Bengali Spoken Digit Classification: A Hidden Markov Model Approach

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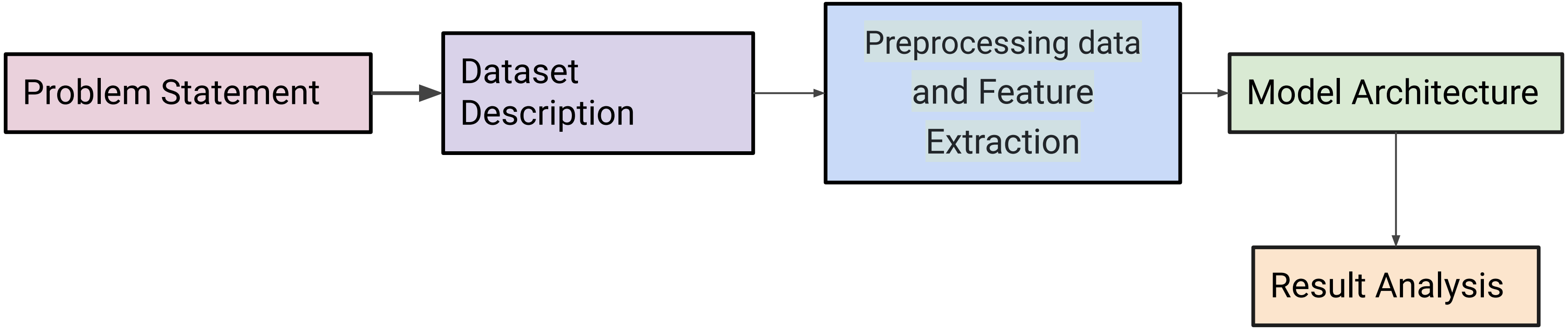
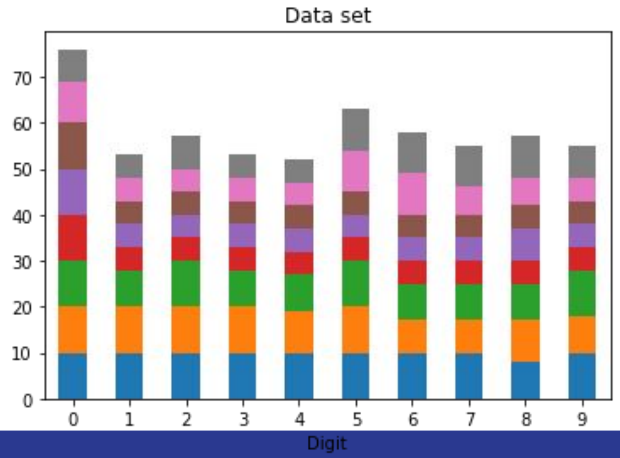

Problem Statement
Dataset Description
Preprocessing data and Feature Extraction
Model Architecture
Result Analysis

Dataset Description

Dataset Description

- A dataset containing 600 audio file (.wav format) was created for the experiment.
- Eight people from various parts of the State were asked to give their voice recordings Using “QuickRec” App.



Bengali word	Bengali pronunciation	English word	English numerical
শূন্য	shun-no	zero	0
এক	a-k	one	1
দুই	du-i	two	2

Preprocessing and Feature Extraction

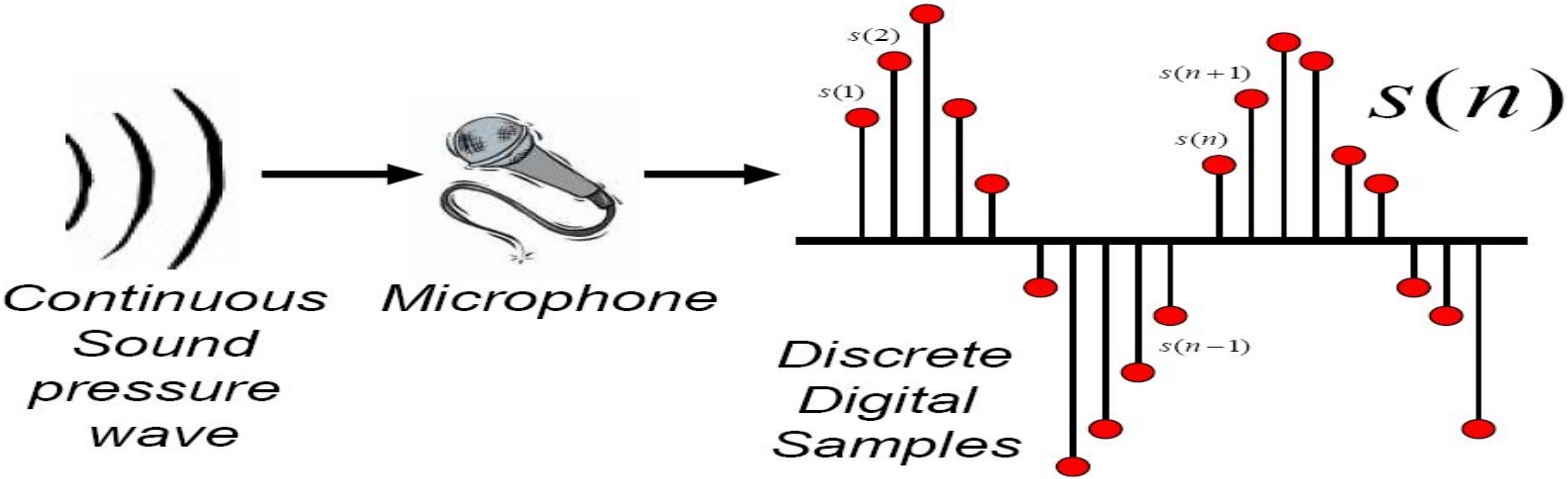
Discrete Representation of Signal :

Analog-to-digital conversion has two steps :

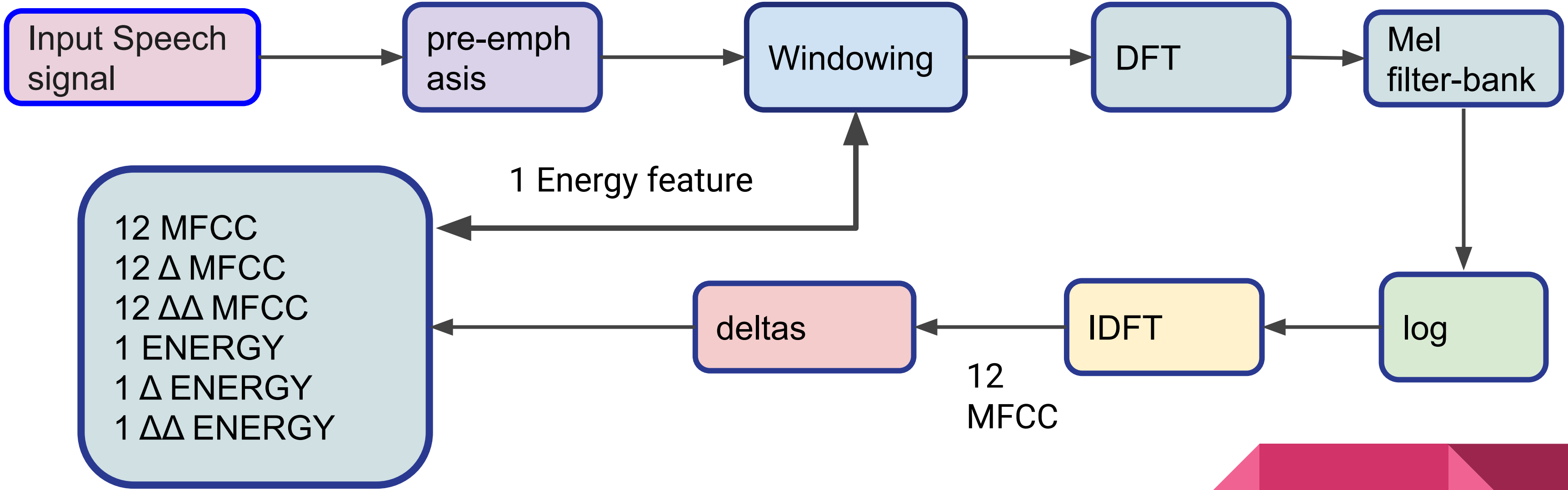
Sampling = 2 * Nyquist frequency

+

Quantization = store the amplitude value as 8 bit or 16 bit



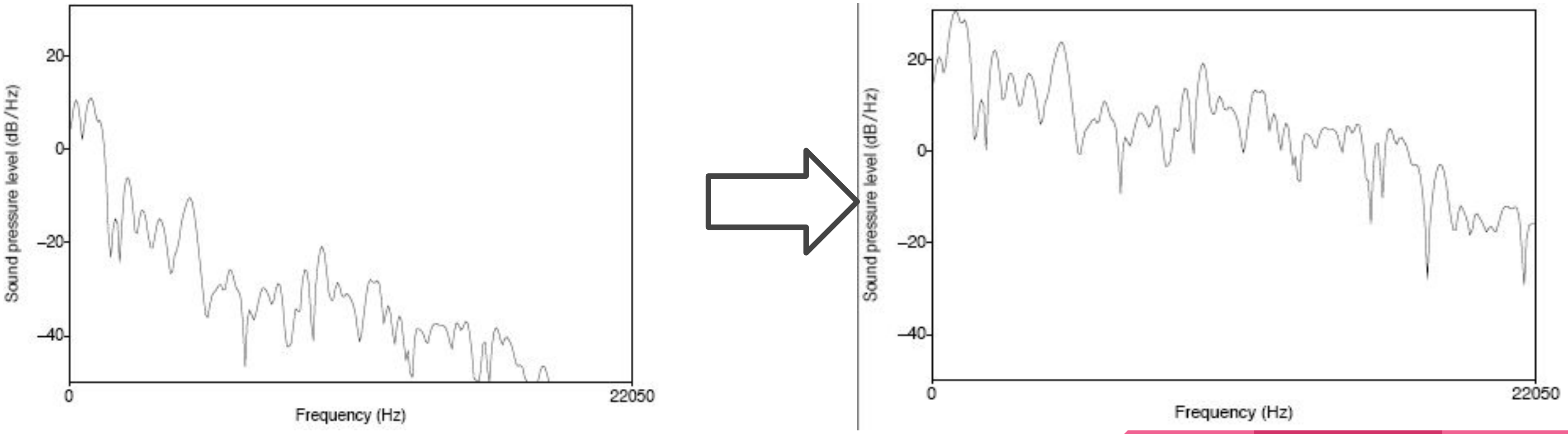
Preprocessing data and MFCC Feature Extraction :



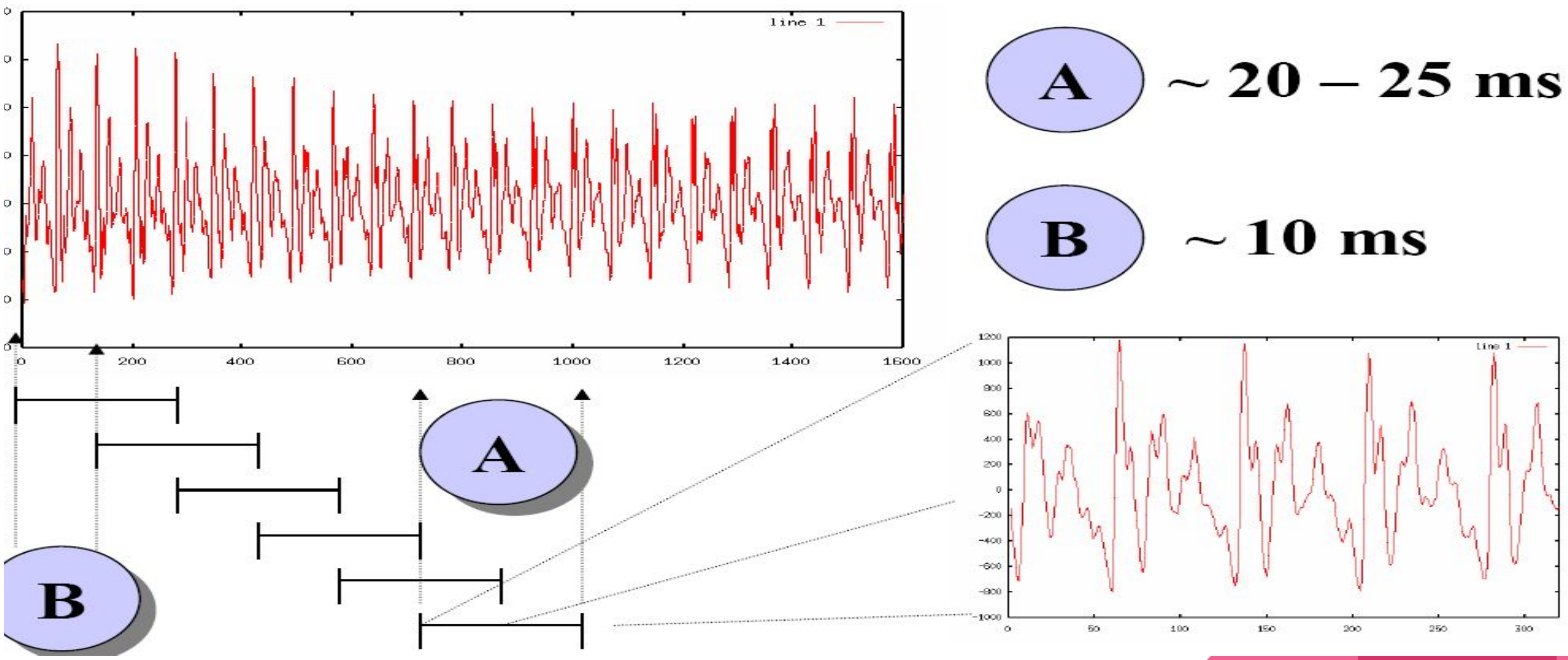
Preemphasis :

- The spectrum for voiced segments has more energy at lower frequencies than higher frequencies. This is called **spectral tilt**
- Spectral tilt is caused by the nature of the glottal pulse

Spectral slice from the vowel [aa]



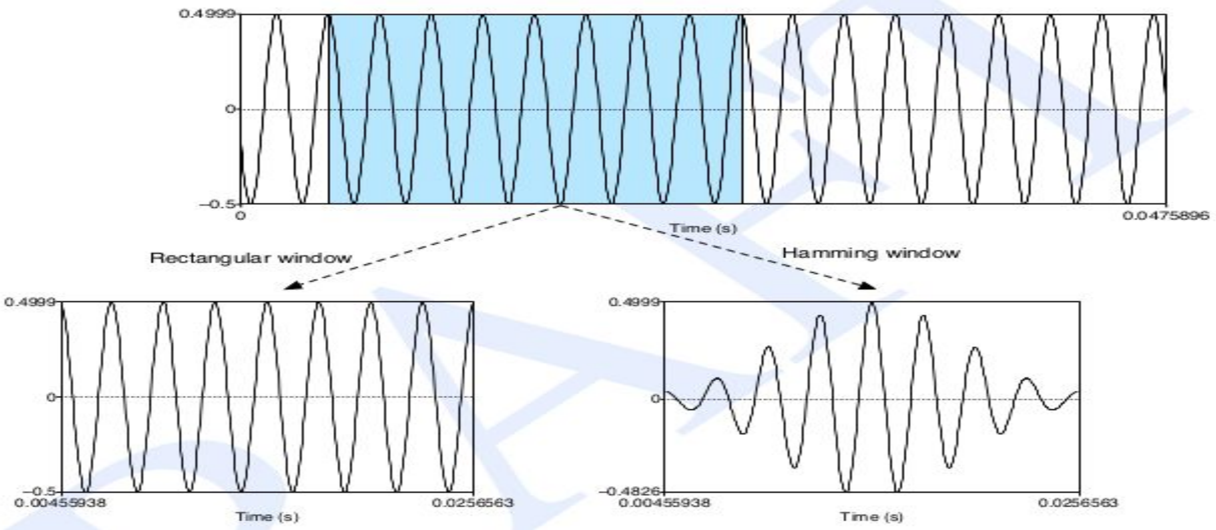
Windowing :



Common window shapes :

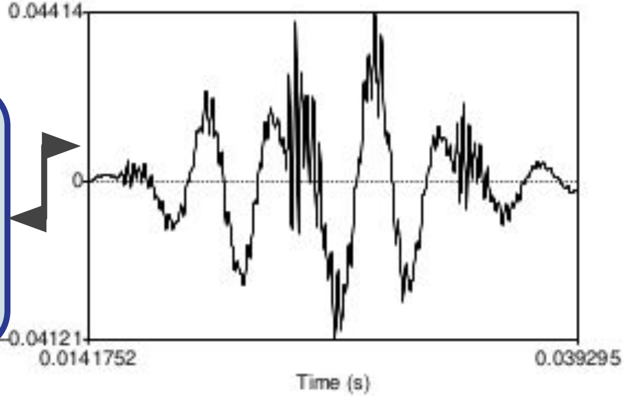
$$\text{rectangular} \qquad w[n] = \begin{cases} 1 & 0 \le n \le L-1 \\ 0 & \text{otherwise} \end{cases}$$

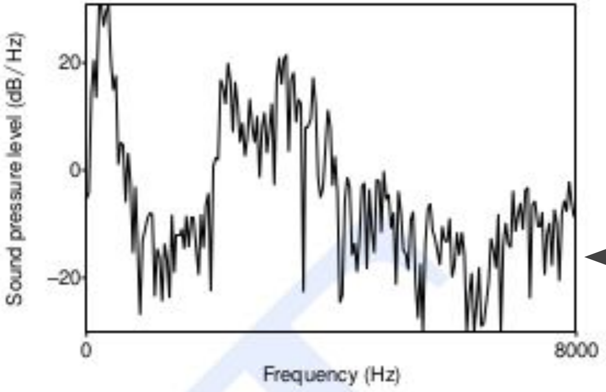
$$\text{hamming} \qquad w[n] = \begin{cases} 0.54 - 0.46\cos\left(\frac{2\pi n}{L}\right) & 0 \le n \le L-1 \\ 0 & \text{otherwise} \end{cases}$$



DFT :

25 ms windowed portion





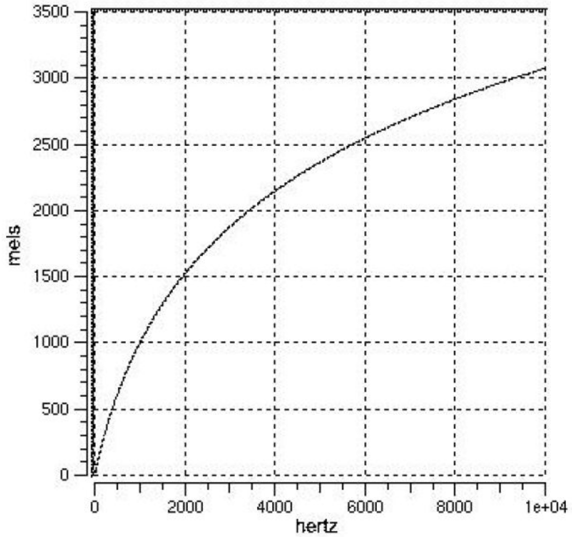
Spectrum compute d by DFT

Mel Scale :

- **Human hearing is not equally sensitive to all frequency bands**
- **Less sensitive at higher frequencies, roughly > 1000 Hz**
- **I.e. human perception of frequency is non-linear:**

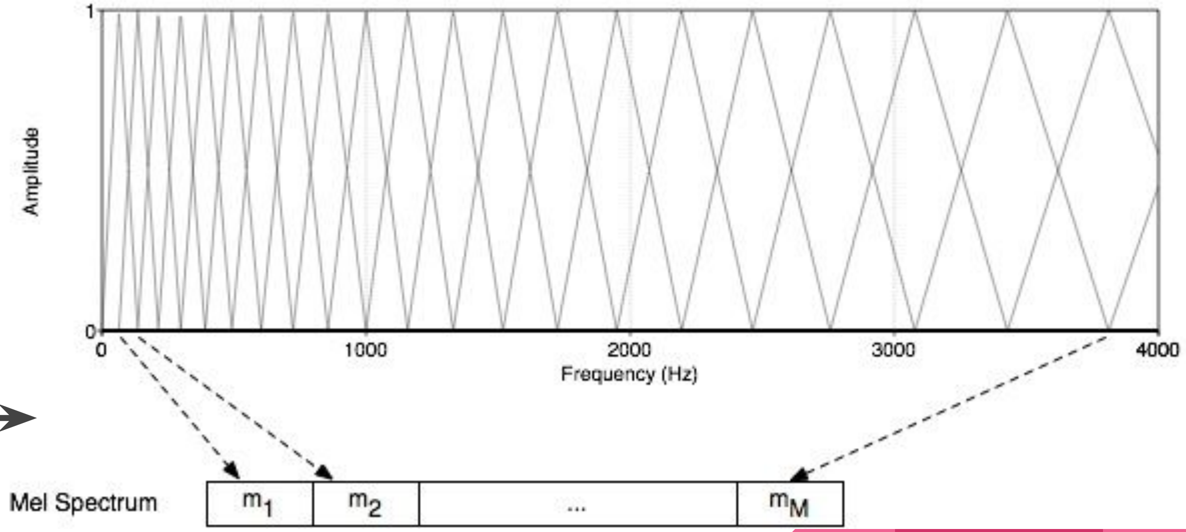
A mel is a unit of pitch
Definition: Pairs of sounds perceptually equidistant in pitch
Are separated by an equal number of mels

$$\mathrm{Mel}(f) = 1127 \ln\left(1+(f/100)\right)$$



Mel Filter bank
Uniformly spaced before 1 kHz
logarithmic scale after 1 kHz

Each triangular filter collects energy from given frequency range



The Cepstrum : IDFT

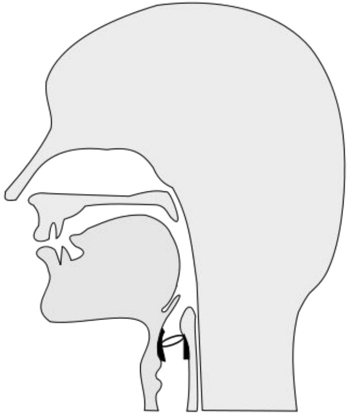
Speech = Convolution of vocal tract frequency response with glottal pulse

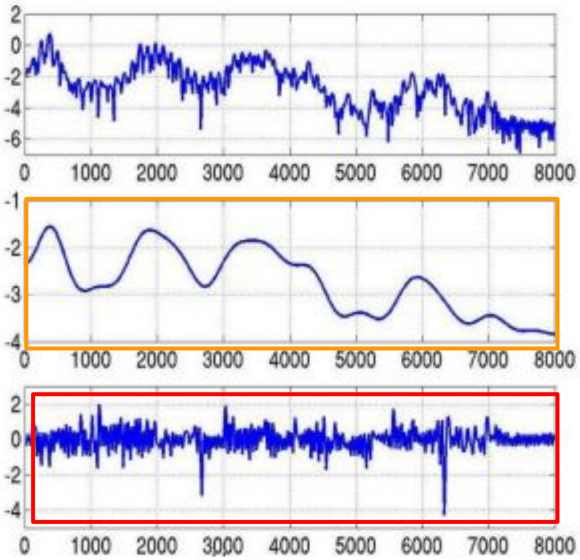
$x(t) = e(t) * h(t) \Rightarrow X(t) = E(t) * H(t) \Rightarrow \log(X(t)) = \log(E(t)) + \log(H(t))$

$\boxed{\text{Log (X(t))}} \equiv \boxed{\text{log(E(t))}} + \boxed{\text{log(H(t))}}$

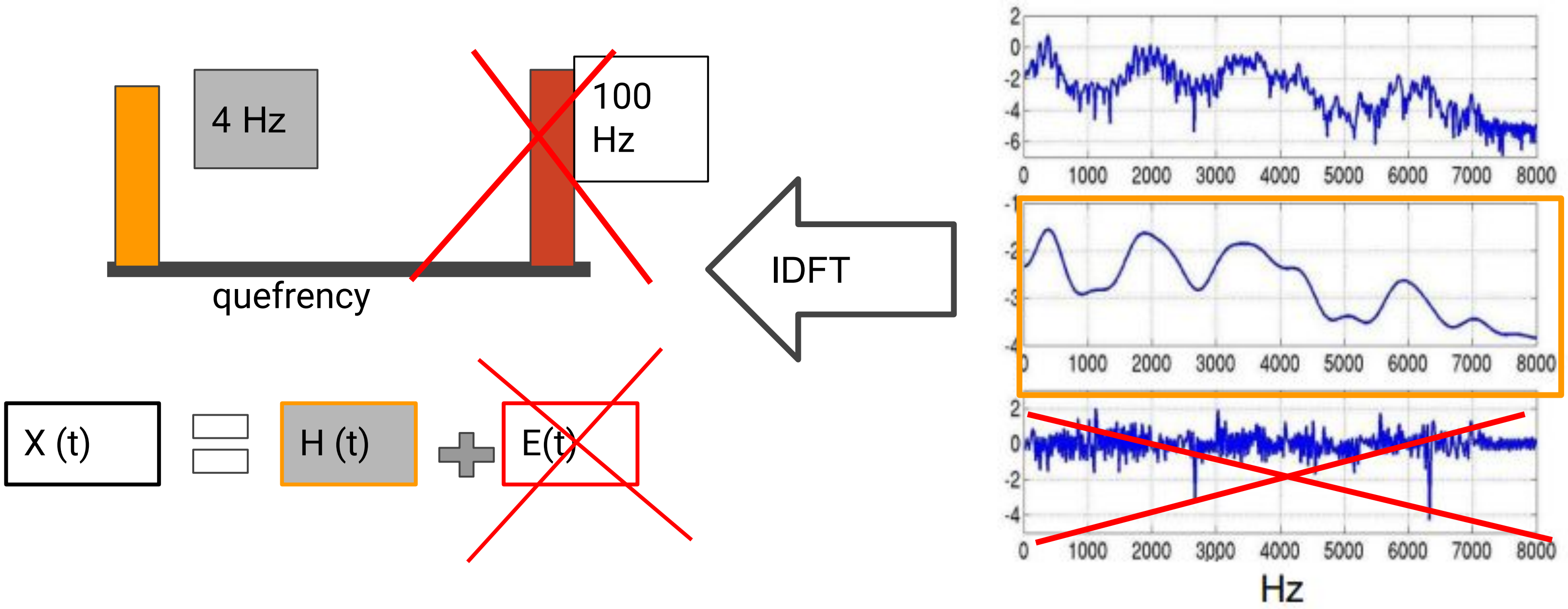
log(H(t)) → Vocal tract frequency response

log(E(t)) → Glottal pulse





The Cepstrum :



Feature :

- The cepstral coefficients do not capture energy
- So we add an energy feature
- Also, we know that speech signal is not constant
- So we want to add the changes in features (the slopes).
- We call these delta features

$$d(t) = \frac{c(t+1) - c(t-1)}{2}$$

c(t) = cepstral value at time t

- We also add double-delta acceleration feature

12 MFCC
12 Δ MFCC
12 ΔΔ MFCC
1 ENERGY
1 Δ ENERGY
1 ΔΔ ENERGY

HMM Architecture

Our main goal :

“What is the most likely word out of all words in the language L given some acoustic input O?”

Input O = $o_1, o_2, \ldots, o_T$

L = { শুন্য ,এক,...,,নয় }

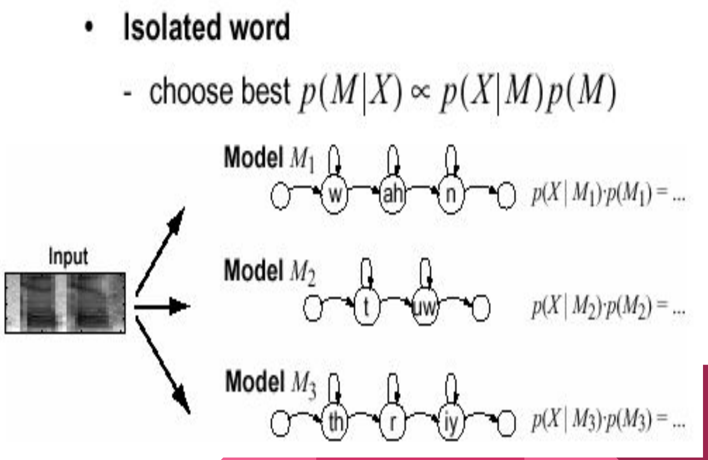
$\hat{W} = \operatorname{argmax} P(W|O) \quad W \in L$

$\hat{W} = \operatorname{argmax} P(O|W)\,P(W) \quad W \in L$

HMM

Acoustic Model

Language Model



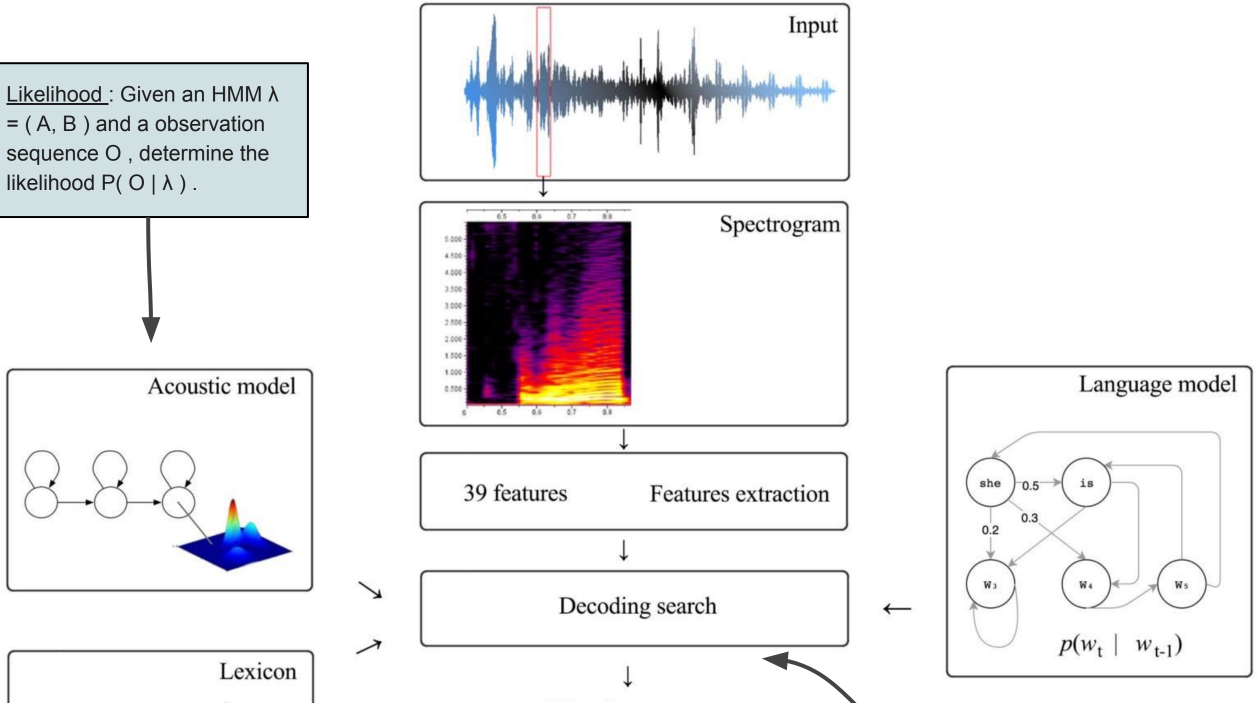
Overall Architecture :

Forward Algorithm

Likelihood : Given an HMM λ = (A, B) and a observation sequence O , determine the likelihood P(O | λ) .

Baum-Welch Algorithm

Learning : Given an observation sequence O and the set of states in the HMM , Learn HMM parameter A and B



Word sequence

$$W^* = \arg\max_{W} P(W \mid X)$$

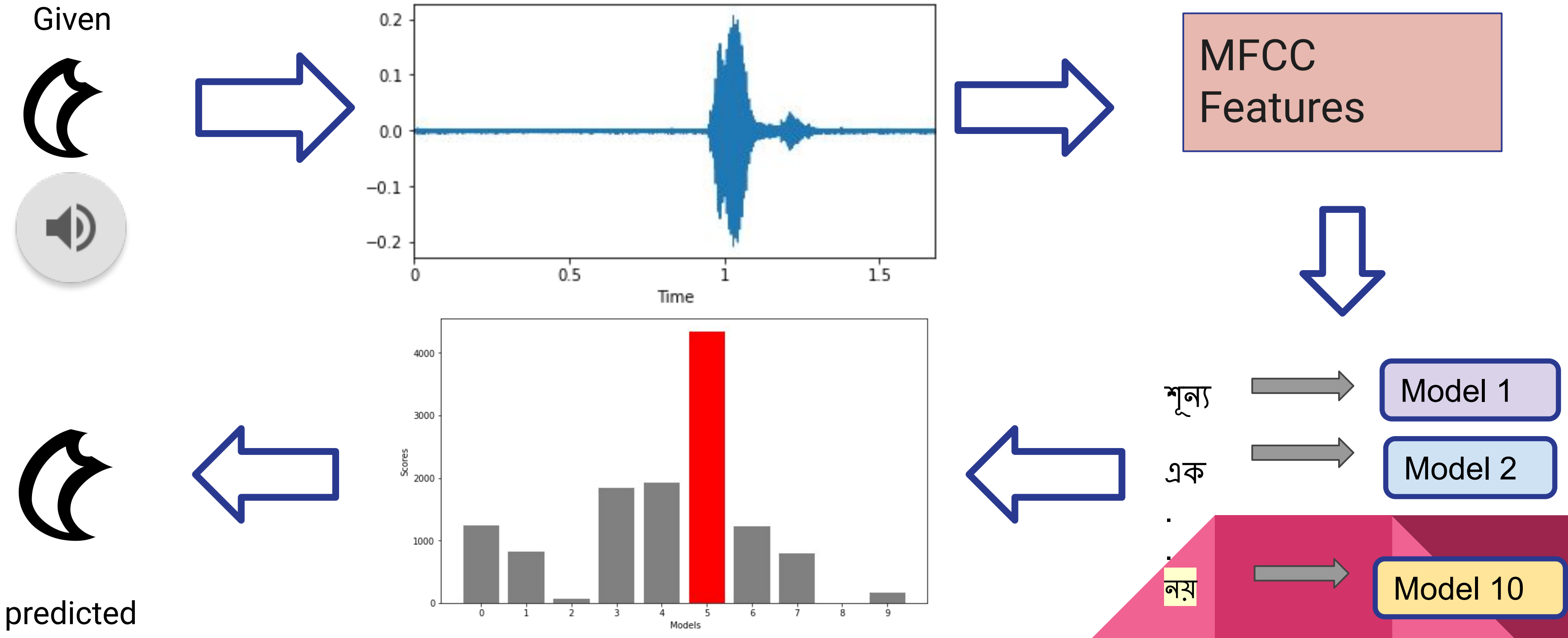
$$W^* = \arg\max_{W} p(X|W) \quad P(W)$$

word sequence acoustic model language model

Viterbi Algorithm:
Given an observation sequence O and an HMM λ = (A, B) , discover the best hidden sequence Q

Tutorial on HMM
Link :
https://docs.google.com/presentation/d/1JUBvTYGM1cepqNkQ39oM3zVpAzEWJni_dF51pz5_scg/edit?usp=sharing

Example :

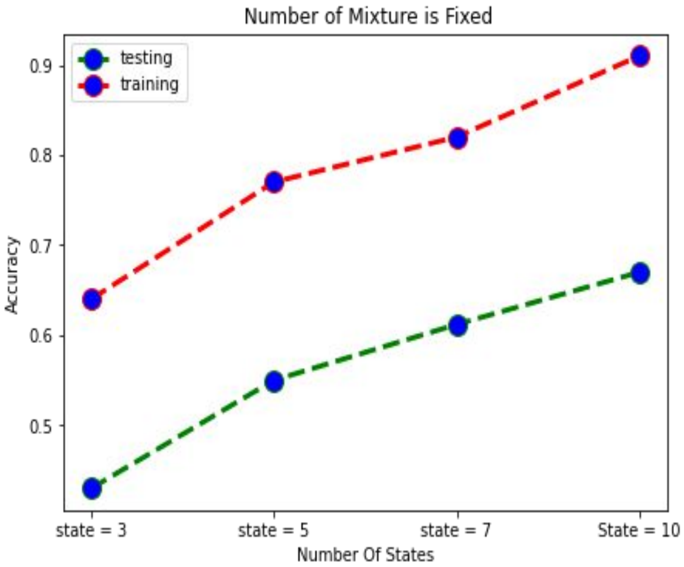


Given
৫
0.2
0.1
0.0
−0.1
−0.2
0
0.5
1
1.5
Time
MFCC
Features
শূন্য
এক
নয়
Model 1
Model 2
Model 10
4000
3000
2000
1000
0
Scores
0 1 2 3 4 5 6 7 8 9
Models
৫
predicted

Result Analysis

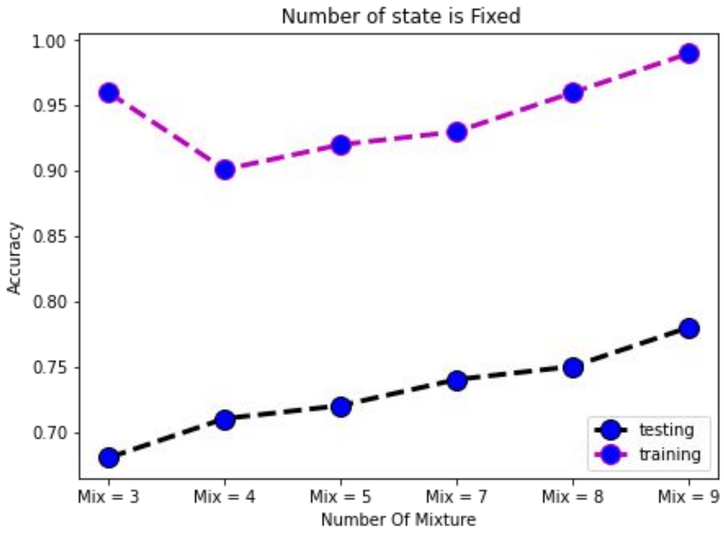
Total Data = 600
Train Data = 478
Test Data = 122

Number Of States	Number Of MIxture	Number Of Iteration	Training Accuracy	Testing Accuracy
3	2	100	64%	43%
5	2	100	77%	55%
7	2	100	82%	61%
10	2	100	91%	67%



Changing Parameters :

Number Of States	Number Of MIxture	Number Of Iteration	Training Accuracy	Testing Accuracy
10	3	100	96%	68%
10	4	100	90%	71%
10	8	100	96%	74%
10	9	400	96%	76%

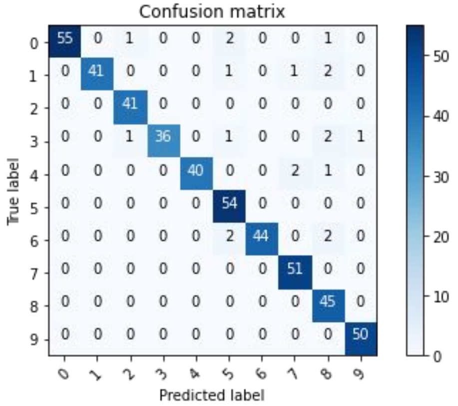


Data = 478

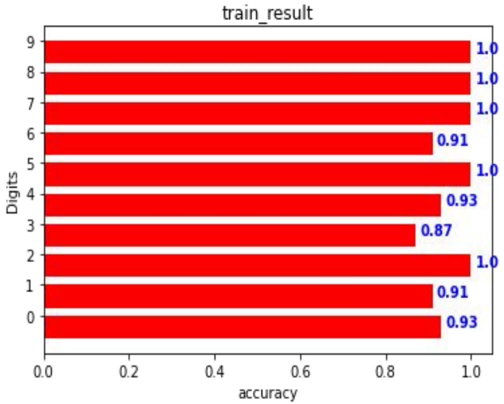
Training Analysis

Accuracy = 96%

Confusion Matrix for training set



Digit wise accuracy for training set

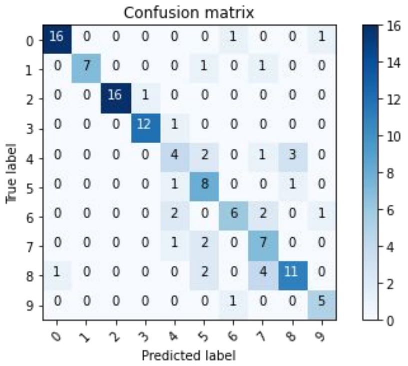


Data = 122

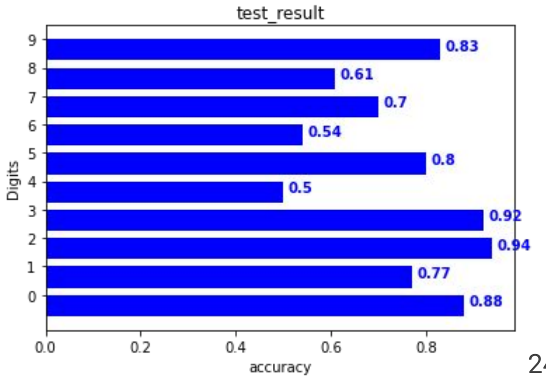
Testing Analysis

Accuracy = 76%

Confusion Matrix for test set



Digit wise accuracy for test set



Any Questions

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Thank
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