Chapter 1 Introdution

1. Filters

- A filter is a device or system that processes (or reshapes) the input signal according to some specific rules to generate an output signal.

- Linear filter
  There is a linear relationship between input and output of the filter

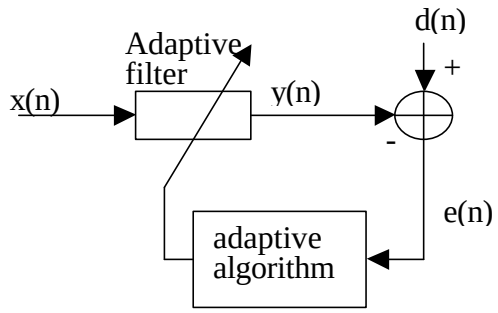
  $x_1 \longrightarrow y_1$
  $x_2 \longrightarrow y_2$
  then $ax_1 + bx_2 \longrightarrow ay_1 + by_2$

- Nonlinear filter
  There is a nonlinearity between input and output of the filter

  e.g.
  $x_1 \longrightarrow y_1 = x_1^2$
  $x_2 \longrightarrow y_2 = x_2^2$
  $x_1 + x_2 \longrightarrow (x_1 + x_2)^2$

2. Adaptive Filters

2.1 General Adaptive Filter Configuration



- Characteristics of adaptive filters：

(1) They can automatically adjust(or adapt) in the face of changing environments and changing system requirements.
(2) They can be trained to perform specific filtering or decision-making tasks.
(3) They should be some “adaptation algorithm” for adjusting the system’s parameters.

- Filter Structure

(1) Transversal filter structure (FIR filter)
(2) IIR filter structure
(3) Lattice filter structure
(4) Nonlinear filter structure (Volterra filter)

- Adaptation Approaches

(1) Approach based on Wiener filter theory … Filter optimization from stochastic framework
The optimum coefficients of a linear filter are obtained by minimization of its mean-square error (MSE).

(2) Method of least squares … Filter optimization from deterministic point of view
The performance index is the sum of weighted error squares.

Adaptive algorithm：

(adaptation algorithm)

- Objective：

  To set the filter parameters, $\bar{q}(n)$, in such a way that its output tries to minimize a meaningful objective function F involving the reference signal (or desired signal).

- Minimization algorithms：

(3) Newton's method
(4) Quasi-Newton method
(5) Steepest-descent method

- Definition of objective function F(θ (n))：

(1) mean-square error
(2) least-square error
(3) weighted least square
(4) instantaneous square value

Note：

(1) $F(e(n)) = E[|e(n)|^2]$

(2) $F(e(n)) = \frac{1}{n+1}\sum_{i=0}^{n}|e(n-i)|^2$

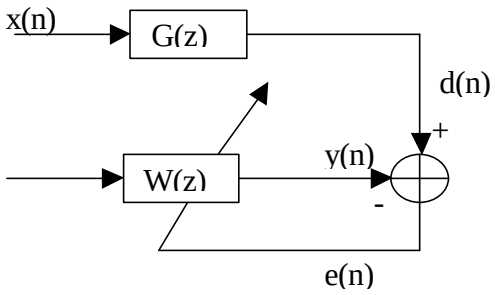
(3) $F(e(n)) = \sum_{i=0}^{n} l^i |e(n-i)|^2$

λ is a constant smaller than 1.

(4) $F(e(n)) = |e(n)|^2$

3. Applications of Adaptive Filters

(a) System modeling



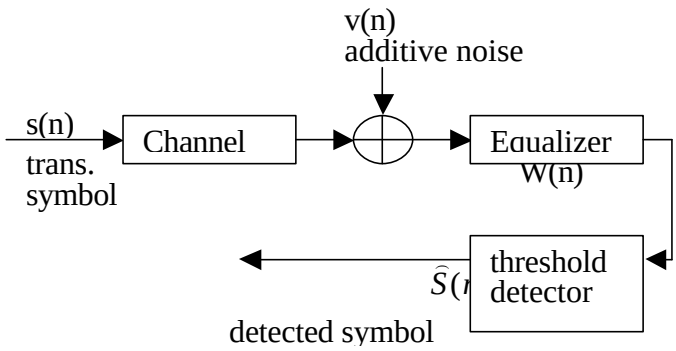
applications：

- system identification
- echo cancellation

(b) Inverse modeling

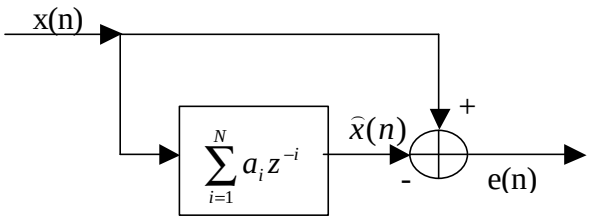
Also known as “deconvolution” Application：

Equalization of communication channel

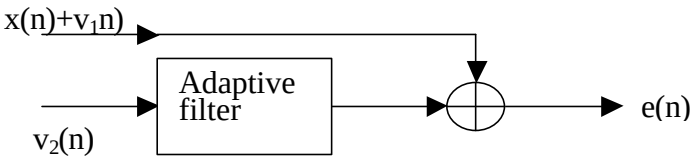


$W(z) \approx z^{-\Delta} / H(z)$

(c) Signal prediction



(d) Signal enhancement



$v_1(n)$ & v_2 (n) are correlated noise signals