EECS 225D Lecture 21
Pitch Detection of Speech and Music

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0. Notes

Midterm result:
- median = 42/60
- 75 percentile = 48/60
- 25 percentile = 36/60
- highest score = 57/60

Reading for Friday:
- handout (Jont Allen)

1. Frequency and Pitch

1.1 Frequency Ranges of Musical Sounds

Most instruments produce very little sound above 10 kHz and what is produced in this region is associated with noises such as bow scrapings, clinking of keys, and so forth. The tone quality of most instruments is very little affected by cutting off all frequencies above 10 kHz.
The useful range of fundamental frequencies of tones produced by musical instruments is considerably less than the audible frequency range. The highest tone of the piano has a frequency of 4186 Hz and the lowest tone has a frequency of 27.5 Hz.

1.2 Factors Affecting Pitch

Pitch is subjective evaluation of the frequency of the sound; for any given frequency there will be perceived a certain pitch, but the perception may be different in different situations, so that a specific frequency will not always have the same pitch.
To begin with, a sound must last a certain length of time in order to be assigned any pitch at all. The number of cycles required to ascribe a definite pitch to a tone depends on the frequency, and is such that on the average a sound must last 0.013 seconds to give a sensation of pitch.
The pitch of a sound of given frequency depends to some extent on its intensity. If the loudness of a pure tone is increased, a change in pitch may occur; it is generally downward at low frequencies and upward at high frequencies.

1.3 Pitch Discrimination

The ear is able to hear quite small changes in pitch. At frequencies up to about 1000 Hz, the ear can hear changes of about 3 Hz, which is equivalent to 0.05 semitones. This accounts for the poor pitch discrimination at the low end of the hearing range. At 30 Hz, for example, a 3 Hz change amounts to 10%. At higher frequencies the pitch discrimination stays constant at about

0.25%, or 0.04 semitones.

2. Consonance & Dissonance

2.1 Consonance

As long as we are willing to restrict our music to a single melody, it does not matter much how we choose the frequencies for the notes of the scale. However, music long ago passed the single-melody stage and as soon as we allow for the production of more than one note at a time, we must take into account how the combination will sound. A combination of two or more tones of different frequencies that is generally agreed to have a pleasing sound is called a *consonance*.

The Greek scholar Pythagoras is credited with the first observation of what constitutes consonance in a combination of two tones. He used for this purpose an instrument called a *monochord* (Fig. 1). With this instrument, it was found that the sounds from the two segments set into vibration simultaneously were consonant when the lengths of the segments were in the ratio 1:1, 1:2, 2:3, or 3:4.

2.2 Intervals

The ratio 1:1 is rather trivial; it is two tones of the same frequency and is called a *unison*; it would be expected to be consonant. The frequency ratio 2:1 is the *octave*, the ratio 3:2 is the *fifth*, and 4:3 is the *fourth*. This terminology refers to the keyboard on the piano.

In the evolution of music long ago there were added two new consonant intervals. These are the *major third*, with the frequency ratio 5:4, and *minor third*, with ratio 6:5. Associated with these will be their inversions, the *minor sixth*, with the ratio 8:5, and the *major sixth*, with the ratio 5:3.

The use of major and minor thirds resulted in the development of a very important three-note combination. The *major triad*, with the ratio 4:5:6, and the *minor triad*, with the ratio 10:12:15.

3. Scales

The useful frequency range to be covered by musical instruments was from 27 to 4200 Hz. In this region there are an infinite number of frequencies. The ear will not distinguish frequencies that are too close together, but with the pitch discrimination of 0.04 semitone for a good ear, there are 25 distinguishable pitches in one semitone. This will allow for a large number of pitches in the musical range, many more than have been needed. Out of this large number we select certain discrete frequencies for musical purpose; the array of chosen frequencies is called a scale.

3.1 Diatonic Scale

This scale is based on the perfect fifth. The derivation of this scale is illustrated in figure 9.2.

3.2 Just Scale

The just scale is based on three major triads and two minor triads, with all their intervals just. See figures attached.

3.3 Tempered Scale

The tempered scale divides octave into equal ratio. In this scale, the interval C-C$^{\#}$ is the same as the interval C$^{\#}$-D, and so forth. If we denote the value of this interval by *a*, the relative frequencies (in terms of the number *a*) will be then be as given in Figure 10.

References

John Backus, "The Acoustical Foundations of Music", W.W. Norton & Company, 1979