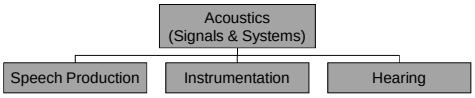
Acoustics of Speech and Hearing

Lecture 4

Harmonic Analysis/Synthesis

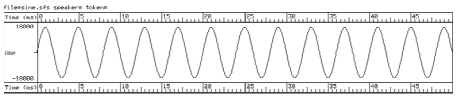
Overview



- Classification of sounds
- Simple & complex periodic sounds
- Measurement of the waveform shape of complex periodic sounds
- Amplitude Spectrum

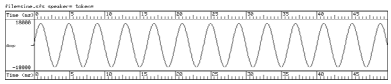
Sound

- Pressure variations
  - atmospheric pressure ± a little bit
- Microphone converts to voltage
- Oscilloscope displays voltage change with time (*a waveform*)

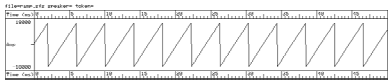


Classification of Waveforms

- Periodic Waveforms
  - Simple

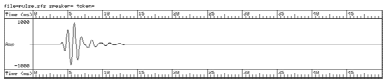


  - Complex

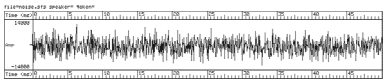


Classification of Waveforms

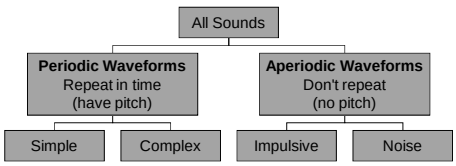
- Aperiodic
  - Impulse



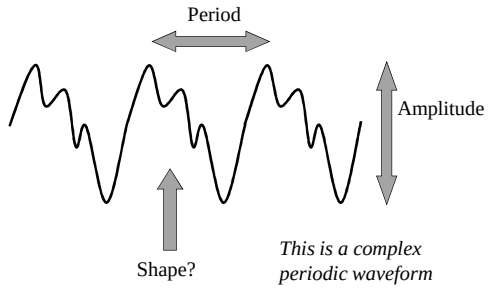
  - Noise



Classification of Waveforms

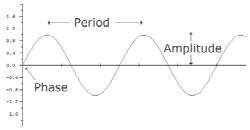


How to Measure a Waveform?



Sinewaves are Easy to Measure

- Simple Periodic Waveforms
  - called *sinusoidal* waveforms
  - only need to know 3 things:
    - period (or frequency), amplitude & phase



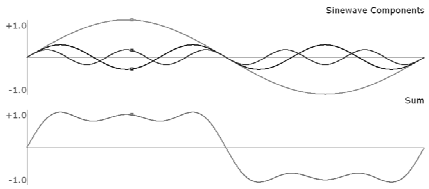
So let's describe complex sounds in terms of sinewaves!

Waveform Analysis (into sinewaves)

- of Complex Periodic Waveforms
- Key idea:
  - **if** we can reduce a complex period waveform to a combination of sinewaves,
    then we can describe it using information about the frequency, amplitude and phase of each component sinewave.
- Joseph Fourier (1768-1830)

Combining Sinewaves

- Example: build a square(-ish) wave



  - If repetition frequency = 200Hz
  - Then we've used sinewaves at 200Hz (green), 600Hz (blue), 1000Hz (red)

Fourier Analysis in Words

1. We want to analyze a complex periodic waveform
2. We assume we can build it by adding together a number of sinewaves
3. We find out that not all sinewaves are useful
4. The only sinewaves we need are those that complete a whole number of cycles within one period of the complex
5. That is: those sinewaves that occur at frequencies which are whole number multiples of the repetition frequency
6. The reason being that otherwise the sum would not have the same period as the complex

Harmonic Analysis

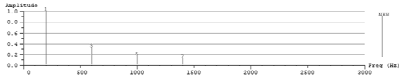
- Terminology
  - repetition frequency of a complex periodic waveform: **Fundamental frequency**
  - sinewave component at a multiple of the fundamental frequency: **Harmonic**
- Fourier's Basic Principle:
  - "*ALL* complex periodic waveforms can be analysed into a sum of harmonics".

The Spectrum

- Could list results of analysis like a recipe
  - To build a square wave, take
    - 1.00 of harmonic 1
    - 0.33 of harmonic 3
    - 0.20 of harmonic 5
    - etc
- Or could plot analysis on a graph
  - Harmonic synthesis program

The Spectrum

- A **Spectrum** is a plot of the results of harmonic analysis



  - Frequency of harmonic: horizontal axis
  - Amplitude of harmonic: vertical axis
  - Phase of harmonic: not shown

Spectral Analysis

- Analysis is the reverse of synthesis
  - finding out which harmonics you need to add together to make a given complex periodic waveform
- Spectral analysis
  - perform harmonic analysis and plot results on a spectrum.

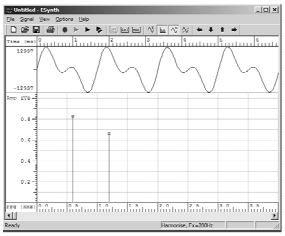
Psychoacoustics

- Loudness
  - related to intensity
- Pitch
  - related to fundamental frequency
- Timbre
  - related to relative amplitude of harmonics
    (at least for complex periodic waveforms)

Summary

- Types of waveform
- Fourier analysis of complex periodic waveforms
  - Harmonics
  - Fundamental frequency
- Amplitude spectrum
  - Allows us to make measurements of the quality of sounds

Lab Experiment



- ESynth program
- Build waveforms from sinewaves
- Build vowels from sinewaves
- Analyse real vowels into sinewaves