Recitation 9

Friday, November 8, 2024 9:58 AM

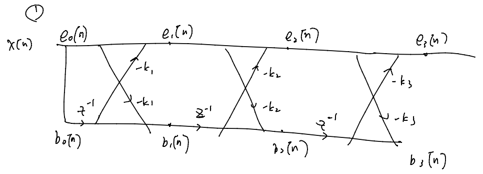
① Lattice Filter (all-zero / all-pole

② Estimate LPC Gain

③ Hint on Computer Homework

④ ~~why b is backward err signal~~

①



$e_i(n) = e_{i-1}(n) - k_i b_{i-1}(n-1)$ ✓ ⟶ ①

$b_i(n) = -k_i e_{i-1}(n) + b_{i-1}(n-1)$ ✓ ⟶ ②

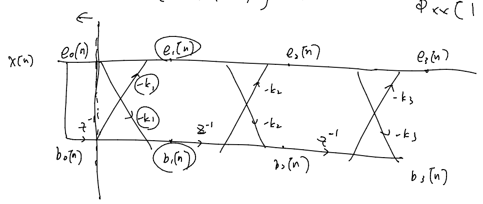
PARCOR

$$\xi_f^2 = E[e_i^2(n)] = E\left[\left(e_{i-1}(n) - k_i b_{i-1}(n-1)\right)^2\right]$$

$$\frac{\partial \xi_f^2}{\partial k_i} = E\left[-2\left(e_{i-1}(n) - k_i b_{i-1}(n-1)\right) b_{i-1}(n-1)\right] = 0$$

$$E[e_{i-1}(n) b_{i-1}(n)] = k_i E(b_{i-1}^2(n-1))$$

$$k_i = \frac{E[e_{i-1}(n) b_{i-1}(n)]}{E(b_{i-1}^2(n-1))} \checkmark = \frac{\phi_{xx}(0,1)}{\phi_{xx}(1,1)} = \frac{\phi_{xx}(1)}{\phi_{xx}(0)}$$

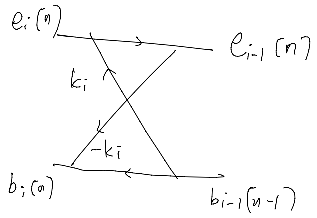


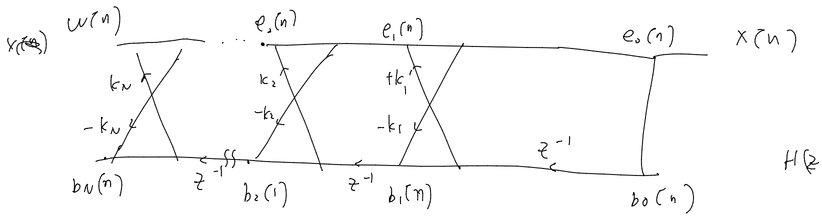
$$H(z) = A(z) = 1 - \sum_{k=1}^{p} \alpha_k z^{-k}$$

All-pole

$$e_{i-1}(n) = e_i(n) + k_i b_{i-1}(n-1)$$

$$b_i(n) = -k_i e_{i-1}(n) + b_{i-1}(n-1)$$





$$H(z) = \frac{1}{A(z)}$$

stable if $|k_i| < 1 \quad \forall i$

Estimate the LPC Gain

$$w[n] \longrightarrow \boxed{H(z)} \longrightarrow x[n]$$

$\sigma_w^2 = 1$

$$H(z) = \frac{G}{1 - \sum_{k=1}^{p} \alpha_k z^{-1}}$$

YULE-WALKER EQ . hw 7.4

$$\phi_{xx}(m) = \begin{cases} \sum_{k=1}^{p} \alpha_k \phi_{xx}(m-k) + G^2 \cdot \sigma_w^2 , & \text{for } m=0 \\ \sum_{k=1}^{p} \alpha_k \phi_{xx}(|m-k|) . & \text{for } m \geq 1 \end{cases}$$

$$G^2 = \left(\phi_{xx}(0,0) - \sum_{k=1}^{p} \alpha_k \phi_{xx}(0,k)\right) / \sigma_w^2 \quad (\text{COVARIANCE})$$

$$= \left(\phi_{xx}(0) - \sum_{r=1}^{p} \alpha_k \phi(k)\right) / \sigma_w^2 \quad (\text{Autocorrelation})$$

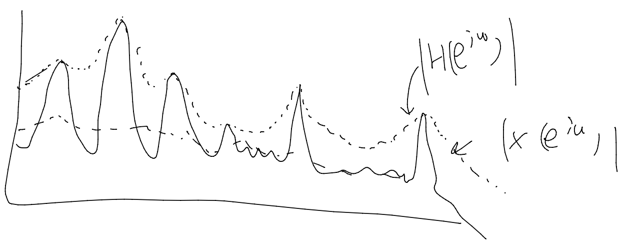
$$H(z) = \frac{G}{A(z)} = \frac{X(z)}{W(z)}$$

$$e[n] = x[n] - \sum_{k=1}^{p} \alpha_k x[n-k]$$

$$E(z) = X(z) A(z) = G\, W(z) \qquad A(z) = \frac{G}{H(z)}$$

$$\frac{1}{2\pi} \int_{-\pi}^{\pi} |E(e^{jw})|^2 dw = \frac{1}{2\pi} \int |X(e^{jw})|^2 |A(e^{jw})|^2 dw$$

$$= \frac{G^2}{2\pi} \int \frac{|X(e^{jw})|^2}{|H(e^{jw})|^2} dw$$



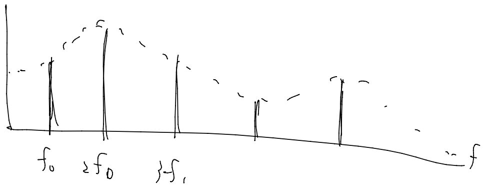
O.S. Fig 11.2

Problemset C7.2

$S(z)$

$W(z)$: excitation signal

Voiced



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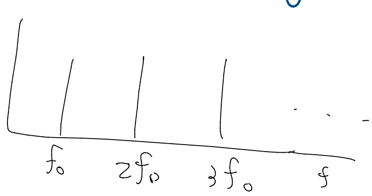

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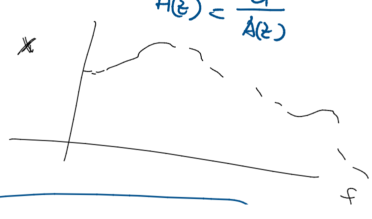
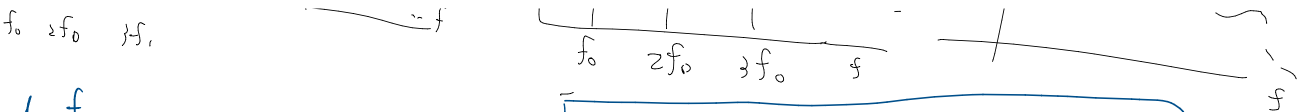
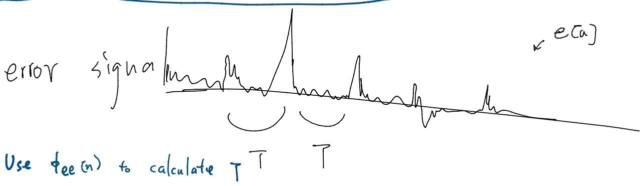
$$H(z) = \frac{G}{A(z)}$$



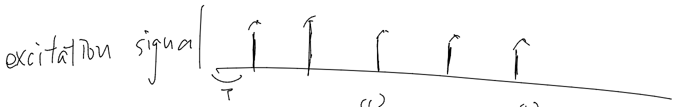


How to determined f_0



Use $r_{ee}(n)$ to calculate T

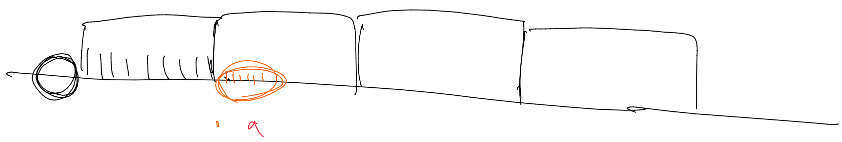
note for males voice $90 \le f_0 \le 160$ Hz



$W^{(1)}(z)$ $W^{(2)}(z)$

$A^{(1)}$ $A^{(2)}$

$G^{(1)}$ $G^{(2)}$



zf, used as zi for next frame, IIR version of OLA

Voiced signal: $S(n) = W(z) * \dfrac{G}{A(z)}$ (impulses: $W(z)$)

Unvoiced signal: $S(n) = W(z) * \dfrac{G}{A(z)}$ (white noise: $W(z)$)