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Adaptive Filters
Prediction and System Identification

Adaptive Filters

- Adaptation - the ability of a system to cope with unexpected disturbances of the environment

- Adaptive System - a system whose characteristics are alterable or adjustable in such a way that its behavior or performance improves according to some measure

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Characteristics of Adaptive Systems

- Self-adjusting in the face of non-stationary environments and changing system requirements
- Trained, rather than synthesized, to perform particular filtering operations
- Non-linear systems with time-varying parameters

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Characteristics of Adaptive Systems

- Inherently difficult to analyze

- Have the potential to outperform non-adaptive systems

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Characteristics of Adaptive Systems

- In general, the design of non-adaptive filters requires *a priori* knowledge of the characteristics of the signals involved.

- Given this knowledge, *optimal* filters may be designed.

- However, as signal characteristics change, these filters may be rendered *sub-optimal*.

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Characteristics of Adaptive Systems

- If knowledge of signal characteristics is inaccurate, incomplete, or unavailable, optimal filter design may not be possible.

- In such cases, adaptive filters that continually seek optimum performance may be of use.

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Characteristics of Adaptive Systems

- In general, adaptive systems must be considered *non-linear*.

- We will consider so-called *linear adaptive filters* - if adaptation is disabled, they become linear filters.

- These are useful. They are mathematically tractable and relatively easy to design.

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Characteristics of Adaptive Systems

- Adaptive filtering is at the core of much digital signal processing.

- Adaptive filters do not rely on prior knowledge of signal statistics or characteristics to the same extent as non-adaptive filters.

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Closed Loop Configurations

- Define the following signals.

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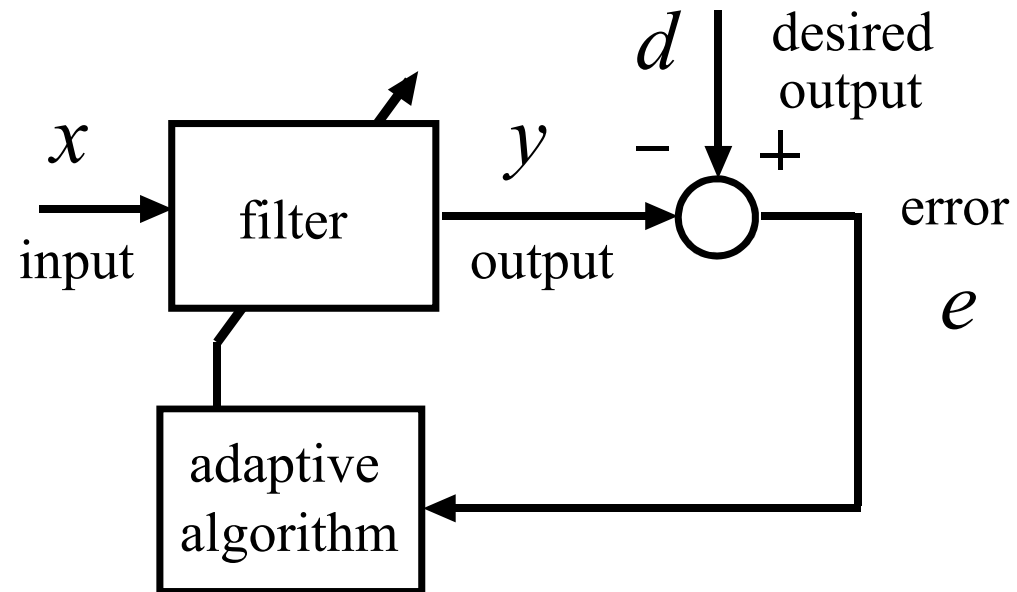
Closed Loop Configurations

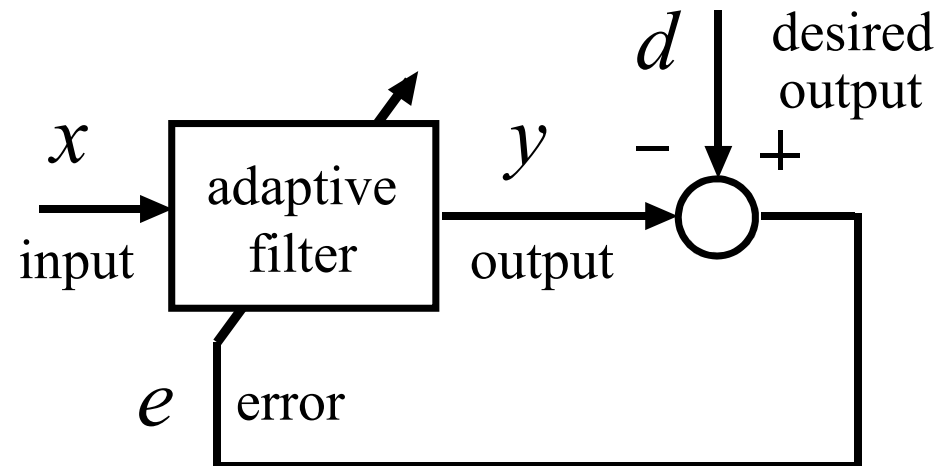- Alternatively, represent adaptive filter as a single block.

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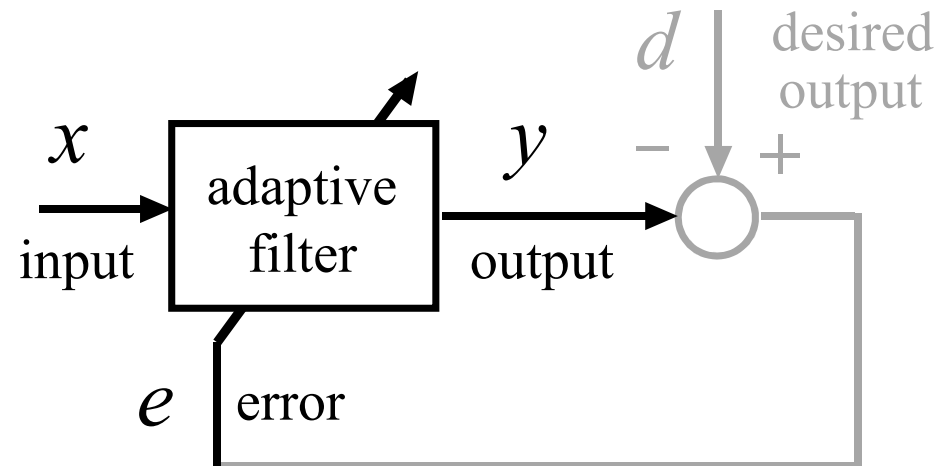
Closed Loop Configurations

- Different closed loop configurations are concerned primarily with how desired output d is derived.

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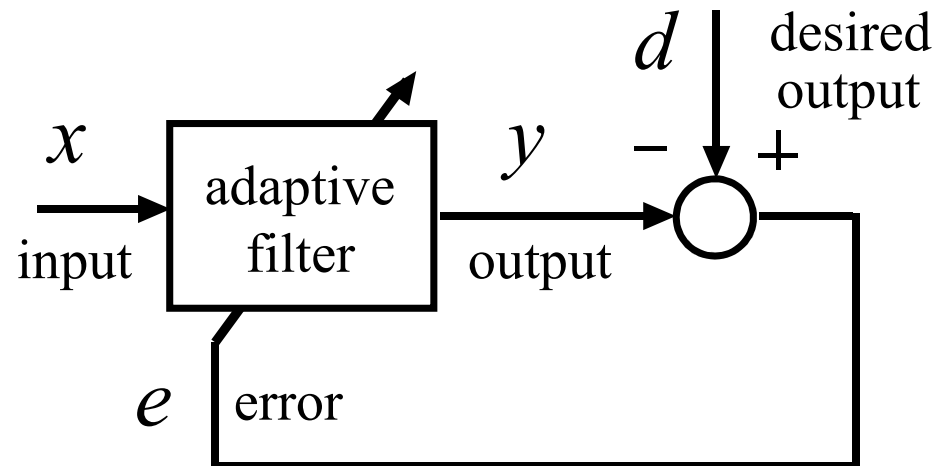
Closed Loop Configurations

- In each case, however, the adaptive algorithm attempts to minimize error e in some sense.
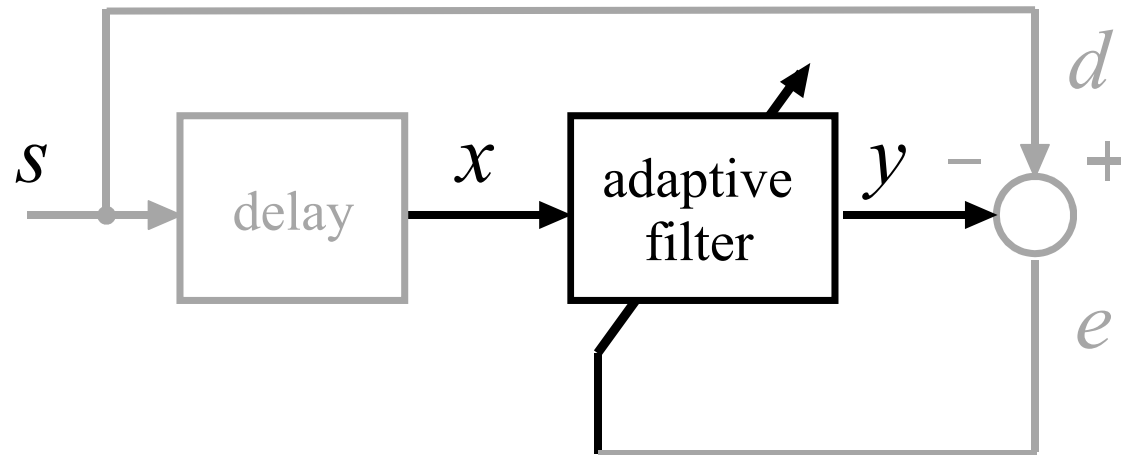
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a) Prediction

- A *delayed* version of the desired signal s is fed to the adaptive filter, which tries to predict the *current* value of the desired signal.
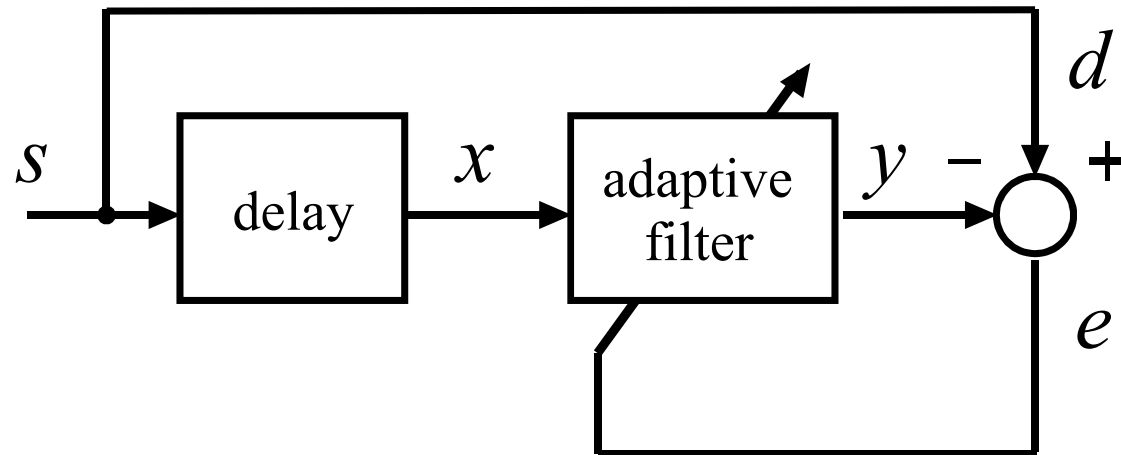
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a) Prediction

- A *delayed* version of the desired signal s is fed to the adaptive filter, which tries to predict the *current* value of the desired signal.

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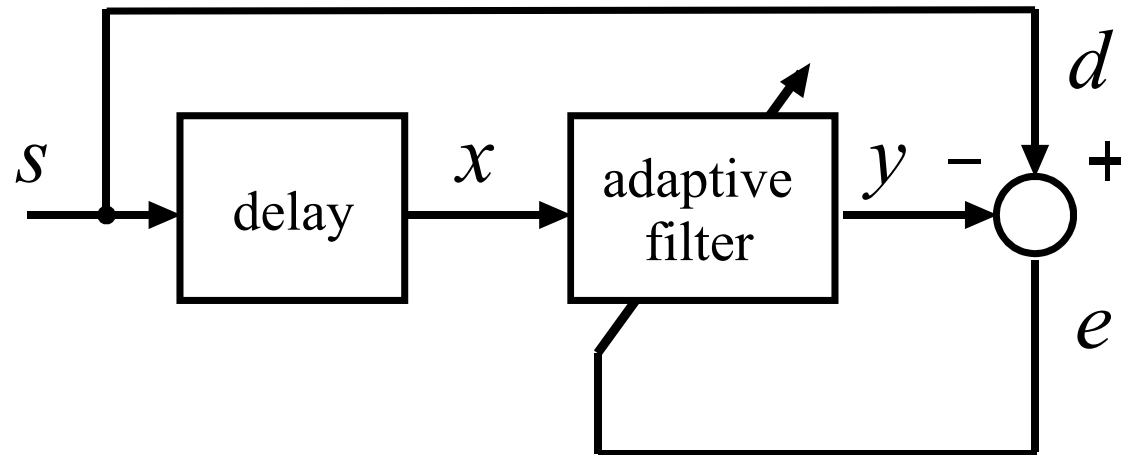
a) Prediction

- Prediction is used in signal encoding and noise reduction.
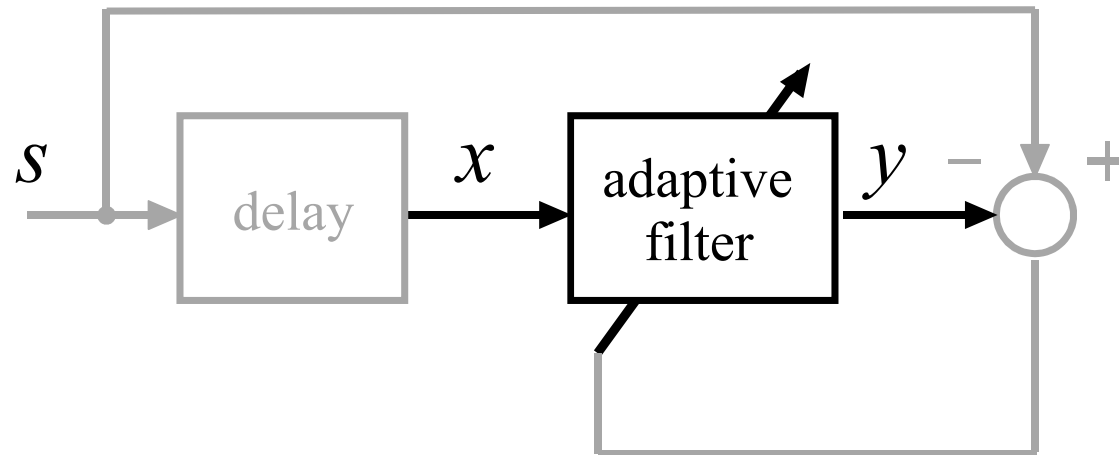
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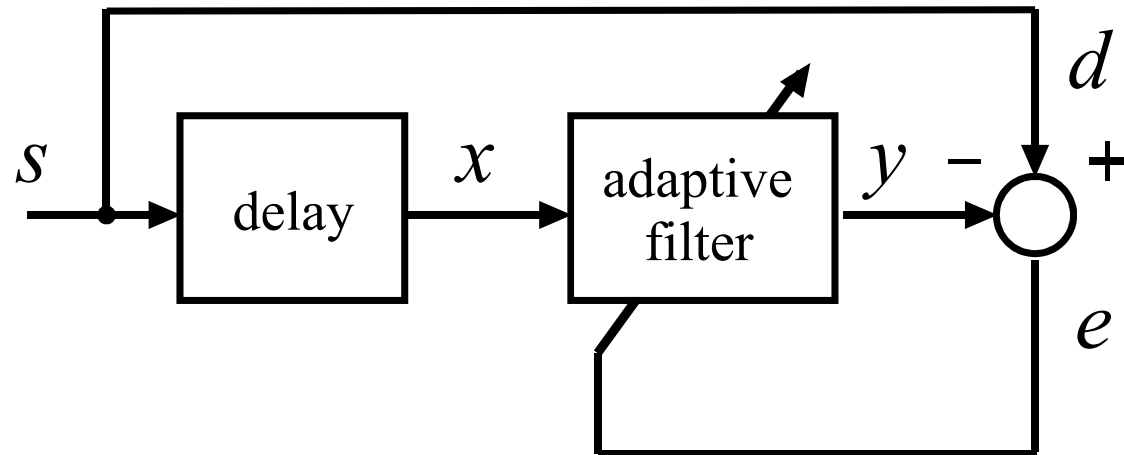
a) Prediction

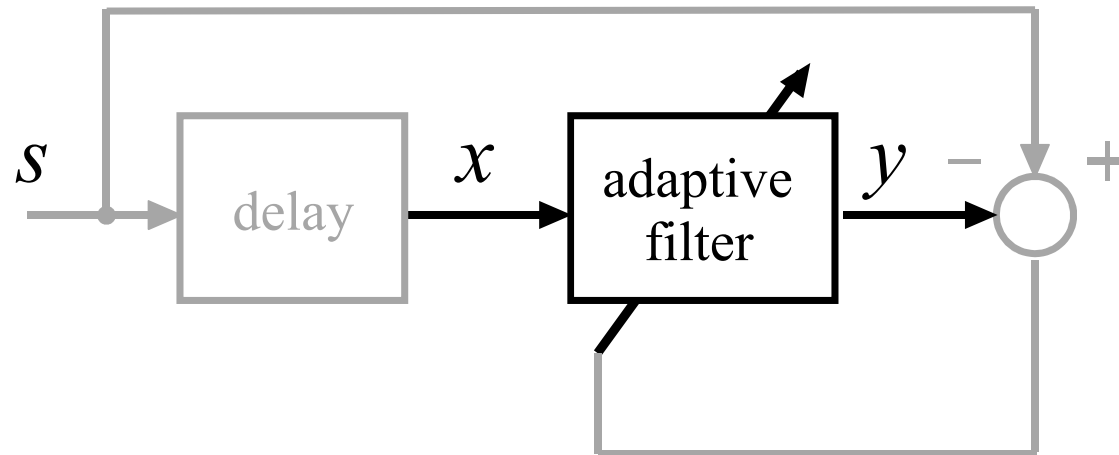- Filter learns about the process by which the signal s is produced.

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a) Prediction

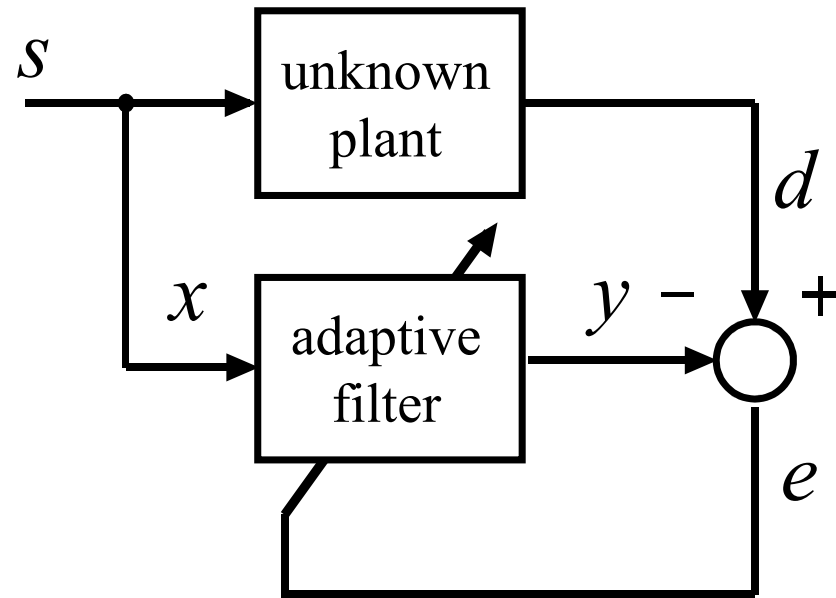- Once filter has been trained, disable adaptation and remove d.

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a) Prediction

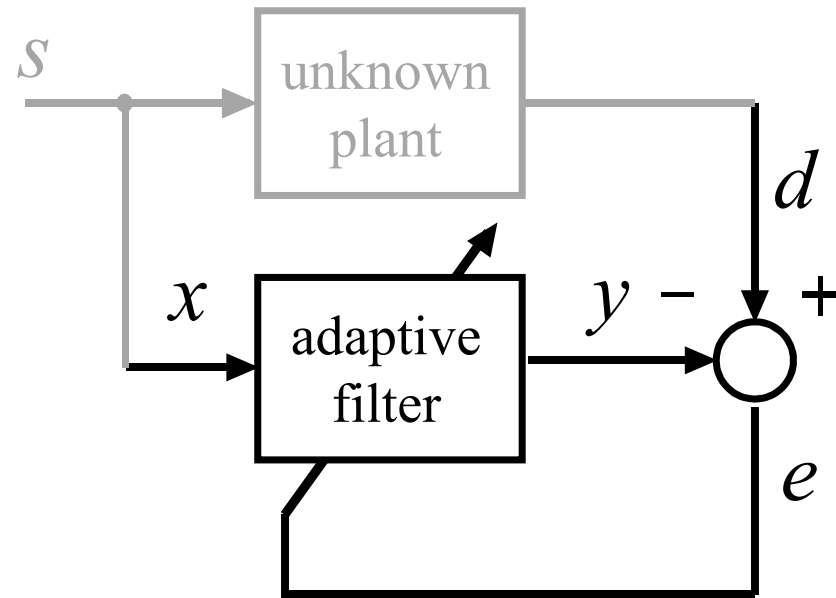- Filter now predicts future values of x from past values.

b) System Identification

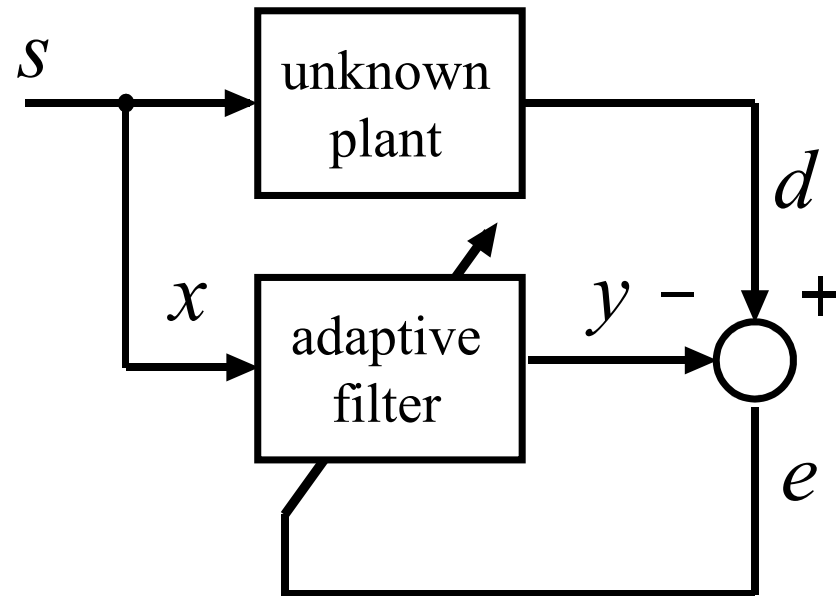- Broadband signal s applied to inputs of both unknown system and adaptive filter

b) System Identification

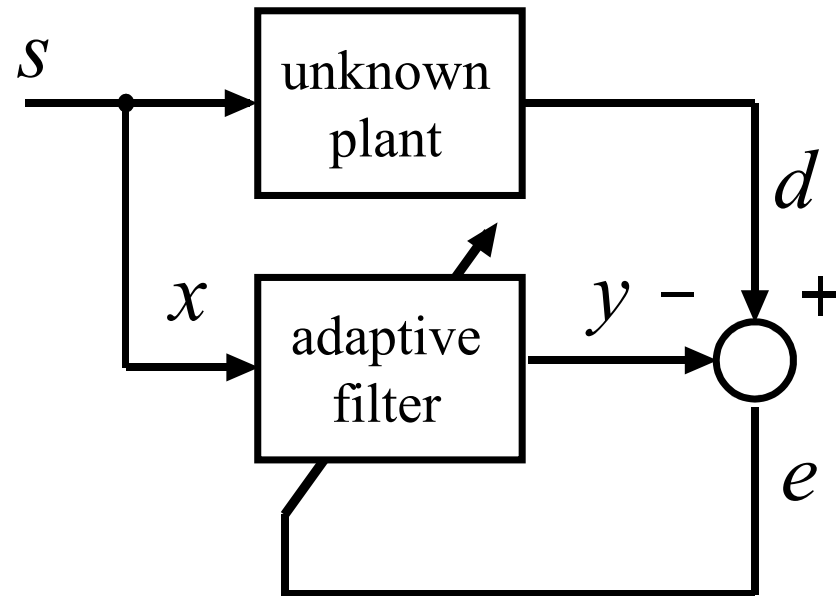- Broadband signal s applied to inputs of both unknown system and adaptive filter

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b) System Identification

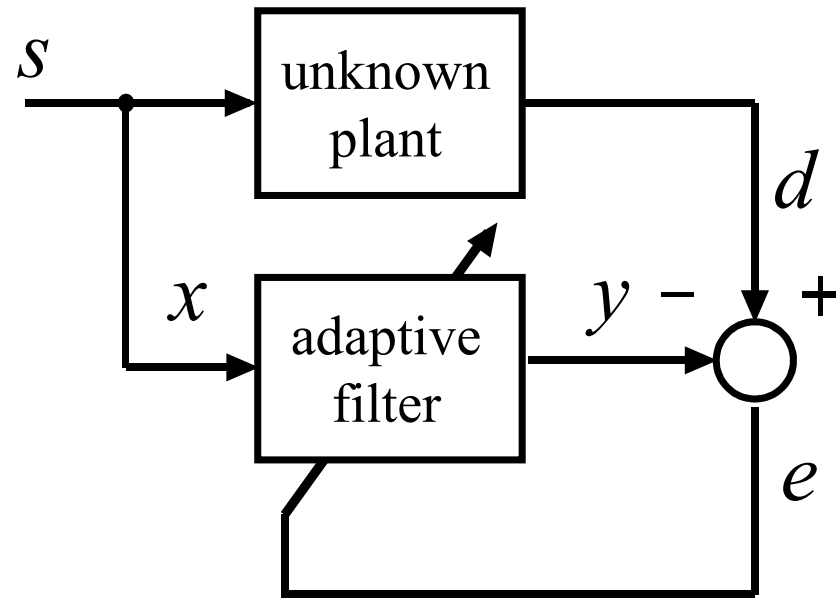- Adaptive filter tries to emulate characteristics of unknown plant.

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b) System Identification

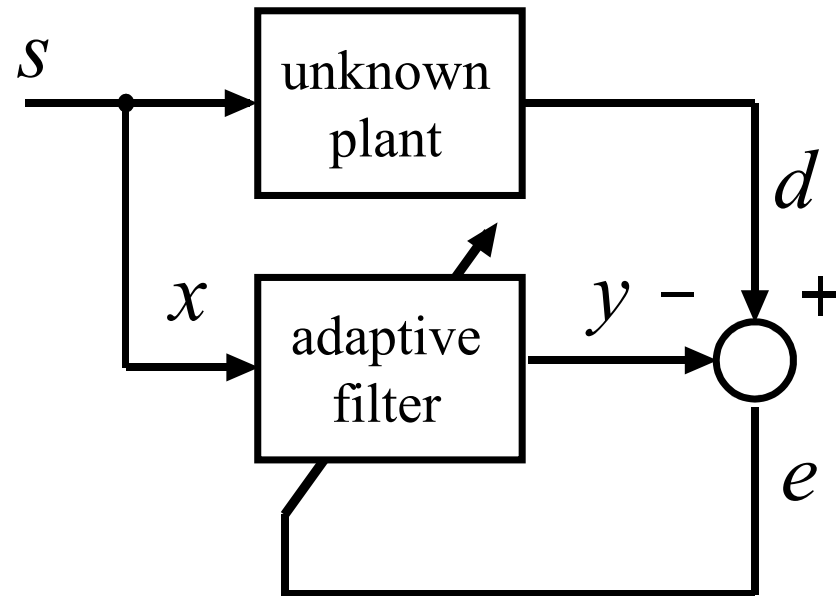- After (successful) adaptation, plant characteristics have been *identified*.

b) System Identification

- Adaptive filter has learned input-output characteristics of unknown plant.

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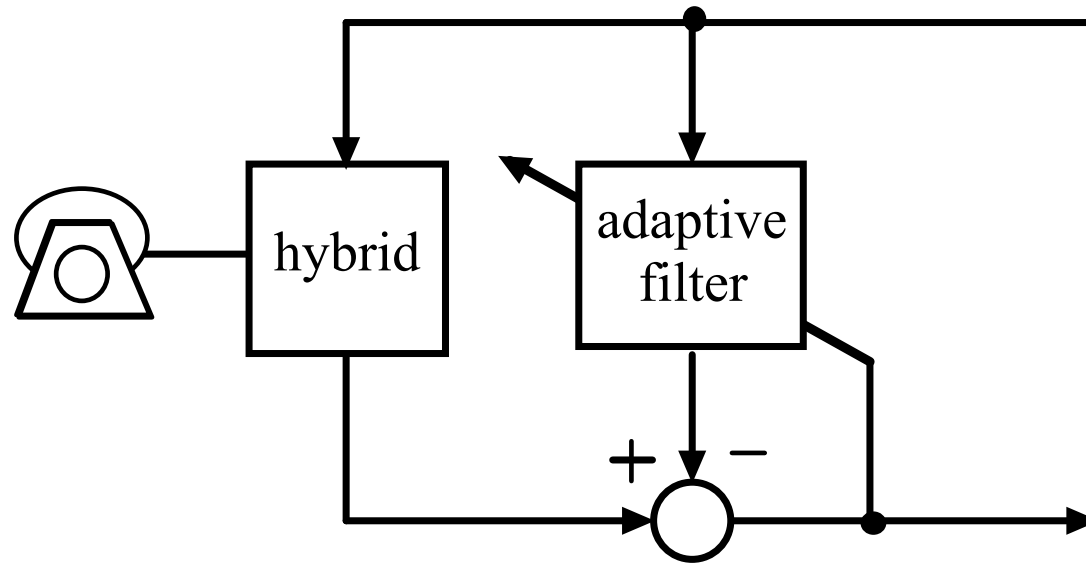# b) System Identification

- Similar inputs to adaptive filter and unknown plant will yield similar outputs.
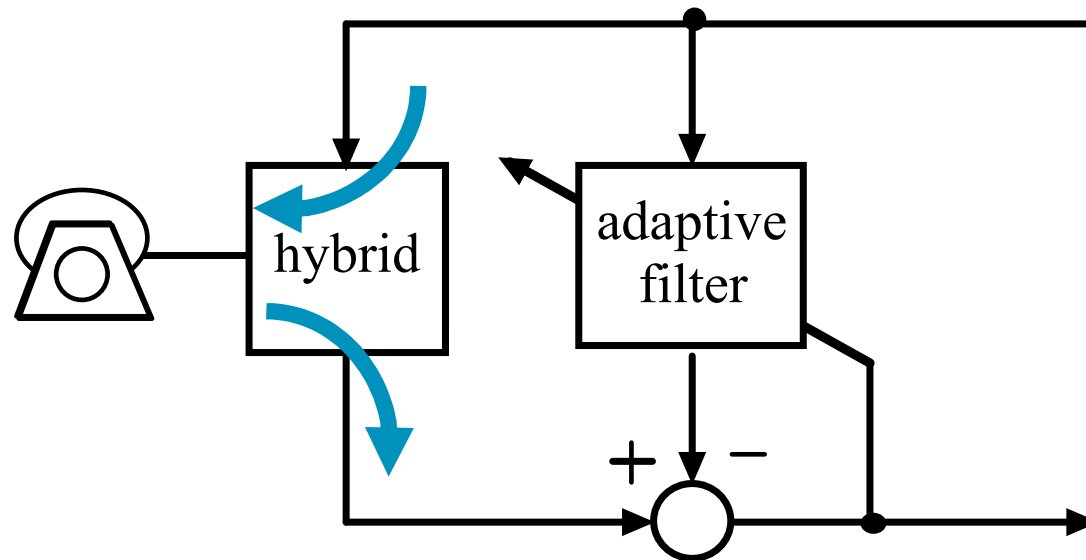
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b) System Identification Application
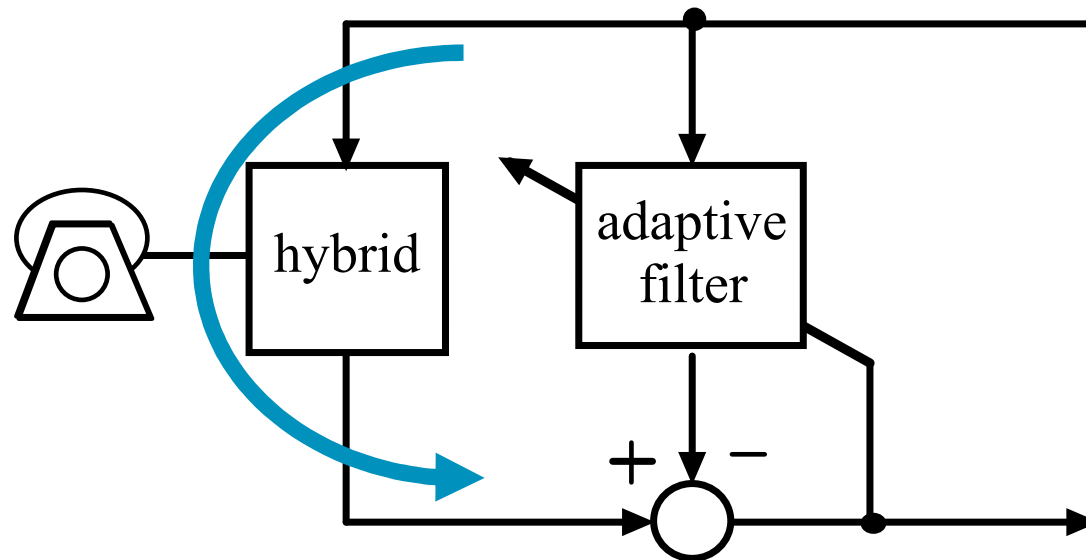
- Long-distance telephone echo cancellation

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b) System Identification Application

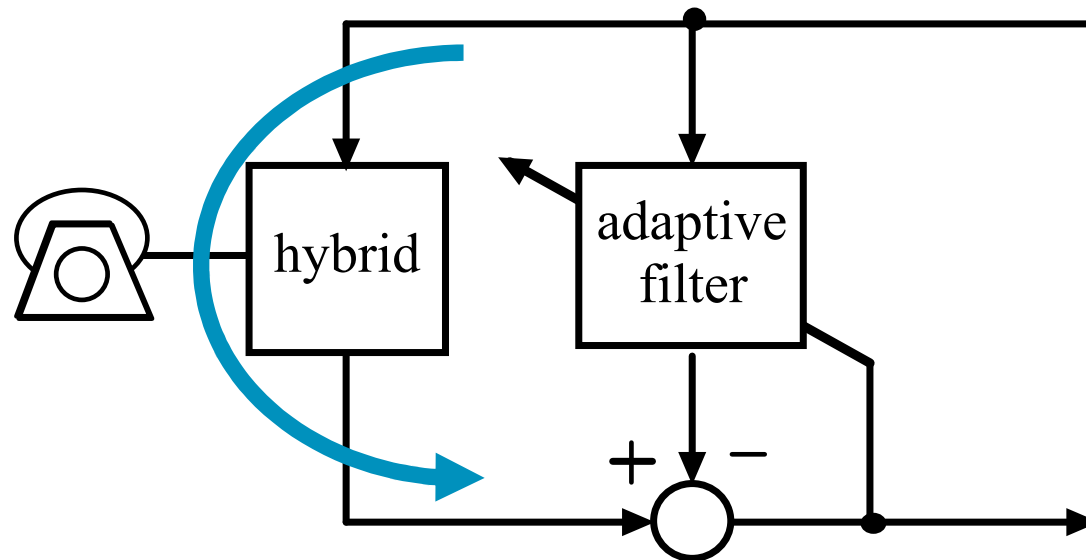- Ideally, hybrid routes incoming signal to and outgoing signal from telephone.

b) System Identification Application

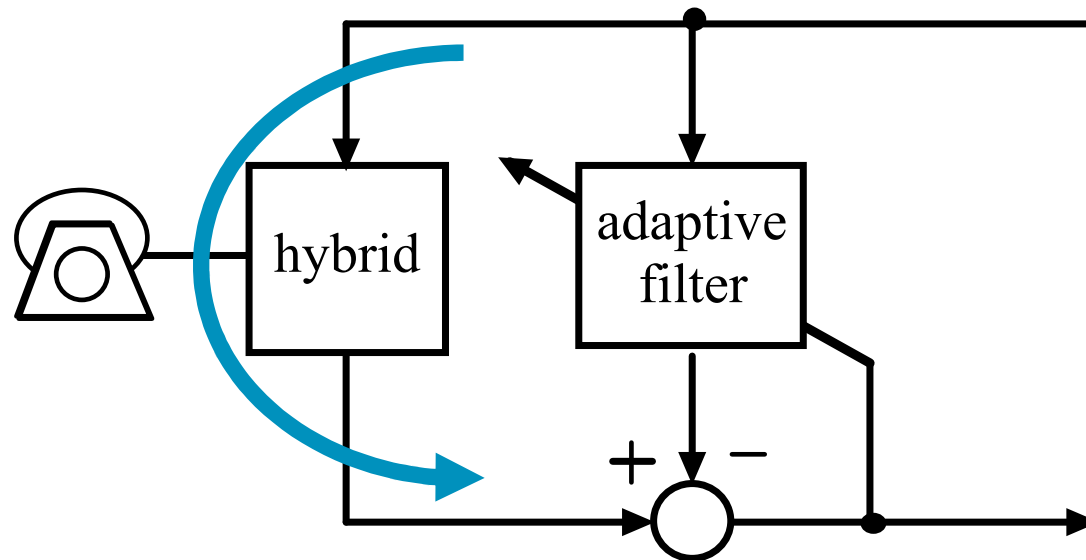- Due to impedance mismatches, some of the incoming signal is returned.

b) System Identification Application

- Resultant *echo* can be distracting if connection is long-distance.

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b) System Identification Application

- This *hybrid leakage path* is modeled by the adaptive filter.

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b) System Identification Application

- Adaptation should be disabled in the presence of an outgoing signal.

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