Speech recognition and synthesis

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- Pitch and F0
- Spectrum
- Spectrograms
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Introduction

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All technology starts with quantitative modelling

- Speech technology is about speech sounds
- Only limited knowledge of human speech production and perception is necessary for modeling speech sounds
- In practice, knowledge about human speech is only used implicitely

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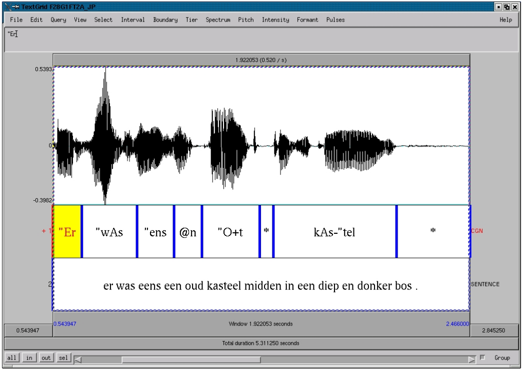
Waveforms: Oscillogram



"Er was eens een oud kasteel"

- Display of presure versus time
- Words are aligned with sound
- Using computer readable (SAMPA) phoneme symbols

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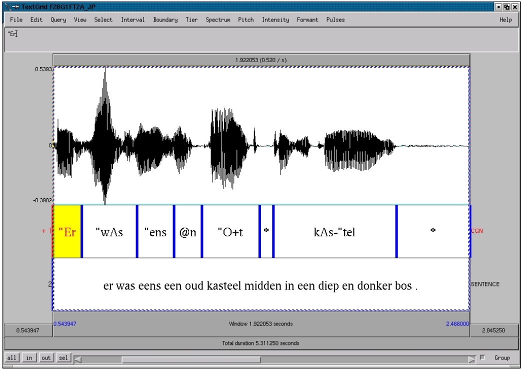

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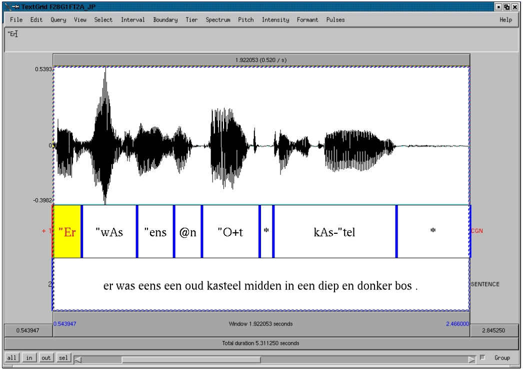

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Waveforms: Digital sound and band-width

1.5 ms of an /s/ sound from "was"

- Samples taken at 44.1 kHz (CD audio)
- Quantisize at 16 bit (≈ 65000 amplitude levels)
- Maximum audio frequency 22.05 kHz (Nyquist frequency) but generally *much* less
- Dynamic Range ≈ 96*db* (≈ 6*db*/*bit*)

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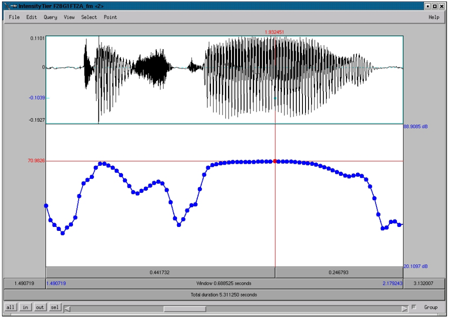

Intensity contour of "Kasteel"

- Intensity versus amplitude
- Intensity in db ($10 \cdot log_{10}(SoundEnergy)$)
- Intensity you hear is not the intensity you measure $\Rightarrow$ correct for human perception (dBA)

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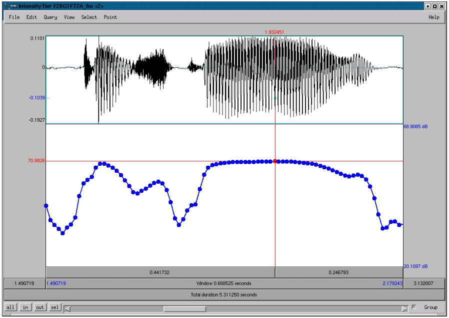

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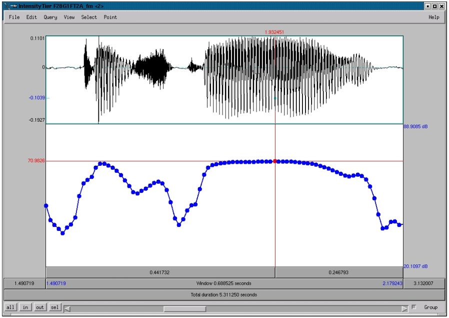

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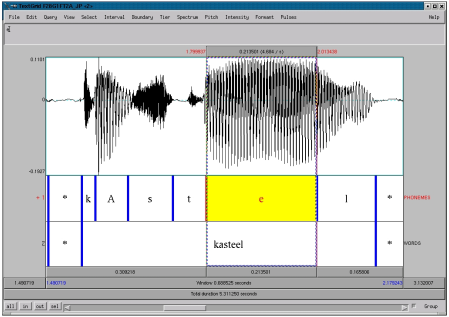

Phoneme segmentation of "Kasteel"

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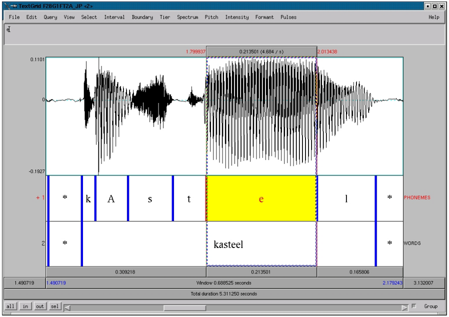

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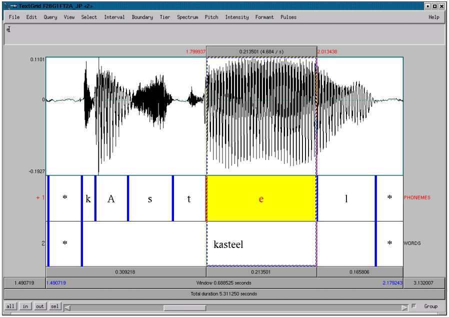

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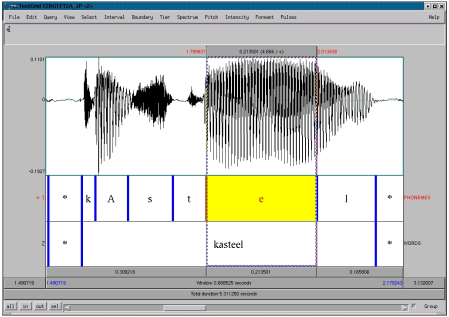

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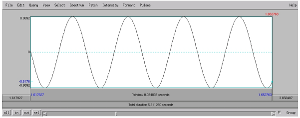

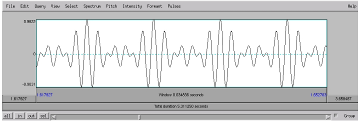

Pitch or F_0 is the *perception* of a harmonic sequence. Generally, perceived *pitch* is the:

- frequency of a pure tone (top, 125 Hz)
- distance between the components in a mixture of harmonic tones (eg, 125 Hz)
- closest harmonic fit in complex sounds (bells)

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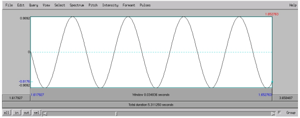

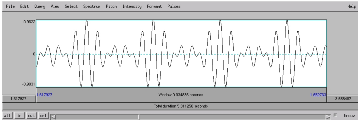

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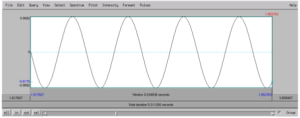

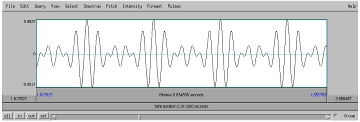

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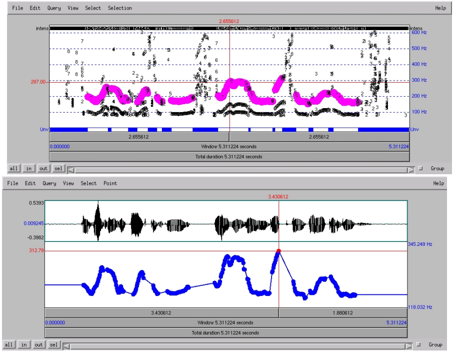

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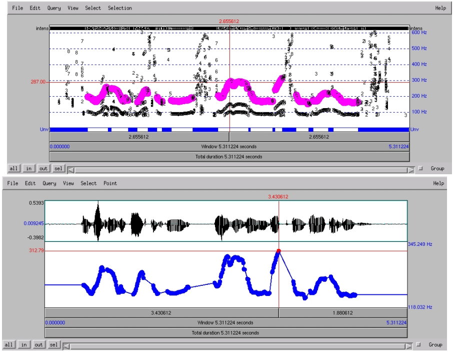

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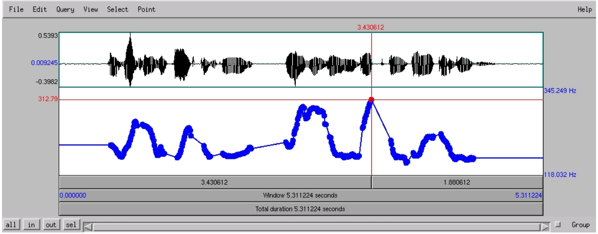

Hummed sound

F_0 makes the melody, or intonation, of an utterance

- There is a general decrease of F_0 over an utterance: The *declination*
- F_0 movements indicate emphasized words: pitch *accents*
- F_0 movements and *declination resets* indicate boundaries

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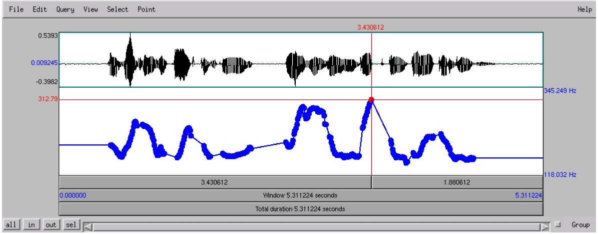

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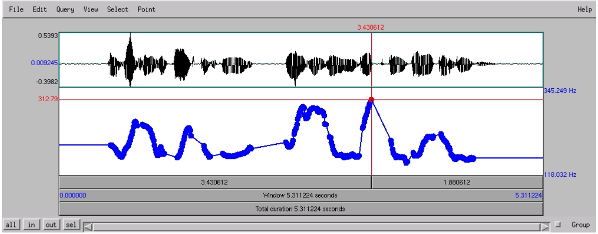

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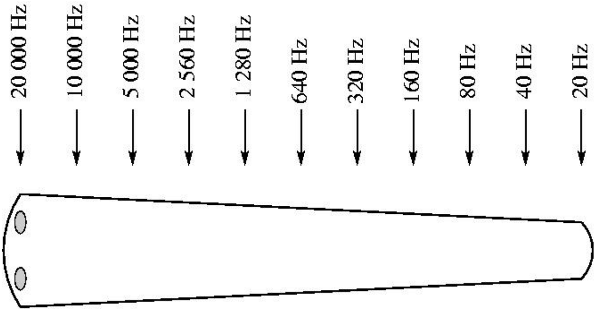

Frequency map of the cochlea from [Moore(2003)]

- The ear analyses sounds roughly into $Log\,(Power\,(Frequency))$ vs. $Log\,(Frequency)$
- Speech is analyzed in the same way
- Use power spectra of sounds

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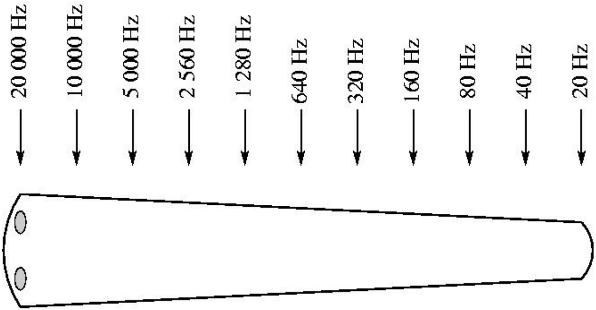

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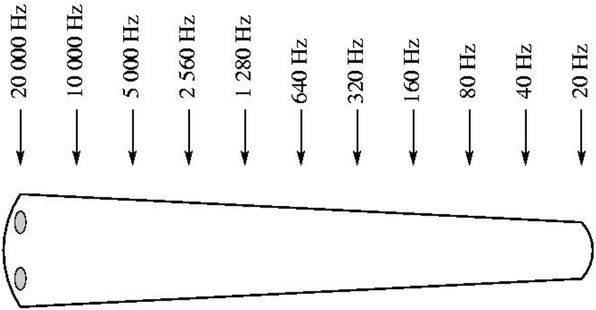

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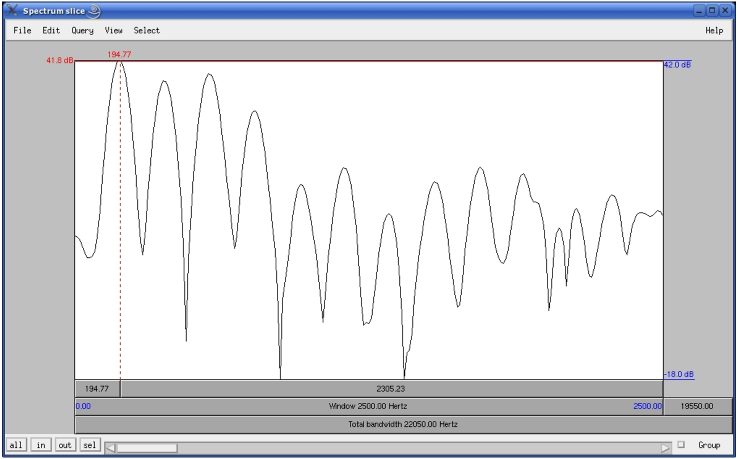
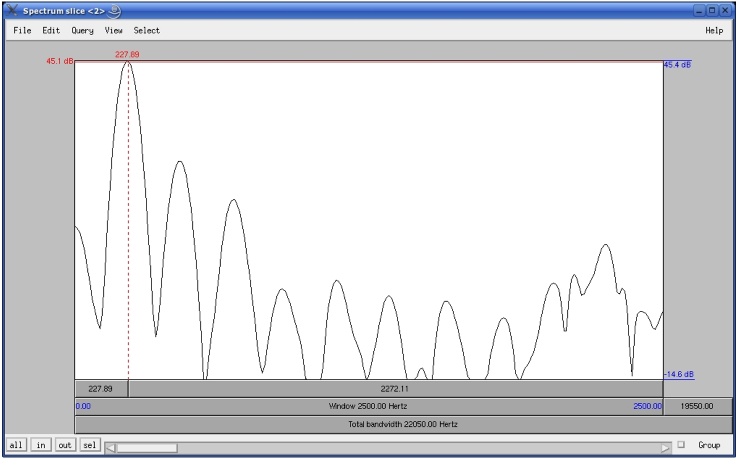
Spectrum: Example of /ε/



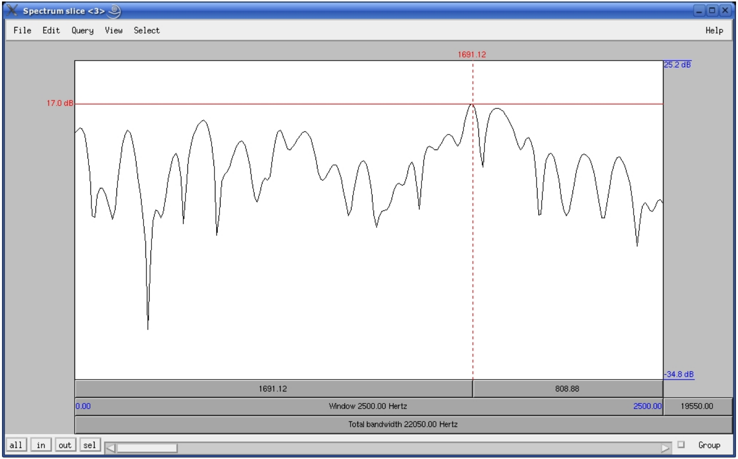
Note the harmonic structure and the "bumps"

Spectrum: Example of /n/



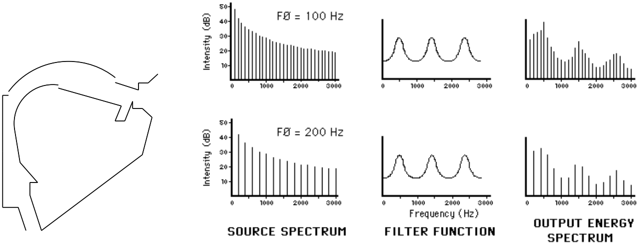
Note the harmonic structure and the low level of high frequencies

Spectrum: Example of /s/



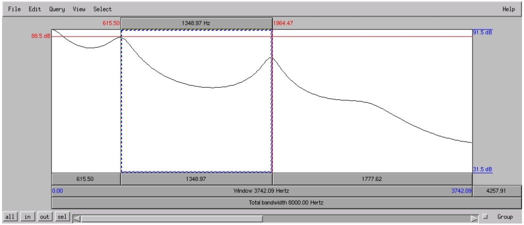
Note the noisy structure and the broad bandwidth

Spectrum: Source Filter model of speech



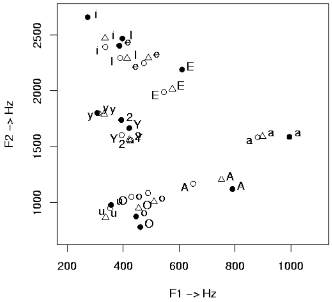
Sound enters the oral cavity (vocal tract) from below and is filtered by the resonances of the cavity

Spectrum: Resonances and formants



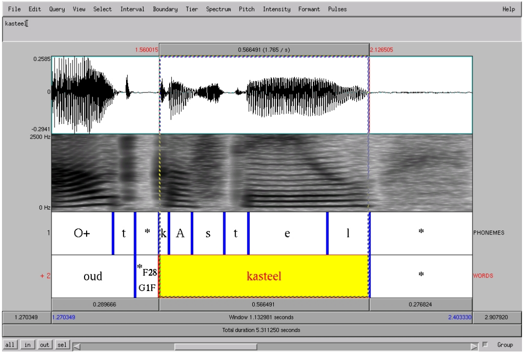
Oral cavity filter function of /ɛ/ (LPC model). Peaks are formants F_1 and $F2$.
The resonances of the vocal tract are called Formants, and numbered from below, i.e., F_1, F_2, F_3, $\cdots$. Normally, the first three are sufficient to describe (voiced) speech.

Spectrum: Vowel Formant space



Vowel formant space of Dutch.
Only two formant values, F_1 and F_2, suffice to identify a vowel (in the ideal case). However, in normal speech, there is so much overlap and variation that it remains almost impossible.

Spectrograms



A spectrogram shows the development of the spectrum in time (darker is more power)

- A spectrogram shows the harmonics
- Vowels, fricatives, and plosives are visible

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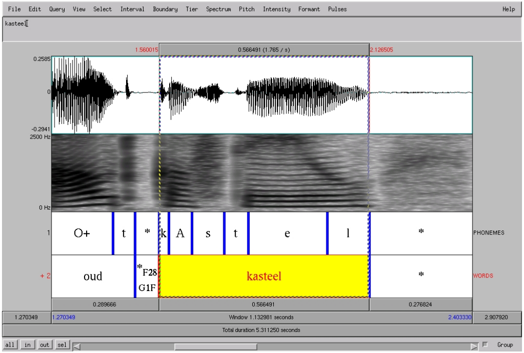

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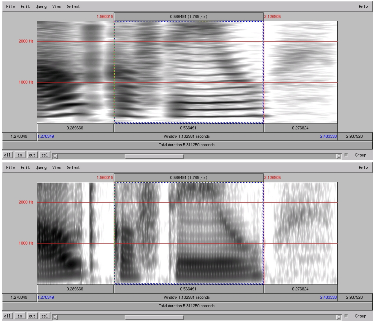
Spectrograms: Narrow versus Wide band



Two views on spectrograms

- Narrow-band (top): High frequency resolution, low time resolution
- Wide-band (bottom): Low frequency resolution, high time resolution

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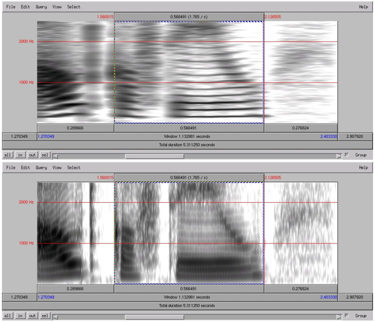

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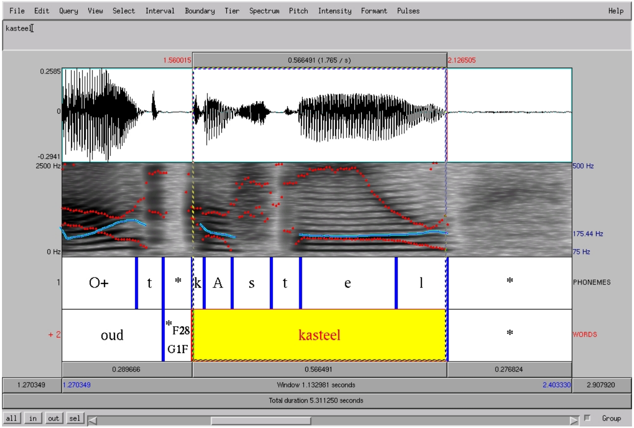
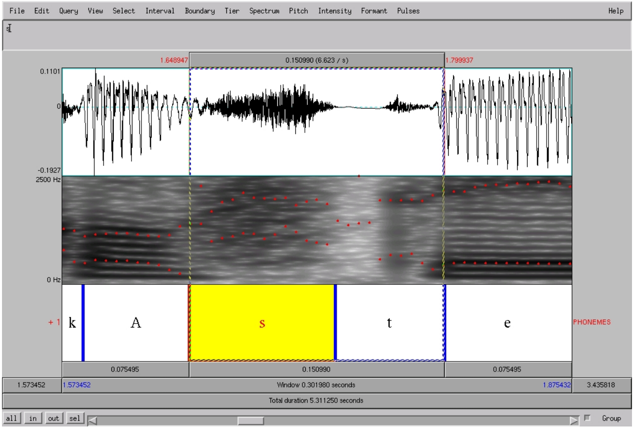
Spectrograms: Formant and Pitch tracking



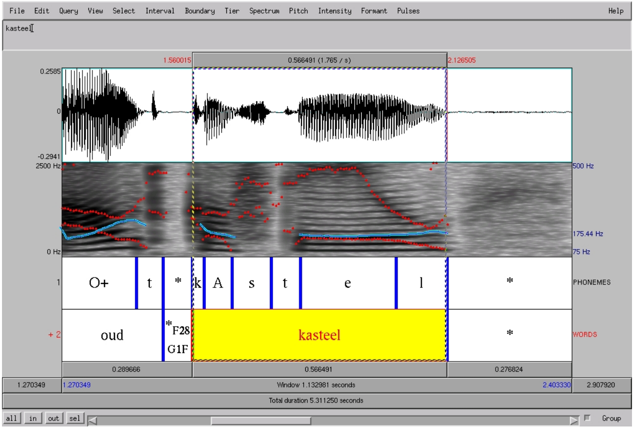
Formants (red dots) and Pitch (blue line) can be automatically determined and plotted into a spectrogram.

Spectrograms: Noise and bursts



Fricatives are visible as gray noise patches. Plosives as a silent part followed by a noisy burst.

Spectrograms: Spectrogram reading



It is actually possible, after a few weeks training, to read spectrograms. All the information needed to "understand" the speech is in the spectrogram [Lander and Carmell(1997)].

Transcription: Transliteration

Before anything can be done with speech, it has to be written down and transcribed

- Write out orthographically what was said (and check it)
- Align chunks of text roughly with the stretches of speech
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Human annotator transcriptions: Difficult and expensive

- Accents, stress, and boundaries (always ambiguous)
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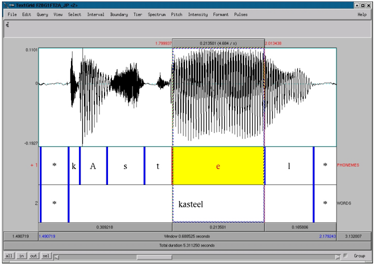

Phonemes are not pearls on a string

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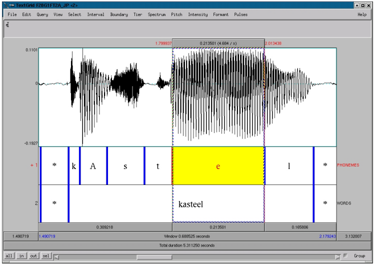

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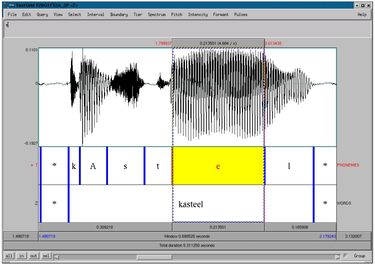
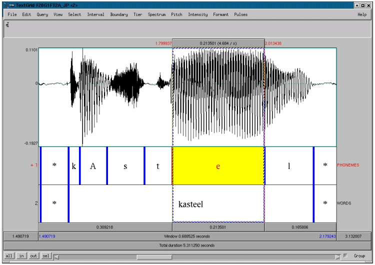
Transcription: Identifying and annotating phonemes



Phonemes are not pearls on a string

- Phonemes always overlap and are extremely variable
- A phoneme you hear can appear absent in the waveform
- It is often unclear what phonemes were uttered
- Sometimes, even the order is unclear

Transcription: Identifying and annotating phonemes



Phonemes are not pearls on a string

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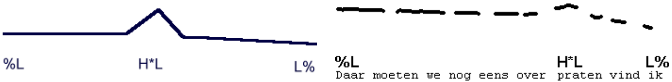
- Sometimes, even the order is unclear

Transcription:
ToBI like systems for intonation transcription



ToDI symbols
[Gussenhoven et al.(2003)Gussenhoven, Rietveld, Kerkhoff, and Terken]
(IP: Intonational Phrase)

High	Low	description
H*	L*	high/low accent
H	L	upward/downward movement after L*/H*
H%	L%	rising/low ending of IP
%H	%L	high/low beginning of IP
%HL		Initial falling pitch not marking accent
%		half-completed fall/rise at end of IP
!H*		downstepped H*

Assignment- 3 Spectrogram and spectrum

See BlackBoard for full description

- Use a recorded sentence (assignment 2).
- Determine durations of all vowels (max 10)
- Determine the spectrum of a single (monophthong) vowel
- Calculate the spectrogram
- Draw waveform, spectrum, and spectrogram

Assignment- 3 Spectrogram and spectrum

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Assignment- 3 Spectrogram and spectrum

Measuring Speech
Introduction
Waveforms
Pitch and F0
Spectrum
Spectrograms
Transcription
Assignment
Bibliography

See BlackBoard for full description

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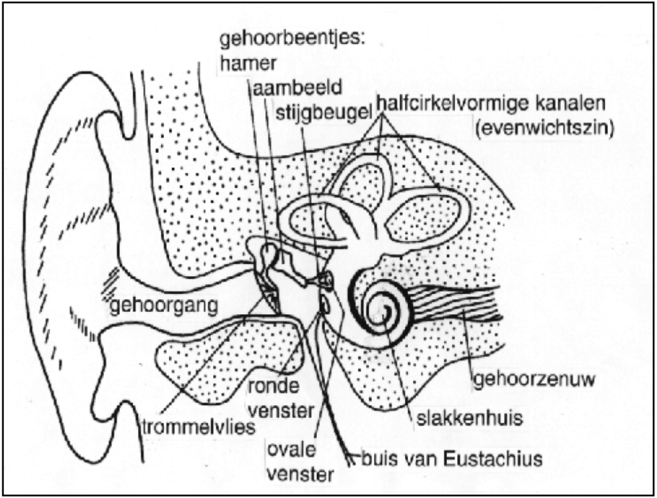
Appendix A

The inner ear



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