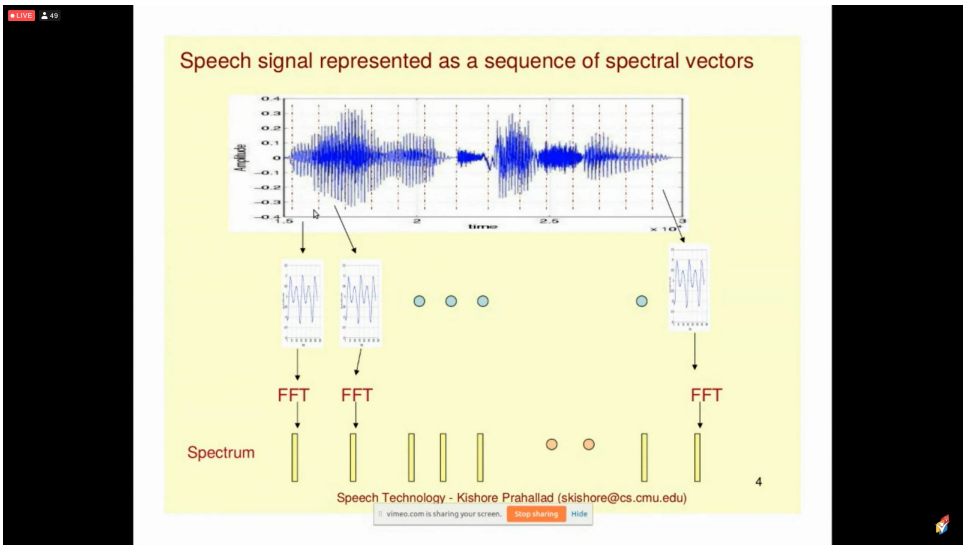
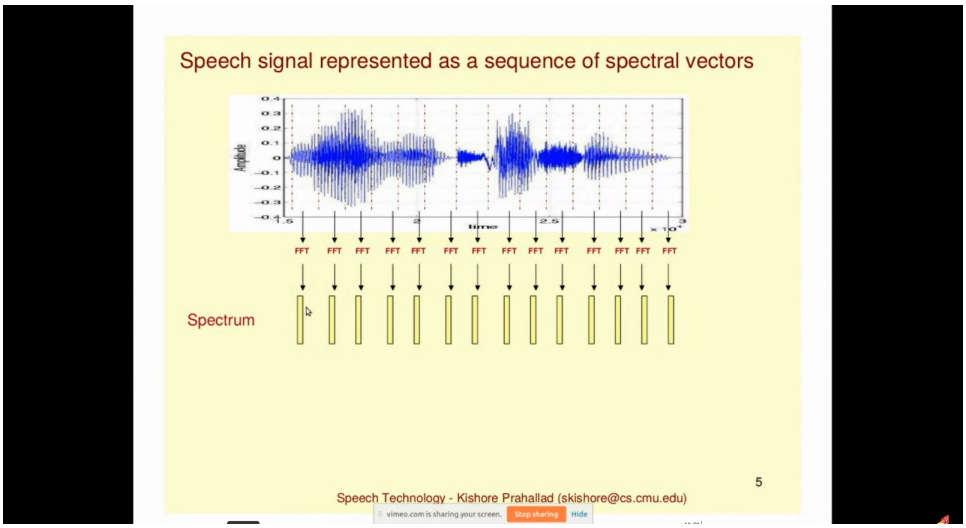
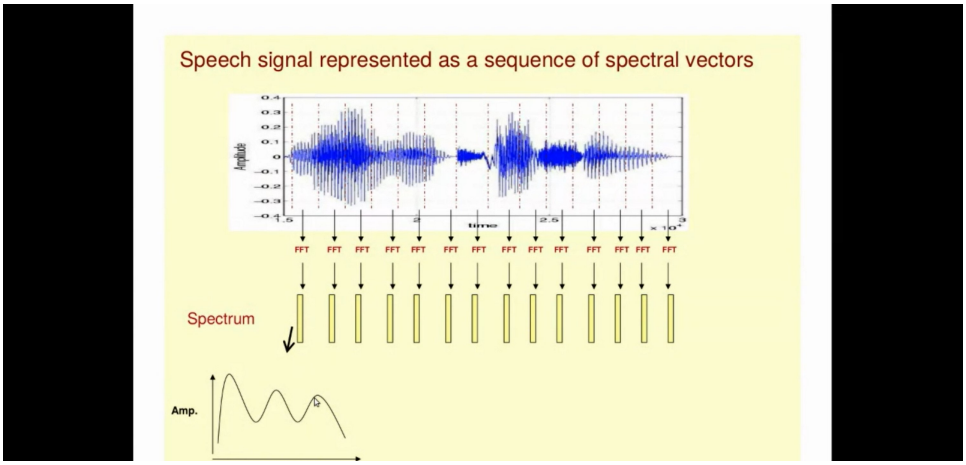
Introduction to Feature Extraction

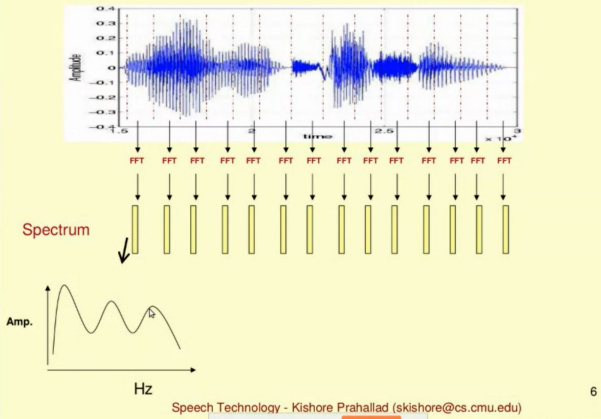
07 April 2021 12:57 AM







Speech signal represented as a sequence of spectral vectors



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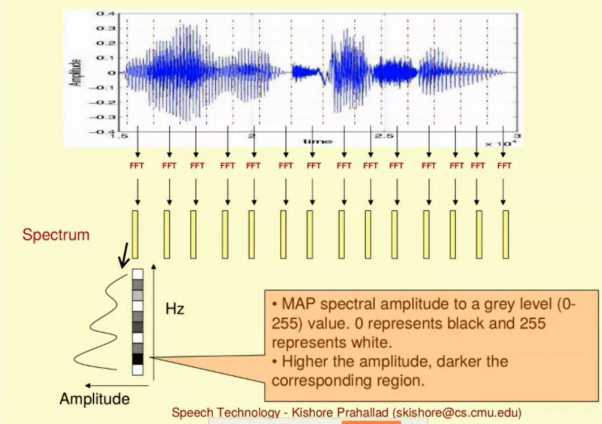

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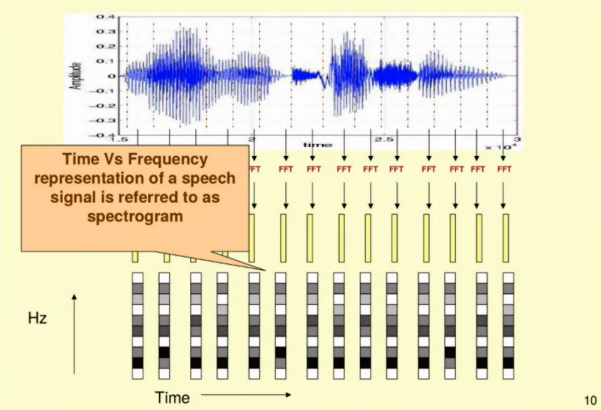

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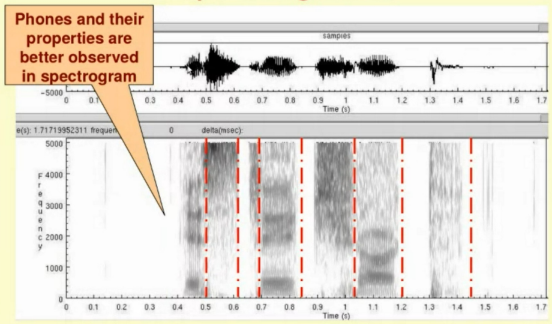
Why we are bothered about spectrograms



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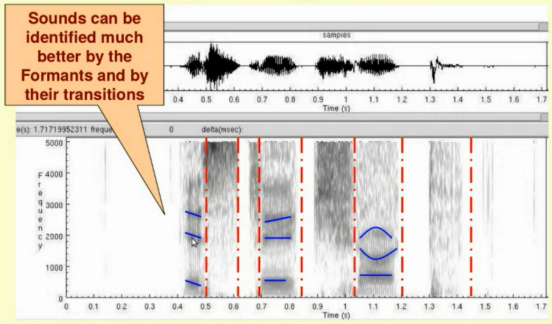

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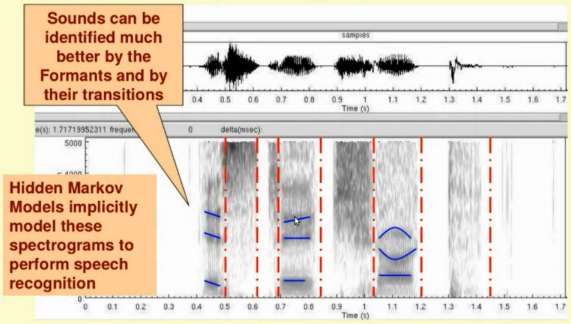
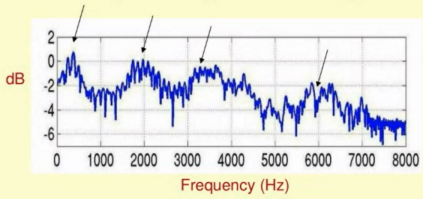


Usefulness of Spectrogram

- Time-Frequency representation of the speech signal
- Spectrogram is a tool to study speech sounds (phones)
- Phones and their properties are visually studied by phoneticians
- Hidden Markov Models implicitly model spectrograms for speech to text systems
- Useful for evaluation of text to speech systems
  - A high quality text to speech system should produce synthesized speech whose spectrograms should nearly match with the natural sentences.

Cepstral Analysis

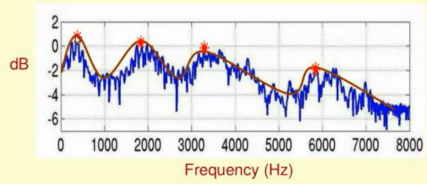
A Sample Speech Spectrum



- Peaks denote dominant frequency components in the speech signal
- Peaks are referred to as formants
- Formants carry the identity of the sound

What we want to Extract? – Spectral Envelope

- Formants and a smooth curve connecting them
- This Smooth curve is referred to as spectral envelope

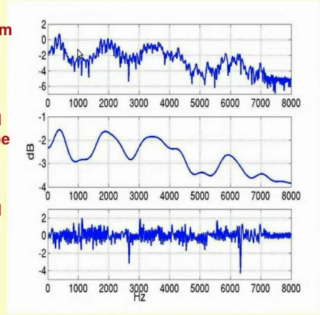


Spectral Envelope

Spectrum

Spectral Envelope

Spectral details



Spectral Envelope

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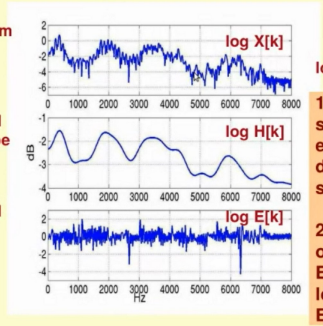


log X[k] = log H[k] + log E[k]

1. Our goal: We want to separate spectral envelope and spectral details from the spectrum.

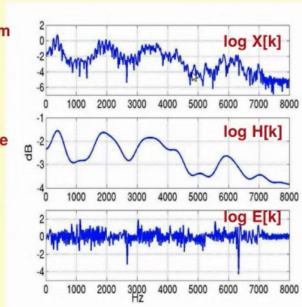
2. i.e Given log X[k], obtain log H[k] and log E[k], such that log X[k] = log H[k] + log E[k]

Spectral Envelope

Spectrum

Spectral Envelope

Spectral details



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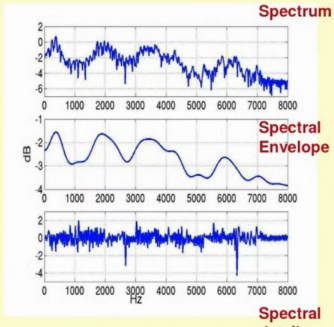
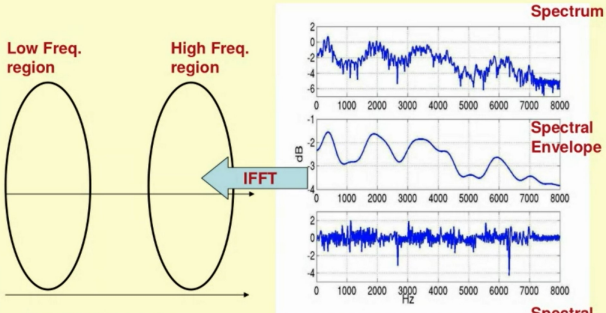
2. i.e Given log X[k], obtain log H[k] and log E[k], such that log X[k] = log H[k] + log E[k]

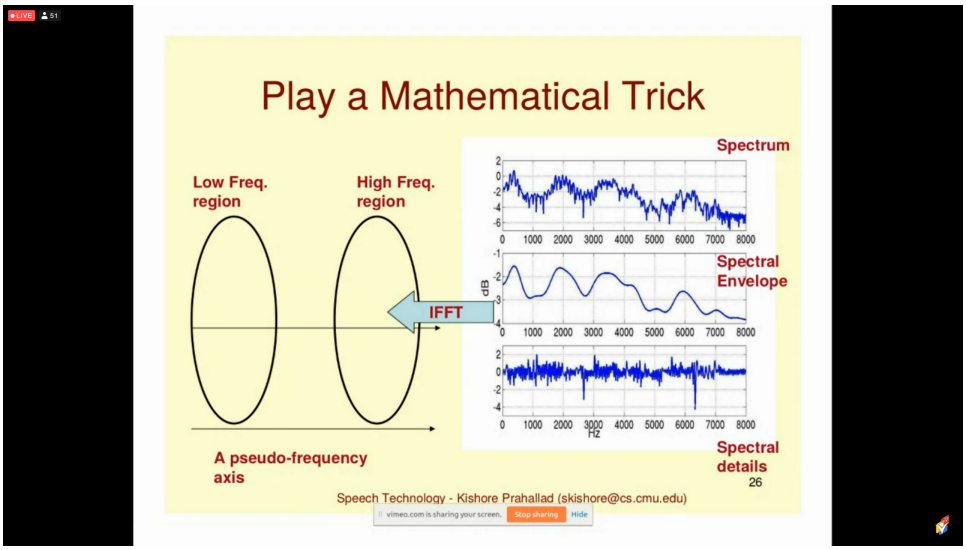
Play a Mathematical Trick

- Trick: Take FFT of the spectrum!!
- An FFT on spectrum referred to as Inverse FFT (IFFT).
- Note: We are dealing with spectrum in log domain (part of the trick)
- IFFT of log spectrum would represent the signal in pseudo-frequency axis



Play a Mathematical Trick




Play a Mathematical Trick
Low Freq. region
High Freq. region
IFFT
Spectrum
Spectral Envelope
Spectral details
A pseudo-frequency axis
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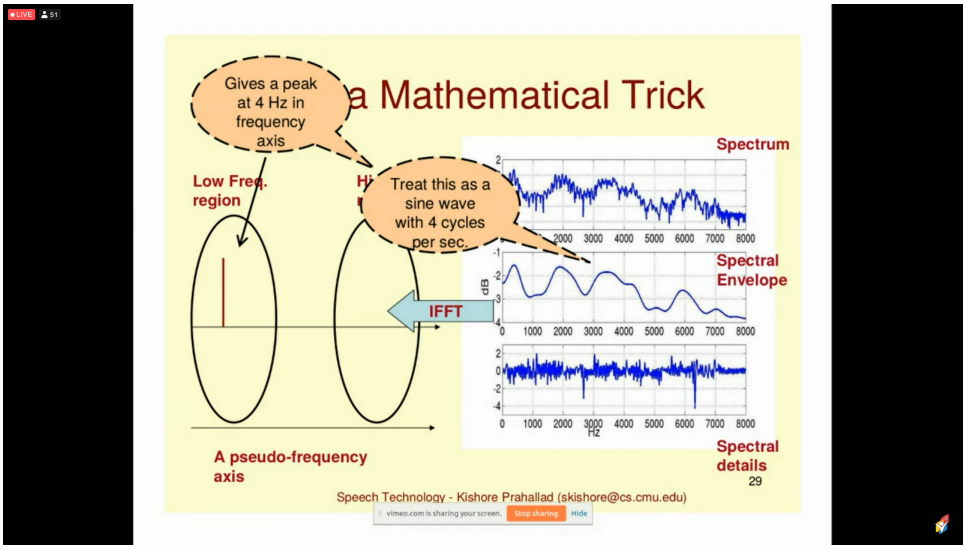
26


Gives a peak at 4 Hz in frequency axis
Treat this as a sine wave with 4 cycles per sec.
Low Freq. region
IFFT
Spectrum
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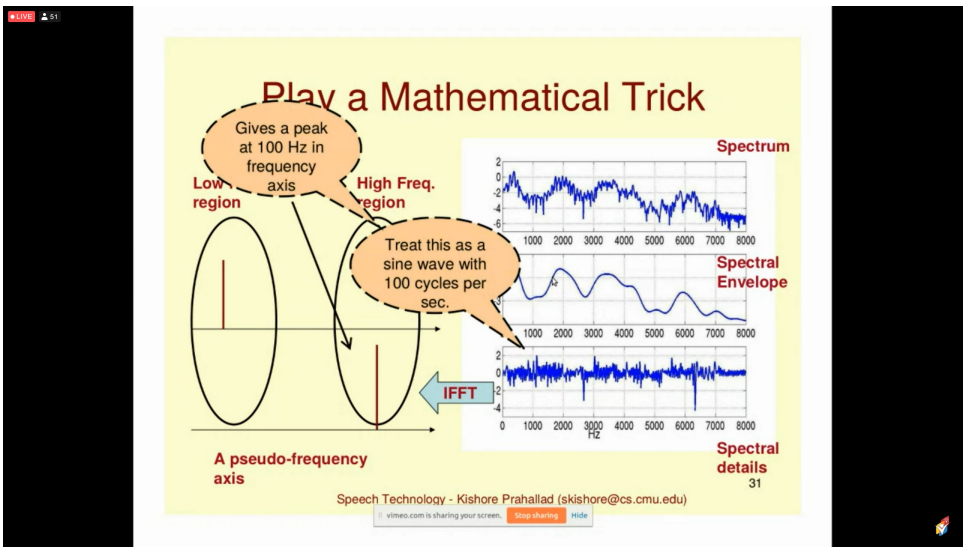
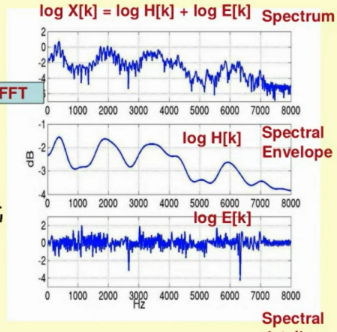

Gives a peak at 100 Hz in frequency axis
High Freq. region
Treat this as a sine wave with 100 cycles per sec.
IFFT
Spectrum
Spectral Envelope
Spectral details
A pseudo-frequency axis
Speech Technology - Kishore Prahallad (skishore@cs.cmu.edu)
31

Play a Mathematical Trick

x[k] = h[k] + e[k]

IFFT

log X[k] = log H[k] + log E[k]



If you know x[k]
Filter the low frequency region to get h[k]

A pseudo-frequency axis

Cepstral Analysis

$$X[k] = H[k]E[k]$$

$$\|X[k]\| = \|H[k]\| \; \|E[k]\|$$

$\|.\|$ –denotes magnitude

Take Log on both sides

$$\log\|X[k]\| = \log\|H[k]\| + \log\|E[k]\|$$

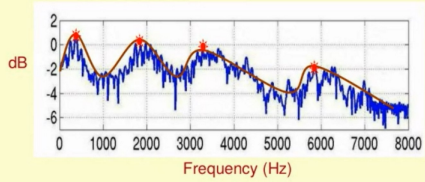
Taking inverse FFT on both sides

$$x[k] = h[k] + e[k]$$

Mel-Frequency Analysis

Review: What we did

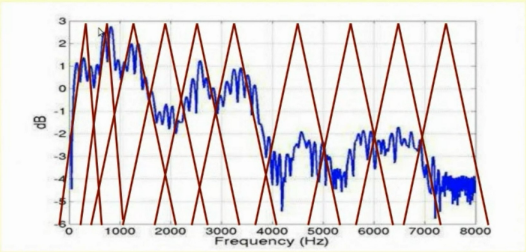
- We captured spectral envelope (curve connecting all formants)
- BUT: Perceptual experiments say human ear concentrates on certain regions rather than using whole of the spectral envelope….



Mel-Frequency Analysis

- Mel-Frequency analysis of speech is based on human perception experiments
- It is observed that human ear acts as filter
  - It concentrates on only certain frequency components
- These filters are non-uniformly spaced on the frequency axis
  - More filters in the low frequency regions
  - Less no. of filters in high frequency regions

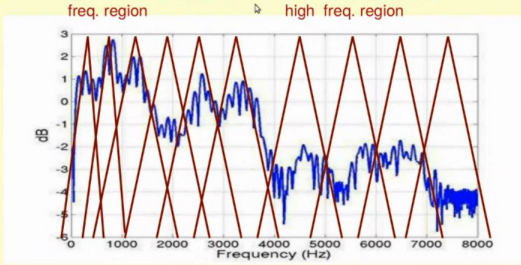
Mel-Frequency Filters



Mel-Frequency Filters

More no. of filters in low freq. region

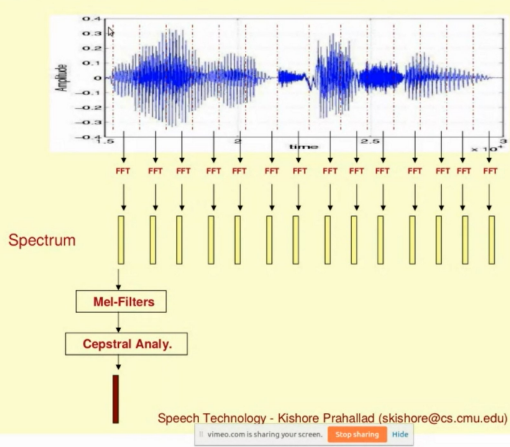
Lesser no. of filters in high freq. region



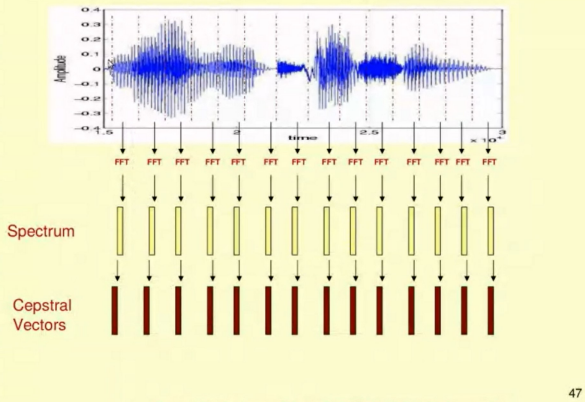
Mel-Frequency Cepstral Coefficients (MFCC)

- Spectrum → Mel-Filters → Mel-Spectrum
- Say log X[k] = log (Mel-Spectrum)
- NOW perform Cepstral analysis on log X[k]
  - log X[k] = log H[k] + log E[k]
  - Taking IFFT
  - x[k] = h[k] + e[k]
- Cepstral coefficients h[k] obtained for Mel-spectrum are referred to as Mel-Frequency Cepstral Coefficients often denoted by *MFCC*

Speech signal represented as a sequence of spectral vectors



Speech signal represented as a sequence of CEPSTRAL vectors



Why we are going to use MFCC

- Speech synthesis
  - Used for joining two speech segments S1 and S2
  - Represent S1 as a sequence of MFCC
  - Represent S2 as a sequence of MFCC
  - Join at the point where MFCCs of S1 and S2 have minimal Euclidean distance
- Used in speech recognition
  - MFCC are mostly used features in state-of-art speech recognition system

Summary: Process of Feature Extraction

- Speech is analyzed over short analysis window
- For each short analysis window a spectrum is obtained using FFT
- Spectrum is passed through Mel-Filters to obtain Mel-Spectrum
- Cepstral analysis is performed on Mel-Spectrum to obtain Mel-Frequency Cepstral Coefficients
- Thus speech is represented as a sequence of Cepstral vectors
- It is these Cepstral vectors which are given to pattern classifiers for speech recognition purpose