Modelling Physical System - Miniproject

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Contents

Chapter 1

Purpose

The purpose of this project was to implement a rain/wind sound synthesis based on models developed by researchers.

Chapter 2

Method

This chapter will start by explaining the rain models that was implemented in this study and in with the algorithm used for sound synthesis. The sampling rate (fs) was 44100 Hz, the maximum length of a rain sound, other than the rain background, was a single fs before being cut off. Both the rain background and wind sound had a maximum length of the total audio length minus a half sampling rate.

2.1 Rain Sound Model

The models that was originally going to be used to generate the rain sounds were from the work by Verron and Drettakis [1]. However, in some few cases other models were used, the chirped impact atom for bubbles sounds 2.1 was replaced with the model 2.2 that Verron and Drettakis had based their model on, which was from [2].

$$x_1(t) = a\sin(2\pi \int_0^t f(vd)dv)e^{-\alpha t} \tag{2.1}$$

$$i(t) = a\sin(2\pi f t)e^{-dt} \tag{2.2}$$

The reason for this was that 2.2 gave a better idea about how to produce a specific sound out from values that a bubble could have. The resonance frequency f was given as $f = 3/r$, where r is the radius of the bubble in meters between 15 cm and 0.15 mm. The equation also contain d which is after [2] the relation between the frequency and damping of the bubble sound.

$$d = 0.43/f + 0.0014f^{-3/2} \tag{2.3}$$

This equation is valid for bubbles that is larger than 0.15 mm. A bubble also produce a rising pitch when the bubble is formed close enough under the surface. [2] gives the equation for a rising bubble as the making the frequency time dependent on

$$f(t) = f0(1 + \sigma t) \quad (2.4)$$

f0 is the Minnaert frequency, but in this study it was set to be $f = 3/r$, and $\sigma = \varepsilon d$, where $\varepsilon = 0.1$ or below, lower values would indicate a slower and/or deeper bubble [2].

The gain a was calculated as

$$a = Dr^{\alpha}, \alpha = \text{between 1.5 and 2} \quad (2.5)$$

where $D = \text{between (0 and 1)}^{\beta}, \beta = 1$.

The gain should have been calculated as $a \approx r\sqrt{ru}$, where u is the average inward normal velocity of the bubble boundary [2], but it was decided to simplify it in the form of 2.5.

Another model Verron and Drettakis [1] used was for when rain hit rigid or deformable objects that exhibited a noisy response. After them it would produce a brief noisy sound and this sound was created using eight contiguous subbands of noise spread evenly on the Equivalent Rectangular Bandwidth (ERB) scale and given as

$$x(t) = \sum_{i=1}^{8} a_i s_i(t) e^{-\alpha_i t} \quad (2.6)$$

S_i is a subband of noise with amplitude a_i and decay α_i.

The last implemented rain sound was the rain background noise which also made use of subbands of noise spaced evenly on the ERB scale.

$$x(t) = \sum_{i=1}^{32} a_i(t) s_i(t) \quad (2.7)$$

The ERB scale is given as $ERB(f) = 21.4\log_{10}(0.00437f + 1)$ between 100 Hz and 10000 Hz, where f is in Hz [4]. For both 2.6 and 2.7 the noise was for each sample randomly generated between -0.5 and 0.5 and was the same value for each subband.

The a_i in their study for both 2.6 and 2.7 was extracted from rain sound samples, however, the actually values were not given, hence in this study the a_i were arbitrary chosen rather then selected out from actually rain sound. The same goes for α used in 2.6. All these values were randomly chosen each time they had to play

A model that Verron and Drettakis had implemented, which was not used in this project, was a model for raindrops hitting resonate surfaces. The reason for this was that it did not work as it produced weird results, however, this was most likely be because of wrong values being used. This model also required the values for the parameters being extracted using an analysis method based upon the Discrete Fourier transform [3].

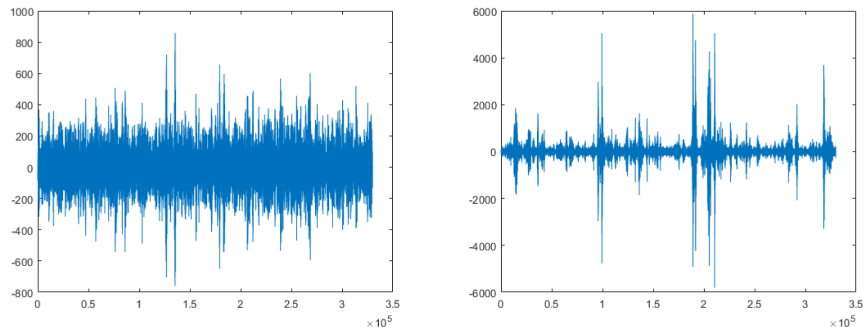

Figure 2.1: Left plot the modes have maximum frequency of 1150 Hz. The Right plot the maximum frequency is 1550 Hz

It was also decided to implement a wind sound synthesis. The wind model that Varron and Drettakis recommended was not implemented as there were some unsureness about how it should be implemented and it could not be found in the reference they gave. Instead of it was decided to use modal mode. In this project two modal models was implemented as

$$\text{mode}_i(t) = 2R_i \cos(\theta)\text{mode}_i\text{n}1 - R_i R_i \text{mode}_i\text{n}2 + y(t) \tag{2.8}$$

$$\theta = (2\pi f)/fs \tag{2.9}$$

$$R_i = e^{-d/fs} \tag{2.10}$$

The frequency f for the first modal mode was could range between 700 and 1150 Hz and the first modal mode d was 60. For the second modal mode the frequency could range between 250 and 1150 Hz and the d was 90. $\text{Mode}_i\text{n}1$ and $\text{mode}_i\text{n}2$ were past output of mode_i. Note that it the frequencies were allowed above 1550 Hz it could stop sound like wind. Also this is the only sound synthesis implemented that are affected by the sampling rate.

Equation 2.8 is based upon a harmonic oscillator in the modal synthesizer form, but with two modes.

2.2 Algorithm

The algorithm implemented the equations given in the section before this, hence the focus of this section is to explain how the a specific rain sound was chosen. The length of the sound vector created in this study was $fs * l, fs = 44100$, l being a number to determinate the length of the audio.

For each sample of the audio length the algorithm would check if a specific variable, qq, was above $fs/1.2$ and if the end of the audio length was further away than one fs. When these parameters were true the specific variable qq was set to fs and the algorithm would create a random number between 1 and 10 and if under 7 it would create a bubble sound. Another random number between 1 and 10 would be created and if above 3 it would create a rigid or deformable object sound.

Both the background rain sound and wind sound was calculated outside after the algorithm had created all bubbles and rigid/deformable sounds. Both sounds were created with the length - fs of the audio file.

Chapter 3

Results

The algorithm ended up being able to create realistic sounds of water bubbles. The rest of the sounds for rain, these being the rigid/deformable sound and the background rain sound, did not sound realistic.

Because of the lack of the actually values that was required for 2.6 and 2.7 meant that these two did not produce sounds that fully sounded like rain. The background rain kind of sounded like processed noise. The rigid and deformable rain sound sounded kind of "clicky", however, it, like the background sound, had arbitrary chosen values. The arbitrary decays could, rarely, be quite noticeable as some time it would last quite a long time as it would last over a second, e.g. by letting the maximum length of a rigid and deformable rain sound be $2fs$, one of them lasted 80597 samples, another lasted 52466 samples.

The wind sound lacked the changes as the windspeed increase and decrease that normally can be observed in wind, rather it was constant with some randomness from the changes to the frequencies of the two modes.

The final combined sound could look like the one given in 3. As it can be seen the actual bubble and rigid/deformable sounds are hard to observe in the plot, but they were audible.

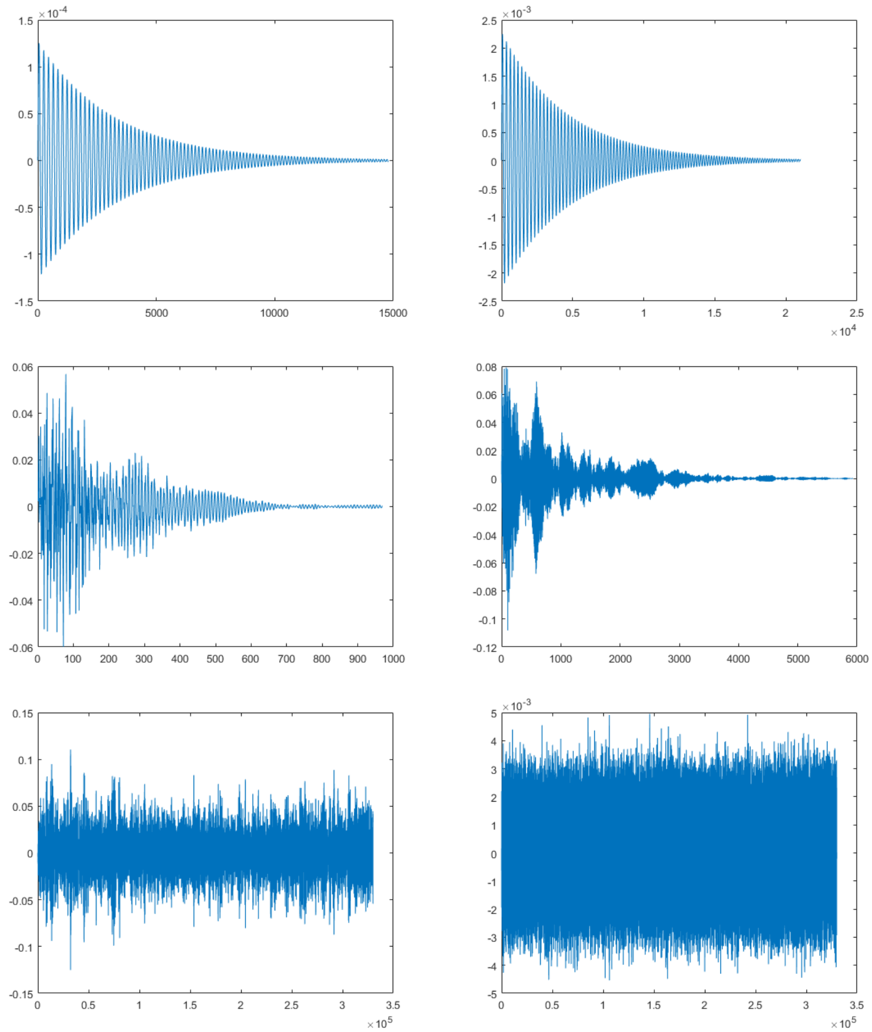

Figure 3.1: Plots of the individual sound generated from the sound synthesis. The top two plots are the bubble equation. The two middle plots are when rain hits a rigid or deformable object. The bottom plot is the wind to the left and to the right is the background rain

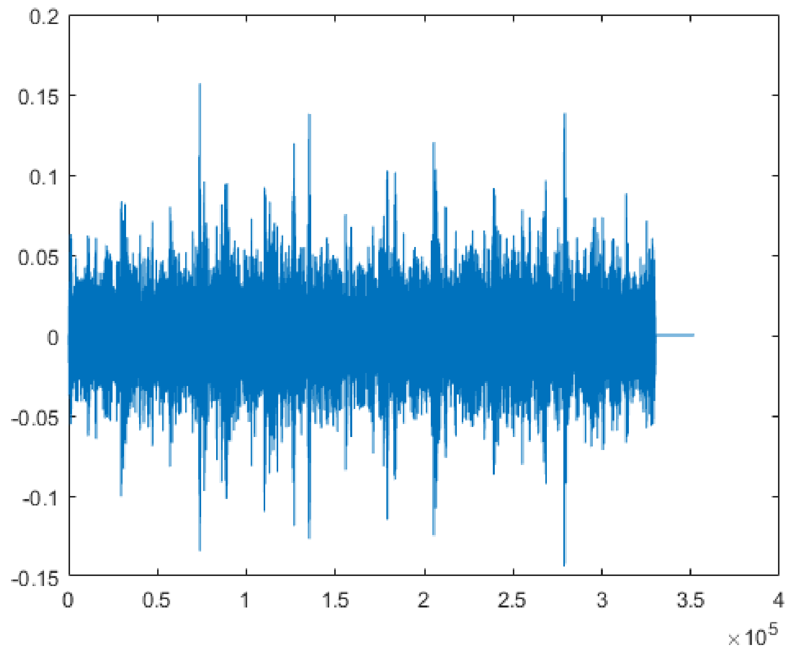

Figure 3.2: A combined sound clip

Chapter 4

Conclusion

The purpose of this project was to develop environmental sounds in the form of rain and wind. The algorithm implemented the sound of bubbles that is created when raindrops hits water, the sound of rain hitting rigid and deformable objects, the background rain sound, and wind. However, the values needed to create realistic rain rigid/deformable and rain background sounds were arbitrary values and not extracted out from sound samples, so these sounds did not sound real.

Reference

[1] C. Verron and G. Drettakis, "Procedural audio modeling for particle-based environmental effects," in 133rd AES Convention, 2012.

[2] K. van den Doel, "Physically-based models for liquid sounds," in Proceedings of ICAD 04-Tenth Meeting of the International Conference on Auditory Display, 2004

[3] M. Aramaki, M. Besson, R. Kronland-Martinet, and S. Ystad, "Controlling the Perceived Material in an Inpact Sound Synthesizer", IEEE Transactions on Audio, Speech, and Language Processing, Vol 19, no. 2, 2011

[4] Equivalent Rectangular Bandwidth, https://ccrma.stanford.edu/~jos/bbt/Equivalent_Rectangular_Bandwidth.html