Music 175: Timbre

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Timbre

- **Timbre:**

  That quality of a sound that distinguishes it from other sounds having the same pitch and loudness.

- All quantifiable aspects of a sound contribute to timbre, but the most important is the **final perception of the listener**.
- Timbre is a result of a sound source, but can also be affected by our own listening apparatus—and critical bands.
- Important timbral factors:
  - average spectral shape (spectral rolloff of monotonically decreasing spectra)
  - "bumpy" spectra (formants)
  - "holy" spectra (missing harmonics)
  - time variation

Average Spectral Shape

- **Rolloff:** how rapidly the energy falls off as you go into the higher partials/harmonics.
- See rolloff.m: examples showing harmonic intensity falling off by 0 dB, 3 dB, 6 dB, 9 dB, and 12 dB per octave (respectively, from bottom to top).

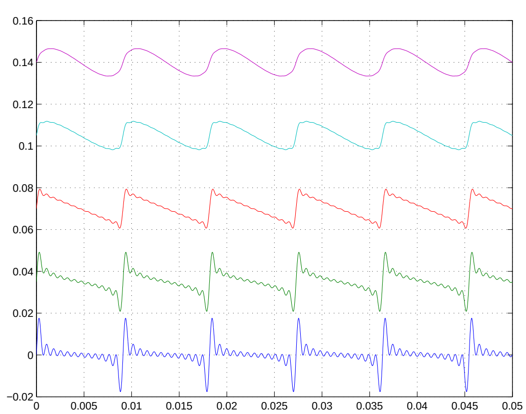

Figure 1: Spectral rolloff.

Monotonically Decreasing Spectra

- Listen progressively—they sound less bright.
- 0 dB/oct: harsh and buzzy sound
  - like the waveform near the player's mouth (or reed) in an oboe.
- 6 dB/oct: sawtooth wave—what happens when we increase the harmonics?
  - like a bowed string at the point of bowing—bow pulls the string sideways while they're stuck together, then eventually the string breaks away and slips back.
- 12 dB / oct: a smoother sound.
- 3-9 dB /oct most musically interesting.
- The greater the negative slope of spectral rolloff, the smoother the waveform, and the less bright/buzzy the sound.
- How does average spectrum effect timbre?
  - consider equal loudness curves to determine which spectral components are most important.

Formants

- Another important class of spectra are those that contain formants (peaks in the spectral envelope).

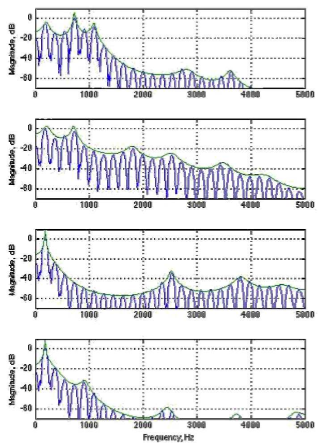

Figure 2: Spectra of different voiced vowel sounds: bart, bat, food, beet.

- Notice 3 principal formants characteristic of a vowel.
- Listen to aah.wav, ee.wav, eh.wav

Musical Instrument Formants

- The violin has many more formants than the human voice, though they don't change in time (as do those in the voice).

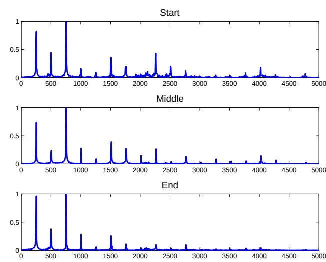

Figure 3: Violin spectrum, beginning, middle and end of a note.

- Woodwinds have fewer formants than the human voice, but they are strong and perceptually important.
- If a formant moves with pitch, the waveshape is (relatively) constant with pitch (can sound artificial).
- Fixed-frequency formants will have a spectrum that changes with pitch (potentially more interesting).

Missing Harmonics

- See holytones.m
- spectrum 1: 24 successive harmonics, with a rolloff of 3dB/oct.
- spectrum 4: the first 6 harmonics are present: 7, and 9 are left out.
- Why omit more higher harmonics than lower?
  - Critical band is 100 at low frequencies
  - changes gradually to around 20% of the frequency (minor 3rd) at higher frequencies
- If 2 sinusoids of the spectrum are
  - separated by several CBs, they don't interact and can be heard separately.
  - closer they are in frequency, they sound more fused.
  - within a CB, they sound harsh.
- Successive lower harmonics of low pitches are separated by more than a CB.

- The higher the harmonic number, the closer the harmonic spacing in CBs.
- spectrum 7: higher partials are spaced more than a CB apart (holy)
- spectrum 8: same number of partials as 7, but higher partials are deliberaltely moved closer together
- Violin tends to approximate such an effect:
  - coupling between string and soundboard rises and falls rapidly with frequency
  - valleys tend to eliminate higher harmonics that are very close in frequency
- Why holy tones 5, 6, and 7?
  - leaving out partials produces a *coloration*—may have similar "holiness" but still sound different because different partials are omitted.
- Spectrum 9 has a distinctive "octavely" quality.
- Organs use this effect:
  - different holy tones are produced using a mixture of an 8-foot stop, a 4- foot stop, and a 2-foot stop.
  - the 4-foot (an octave up) and the 2-foot (two octaves up) stops add higher harmonics, at two

and four times the harmonic spacings of the 8-foot stop.

- Organ demonstration: Click to listen

- Orchestation:
  - doubling an instrument doubles a harmonic at one or two octaves above.
  - Bolero (Ravel) with trumpet and flute in octaves. Click to listen
  - La Mer (Debussy) with trumpet and english horn in unison Click to listen

Time Variation in Sounds

- Amplitude envelopes: rapid rise and slow falls give a struck or plucked sound.
- Vibrato:
  - Voice: Maria Callas: Casta diva (1:20) Click to listen
  - instruments usually have vibrato/tremelo due to coupling of human performer.
  - Violin: Click to Listen (start at 25s)
  - Leslie speaker: Click to listen
  - Vibrato in theremin: Click to listen
- The wah-wah effect:
  - similar to vibrato, except it is higher resonances are gliding periodically.
  - Trumpet (different mutes): Click to listen
  - Miles Davis uses a wah-wah pedal (check out 1:00): Click to listen
  - Bon Jovi, Livin' on a prayer (talk box): Click to listen

- Yodeling:
  - exagerated breaks between chest and head registers
  - Click to listen
  - Click to listen—Franzl Lang

Timbre Space

- Grey used multidimensional scaling to define a "timbre space".
- Musical instrument are laid out by similarity.

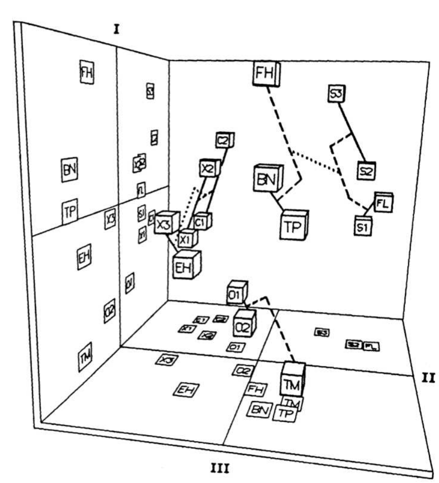

Figure 4: Grey's Timbre Space.

Multidimensional Scaling

- Timbre perception research looks at salient features (dimensions) of classes of sound.
- Timbre is a multidimensional attribute of sound.
- **Multidimensional Scaling**:
  - a means of visualizing similarity between data points (e.g. as contained in a distance matrix);
  - placing data in N-dimensional space, preserving distances between data.

Grey's experiment

- Grey's two (2) psychological distance measurements:
  1. judgement of timbral similarity:

     d = 1/similarity
  2. accuracy in associating specific names to notes:

     d $\propto$ number of confusions
- Stimulus notes were
  1. equalized for pitch, loudness, and duration;
  2. synthesized from recording, allowing for:
     - alteration of frequency, amplitude, and duration.
     - known physical properties (synthesis parameters);
     - control over complexity of physical makeup.
- Grey's experiment consisted of:
  - 35 data sets (musical subjects)
  - 16 different instrument recordings player:
    * E-flat (above middle C)
    * duration 280-400 ms

    * 240 trials: $n(n-1)$ possible pairs of $n = 16$ notes.
  - listener's similarity ratings:
    1. 1-10: very dissimilar
    2. 11-20: average level of similarity
    3. 21-30: very similar