ELE00087M PureData Report

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Introduction

Tartini Tones

A combination tone is a psychoacoustic phenomenon that occurs when two tones are played and a third, resultant tone is heard. First coined as 'Tartini tones' after their discovery by 'Giuseppe Tartini'.[1] This psychoacoustic phenomenon occurs when two pure tones are play at a frequency interval of greater than 50hz, this is where limits of acoustic beating can be perceived and is instead perceived as a separate tone. If played at a loud volume a third much quieter sub-harmonic will be heard, this being the frequency interval.

A similar result can be experienced through the missing 'Missing Fundamental' phenomenon [2] where the brain will 'fill in' the fundamental due to the set of tone's relationship to one another. This means that in a 'perfect fifth' interval with a frequency ratio of 3:2, if $f1$ is omitted, leaving the sum of $f3, f6, f9$, and $f2, f4, f6, f8$ the brain will 'fill in the gap'.

The science behind the 'Tartini Tone' phenomenon proposes that much like you're brain finds the difference in frequencies, in order to calculate interval. It was thought that due to the non-linearity of the inner ear, that the third tone's cause was intermodulation distortion.[3] However, it is now suspected that due to the ability to experience this phenomenon with headphones, having each tone in a separate ear, it is instead a neural phenomenon oppose to a physical one, similar to binaural beats.

Below is an example of the nature of 'Tartini Tones' in the context of a musical score.

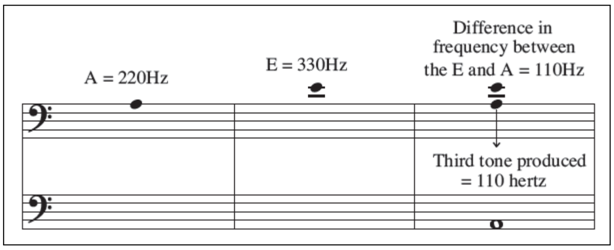

Figure 1: An example of how a 'perfect fifth' interval can create an octave below 'Tartini tone'[4]

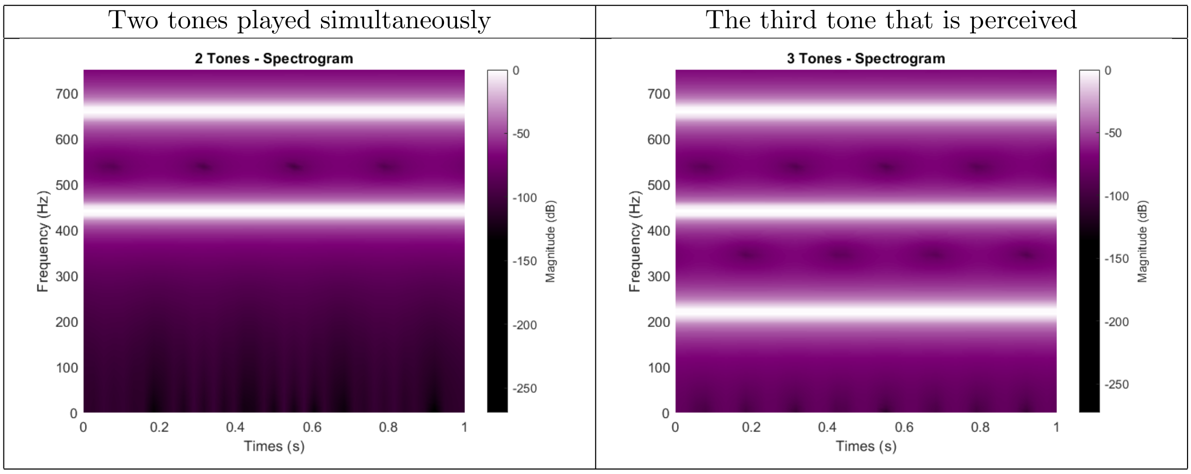

Figure 2: Another example presented in the time/frequency domain

Purpose

The purpose of this investigation was to find out the perception accuracy when changing the frequencies used. The intent is to see how accurate a person can be once calibrated between the range of 800-1300hz, with the 'Tartini Tones' always occurring above 200hz.

The Patch

Audio Engine

This experiment is done by randomising the interval between two sine oscillators, thus providing the two sources with differing frequencies.

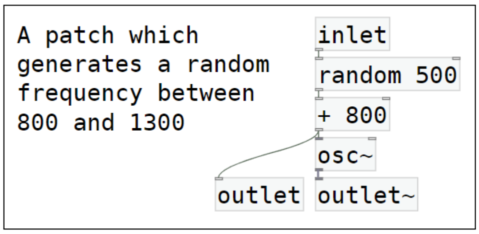

Figure 3: Patch used to generate a single signal

With two of these blocks producing random wave there is the possibility that they will happen upon a very similar frequency, these blocks output the randomised value meaning that they can be analysed. The outputs are used to find the difference between the two numbers giving us our perceived third tone.

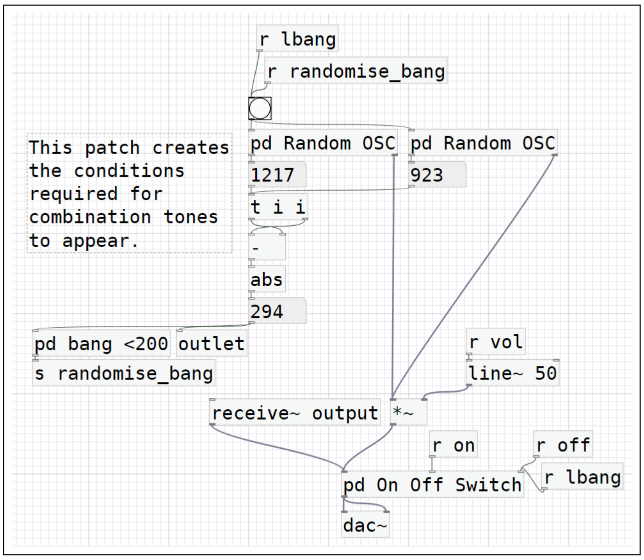

Figure 4: Patch for primary audio engine

These are sent into a sub-patch which calculates whether or the difference is less then 200hz, this is done such that the tone will always be audible in a comfortable range.

Guess Engine

In order for the user to be able to interact with the test the user would use a number field and button to submit their guess. So that people wouldn't have to be spot on the frequency I gave a leniency of 20hz, this seamed to be be enough for someone to get an accurate guess but still provide some challenge.

This engine also allows for the user to reference through and oscillator what their frequency sounds like. This means that they are able to listen to both at the same time. It could be seen that this is 'cheating' however without incredible auditory skills and ear training it would be very difficult to link pitch to a direct frequency.

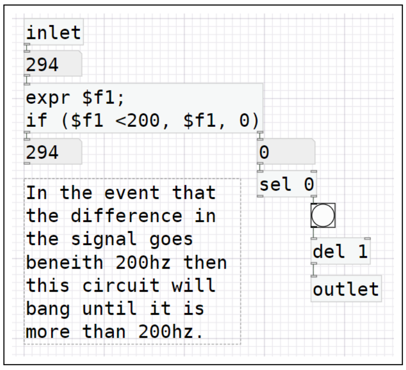

Figure 5: Patch that outputs a bang when input signal is less than 200

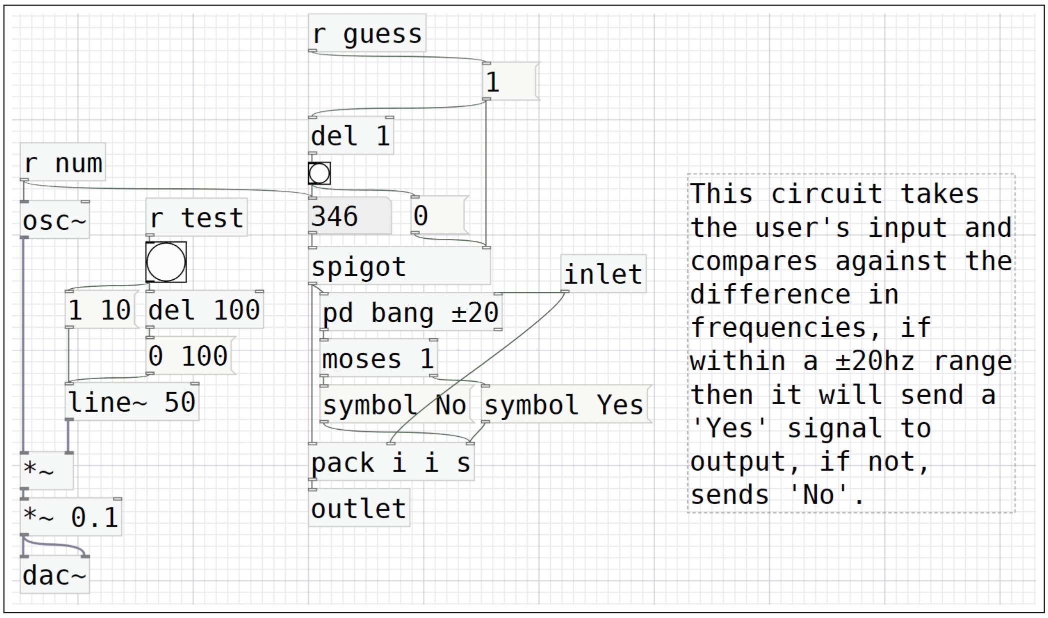

Figure 6: A Patch that decides whether or not the user guess the correct frequency.

Text Engine

In order to output data which can be used for later analysis, the data needed to be captured and then written to a .txt file. This required the use of the [textfile] block and certain sequenced bangs.

Testing Methodology

The Gui

The main page allows access to all the features that a user would need to conduct the test. It allows for calibration, and a small explanation as to how the patch is designed to be interacted with. It also allows the user to dive into the patch to see how it works, with annotations and comments to explain how these phenomenon occur.

Testing

The testing can be carried out by someone at home and does not require assistance. However, someone to explain how the test works and to supervise would be very useful if this test were to go ahead. The testing would follow a simple instruction set:

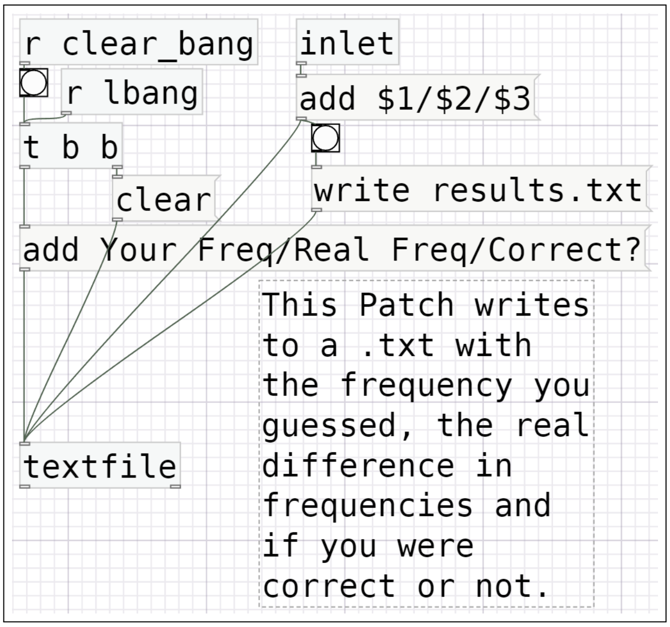

Figure 7: The Patch which allows users to write their results to a text file.

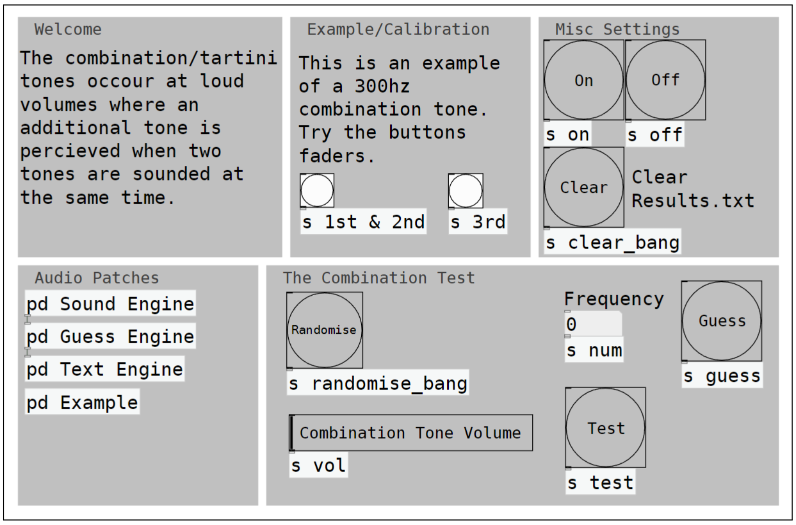

Figure 8: The homepage of the Pure Data file

```
1) Open up the file and calibrate using the 'Example/Calibration' box.
2) Click the 'On' button in 'Misc Settings'.
3) Adjust device volume you should be able to hear the second button's tone when
   only the first button is pressed.
4) Be sure to click 'Clear' before each subject is tested.
5) Click the 'Randomise' button and bring up the 'Combination Tone Volume'
6) Use the 'Frequency' number field and the 'Test' button to reference what tone
   you think you're hearing.
7) Once you have selected a frequency, click 'Guess', then 'Randomise'
8) Repeat steps 5-7 ten times before referencing Results.txt
```

Evaluation

Patch Limitations

The use of PureData means that although the accessibility is far increased with an open-source program, the polish from MAXMSP is sorely missed. The absence of a 'presentation' mode or cable alignment means that patches often look more messy. This could lead to confusion of a user, the inability to 'lock' certain patches means that the user could look into your code and find a way of circumnavigating your system to forge results.

The primary limitation of this patch, and a subject for further study could be the wave shape and how it effects the clarity of the 'Tartini Tone'. 'Giuseppe Tartini' was a violinist and thus had a very rich harmonic structure when he noticed the 'Tartini Tones'. The violin has used this to create techniques inside of double stops where the user purposefully creates tuned 'Tartini Tones' in order to create additional texture. Creating a patch which allows switching of the

Testing Limitations

An interesting observation that was noticed during preliminary testing was the fact that harmonics of the third tone was often guessed. The octave, or the double of frequency may cause inaccuracy in the final data. This adds to the theory that intermodulation distortion is the cause of 'Tartini Tones', as two pure sine waves should not produce additional harmonics without distortion.

Creative Uses

The Bohlen-Pierce Scale is a musical tuning/scale which allows for constrained creative use of the 'Tartini Tones'. Utilising odd harmonic ratios at different frequencies it is possible to create a piece solely in 'Tartini Tones'[5][6]

There are reports of 'Giuseppe Tartini' using the 'Tartini Tones' to calibrate his double stop intonation. If he tuned the 'Tartini Tone' to the difference he wanted, he would be able to tune the exact interval. This has also been used to generate much thicker textures when certain constrains are present.

Smaller pipe organs have been known to generate the note and it's fifth in order to produce an octave below. This is done because often the size constraints of an organ mean that they can not afford the space required to achieve these frequencies naturally. By utilising combination tones it is possible to achieve these lower notes without the worry of space or even possible structural damage from a note with so much energy. This worry is averted as the phenomenon is only perceived by the subject and not a physical property of the moving air.

References

[1] W. L. Hosch. (2013). "Combination tone," [Online]. Available: `https://www.britannica.com/science/combination-tone`. (accessed: 15.12.2020).

[2] J. Beament, *How We Hear Music*. The Boydell Press, 2001, ISBN: 0-85115-813-7.

[3] J. Johnstone, "The generation of combination tones," *Hearing Research*, vol. 3, no. 3, pp. 253–256, 1980, ISSN: 0378-5955.

[4] T. Strad. (2018). "Technique: Minna rose chung on double stopping and tartini tones," [Online]. Available: `https://www.thestrad.com/playing-and-teaching/technique-minna-rose-chung-on-double-stopping-and-tartini-tones-/7571.article`. (accessed: 17.12.2020).

[5] E. Walker. (2001). "The bohlen-pierce scale: Continuing research," [Online]. Available: `http://ziaspace.com/NYU/BP-Scale_research.pdf`. (accessed: 17.12.2020).

[6] J. R. P. Max V. Mathews, *Current Directions in Computer Music Research*. MIT Press, 1991, p. 167, ISBN: 9780262631396.