CREATING A VIRTUAL SUIKINKUTSU

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ABSTRACT

This paper describes the process undertaken to construct a virtual suikinkutsu through sound synthesis. Firstly a description is given of a physical suikinkutsu and its inherent unique sound qualities. The suikinkutsu's physical qualities provide a model for the characteristics required for use by the virtual suikinkutsu. A brief discussion of related works which will aid in informing the virtual suikinkutsu is given. The finished virtual model is described and a comparison is undertaken between recordings made on the virtual suikinkutsu and recordings taken of a physical suikinkutsu. Finally a look into future work on the model is undertaken.

[Keywords: Suikinkutsu, Water, Modal Synthesis]

1. INTRODUCTION

The virtual suikinkutsu is the starting point in a larger project currently being undertaken to create a virtual environment allowing for the design of dynamic soundscapes of Japanese gardens. The larger project will use synthesis techniques to create modules based on sounds located in, and associated with, Japanese gardens. It is hoped that the larger project will be of beneficial use across a number of fields such as landscape design and gaming environments.

A suikinkutsu is, effectively, an upside down pot buried underground. The pot contains a pool of water at its base and a hole in its top, and is usually placed beneath a water-source. When someone enters a garden and washes their hands, the runoff water collects at the top of the suikinkutsu. This water drains through the hole in the top of the suikinkutsu to the pool of water collected at its base. The sound of the water droplets as they hit the pool of water then resonate within the body of the suikinkutsu, forming a unique sound. This process can be viewed in figure 1.

Anecdotally suikinkutsus are said to have been invented in the edo period (1603 - 1867) by a tea ceremony master who liked the soothing sounds they produced. They are then said to have fallen out of favour in the early 20th century and were all but forgotten until the 1980's where they gained somewhat of a renaissance due, in large part, to a newspaper article that sparked a new interest in their use. For a greater description of their history see Watanabe[1]. While not found in every garden, the suikinkutsu, which translates roughly as water koto cave (a koto is a Japanese zither), is typically located beneath a *chozubachi* or *tsukubai*, a water dish used for cleaning hands and the mouth upon entry to the garden. Due to its physical placement in the garden it is quite often one of the first sounds heard upon entry to the garden, and seemed to be a logical point to start the larger project of creating the virtual environment.

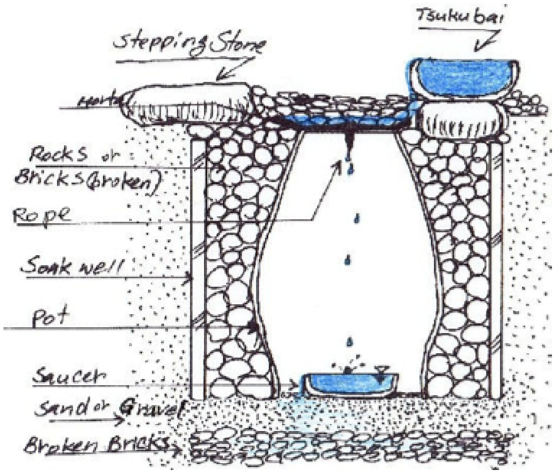

Figure 1: *Cutaway of a suikinkutsu taken from [2].*

Water may flow into the suikinkutsu either at a steady pace or as single droplets, an affect that results in creating a more delicate sound. It is the sound created by the dripping water that is more typically associated with the suikinkutsu and is, as a result, the primary focus of this paper.

2. A SIMPLE MODEL

By studying the sounds of the suikinkutsu it is clear to see that there are two primary elements involved in creating the sound it produces. The first of these elements is the sound created by the water falling from above into the suikinkutsu striking the water located at its base; the sound of a water droplet. The second element is the effect of the suikinkutsu body in resonating the original sound of the water droplet. While there are more variables at work creating the sound (such as construction material, temperature, etc.), it is these two which ultimately can define the sound associated with the suikinkutsu.

It is expected that this model can be achieved by creating a synthesised water sound and placing it within a model of a reso-

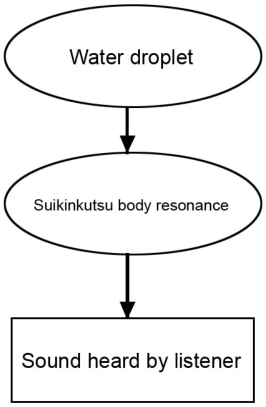

Figure 2: *block diagram of proposed model.*

nant chamber. A block diagram of this simple model can be seen in figure 2.

3. RELATED WORK

It is obvious through looking at the proposed model that the primary focus of related works requires study of water sounds and resonance, the section is separated into the appropriate parts. Creating the virtual suikinkutsu was heavily informed by Watanabe's paper "Analytical study of Acoustic Mechanism of "Suikinkutsu""[1] in which he reports on a number of experiments he undertook in an attempt to understand the sound of the suikinkutsu. Watanabe's results were then further informed by the synthesis techniques mentioned in the following sections. This research lead to a virtual model ready for comparison to a physical suikinkutsu. The related works on synthesis techniques are broken up into the fields of water and resonance.

3.1. Water sounds

Prior work on synthesising the sound of water can be divided into two main categories, models which have focussed on larger bodies of water (such as waterfalls, the ocean's waves, etc.), and the smaller-scale phenomena of water droplets. Research on larger scale sounds have successfully produced good results by the use of wavelets (Miner and Caudell [3]) and granular techniques (Keller and Truax [4]), as well as work undertaken by Dobler [5]. For the modelling of the suikinkutsu it was important to focus on synthesising the sounds of smaller water based events. Research by Doel [6] and Zita [7] both report on the ability to synthesise a single water droplet.

Previous research has cited that the sound created by a droplet lies primarily in the bubble (or bubbles) that form under the surface when an air cavity is created by the force of the droplet hitting the water's surface. For physical equations of how these sounds take place see [8], [9] and [10]. Of primary importance to the droplet sound used for the suikinkutsu model were Doel's findings that there were two overriding factors at play; 'First there is the relation between the frequency and the damping of the bubble sounds...The second perceptual cue that we are hearing a bubble sound could be the rising pitch of a bubble formed close enough under the surface'[6]. Following these guidelines allowed for the creation of a simplified yet realistic bubble sound.

3.2. Resonance

Resonance is a heavily researched area in the field of computer music, much more so than the synthesis of water sounds. In the real world resonance effects almost all sound based events. Guitar bodies, trumpet horns and concert halls are all examples of resonance effecting a source sound (in the aforementioned cases, plucked strings, blown notes and singing voices could all be source sounds). Much research has been done in each of these areas both in the study of the physical properties of resonating chambers and on implementing these properties into computer models. In their work on modelling bell-like sounds in [11] the team at Helsinki University of Technology mentioned of the bell sound that: 'Acoustically we understand it to be composed of decaying sinusoids'[11]; their research then went on to show how source filter and digital waveguide models could be used to synthesise the effect. In [12] Cook presents modal models for synthesis of real world sounds, this "physically informed" synthesis is the basis for the way the resonant chamber of the suikinkutsu will be effectively modelled in this version of the work.

For resonance specific to the suikinkutsu, the modes have been calculated by Watanabe. Watanabe's conclusion that an equation, interpolated using the existing equations for natural modes of a cylindrical cavity and natural modes of a hemispherical cavity, was proven to be quite successful in calculating the suikinkutsu's natural modes. Watanabe's findings were similar to the work of Cook in his model of a blown bottle found in [13], in which he altered an *end correction factor* due to an imperfect sphere. In Watanabe's case he added an *empirical longitudinal mode factor* to interpolate his equations. For a detailed description of modal response see [14].

4. A VIRTUAL SUIKINKUTSU MODEL

Following on from the background research a model was built of a virtual suikinkutsu using the audio programming language SuperCollider[15]. In building the virtual suikinkutsu it was important to keep in mind that it is being designed to be part of a larger system. For this reason where possible keeping CPU usage to a minimum is favourable. The bubble sound was informed primarily by the findings of Doel. Using empirical methods a sinewave oscillator which rises in frequency 2.5 times during it's duration was deemed best. For a 300 Hz bubble a duration of 15 milliseconds was deemed best while for a 2000 Hz bubble a duration of 4 ms was deemed adequate. The duration was scaled to decay linearly between these frequencies.

For the resonant sound of the suikinkutsu an approach similar to that proposed by Wawrzynek in his description of marimba synthesis in [16] was used. A bank of resonators set to the first 14 natural modes of the suikinkutsu body as calculated by Watanabe's equation are excited. Rather than using 14 separate sine wave oscillators to achieve this, the effect can be implemented in SuperCollider with better CPU performance by taking advantage of the Klank unit generator (ugen). To simulate the effect of varying bubble frequencies on the modes of the suikinkutsu, a band pass filter was placed on the Klank ugen's output. The band pass filter used

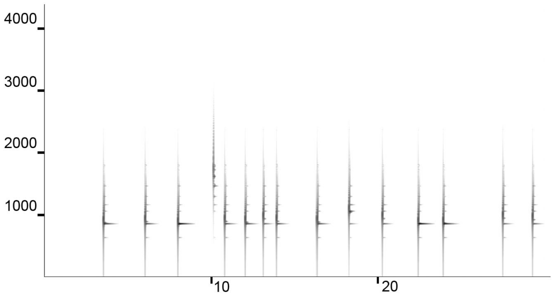

Figure 3: *spectrogram taken from the virtual suikinkutsu. Frequency is represented on the y axis and time on the x axis.*

the generated bubble frequency as it's cutoff frequency. Decay times on each of the frequencies used in the Klank ugen are also taken from Watanabe's findings.

5. RECORDING COMPARISON

No suikinkutsu are known to exist in public gardens in Melbourne (where the research is taking place). To evaluate the virtual model a physical suikinkutsu was built by the author using instructions taken from [2]. A ceramic pot was used to build the suikinkutsu, it measured 30cm deep with a radius of 16 cm. The pot was filled at the base with 6 cm of water. A 30 second sample recording was taken to compare to 30 seconds of generated sound from the virtual suikinkutsu. Spectrograms of the two recordings can be viewed in figures 3 and 4.

A number of observations were made from a comparison of the recordings. Firstly by looking at droplet 4 (located at the 10 second mark) on the virtual suikinkutsu spectrogram (figure 3) it can be seen that the band pass filter has been effective in limiting the sound of modes to those which would be affected by the frequency of the droplet. This is clearly seen to be happening in the physical recording where it is assumed that a greater frequency range of droplets is impacting on the surface. In the case of droplet four the virtual suikinkutsu was working off a bubble frequency of 1621 Hz. In all other instances the virtual suikinkutsu was working off bubble frequencies between 855 to 1045 Hz. If any of these recordings are analysed against one of the sounds taken from the 12th to 16th second mark in the physical recording, it can be seen that the impact of the major mode is close in duration and amplitude (see figure 5). The frequencies of the natural modes which occurred in the physical suikinkutsu however were quite different to those in the virtual suikinkutsu. Watanabe's factor used to interpolate the two equations was obviously required to be altered to gain results for the specific suikniutsu used. This number would need to be set as a variable in the virtual suikinkutsu in order to be able to tune the virtual suikinkutsu to correct modes. The physical suikinkutsu also has a much higher frequency range than the virtual suikinkutsu. In almost all instances of the physical suikinkutsu a short mode can be seen at 2492 Hz. While a mode of 2374 Hz was calculated for the 14th mode of the virtual suikinkutsu it was never actually heard due to the implementation of the band pass filter. A table comparing the real modes and those calculated by the virtual suikinkutsu can be seen in table 1

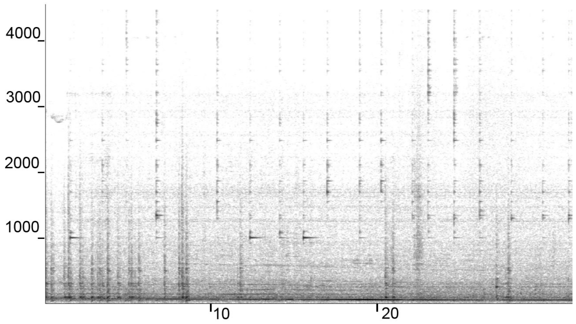

Figure 4: *spectrogram taken from the physical suikinkutsu. Despite the large amount of background noise, droplets and the effect of the suikinkutsu body can be seen as vertical lines with modal peaks, which occur roughly once each second. Frequency is represented on the y axis and time on the x axis.*

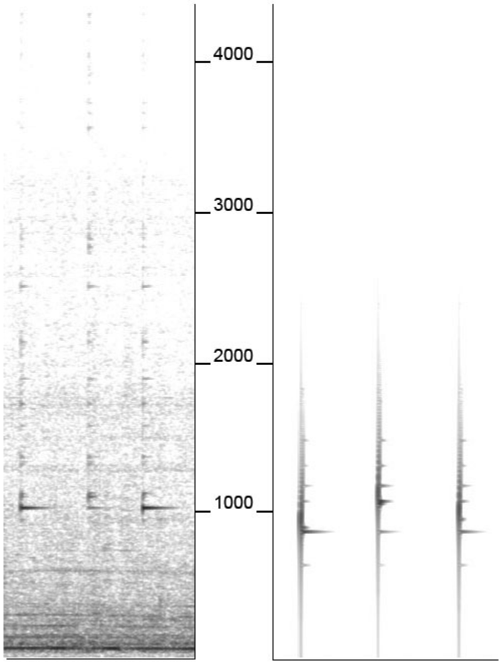

Figure 5: *a closer comparison between the physical recording (left) and the virtual recording (right). Frequency in Hz is given on the y axis and time on the x axis.*

Mode	Real	Virtual
1	590	634
2	899	858
3	929	1060
4	960	1165
5	1012	1297
6	1094	1297
7	1179	1466
8	1264	1467
9	1297	1489
10	1352	1727
11	1705	1782
12	1874	1801
13	2121	1805
14	2492	2375

Table 1: *Frequency (shown in Hz) of modes heard in droplet 6 (see fig. 4) taken from the physical suikinkutsu compared to those calculated by the virtual suikinkutsu.*

6. FUTURE WORK

It has been shown how certain characteristics of one suikinkutsu can be modelled using traditional synthesis techniques, it is however, necessary to improve the algorithm so that a greater range of sounds can be heard from the virtual suikinkutsu. There are three areas that require work for implementation in the next version:

1. Droplet to resonance ratio: Through study of the variety of suikinkutsu recordings found on [17] it is clear that while some suikinkutsu (such as the one made by this author) show little of the original droplet sound and produce more of the resonant sound of the suikinkutsu body, other suikinkutsus have a louder initial droplet. A study of why this takes place and a control to allow for the blending of the two sounds is planned be added to the model.

2. Suikinkutsu body type: It has been noted that suikinkutsus can be constructed from a number of materials. While most appear to be ceramic, metal suikniutsu are not entirely unheard of. Work should be undertaken to study the effect of the construction material on the resonant sound and controls built into the model

3. Flow control and multiple bubble generation: Greater understanding of the droplet flow and responding bubble/droplet frequency should be undertaken. In the author's model only one bubble was created at a time to simulate the droplet, it is clear that in many circumstances more than one bubble forms, it is the author's current theory that this is responsible for the wider frequency response of the resonant sound of the physical suikinkutsu compared to the narrow band limited response given by the virtual model.

7. CONCLUSION

A virtual suikinkutsu has been built in the SuperCollider audio programming language using existing synthesis techniques. Through a study of the physical properties of the suikinkutsu a simple model was proposed using the sound of a droplet and resonance caused by the suikinkutsu body. Study of related works led to a virtual model being designed and implemented. A simple sine wave oscillator was successfully able to mimic the sounds created by a single bubble, which represents the sound of a single droplet falling into a small pool of water. A bank of resonators were able to capture the sound created by the resonance of this droplet's sound by the suikinkutsu body. By combining the sound of the bubble and the resonant bank the virtual suikinkutsu is successful in having similar characteristics to a sound obtained from a physical suikinkutsu. Further work is required to make the virtual suikinkutsu share greater characteristics common in physical suikinkutsu, thus allowing for the virtual model to resemble a greater range of suikinkutsu types.

8. ACKNOWLEDGEMENTS

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