CS 188: Artificial Intelligence

Lecture 18: Speech

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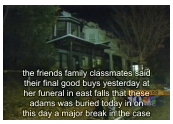
Many slides over this course adapted from Dan Klein, Stuart Russell, Andrew Moore

Speech and Language

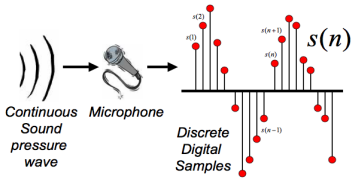
- Speech technologies
  - Automatic speech recognition (ASR)
  - Text-to-speech synthesis (TTS)
  - Dialog systems



- Language processing technologies
  - Machine translation

  - Information extraction
  - Web search, question answering
  - Text classification, spam filtering, etc…

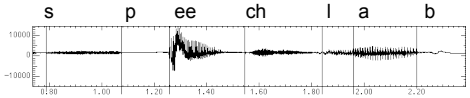
Digitizing Speech



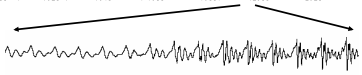
Thanks to Bryan Pellom for this slide!

Speech in an Hour

- Speech input is an acoustic wave form



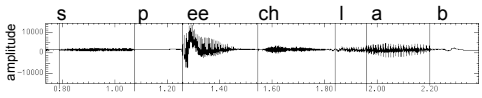
"l" to "a" transition:



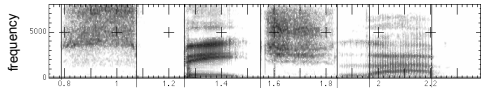
Graphs from Simon Arnfield's web tutorial on speech, Sheffield: http://www.psyc.leeds.ac.uk/research/cogn/speech/tutorial/

Spectral Analysis

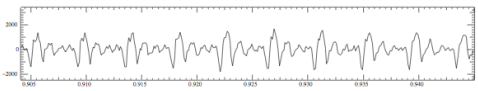
- Frequency gives pitch; amplitude gives volume
  - sampling at ~8 kHz phone, ~16 kHz mic (kHz=1000 cycles/sec)



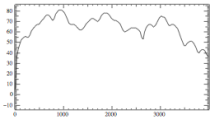
- Fourier transform of wave displayed as a spectrogram
  - darkness indicates energy at each frequency



Part of [ae] from "lab"



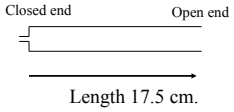
- Complex wave repeating nine times
  - Plus smaller wave that repeats 4x for every large cycle
  - Large wave: freq of 250 Hz (9 times in .036 seconds)
  - Small wave roughly 4 times this, or roughly 1000 Hz

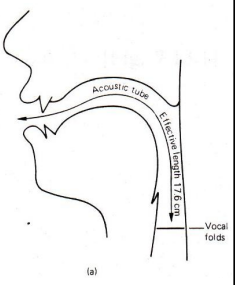


[demo]

Resonances of the vocal tract

- The human vocal tract as an open tube

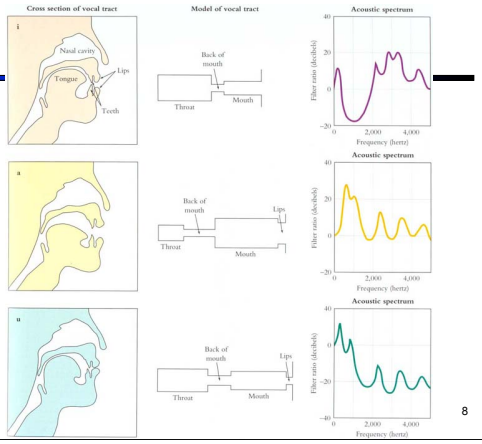




- Air in a tube of a given length will tend to vibrate at resonance frequency of tube.
- Constraint: Pressure differential should be maximal at (closed) glottal end and minimal at (open) lip end.

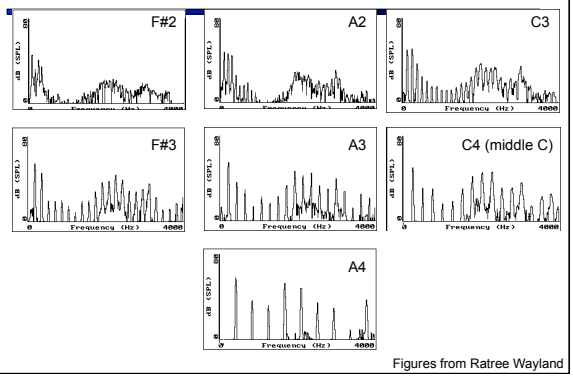
Figure from W. Barry Speech Science slides

[demo]



From Mark Liberman's website

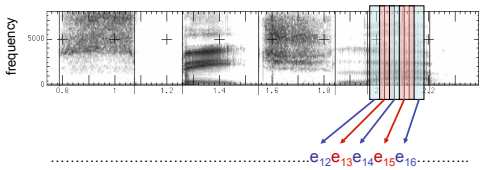
Vowel [i] sung at successively higher pitches



Figures from Ratree Wayland

Acoustic Feature Sequence

- Time slices are translated into acoustic feature vectors (~39 real numbers per slice)

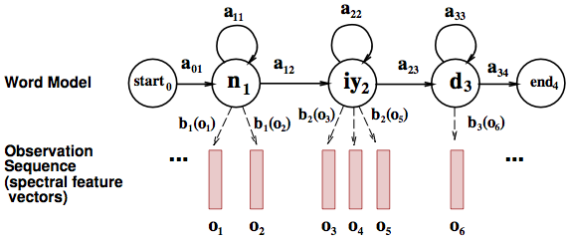


- These are the observations, now we need the hidden states X

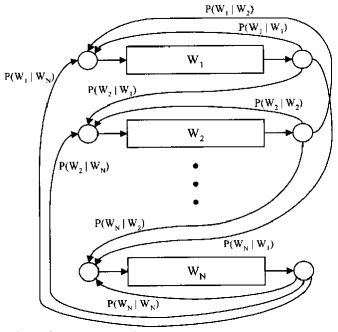
State Space

- P(E|X) encodes which acoustic vectors are appropriate for each phoneme (each kind of sound)
- P(X|X') encodes how sounds can be strung together
- We will have one state for each sound in each word
- From some state x, can only:
  - Stay in the same state (e.g. speaking slowly)
  - Move to the next position in the word
  - At the end of the word, move to the start of the next word
- We build a little state graph for each word and chain them together to form our state space X

HMMs for Speech



Transitions with Bigrams



Training Counts

198015222 the first
194623024 the same
168504105 the following
158562063 the world
…
14112454 the door

23135851162 the *

$$\hat{P}(\text{door}|\text{the}) = \frac{14112454}{23135851162}$$

$$= 0.0006$$

Figure from Huang et al page 618

Decoding

- While there are some practical issues, finding the words given the acoustics is an HMM inference problem
- We want to know which state sequence $x_{1:T}$ is most likely given the evidence $e_{1:T}$:

$$x^*_{1:T} = \arg\max_{x_{1:T}} P(x_{1:T}|e_{1:T})$$
$$= \arg\max_{x_{1:T}} P(x_{1:T}, e_{1:T})$$

- From the sequence x, we can simply read off the words

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