EEE4120F SSDC Project: Milestone 1

23 April 2019

Stefan Schröder (SCHSTE054) and Elle Mouton (MTNELL004)

Introduction

The aim of the Sea Sounds Data Caster project is to encode messages within audio that sounds like relaxing ocean sounds. In order to do this it is necessary to investigate the science behind the sounds of the ocean as well as what is it about the sounds that are relaxing to humans.

The first section will briefly cover the reasons why certain ocean sounds are relaxing to humans. Then further research on the science behind the movement of ocean water and the sounds that result is discussed. Lastly, mathematical analysis using the Fourier Transform is done in order to inspect the features of a recording of real ocean sounds and the findings will then be compared with what was found through the research.

After completing this investigation, it should be clear what features of ocean sounds need to be reproduce in order to create a realistic reproduction when the project is being further implemented.

Why does the ocean sound relaxing

The sound of the ocean is generally considered to be similar to that of white noise. The reason why white noise can be so relaxing is due to the fact that is covers all audible frequencies and thus blocks out external sound [1]. The consistency of waves periodicity provides a soothing pattern to which the listener can relax to, and not be startled by. Constant soothing noise also provides a non disruptive method to satisfy the brains need for sensory input [8], thus allowing the brain relax.

Why does the ocean sound this way

The sound that is produced from the ocean is due to the waves and the wind. Most of the sound is due to the spray of the waves as well as the bubbles and crashing of waves [3]. The sound of the spray increases with the increase in wind speed [4].Waves are formed by a lot of smaller waves or ripples combining together, if the wave gets big enough then it forms what is called whitecaps [2]. These whitecaps are a dense patches of bubbles, they form when the wave becomes too tall to support itself and as a result, the wave will start to crash. Some of the sound of the wave is determined by the bubbles, and is related to the size of them [6]. There tends to be two distributions of bubbles that form in a wave. One being small bubbles, that are less than a millimeter in diameter, and another being large bubbles that are greater than a millimeter in diameter [6]. The larger bubbles are formed when the wave starts to bend and it forms a tunnel, the smaller bubbles form when the wave crashes with other waves or into itself.

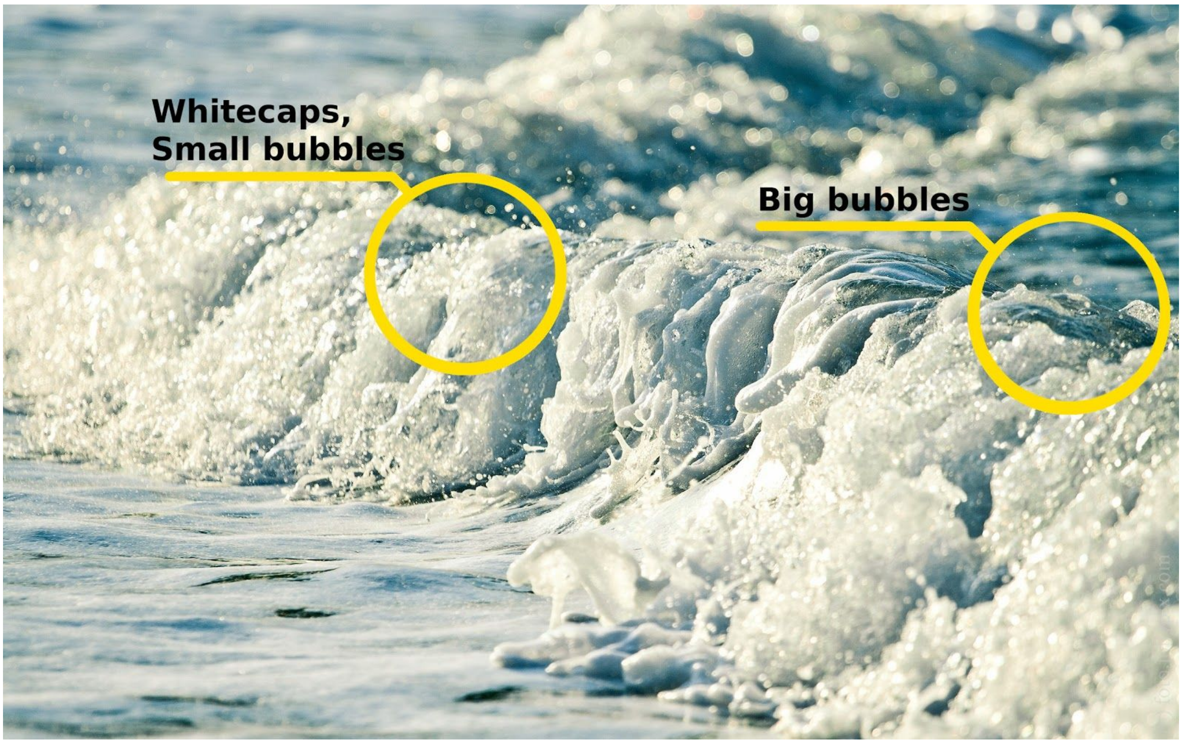

Image showing difference between big bubbles and small bubbles [7]

The sound of these bubbles are generally higher frequency and the waves rolling is a lower frequency. Since the bubbles are a lot smaller than the waves their contribution to the overall sound is less, thus the majority of the sound that is heard when listening to the ocean is the louder crashing of the waves. The resulting sound is within the range of 50Hz - 100 kHz [3]. However, the hearing range of humans only extends from 20Hz to 20kHz [9], therefore we only experience the ocean sounds from 50Hz - 20kHz. At the lower end of the range other factors also influence the sound of the ocean, such as shipping, wind and rain. The waves rolling will fall within the 50Hz range, and the spray as well as the bubbles would be in the +400 Hz range. The different frequencies that are present within the rain are shown in table below.

Frequency (Hz)	Mean (dB re 1 μPa2 / Hz)	Median (dB re 1 μPa2 / Hz)	Standard Deviation (dB re 1 μPa2 / Hz)
50	91.3	90.6	4.8
100	81.0	80.2	4.9
200	75.7	75.2	4.4
400	71.6	71.1	4.0

The mean sound level is the average sound level. The median sound level is the level for which half of the observed sound levels are greater and half are smaller. The standard deviation is a measure of the width of the distribution about the mean. Approximately 68% of the observed sound levels are within one standard deviation of the mean, although the precise percentage depends on the shape of the distribution. At 50 Hz, for example, approximately 68% of the observations at Pt. Sur fall between 85.8 and 95.4 dB re 1 μPa2 / Hz.

The table also shows the distribution of these specific elements and shows their mean, median and standard deviation as it follows a uniform distribution.

As discussed above, the sound produced by ocean waves covers a large band of frequencies. It was also found that “most water features create broadband sound, which means the sound has equal amounts of energy at most audible frequencies.” [1]. This uniform spread of energy in the the frequency domain is also referred to as White Noise.

Mathematical analysis

To determine if the research that was done corresponds to the recordings of real ocean waves, a mathematical analysis was done.

Figure x below shows a 12 second recording of real waves on a beach and Figure y shows the FFT of this recording.

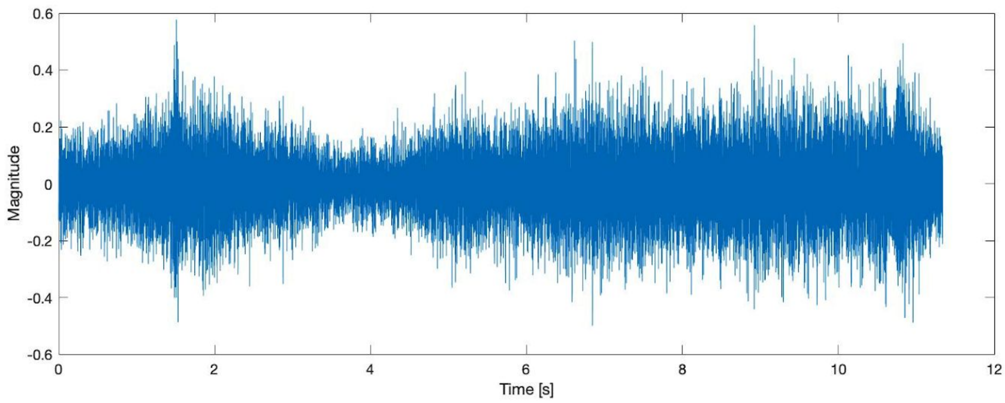

Figure x: Figure showing the FFT of the recorded ocean sounds

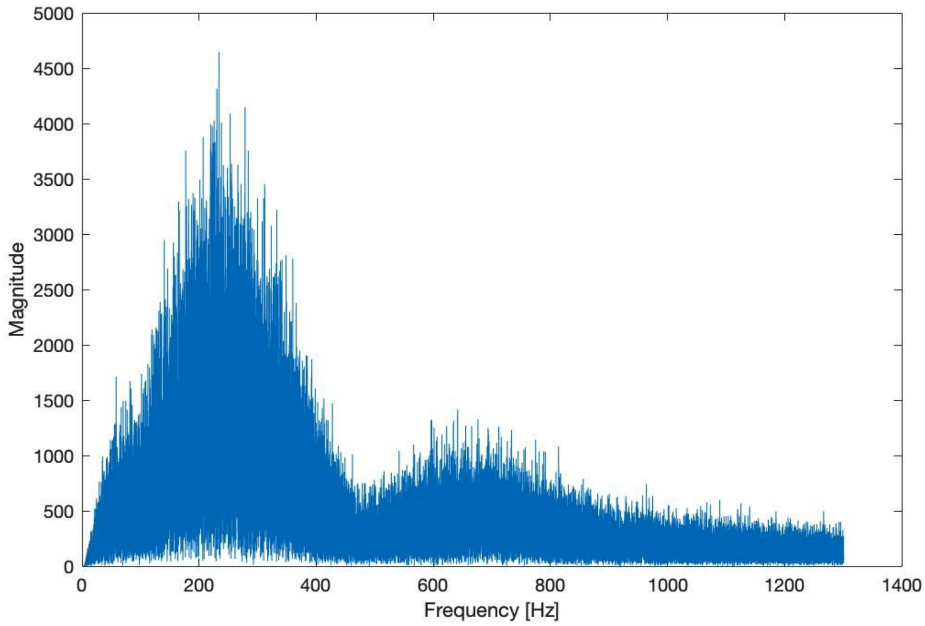

Figure x: Figure showing the FFT of the recorded ocean sounds

From Figure x it can be seen that there is a wide spread of frequencies that make up the sound of the ocean waves. However, there seem to be two main bands of frequencies. One of these bands is centered around a frequency of approximately 220 Hz and the other around 660 Hz. It is also evident that the higher frequency band has a lower amplitude than the lower frequency band.

Relating the findings to the project

From the research and mathematical analysis that was done, it is clear that in order to create a realistic reproduction of the sound of the ocean in the project implementation, certain dominant wave characteristics must be used. The main characteristics that were found was that the sound should emulate white noise which means that the frequencies are included in the wave must have relatively equal power which takes the form or a uniform distribution. It was also found that the range of these frequencies that are audible are mainly between 50 Hz to 20kHz. From the deconstruction of the wave sample, it can be seen that there are also two distinct peaks where the main frequency components are concentrated. These two peaks occur around 220 Hz and 660 Hz, the first of which has a larger amplitude than the second.

References

[1] J. Cooperman, “Catching the Waves: Why the Sound of Water Soothes Us,” *St. Louis Magazine*, 05-Jan-2015. [Online]. Available: https://www.stlmag.com/health/catching-the-waves-why-the-sound-of-water-soothes-us/. [Accessed: 19-Apr-2019].
[2] W. Orem, “Why Do Ocean Waves Sound The Way They Do?,” *A Moment of Science - Indiana Public Media*. [Online]. Available: https://indianapublicmedia.org/amomentofscience/ocean-sounds/. [Accessed: 19-Apr-2019].
[3] “Ocean Noise Variability and Noise Budgets,” *Discovery of Sound in the Sea*, 18-Dec-2018. [Online]. Available: https://dosits.org/science/advanced-topics/ocean-noise-variability-and-noise-budgets/. [Accessed: 19-Apr-2019].
[4] “Waves on Beach,” *Discovery of Sound in the Sea*, 19-Dec-2018. [Online]. Available: https://dosits.org/galleries/audio-gallery/other-natural-sounds/waves-on-beach/. [Accessed: 19-Apr-2019].
[5] Ir and S. Pigeon, “Sweep Noise • Hearing Calibrated • Online & Free,” *Sweep Noise • Hearing Calibrated • Online & Free*. [Online]. Available: https://mynoise.net/NoiseMachines/sweepNoiseGenerator.php. [Accessed: 19-Apr-2019].
[6] S. Graham, “Sound of Breaking Waves Determined by Distribution of Bubbles Inside,” *Scientific American*, 22-Aug-2002. [Online]. Available: https://www.scientificamerican.com/article/sound-of-breaking-waves-d/. [Accessed: 19-Apr-2019].
[7]https://www.wallpaperup.com/14923/Water_blue_ocean_sea_white_waves_frozen_foam_bubbles_bokeh.html
[8] T. Williford and T. Williford, “White Noise and Your Brain: The Science of Sound Machines,” *Apartment Therapy*, 07-Mar-2019. [Online]. Available: https://www.apartmenttherapy.com/sleep-better-the-science-of-sound-machines-168208. [Accessed: 19-Apr-2019].
[9] S. W. Smith, “The Scientist and Engineer's Guide toDigital Signal ProcessingBy Steven W. Smith, Ph.D.,” *Human Hearing*. [Online]. Available: https://www.dspguide.com/ch22/1.htm. [Accessed: 19-Apr-2019].