Chapter 1 Introduction

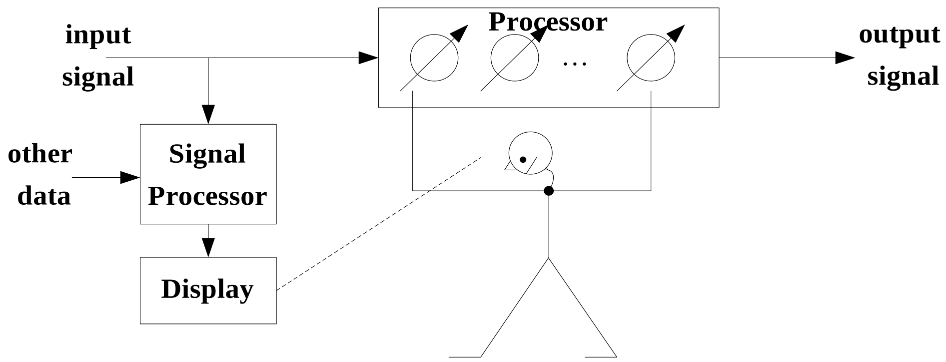
I. Optimal Signal Processing

1) Concerned with the design, analysis, and implementation of processing systems that extract information from sampled data in a manner that is "best" or optimal in some senses.
2) Optimality criteria:
   maximum likelihood (ML)
   maximum a posteriori (MAP)
   minimum mean-squared error (MMSE)
3) Statistics of input signals or data are known or given.
4) *Examples*: linear prediction, inverse filtering.

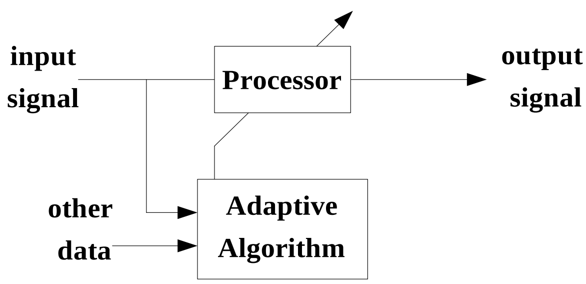
II. Adaptive Signal Processing

1) Concerned with the design, analysis, and implementation of processing systems whose structure (impulse response, filter coefficients …) changes in response to the incoming data.
2) Statistics of input data are unknown or not given.
3) Open-Loop Adaptation:

Concept:



(i)



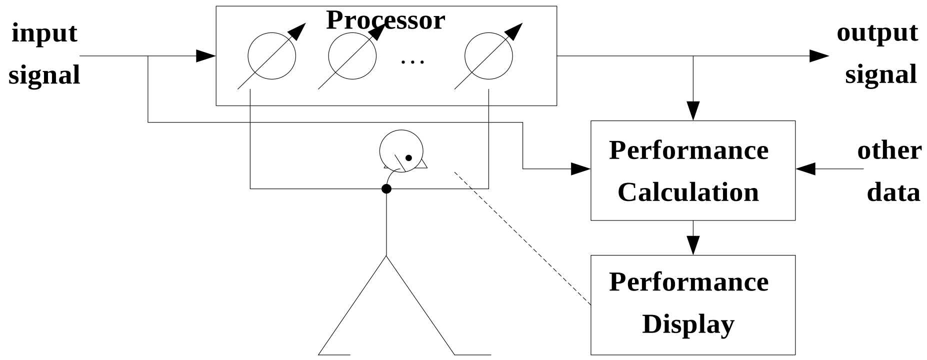
(ii)

■ **Figure 1.1** Open-loop adaptation: (i) concept; (ii) equivalent system [1].

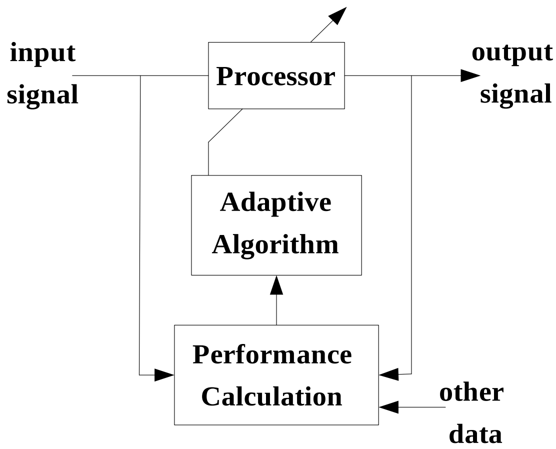
(a) Making measurements of input or environment characteristics.
(b) Applying the information of measurements to a formula or a computational algorithm.
(c) Using the results of (b) to set the adjustment of the adaptive system.

4) Closed-Loop Adaptation

Concept:



(i)



(ii)

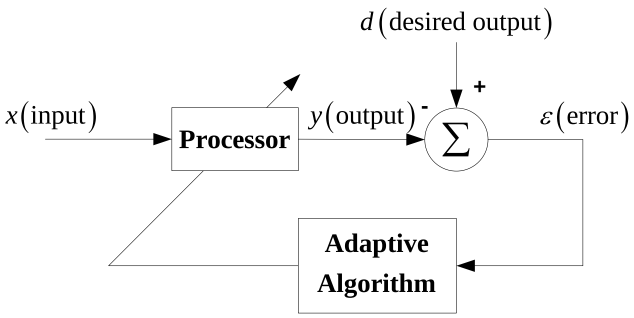
■ **Figure 1.2** Closed-loop adaptation: (i) concept; (ii) equivalent system [1].

(a) Automatic experimentation with the adjustments the system made and knowledge of the system outputs in order to optimize a measured system performance.
(b) Workable in many applications where no analytic synthesis procedure either exists or is known.
(c) Can be used effectively in situations where physical system component values are variable or inaccurately known.

Note: In general, the open-loop adaptation involves higher computational complexity than the closed-loop adaptation since it needs to analyze the input data first.

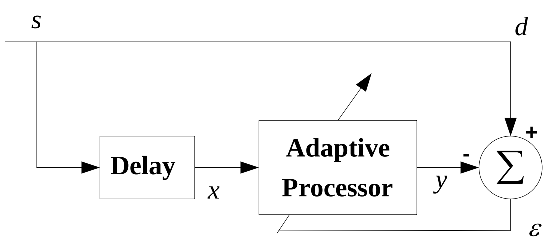
5) How to choose closed-loop and open-loop adaptation schemes? (Not absolutely)
   (a) The availability of input signals and performance indicating signals is a major consideration.
   (b) The amount of computing capacity and the type of computer.

6) Applications of Closed-Loop Adaptation
   (a) Basic configuration



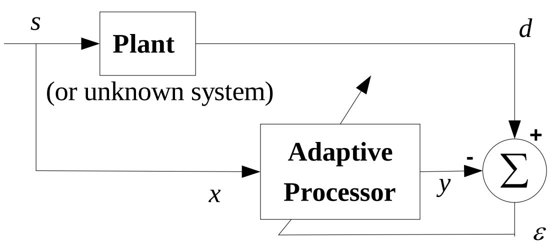
■ **Figure 1.3** Signals in closed-loop adaptation [1].

   (b) Types of applications
   - prediction



■ **Figure 1.4** Prediction [1].

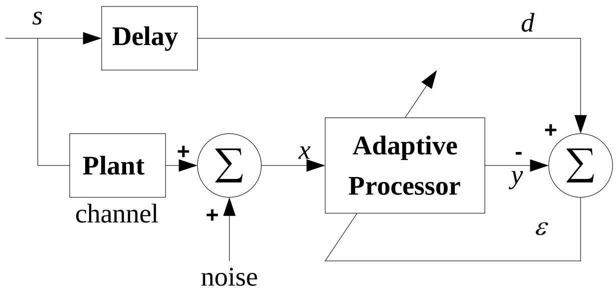
   - system identification



■ **Figure 1.5** System identification (modeling) [1].

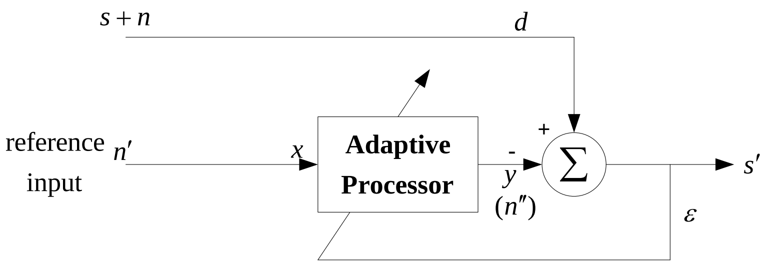
When the training sequence is not well-designed, the approximated impulse response is not generally acceptable.

- inverse modeling



■ **Figure 1.6** Equalization (deconvolution, inverse filtering, inverse modeling) [1].

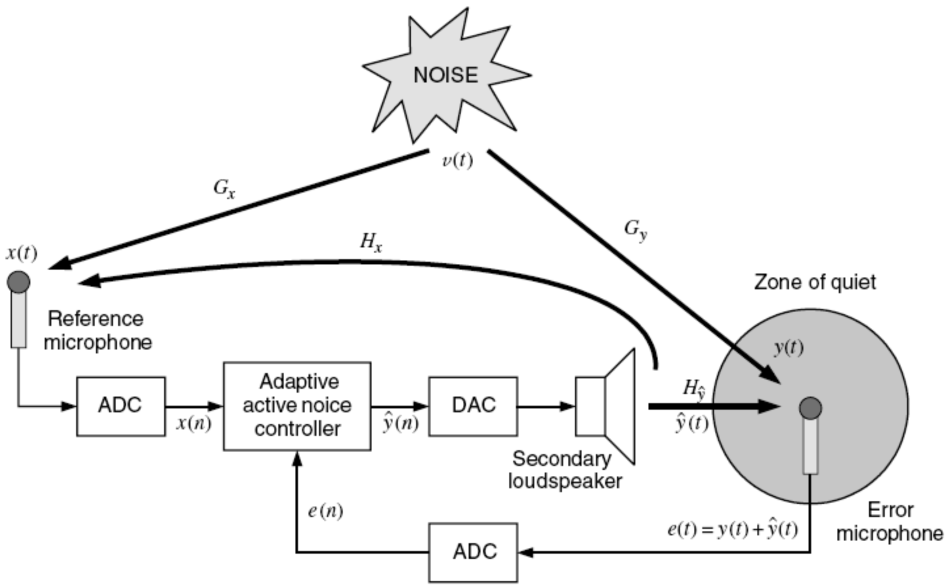
- interference cancellation



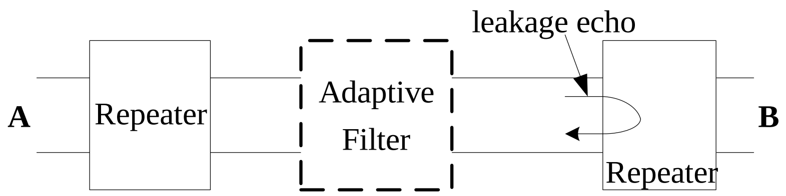
■ **Figure 1.7** Interference cancellation [1].

7) Adaptive Algorithms
   - Concerns:
     stability, convergence speed, convergence accuracy, complexity, and robustness
   - *Example*:
     $\begin{cases} \text{least mean squares (LMS) algorithms} \\ \text{least squares (LS) algorithms} \end{cases}$
   - Structure: FIR, IIR, lattice.

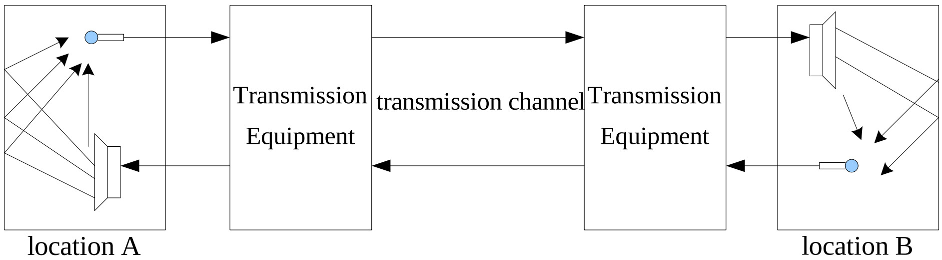
8) Applications of Adaptive Filtering
   - Noise cancellation
   - Line enhancement
   - Time-delay estimation
   - Echo cancellation
   - Equalization
   - Interference cancellation or suppression
   - Differential PCM



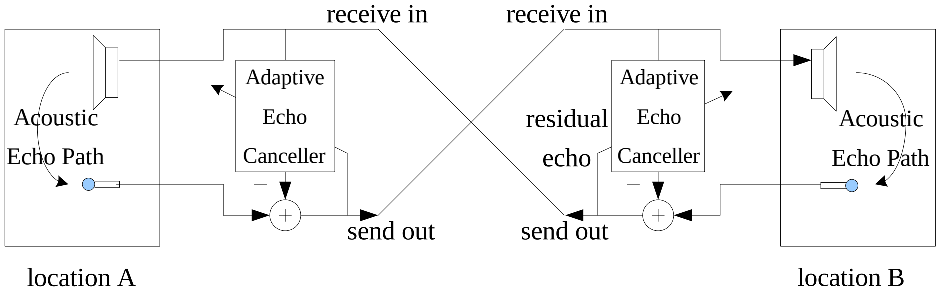
■ **Figure 1.8** Block diagram of the basic components of an active noise control system [3].



■ **Figure 1.9** Echo cancellation in telecommunications.



■ **Figure 1.10** Typical teleconferencing system without echo control [3].



■ **Figure 1.11** Principle of acoustic echo cancellation using an adaptive echo canceller [3].

Table I Classification of Adaptive Filtering Applications [3]

Application Class	**Examples**
System Identification	Echo Cancellation Adaptive Control Channel Modeling
System Inversion	Adaptive Equalization Blind Deconvolution
Signal Prediction	Adaptive Predictive Coding Change Detection Radio Frequency Interference Cancellation
Multisensor Interference Cancellation	Acoustic Noise Control Adaptive Beamforming

References

[1] B. Widrow and S. D. Stearns, *Adaptive Signal Processing*. Englewood Cliffs, NJ: Prentice-Hall, 1985.

[2] P. M. Clarkson, *Optimal and Adaptive Signal Processing*. Boca Raton, FL: CRC, 1993.

[3] D. G. Manolakis, V. K. Ingle, and S. M. Kogon, *Statistical and Adaptive Signal Processing*. Singapore: McGraw-Hill, 2000.