Exercises for Musical Analysis and Synthesis in Matlab

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1. Analyze .wav files of two different instruments. Identify the fundamental frequency in the wave form and power spectrum for each case. Do the relative amplitudes of the harmonics explain the timbres of the instruments?

2. The human mind can identify a pitch even if the fundamental and lower harmonics are missing. Synthesize sounds where $p_1 = 0$, $p1, p2 = 0$ and $p1, p2, p3 = 0$. What pitch do you hear? Can you still recognize the fundamental in the wave form or the power spectrum?

3. Helmholtz suggested the following power spectrums to synthesize vowels [1, p. 123, 543].

		p_1	p_2	p_3	p_4	p_5	p_6	p_8	p_{16}
U	oo as in boot	ff	mf	pp					
O	oh as in no	mf	f	mf	p				
A	ah as in caught	p	p	p	mf	mf	p	p	
E	eh as in bed	mf		mf			ff		
I	ee as in see	mf	p				p		mf

   Use `synthesize.m` to produce these vowels.

4. According to equation 7 in the text, each mode may have a phase shift γ_n. Revise `synthesize.m` to include phase shifts, and create a sound where the second harmonic is shifted from the first. Does this shift affect the waveform, spectrum, or sound of the note? After doing this same test with electromagnetically forced tuning forks, Helmholtz concluded that phase shifts do not affect the sound.

5. When two notes with fundamental frequencies f and $\tilde{f}$ are played together and exactly on pitch, one may hear a difference tone $\left|f - \tilde{f}\right|$ which is lower than the original notes or a summation tone $f + \tilde{f}$ which is higher. Sketch the waveforms of the fundamental of a note and its fifth to explain why difference and summation tones can be heard, and try to produce them with Matlab.

6. Beats can be produced by playing two strings of slightly different frequencies simultaneously. Plot $\sin 2\pi f t$, $\sin 2\pi(f + \epsilon)t$, and their sum to show this effect. Use a trig identity to rewrite the sum as the product of a fast wave and a slow wave.

7. Helmholtz said 33 beats per second is the most painful beat rate to listen to. If $f = 261.63$ Hz (middle C) what lower frequency, when played with f, produces 33 beats per second? Do the same for $f = 523.25$ Hz (high C) and see what notes your calculated frequencies correspond to. Create these beats with Matlab and see if you agree with Helmholtz.

References

[1] H. Helmholtz. *On the Sensations of Tone*. Dover, fourth edition, 1980. Translated by A.J. Ellis, originally published 1877.