REPRESENTATION OF SOUND IN 3D

LI-MIN TSENG[1] and JUNE-HAO HOU[2]
[1,2]*National Chiao Tung University*
[1,2]*{daffodils9966|jhou}@arch.nctu.edu.tw*

Abstract. This study is based on Chladni figures and tries to spatially extend its representation of sound. The current Chladni figures only see parts of the sound. There should be more spatial representation of sounds because they are transmitted in space. This study explores how to capture and reconstruct invisible sound information to create three-dimensional forms. A series of steps are taken to record Chladni figures of different frequencies and decibels. Pure Data is used to generate sounds. The Chladni figures are captured in Grasshopper and converted into point clouds. These point clouds are processed by using different algorithms to produce layers of superimposed state from which 3D forms of sound can be generated and fabricated. Through the proposed methods of processing and representation, sound not only stays at the level of hearing, but can also be seen, touched, and reinterpreted spatially. With the spatial forms of sound, viewers no longer perceive sound through single but multiple states. This can help us comprehend sound in a vast variety of ways.

Keywords. Sound visualization; Form-finding; Spatial-temporal; Chladni figures; Cymatics.

1. Introduction

1.1. RESEARCH MOTIVATION AND CONTEXT

Sound is ubiquitous in our lives, but it is too common around us so that we are not particularly aware of its existence. We can only quickly perceive it by auditory organs. Therefore, how do diversities of sounds give everyone a particular sense? If we can “see” these disparate sounds, what do they look like? Most of us understand sounds through ears, but can’t we comprehend sounds in other ways? There are sound projects that will be depicted in the following.

1.1.1. Chladni figures by Ernst Chladni in 1787

In the field of visual sound, the study by Ernst Chladni called Chladni figures is the most typical. Drawing a metal plate with a violin bow until resonance will create nodes and antinodes at specific locations; thus, creating complex geometric patterns. It is the classic presentation of sound in 2D visualization. (Chladni 1787, Figure 1) Moreover, Hans Jenny, who is a physician and natural scientist, coined the term Cymatics to describe the typically acoustic consequences of sound

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wave phenomena. (Jenny 1967) In 2002, John Stuart Reid started to develop the CymaScope scientific instrument, which can convert sound into visible geometric patterns. (Cymasope.com 2017) Therefore, people are also gradually inquisitive about several dimensions of sound visualization and try to create a series of 3D Chladni projects.

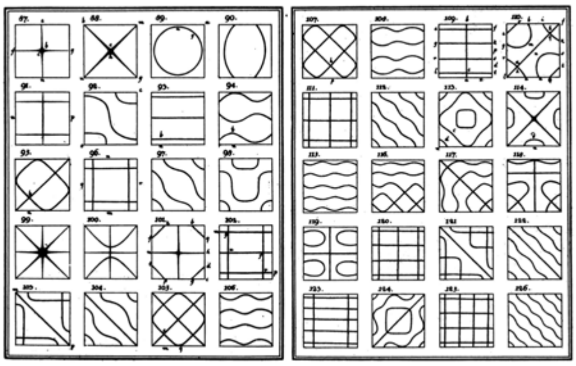


Figure 1. Chladni figures by Ernst Chladni in 1787 (Chladni 1787).

In the 3D Chladni research project, mathematical derivation and setting of conditional boundaries present the physics behind Chladni figures. With the advance of computer programs, the third dimension can further deduce from the physical and mathematical formulations of oscillation. In MATLAB, both a spectral and finite difference method is used to produce Chladni figures. Finally, images of 3D Chladni are created by employing Max / Msp / Jitter. (Skrodzki, Reitebuch and Polthier 2016) This method simulates the appearance of 3D Chladni with a numerical formula.

1.1.2. Kundt Tube by August Kundt in 1866

The acoustic equipment, Kundt's Tube, was invented in 1866 by German physicist August Kundt. The tube is transparent and encompasses some fine powders inside. The speaker at one end of the tube is responsible for emitting different frequencies, and the piston at the other end of it can be adjusted. When the length of the air column is some multiple of half wavelengths, the two opposite direction of waves create interference and produce standing waves. The fine powders are disturbed easily by the airflow back and forth, which shows how sound waves move between nodes. (Kundt 1866, Figure 2) With each difference in sound frequency, miscellaneous fluctuation patterns are produced. Viewers can immediately hear and see sound changes accordingly. Through the subtle variations in these sounds, different curved shapes are constructed. It makes us see a great diversity of sound surfaces in the spatial depth and width, and it can present sound in a three-dimensional space.

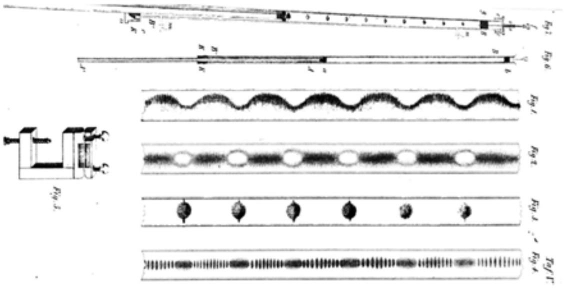


Figure 2. Kundt’s Tube by August Kundt in 1866 (Kundt 1866).

1.1.3. Rubens’ tube by Heinrich Rubens in 1905

The Rubens‘ tube was invented in 1905 by German physicist Heinrich Rubens. A row of small holes is drilled at a fixed distance on a long tube and sealed at both ends of the long tube. One end is connected to a speaker, and the other end is connected to flammable gas. If the length of a tube is equal to an integral multiple of the longitudinal wavelength, a standing wave will be formed, which will cause a change in the pressure of a gas in the tube. Because of variations in oscillating pressure, flammable gas will be released in distinct heights. Through each combination of varied flames, the positions between nodes and antinodes can be seen, which affect the sound shape produced. (Rubens and Krigar-Menzel 1905) (Gee 2009, Figure 3 left) In addition, a Danish science demonstrator group called Fysikshow displays the 2D Rubens’ tube in 2014. (Nielsen and Muller 2014, Figure 3 right) Its presentation shows that sounds can be presented in multi-dimension. Due to an innovative alteration of creative medium and variable dimensions, this project conveys different appearances on sound expressiveness.

Figure 3. Rubens‘ tube in 1905 and 2D Rubens’ tube in 2014 (Gee 2009 left; Nielsen and Muller 2014 right).

1.1.4. Cool Sound and Water Experiment by Brusspup in 2013

In this sound project, the first step is to make the rubber hose to connect the faucet and then pass down through the speaker. The next step is to hang the hose from the bottom of the speaker with approximately 1 to 2 inches and secure the hose to the speaker with tapes. The purpose is to ensure the hose actually contacts the speaker so that the speaker vibrates and triggers the hose. The last step is to set up a camera at the end of the hose, play 24Hz audio, turn the faucet on, and shoot at 24 frames per second. The images will display water which seems to be frozen in space, and changes the original form. Through the changes of sound frequencies, when the frequency is adjusted to 23Hz, it looks like moving backward. However, when the frequency is adjusted to 25Hz, the water flow seems to move forward in slow motion. (Brusspup 2013, Figure 4) These phenomena make us see the visual representation that is transformed when the time information of sound is added. Therefore, each sound becomes a tangible entity. This project is a perfect conversion of digital media shooting and sound synchronization. It provides an advanced way to visualize sound.

Figure 4. Cool Sound and Water Experiment by Brusspup in 2013 (Brusspup 2013).

1.2. RESEARCH PROBLEMS

This study is inspired by the above sound projects because they demonstrate that sounds are able to be visualized in space. Even though some projects are linear and vertical representations by directly presenting the waveforms of sound during vibration processes, each has its own distinctive characteristics of expression and different techniques, through which sounds are transformed into physical existence with visible appearances. Accordingly, this study is curious about Chladni figures, introduced in the first sound project, and how to represent them in 3D. In 2013, Ricky van Broekhoven produced a series of sound shapes projects by stacking frequency patterns and attempted to present 3D Chladni appearance. (Studiovanbroekhoven.com 2019) Therefore, this study combines the spatially expressed in projects one and two, the change of medium in project three, and the temporal of project four. Through sound capturing, images processing, and reconverting the fabricated medium, sound can be transformed into cymatic 3D.

To further understand cymatic 3D, this study investigates how to create invisible sound information to constitute a three-dimensional form. Most of the graphics constructed by Chladni figures exist in 2D, but the vibration of sound in space is a three-dimensional state. In sound shapes projects of Ricky van Broekhoven, he only stacked 2D frequency patterns, which lacked the conversion of different representations. As a result, this study attempts to present more possible states of cymatic 3D by recapturing the superimposing of cymatic 2D in different dimensions. The superimposing of diversified sound information can be more concrete to express the organic form of sound in space. This study tries to find out the possibility of sound in three-dimensional space by using a series of capture and representation techniques. By constructing a stereoscopic appearance of sound, viewers can gain more experience in sound reception.

1.3. RESEARCH PURPOSES

This study is not intended to verify sound science or to justify the results of resonance experiments. Instead, we expand the possibilities of its representation by understanding sound and inspire people to observe sound information from different aspects. By creating an alternative way for people to perceive sound, three factors, including time, decibels, and frequency, are integrated to record the processes when sound is transmitted. Through interactive changes of these three elements, the innovative shape of sound can be constructed, which can help people imagine the sound space. Consequently, this study takes a series of slicing images under different decibel and frequency dimensional experiments. These sound images are imported into Grasshopper for taking points in them, and these points will perform geometric processing through feasible algorithms. Then, the 3D superimposed state of each slicing image is formed, and the shapes of sound variations are constructed in the fixed dimension.

2. Setup and Data Collection

2.1. EXPERIMENTAL SETUP

The experimental setup shown below is common for cymatics. (Grant 2009) In this study, sound is generated by Pure Data. The fulcrum is in the middle to fix a platform, and there is photographic equipment placed on top to record images. After preceding tests of diverse vibrating platforms, this study chooses to use a square aluminum plate with a size of 30x30x0.1 centimeters. Because square aluminum plates are extremely light and the measure is common, one fulcrum can stabilize it easily.

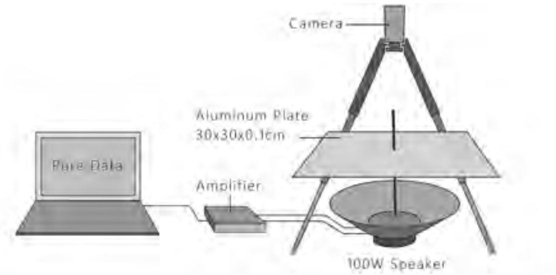


Figure 5. Setup System Diagram.

2.2. DATA COLLECTION PROCEDURES

There are three experiments for data collection and process. The main operations of this study mainly focus on the post-processing of recorded images. Therefore, Experiment One and Two will briefly describe data collection processes. First, Experiment One is fixed at the same decibel but different frequencies. The test frequency for this study is 100-400 Hz, and the process that the fine sand on the aluminum plate gradually moved and gathered is recorded during vibrations. In addition, Experiment Two is fixed at the same frequency but different decibels. The test decibel is 0-83 dB. Finally, Experiment Three is the time strobe procedure for sound images that are collected from the above Experiment One and Two, which is described in the next third chapter.

3. Sound Images Processing

The following image post-processing flow chart is sound processing steps. After Experiment One and Two in the second chapter, the third chapter begins the post-processing of sound images. The slices of the sound images recorded during the vibration process are taken out at a specific time on the time axis by using Adobe Premiere. The images are sequentially inputted to Grasshopper in order to distinguish the color brightness and generate point clouds in each image. The images in different dimensions are successively superimposed to produce cymatic 3D multiple types.

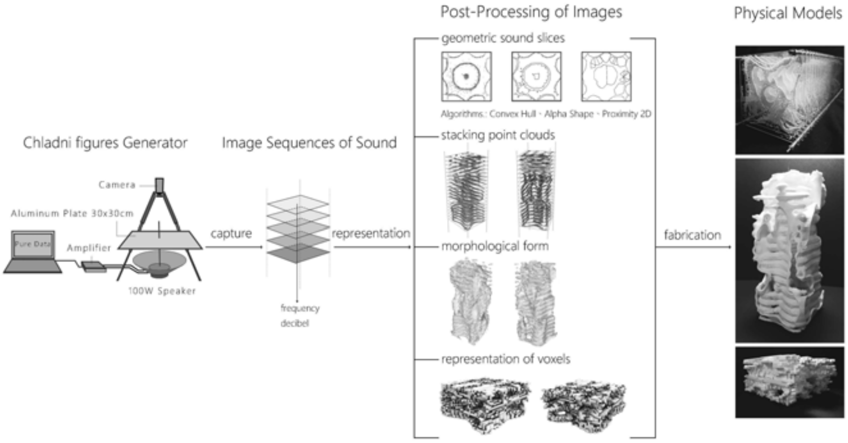


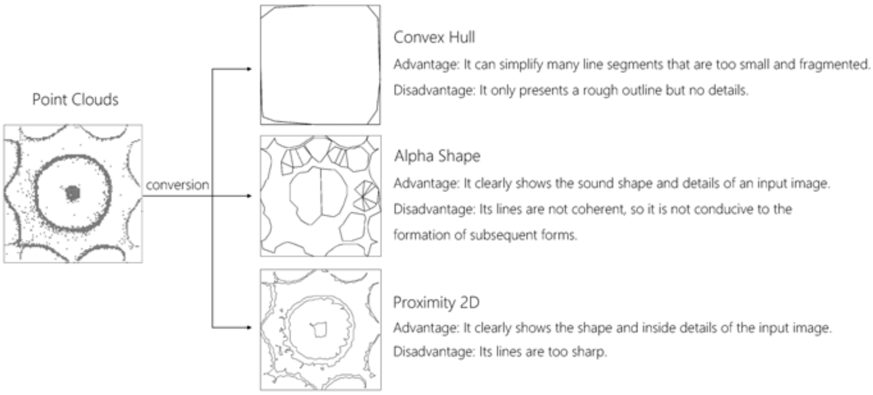
Figure 6. Sound Processing Steps.

3.1. VISUALIZATION OF SOUND BY IMAGE SEQUENCES

The captured sound images are consecutively read into Grasshopper, and then Grasshopper's number slider can be used to scale images setting of the final output. Furthermore, Grasshopper's component image sampler is used to detect the grayscale value and brightness of the input images. Points of the images are outputted with the numerical value of the grayscale between 0-1. The distribution and density of points are determined according to these values. These selected points are superimposed to exhibit the outline of sound in 2.5D. Through a series of post-processing methods, it is more accurate and clear to see the subtle changes in the sound slices. The sound images are converted into point clouds according to the grayscale degree. It can control the numerical output of all parameters for subsequent processing and physical production.

3.2. VISUAL REPRESENTATION METHODS

Through the above Grasshopper process, these point clouds extracted from the images attempt to be presented in various algorithms. It is a creative way to reconstruct cymatic from using a geometric perspective. The following are the different geometric algorithm objects generated by the same sound slicing image. They are Convex Hull, Alpha Shape, and Proximity 2D. After analyzing the advantages and disadvantages of the following disparate algorithms, it is decided to use Proximity 2D first for subsequent 2.5D generation.



Convex Hull
Advantage: It can simplify many line segments that are too small and fragmented.
Disadvantage: It only presents a rough outline but no details.

Alpha Shape
Advantage: It clearly shows the sound shape and details of an input image.
Disadvantage: Its lines are not coherent, so it is not conducive to the formation of subsequent forms.

Proximity 2D
Advantage: It clearly shows the shape and inside details of the input image.
Disadvantage: Its lines are too sharp.

Figure 7. The picture shows the geometric representation of disparate algorithms.

4. Morphological Form of Sound

4.1. SLICING LAYERS OF SUPERIMPOSED STATES

The points taken out from the above post-processing are arranged according to the axial information. The axis can be frequency or decibel information, and it is transformed into an alternative form. As shown in Figure 8 below, the points of each slicing pattern are frequency 236 Hz to 272 Hz from the bottom to top, and the pattern changes every two Hz are superimposed.

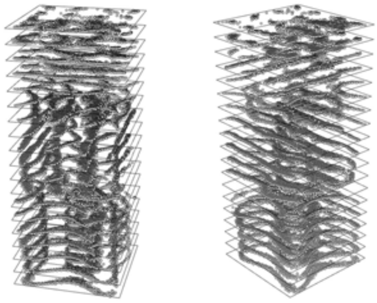


Figure 8. The picture shows that the frequency is 236 Hz to 272 Hz.

4.2. VOLUMETRIC REPRESENTATION

Grasshopper's plug-in, Millipede, is a structural analysis and optimization tool for elemental frames or shells in 3D and 2D. (Michalatos 2014) Therefore, this study uses it to generate the morphology. The boundary of the form is set, and then point clouds arranged are inputted. According to the level of demandable details, the value of the data operation is determined. As shown in Figure 9 below, the left green part is a 3D model of sound frequency in the Grasshopper environment that connects all point clouds through Millipede. The right part shows a 3D virtual model of sound frequency.

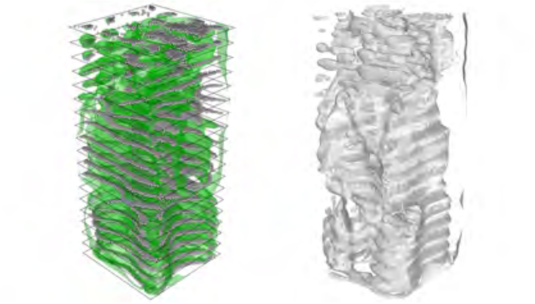


Figure 9. The Form of Sound Frequency.

4.3. PHYSICAL FABRICATION

In the computer environment, forms can be adjusted quickly by setting different parameters. We can see the whole appearance of a model in advance and predict the representation of diverse fabrication. Because various forms of each sound have their characteristic representation, they can be constructed and modified in the 3D environment. Moreover, these forms are able to manufacture into touchable shapes by using a 3D printer.

Figure 10. The Solid Model of Sound Frequency.

5. Conclusion

5.1. RESEARCH DISCUSSIONS

The images of sound have a special pattern because of plates in divergent shapes and material coefficients. However, reaching clear patterns are closely associated with frequency and decibel. After the experimental process in chapter two, the results revealed that the value of frequency and decibel have to match each other because decibels are related to energy and different frequencies also affect a multiple of the wavelength. For example, when the frequency emitted by the speaker causes the superposition of two propagating waves traveling in opposite directions to generate resonance, the entire energy will increase. The decibel value should be reduced so that fine sand will not shake out of the plate. In addition, when the destructive interference of two waves propagating in opposite directions, it means that energy is insufficient and decibel should be increased. The purpose of this study is to capture the patterns and process the images. Because of not using precise scientific instruments, the measurement of decibel generated by Pure Data has some numerical fluctuation. Then, the equilibrium of the plate also influences the accumulation and distribution of fine sand. These unexpected errors may happen during the vibrating experiment.

5.2. RESEARCH RESULTS AND CONTRIBUTIONS

In the researching process of 3D sound formation patterns, this study revisits sound image slices with different axial information in the spatial boundary. Capturing the sound appearances in the space makes the sound, image, and space create a connection among each other. The abstract sound can be transformed into a concrete entity. In the vibration setup, there are three variables: frequency, decibel, and time. These three variables can form the richness of sound. It is no longer just having a uniformity to understand sound; that is, it can be experienced in more sensory ways. Visualizing the shape of a sound and its three-dimensional appearance in space is no longer a dream but a reality that people can actually touch and feel it.

This study of sound representation can transform sound images into point clouds, shaping of different appearances, and make further production. As each representable method is tested separately; therefore, it can be performed in different combinations. This study attempts to find a visual process of sound from 2D to 3D through geometric representation mentioned in the previous chapter. This study finds out the way in which multiple sound messages are converted. It is a certain degree of visual representation of sound.

5.3. FUTURE DEVELOPMENT

Through the representation of sound in this study, it shows that sound can actually have more appearances and diversities. If this process is integrated with the Internet in the future, Chladni figures can be recorded immediately during vibration, transmitted to a computer to generate various shapes, and printed them out completely. Not only does it become a set of timely and interactive performing arts, but viewers can touch a change in the appearance of sound. Furthermore, in the future, with the richness of sound information, it may allow designers to design space and devices through the use of sound shape. Variety methods or changes in the form of sound can make architects imagine the possibility of the unknown space and redefine the new spatial shape. As a result, this study gives rise to a new insight on cymatic 3D, as well as further research on other cymatic related topics.

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