JAMES DYSON FOUNDATION UNDERGRADUATE BURSARY 2019/20

Outreach Activity – What is Sound?

Sound, particularly how it's produced, isn't often given much thought; most people tend to accept that sound is a form of vibration that travels through the air and is detected by our ears. Most GCSE syllabuses cover single-tone or harmonic transverse waveforms; this includes their speed, frequency, wavelength and amplitude. The distinction that frequency corresponds to pitch and amplitude to volume is often made.

The Fourier Transform is an exceptionally powerful tool used across all branches of engineering. The maths involved is clearly an advanced topic not well-suited to a secondary school outreach event. However, it should be possible to share an intuitive understanding of what it does and how it reveals some interesting things about the world around us.

My outreach event would have consisted of three sections; the first would have involved an interactive presentation which recaps GCSE theory and investigates the Fourier Transform using just rotating circles. The second would have been a practical activity, where students aim to make a musical instrument. The third would have been a discussion linking the first two parts, with a "black box" (an FFT program written in MATLAB) revealing the frequencies produced by each group's musical instrument.

My project aimed to use sound data to identify faults on railway lines; this activity attempts to give an intuitive understanding of how sound is generated, along with how instrument properties (size, shape and material) directly influence the sounds produced.

Presentation

Section	Description	Time (minutes)
What is sound? (Discussion)	Students try to answer the question in small groups. This activity aims to highlight what the class already know.	1
Different Sounds (Discussion)	Two sound clips will be played; one of a single-frequency harmonic tone and the other of a guitar string being plucked. Students will be asked what the difference between the two is, and whether anyone can identify the second sound. This is designed to illustrate that complex waveforms consisting of many frequencies allow us to easily identify the instrument, and that trained musicians can even identify the note being played.	2
Different Sounds (Illustration)	The waveform of the single-frequency tone will be shown, followed by the plucked string's. The difference in complexity will be highlighted and students asked to identify where they've seen the single-frequency before (GCSE science/maths).	1
Recap	The single-frequency tone will be investigated, highlighting its amplitude (volume) and wavelength. The concept of frequency (pitch) will be explained.	1
Fourier Series Intro	The idea that any complex sound (like the plucked guitar string) can be made by adding together an (infinite) number of simple harmonics will be introduced.	1

Square Wave Demo	We'll attempt to make a square wave; clearly a single harmonic is a poor approximation. Animation would be used to show that we can draw a sine wave with a rotating circle (Figure 1), and that if we layer circles at the edges of each other, they begin to draw something closer to a square wave (Figure 2). If we continue forever, we approach a square wave.	3
Concept of Fourier Transform	It will be explained that we can do the opposite with maths to find the rotating circles that draw any sound. These circles represent single tones and therefore all of the frequencies that make that sound.	1
Transform Demo	A picture of the frequency-domain data for the plucked guitar string will be shown. It will be explained that spikes represent all of the frequencies that make up the sound.	1

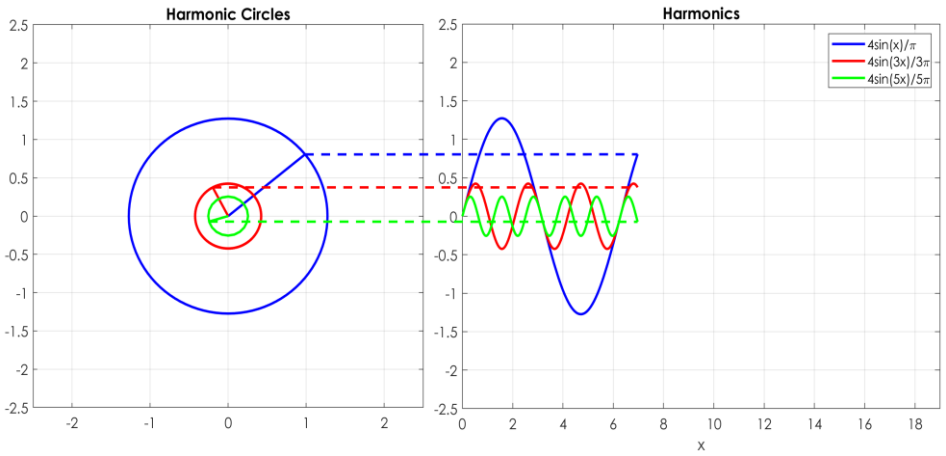

Figure 1: Harmonic tones represented by rotating circles.

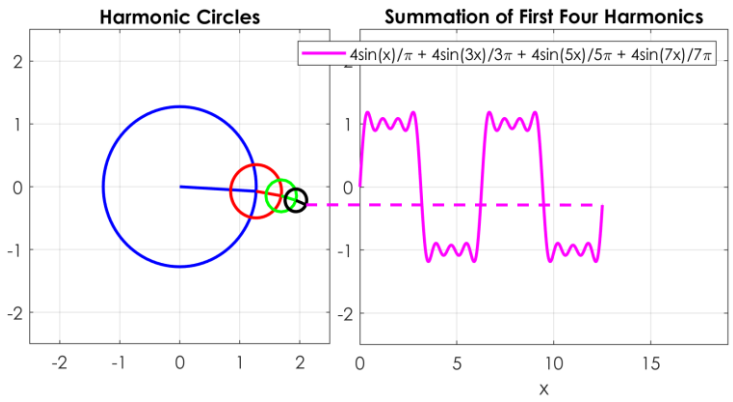

Figure 2: Addition of harmonic tones to produce an approximate square wave.

Practical

The challenge is for students to make a musical instrument capable of producing two sounds. The first must have the highest pitch possible and the second the lowest. Students will be briefed and told to think carefully about how different sizes, shapes and materials might influence the sounds made. They'll then be given ten minutes to build their instruments.

Equipment:

- 1 long (wrapping paper) tube.
- 3 shorter tubes.
- Elastic bands of an assortment of widths, thicknesses, diameters and colours.
- A tissue box.
- A margarine/spread pot.
- Glue.
- Scissors.
- Sellotape.

Discussion

One representative from each group will be invited to explain their instrument, and to record their two notes being played (5 minutes). A MATLAB script will generate the frequency-domain data and identify the harmonics in each case. Students will be allowed to have a copy of this data if they want. We'll spend the remaining time discussing how each group went about creating their frequencies e.g. changing elastic band tension, tube length etc. I'll briefly explain that my project aimed to use these ideas to treat railway track like a musical instrument, where the sounds produced depend on whether a fault is present.

Retrospective

Unfortunate global circumstances meant this activity could not take place. Instead of providing a retrospective of the event, some potential issues are provided below.

The Fourier Transform is a difficult concept to convey in a short amount of time; there is the worry that explanations will not be good enough to provide the understanding desired. In an attempt to mitigate this, the idea was presented to my younger sibling in their final year of secondary school. They were able to grasp the basic ideas, with some more complex ones, such as the "connections" between circles requiring more explanation. However, the important mechanical principles regarding an instrument's production of sound were understood quickly.

The amount of time required to complete the presentation, practical and discussion is short. I'm wary of focusing too much on the presentation without leaving enough time for students to get thoroughly involved with the activity. However, spending too little time may result in important concepts being missed.

There are safety risks associated with the building of musical instruments; for this reason, sharp objects have been restricted to scissors and glue sticks will be used for adhesives.