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Kasus
Sinyal : $x[n] = [1, 2, 0, -1, -2, -1, 1, 2]$
Frekuensi Sampling : $fs = 8Hz$.

Penyelesaian:

Langkah 1 : Pre-emphasis

formula pre-emphasis

$$y[t] = x[t] - \alpha \cdot x[t-1]$$

dengan $\alpha = 0,95$

perhitungan untuk setiap elemen:

- $y[0] = x[0] = 1$
- $y[1] = x[1] - 0,95 \cdot x[0] = 2 - 0,95 \cdot 1 = 1,05$
- $y[2] = x[2] - 0,95 \cdot x[1] = 0 - 0,95 \cdot 2 = -1.9$
- $y[3] = x[3] - 0,95 \cdot x[2] = (-1) - 0,95 \cdot 0 = -1$
- $y[4] = x[4] - 0,95 \cdot x[3] = (-2) - 0,95(-1) = -1,05$
- $y[5] = x[5] - 0,95 \cdot x[4] = (-1) - 0,95(-2) = 0,9$
- $y[6] = x[6] - 0,95 \cdot x[5] = 1 - 0,95 \cdot (-1) = 1,95$
- $y[7] = x[7] - 0,95 \cdot x[6] = 2 - 0,95 \cdot 1 = 1,05$

sehingga diperoleh nilai pre-emphasisnya sebagai berikut:

$$y[t] = [1.05, -1.9, -1, -1.05, 0.9, 1.95, 1.05].$$

Langkah 2 : Framing (Frame Blocking)

parameter :
- Ukuran Frame = 4 Sampel
- overlap = 2 Sampel

Buat frame dengan langkah stride = 2.
Diperoleh :
- frame 1 : [1, 1.05, -1.9, -1]
- frame 2 : [-1.9, -1, -1.05, 0.9]
- frame 3 : [-1.05, 0.9, 1.95, 1.05]

Langkah 3 : Windowing (Hamming)

formula Hamming:

$$w(n) = 0.54 - 0.46 \cos\left(\frac{2\pi n}{N-1}\right) \quad N=4$$

kemudian hitung nilai windowing :

$$x'(n) = x(n) \cdot w(t)$$

perhitungan untuk setiap n :

- $w[0] = 0,54 - 0,46 \cos\left(\frac{2\pi(0)}{3}\right) = 0,08$
- $w[1] = 0,54 - 0,46 \cos\left(\frac{2\pi(1)}{3}\right) = 0,77$
- $w[2] = 0,54 - 0,46 \cos\left(\frac{2\pi(2)}{3}\right) = 0,77$
- $w[3] = 0,54 - 0,46 \cos\left(\frac{2\pi(3)}{3}\right) = 0,08$

Hasil hamming window :

$$w[n] = [0,08, 0.77, 0.77, 0,08]$$

Aplikasikan window ke setiap frame :

- $x'(1) = [1, 1.05, -1.9, -1] \cdot [0,08, 0.77, 0.77, 0.08]$
  $= [0.08, 0.8085, -1,463, -0,08]$
- $x'[2] = [-1.9, -1, -1.05, 0.9] \cdot [0.08, 0.77, 0.77, 0.08]$
  $= [-0.152, -0.77, -0.8085, 0.072]$
- $x'[3] = [-1.05, 0.9, 1.95, 1.05] \cdot [0.08, 0.77, 0.77, 0.08]$
  $= [-0,084, 0.693, 1.5015, 0.084]$

Diperoleh nilai windowing frames sebagai berikut:
- $x'(1) = [0.08, 0.8085, -1.463, -0.08]$
- $x'[2] = [-0,152, -0.77, -0.8085, 0.072]$
- $x'[3] = [-0.084, 0.693, 1.5015, 0.084]$

Langkah 4 : FFT dan Power Spectrum

Formula Transformasi fourier (TTF):

$$X_k = \sum_{n=0}^{N-1} x[n] e^{-j\frac{2\pi kn}{N}}$$

Dilanjutkan dengan menghitung power spectrum:

$$P(f) = \frac{1}{N} |X(f)|^2$$

perhitungan untuk setiap FFT dengan N=4.

- $FFT[1](x'[1]) = FFT([0.08, 0.8085, -1.463, -0.08]$
  $= [-0,65 + 0.j, 1.54 - 0,88j, -2,11 + 0.j]$
  $= [0,6545, 2,33243, 2,1115]$
- $FFT[2](x'[2]) = FFT([-0,152, -0.77, -0.8085, 0.072])$
  $= [-1.66 + 0.j, 0.66 + 0,89j, -2,6 + 0.j]$
  $= [1,6585, 1,395469, 2625]$
- $FFT[3](x'[3]) = FFT([-0.084, 0.693, 1.5015, 0.084]$
  $= [2.19 + 0.j, -1.58 - 0.61j, 0.64 + 0.j]$
  $= [2.1945, 1.69849, 0.6405]$

Aplikasikan FFT kedalam power spectrum:

- $P[1] = \frac{[0.6545^2, 2.33243^2, 2.1115^2]}{4}$
  $= [0.1071, 0.7926, 1.1146]$
- $P[2] = \frac{[1.6585^2, 1.3755^2, 2625^2]}{4}$
  $= [0.6876, 0.2849, 0.0172]$
- $P[3] = \frac{[2.1475^2, 1.69849^2, 0.6905^2]}{4}$
  $= [1.2039, 0.7211, 0.1025]$

Diperoleh nilai power spectrum sebagai berikut:

- $P[1] = [0.1071, 0.7926, 1.1146]$
- $P[2] = [0.6876, 0.2849, 0.0172]$
- $P[3] = [1.2039, 0.7211, 0.1025]$

Langkah 5: Mel filter Bank

Dengan filter:
- Filter 1: [1, 0.5]
- Filter 2: [0.5, 1]

perhitungan mel filter dari setiap frame:

- $P[1] = [1.34988434, 1.51089322]$
- $P[2] = [0.29360234, 0.15972109]$
- $P[3] = [0.77245284, 0.46314647]$

Langkah 6: log Energies dan DCT

Formula log energies:

$$\tilde{E}_{log}(f) = \log(P(f) + \varepsilon)$$

Dimana, $\varepsilon = 10^{-8}$

Perhitungan log energies:

- $\log(E[1]) = \log([1.34988434, 1.51089322] + 10^{-8})$
  $= [0.30001152, 0.41270102]$
- $\log(E[2]) = \log([0.29360234, 0.15972109] + 10^{-8})$
  $= [-1.22552897, -1.83432609]$
- $\log(E[3]) = \log([0.77245284, 0.46314647] + 10^{-8})$
  $= [-0.25881843, -0.76971191]$

Kemudian, hitung DCT dengan hasil perhitungan log energies, dengan formula sbg:

$$C_k = \sum_{n=0}^{N-1} x_n \cdot \cos\left(\frac{\pi}{N} \cdot \left(n + \frac{1}{2}\right) k\right)$$

Perhitungan nilai DCT dengan mengambil 2 koefisien pertama:

- $MFCC(E\log[1]) = DCT([0.30001152, 0.41270102])$
  $= [0.50396389, -0.07968351]$
- $MFCC(E\log[2]) = DCT([-1.22552897, -1.83432609])$
  $= [-2.16364260, 0.43048457]$
- $MFCC(E\log[3]) = DCT([-0.25881843, -0.76971191])$
  $= [-0.72683238, 0.36170469]$

Sehingga, diperolehlah nilai MFCC (Mel frequency Cepstral Coefficients) dengan sinyal $(x) = [1, 2, 0, -1, -2, -1, 1, 2]$ sebagai berikut:

- Frame 1: [0.50396389, −0.07968351]
- Frame 2: [−2.16364260, 0.43048457]
- Frame 3: [−0.72683238, 0.36170469]