Investigating components of sound waves

Introduction: My name is Andrew Meyenn, I am doing the course out of interest, am semi retired but continue to work one day lecturing at a Uni in Melbourne, Australia and supporting Computer Science education. I am interested in music and have never done any music production. I have played over a long period of time but never seriously, went down another path. All the best

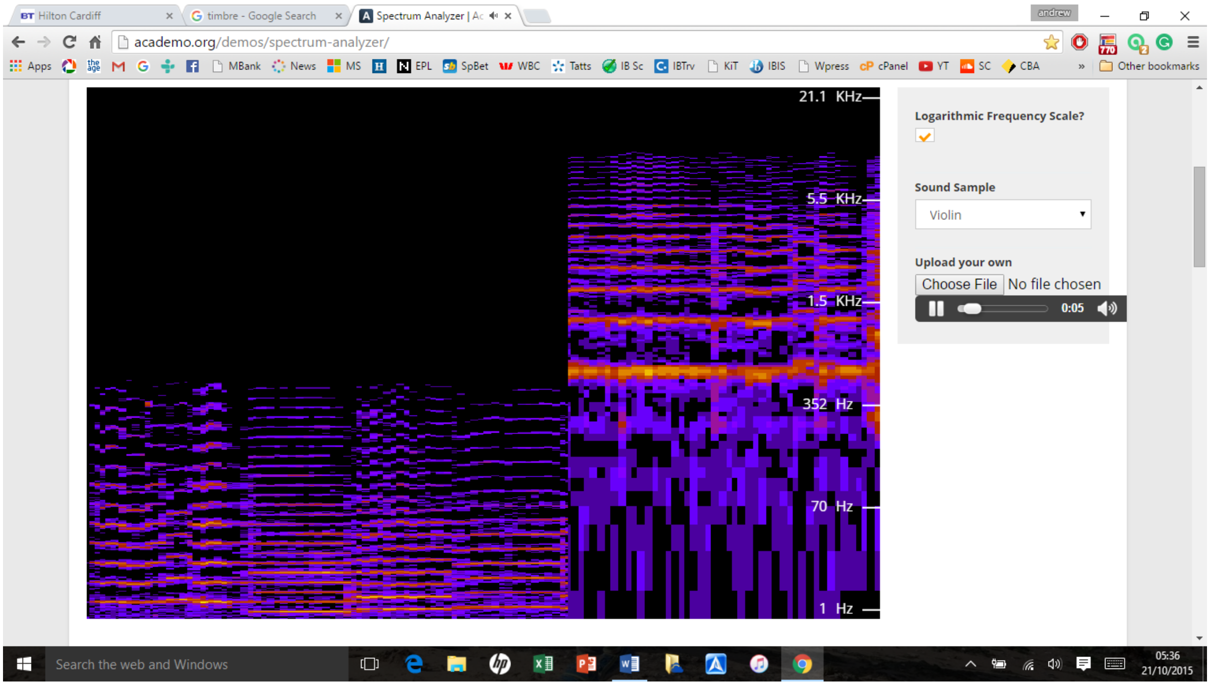
Lesson

Our aim is to explore some of the basic features of sound waves, and to consider more specifically the individual notes in the C Major scale.

Action 1: Please run the link below or copy and paste into a web browser to access the online spectrum analyser.

http://academo.org/demos/spectrum-analyzer/ you will see a screen like the one shown. On the right use the Sound Sample drop down list and select Violin – initially you will see the condensed stream, if you click Logarithmic frequency scale the stream is stretched.

Exploration – replay the sound, select and study the diagrams produced from the other sounds on the list, if you have time you can also upload your own sounds to explore.



Question – what are we looking at? What are the dimensions? What do the colours mean?

You are looking at streaming diagram flowing right to left which is termed a spectrogram.

X-access – this represents time, the stream moves across showing the current time at the right.

Y-access – this represents the frequency of the sound wave at each point in time (how many times repeated per time unit). But why is each horizontal line made of many frequencies? You will note the frequency range from the low of 1Hz all the way to 21.1kHz and that each time period seems to have many frequencies present.

What can we conclude from this observation?

Imagine you were the first person to see this spectrogram?

How would you explain it?

The explanation is that a single sound is comprised of many sound frequencies and this repeats constantly during the length of the sound. Black gaps indicate no sound (is there really no sound at that point?).

Lastly, what do the colours (colors) mean or represent?

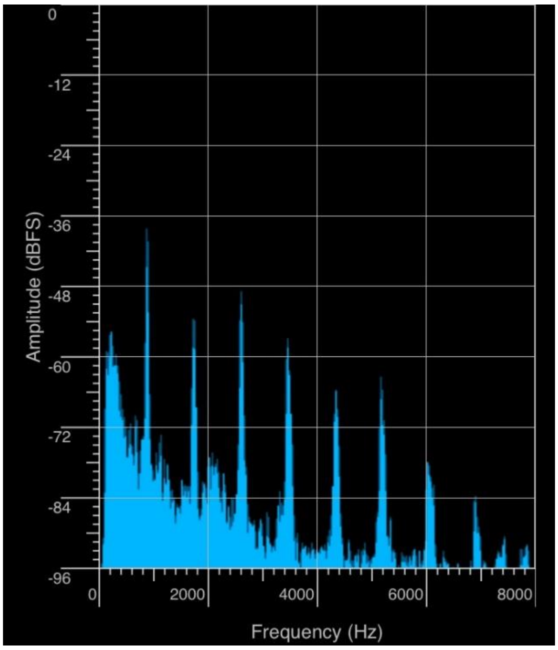
You may recall the term amplitude being the height and depth of a wave, the larger the amplitude the stronger the presence. In sound the amplitude indicates intensity of the sound. In the spectrogram the reddish colours indicate high intensity (loudness) and blue low intensity.

Theory summary so far– at any point in time a sound wave is made up of many components of different frequencies and amplitudes, the mixture produces the sound we here.

Action 2: A useful iPhone/iPad app is called Sprectrum View from Oxford Wave Research, available via the App Store in the normal way. It would be very helpful to get this, there is a free version. The way I have used this, is to simple record sounds and then save screen shots – this feature may only be available in the chargeable version.

Question: Can we see the different components of a sound wave at a point in time and are all the components of equal or differing importance in producing the sound?

Exploration: The diagram below is taken from the Violin music played above at a particular point in the spectrogram. This was produced by recording the sound produced using the App. Study it carefully, what do you see?



This graph shows clearly that at any time point there are many frequencies or waves present, and that between 8 to 10 are more pronounced. It can also be seen that the amplitude or loudness contribution decreases as the frequency increases e.g. 2000Hz has much higher amplitude than the 7000Hz.

Another thing we can note is the even gap between the peaks – this is a characteristic of what is termed the harmonic series. Without getting too mathematical, if we determine the starting frequency (f) then each peaking frequency is an integer multiple e.g. f, 2f, 3f, and so one with f being the frequency with the initial largest amplitude. In the above if we approximate f=900Hz, we have 2x900=1800, 2x900 = 2700 etc, more less fits. It is a very rough calculation.

The pitch of the note is determined by the starting frequency with the highest amplitude i.e. difference between C natural and the rest of the scale is determined by the dominate starting frequency. The rest of the frequencies combine to give the overall sound and tone.

Additionally, there is the concept of overtones which are the frequencies in between the peak frequencies. There is not time to go into further aspects of this.

Action 3 & Exploration: Listed below are several diagrams showing the C major scale from middle C generated on a computer piano. It is recommended that you access this or just use a normal instrument - http://www.bgfl.org/bgfl/custom/resources_ftp/client_ftp/ks2/music/piano/ . The last diagram shows the spectrogram of the C major scale from which the individual notes diagrams were taken. Explore each image and compare, what differences and similarities can be found?

Remember the snap shot of the harmonics is taken slightly after the initial start of the sound – caused by my delay in taking the picture. Middle C for instance is around 263Hz, looking at the diagram this is shown but not accurately. The next note of D has a frequency 247 and so on.

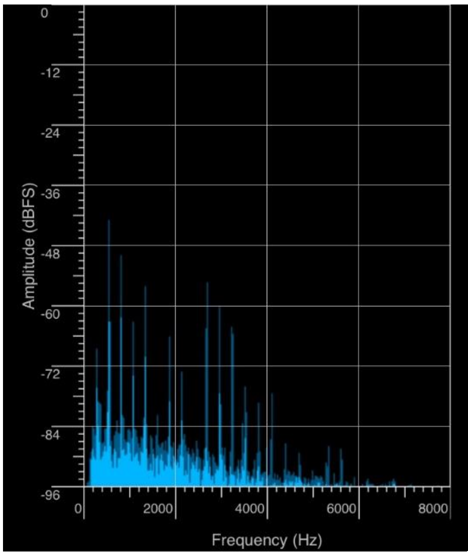


Figure 1: C

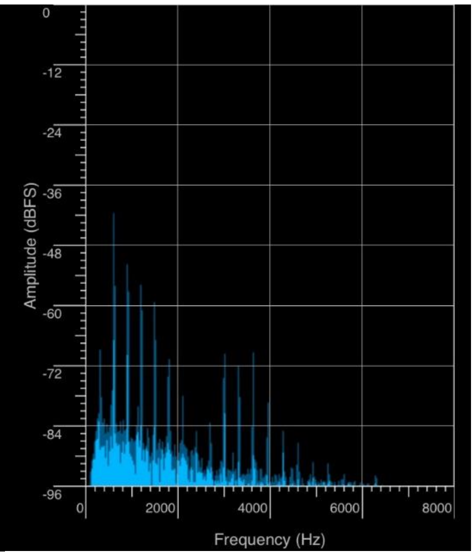


Figure 2: D

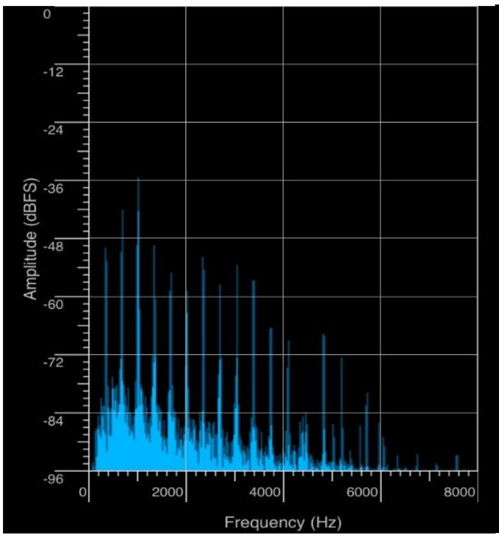


Figure 3: E

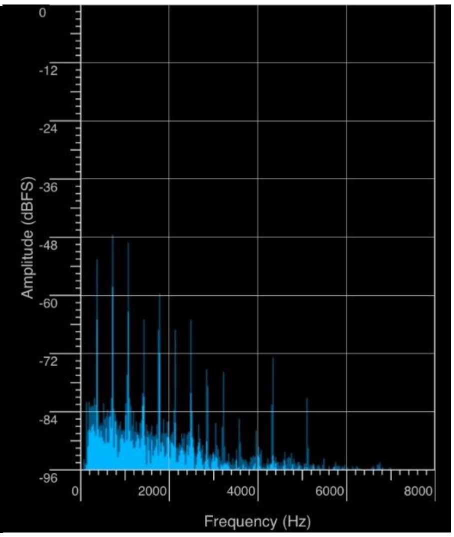


Figure 4: F

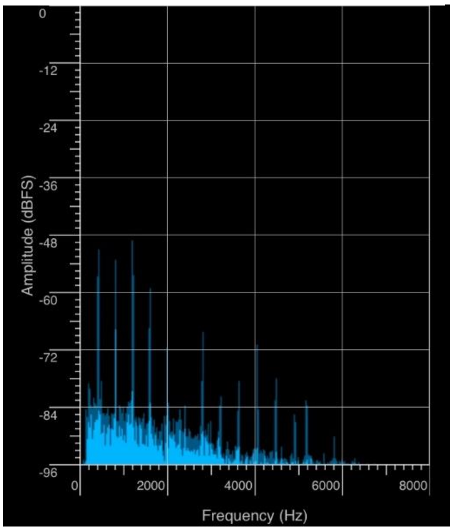


Figure 5: G

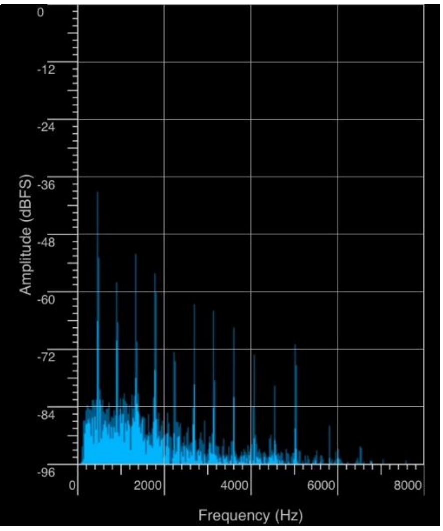


Figure 6: A

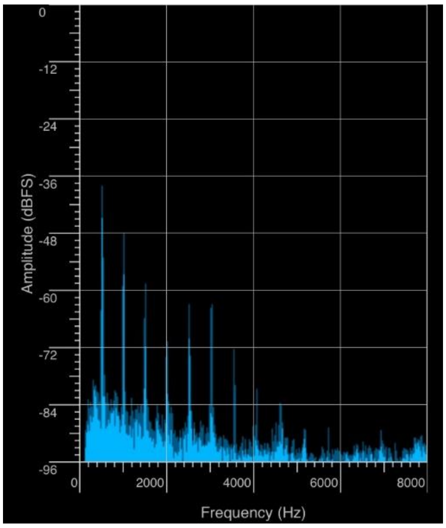


Figure 7: B

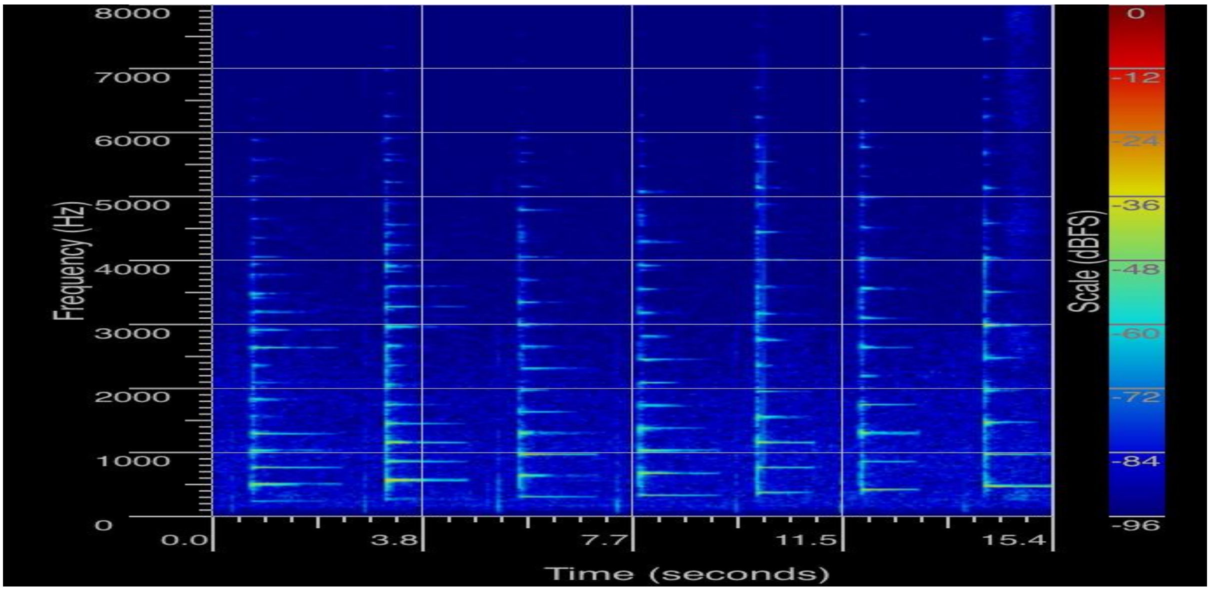


Figure 8: Scale – left is C, then D etc to B on the right.

Each of the note diagrams show clearly the different harmonic series and the dominate frequency from which the pitch is determined. Figure 8 shows each note being played and allowed to die away. The start of the note i.e. depressing the note is called the attack and the sound then decays away as the frequencies loses intensity.

We are out of time! Sorry, this is a fascinating area.

Conclusion – what has been learnt (hopefully)

Sound waves are comprised of many waves of differing frequencies.

Each frequencies component part has an amplitude which indicates intensity, the larger the loudest.

A Spectrogram shows this collection of frequencies and colours each depending on the intensity. Typically, it can be seen that the lowest frequencies have the highest amplitude, this determines the pitch and then as the frequency increases the amplitude decreases.

From the time shots the frequency components can clearly be seen, there is a pattern of peaks which decrease in amplitude and form the harmonic sequence of the sound, and also there exist many other smaller amplitude frequencies, all combine to produce the sound we hear.

Additional Exercises:

Look at basic chords, 3rd, P4, P5, Major 6 etc.

Look at the minor scale and minor chords.

Finally explore the notion of Timbre.

Finally, thank you for reading, I hope this has been a worthwhile exercise for you and you have gain a better understanding of the components of a sound.

Reflection – I have learnt a lot about waves, and explored a number of software tools, the App referred to has been really interesting to me, it has taken me back to primary research days and just wonder at the way research and teaching can be aided by such software. I have been like a kid and very excited, and have ranged far and wide, but hopefully been focused in the lesson. One interesting area I looked at were creeks in forests and rain on roofs – the distribution is rectangular and completely different to that created by a musical instrument. I have found the experience very rewarding and illuminating, trust my lesson is not boring but gets you interested also.

(Lesson 1098 Words)