelerometers of the iPhone. These are implemented with OpenGL ES2.0 and Objective-C.

Figure 1 System Overview



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These visuals switch dynamically during live performances according to the music. This means the performers directly controls visual of the iPhones at audiences' hands. We believe this circumstance brings the audience a sense of presence in the venue.

4.3 Cryptone Version 2.0

In version 1.0, Cryptone applies to the music called electronica, which uses computer generated sounds, including those similar to white noise. Sounds like white noise cause a malfunction in recognition for Cryptone because they include many high frequency sounds used in USC. Cryptone often reacted with music performances that do not use USC.

All of these malfunctions are not bad, because audiences can increase their chances to enjoy Cryptone. Of course, we need communication without malfunctions for serious situation. Therefore we redefined sound IDs to add IDs that seldom produced malfunctions. 2

4.4 Re-definition of Sound IDs

While the original USC directly uses DTMF IDs, we re-defined new IDs through the combination of the time series of two DTMF IDs to avoid malfunction. The 12th ID of DTMF is used for the pre-tone of the series, and following tones are selected from 1st ID to 6th ID, as shown in table 1. Therefore, new IDs consist of the time series of two 0.2 second DTMF IDs, as described in table 2.

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Table 2 New Sound IDs

New ID number	Pre DTMF ID (0.2sec)	Post DTMF ID (0.2sec)
New ID 1	DTMF 12	DTMF 1
New ID 2	DTMF 12	DTMF 2
New ID 3	DTMF 12	DTMF 3
New ID 4	DTMF 12	DTMF 4
New ID 5	DTMF 12	DTMF 5
New ID 6	DTMF 12	DTMF 6

These new IDs are utilized for visuals that display definite information, such as the artist names. This version of Cryptone was demonstrated at NxPC.LIVE Vol.12, which was held at SECO in Shibuya on March 24th, 2012.

4.5 CryptoneRef

Cryptone has realized the interaction from the performers, who are playing music, to the audience. As the next step, we try to realize the interaction from the audience to the performers and the venues. The reactions of the audience are reflected to the venue as a visual, by which the performers and the audience can share atmosphere or groove of the venue. This consists of a part of the overall Cryptone as an artwork.

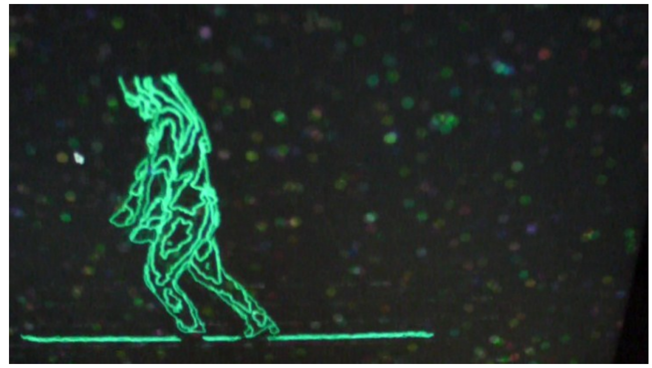

Figure 2 A snapshot of CryptoneRef

CryptoneRef represents the visual images that change according to the volume of the USC sound generated by the audience shaking their iPhones at the venue. As shown in figure 4, the visual of particle size varies with shaking iPhones, and in this example, motion and appearances of the performer and the audience are displayed as visuals generated from images and depth data obtained with a Kinect.

The demonstration was held at NxPC.LIVE Vol.13 in IAMAS OS, Ogaki, Japan, on June 8th, 2012. In this experiment, we found difficulty in recognizing the low volume USC emitted by iPhones, among the high volume sounds. We utilized a built in microphone on a MacBook Pro. We think that the effect of auto gain control, which reduces high frequency sound of USC, makes it difficult to recognize USC. We have introduced an audio mixer and a microphone to solve such problems. Only high frequency sounds passed to the system via the audio mixer, which provided for more precise recognition of USC.

5 Discussions

We still do not have enough experimental results, so more demonstration will be needed for large amounts of audiences. However, we confirmed that our system has been able to bring new experiences and new expressions into the venue of music entertainment, due to impressions of the people who had such experiences. Based on the opinions obtained by our observations and from people in the venue, possible advantages are summarized as follows.

- Interaction between the performers who are playing music and the audience

It is very difficult incorporating the interaction of the audience in the performance of music. The performers are concentrating on their music performance, which leaves no room for manipulation of the interaction with the audience. In Cryptone, it is possible to combine manipulations of said interaction into their sound with minimal impact on their music performance.

- Individualization of visual experiences

For visual expressions in musical events, it is common for the audience to look on the screen of the venue. In Cryptone, audiences gaze in close visual of individual iPhone at their hand, this individualization of visual expression provide new experience on the venue. They also create a lighting environment for the venue by many screens' bright of iPhones functions as the lights.

- Ability of the music performers to control visuals

As another merit of USC, music performers are able to control their own visual expressions. Most musicians will only do musical performances, but by utilizing USC, musicians can also control visuals via their music performance.

- Interaction from the audience to the performers

It happens usually that the performers varying their performance, such as change songs, according to reaction of the audience. This is one of ways for implicit interaction of the performer and the audience. In CryptoneRef, we evolve these interactions by explicitly presenting the reaction of the audience to the venue and the performers. Further interaction by the performer to the audience will be expected for the next stage of research, although we can show the possibilities of experience in music experiences.

6 Conclusions

We confirm the possibility for a novel experience in music entertainment by utilizing high frequency DTMF sound IDs to enable the interaction between the performer and the audience. Our systems are easy to introduce to musical performances.
Although the amount of information that can be handled with USC is very limited, it still has the ability to enhance interaction by combining other information such as another sound IDs, location information, time, and so on. For example, we use the combination of two time series of sound IDs for a more precise combination. This new ID takes more time to be recognized, but it achieves precise communication in serious situations.
In future research, we will consider the possibility of further interaction at venues of musical entertainment, and the possibility of communication of USC by combining other information.
In this paper, we described interaction at venues for music performance, but we think USC can also apply widely to public spaces or digital signage.

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