L1

Applications of audio ML:

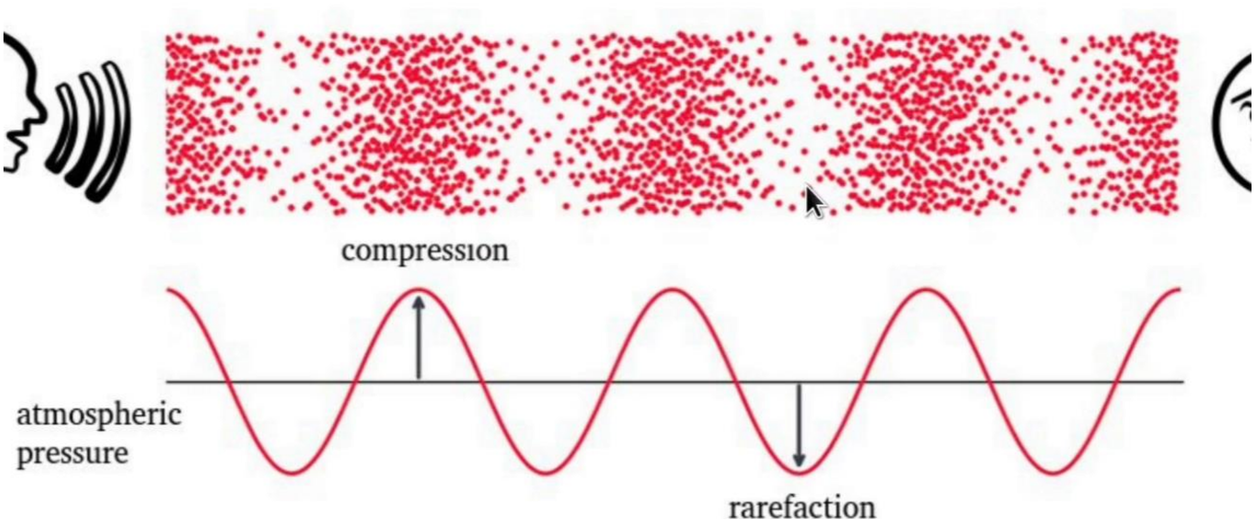
- Classification, speech recognition, denoising/upsampling, music information retrieval
    - Music has sub applications: instrument recognition, etc.

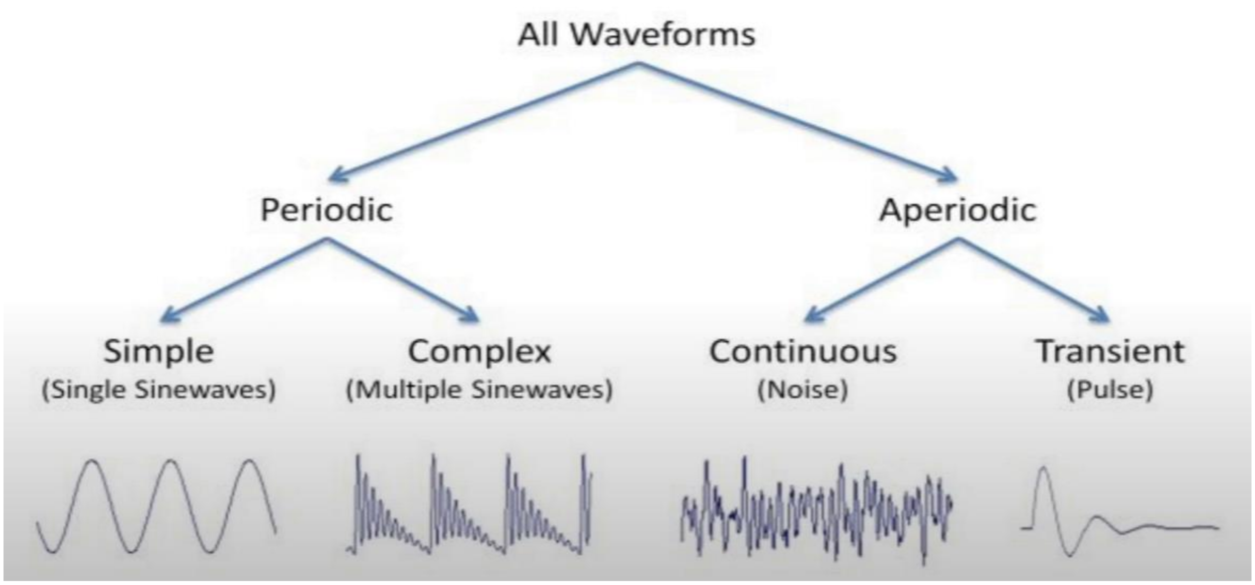
Topics:

- Sound waves, DAC/ADC, time-frequency domain audio features
- Audio transformations
    - Fourier/STFT, Constant-Q, Mel Spectrograms, Chromograms

L2

Sound is produced by vibrations, causing air molecules to oscillate. Changes in air pressure create a mechanical wave.





Equation for a simple sine wave

y(t) = Amplitude * sin(2pi * frequency * time + phi (phase))

The **period** is between each peak or dips. **Frequency** is the inversion of the period, number of cycles per second. **Amplitude** is the vertical distance between 0 and the peak or dip of the current point. **Phase** tells us the position of the waveform at time 0, and we are able to shift the waveform.

Perceptually, **larger amplitudes** will have **larger sounds**. This makes sense, because amplitude measure change in air pressure, which in perception results in higher noise.

Pitch is the perception of frequency. It's logarithmic and is perceived similar if differ by a power of 2. Beginning concept of octave. Each increase in octave, the same note will have double the frequency in Hz.

Pitch to Frequency Equation: $F(p) = 2^{\frac{p-69}{12}} * 440$

Ratio between two subsequent semitones: $\frac{F(p+1)}{F(p)} = 2^{1/12} = 1.059$

Cents are a subdivision of semitones. There are 1200 cents in Octaves, and 100 cents in semitone.

L3

Intensity, loudness, and timbre

Sound power is the rate at which energy is transferred. Energy per unit of time emitted by a sound source in all directions. Measured in watts (W).

Sound intensity is sound power per unit area. Measured in watts/meters squared (W/m^2)

Questions: How much power is there in thunder, concerts? Answer: Only 1 Watt.

Humans can perceive sounds with very small intensities.

- Threshold of hearing (TOH): 10^{-12} W/m^2
- Threshold of pain (TOP): 10 W/m^2
- Humans can perceive an incredible amount of intensity range before reaching TOP.

Intensity level is measured in decibels (dB) and is logarithmic in scale.
Decibel is a ratio between two intensity values.
Intensity of Reference (TOH) is used as a baseline to create a decibel measurement.

Equation for intensity level: : $dB(I_{TOH}) = 10\log_{10}\frac{I}{I_{TOH}}$

At 0 decibel, the threshold of hearing is reflected. Every 3 decibel, intensity doubles.

Source	Intensity	Intensity level	× TOH
Threshold of hearing (TOH)	10^{-12}	0 dB	1
Whisper	10^{-10}	20 dB	10^{2}
Pianissimo	10^{-8}	40 dB	10^{4}
Normal conversation	10^{-6}	60 dB	10^{6}
Fortissimo	10^{-2}	100 dB	10^{10}
Threshold of pain	10	130 dB	10^{13}
Jet take-off	10^{2}	140 dB	10^{14}
Instant perforation of eardrum	10^{4}	160 dB	10^{16}

From: Fundamentals of Music Processing Fuller

Loudness is a subject measure of intensity. It is the perception of a sound's intensity. Depends on duration/frequency of a sound and age. It is measured in phons.

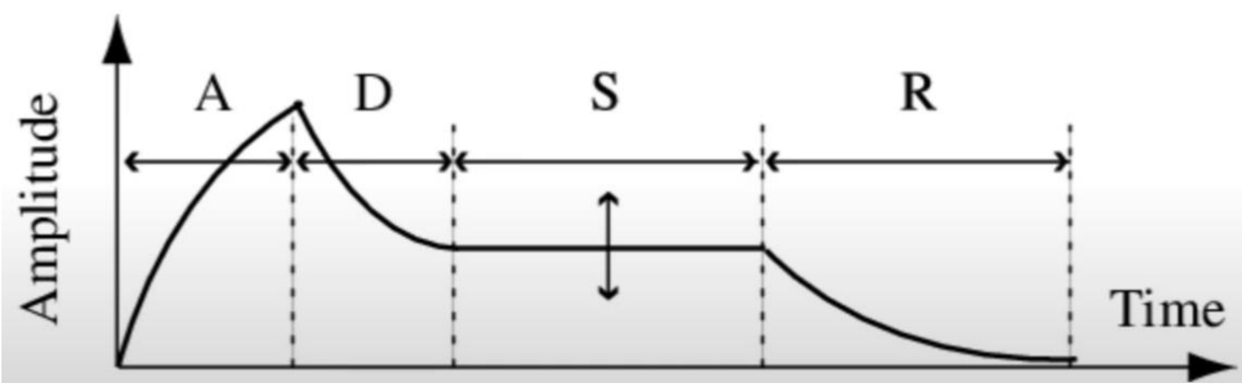
Phons are a measure of perceived loudness, even at different intensity levels. At lower frequencies, sounds are perceived less loud even at the same intensity.

Timbre is the 'color' of sound. The remaining difference between two sounds with the same intensity, frequency and duration. Words such as 'bright, dark, dull, harsh, etc.' describe timbre. Multi-dimensional measure of sound.

- Sound envelope
- Harmonic content
- Amplitude/frequency modulation

Sound Envelope

Attack-Decay-Sustain-Release Model



Harmonic Content

Complex Sound is a superposition of sinusoids. A **partial** is a sinusoid used to describe a sound.

Fundamental frequency is the lowest partial.

Harmonic partial is a frequency that is a multiple of the fundamental frequency.

- i.e. f1 = 440 hz, f2 = 2 * 440 = 880, f3 = 3 * 440 = 1320, ...
- Inharmonicity indicates a deviation from a harmonic partial.

Spectrograms show the intensity of a frequency at a specific time in the duration of an audio sample.

- One reason why two sounds may be different, despite having the same intensity, frequency and duration, is the distribution of harmonic partials. This can be shown with a spectrogram.

Frequency Modulation is periodic variation in frequency, aka vibrato. Apply a messenger signal with frequency modulation on a carrier signal to achieve effect.

Amplitude Modulation is a periodic variation in amplitude, aka tremolo. Apply a messenger signal with amplitude modulation on a carrier signal to achieve effect.