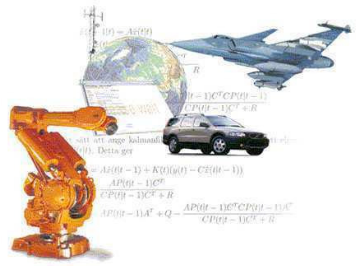
Nonlinear control

Lecture 8



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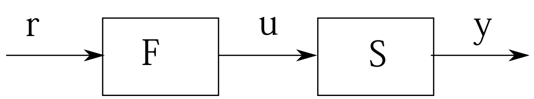
Review of course

- Geometric control theory
  - input-output linearization
  - controller canonical form
  - observer canonical form
- Lyapunov theory
  - Stability results
  - Lyapunov design: back-stepping etc.
- Design methods
  - Optimal control
  - Extensions of H_∞
  - Physics in Control

All this is about feedback. What about feedforward?

Feedforward from reference signal



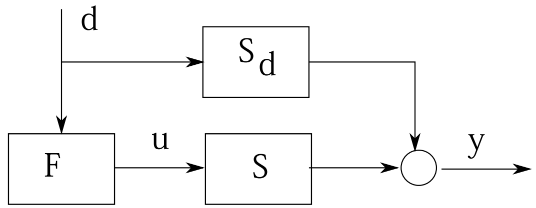
Choose F to get

$$y = S(Fr) \Rightarrow y = r$$

F has to be chosen as the inverse:

$$F = S^{-1}$$

Feedforward from disturbance



$$y = (S_d + SF)d$$

The disturbance is eliminated if

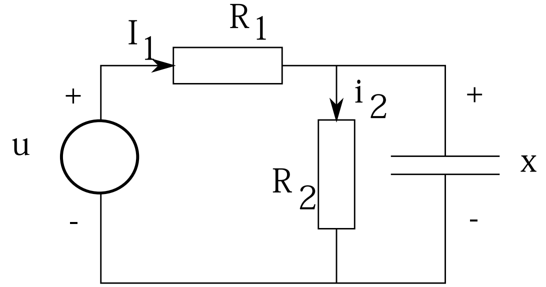
$$F = -S^{-1}S_d$$

Inverses of dynamic systems

Feedforward requires a system inverse.

- Inversion of SISO linear systems is easy, e.g. $\frac{s+b}{s^2+s+1}$ has the inverse $\frac{s^2+s+1}{s+b}$
  but
  - The inversion is only exact if the initial conditions match.
  - Nonmatching initial conditions is OK if both system and inverse have all poles strictly in the left half plane. ($b > 0$ in example above)
  - A strictly proper system gets an improper inverse (i.e. a system containing differentiators)
- Inversion of nonlinear systems?

A nonlinear circuit example



$$\dot{x} = I_1 - I_2, \quad I_1 = u - x, \quad I_2 = g(x)$$

Input: voltage u, Output: current I_1

$$\dot{x} = -x - g(x) + u$$
$$y = -x + u$$

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The circuit and its inverse

$$\dot{x} = -x - g(x) + u \qquad \dot{\hat{x}} = -g(\hat{x}) + r$$
$$y = -x + u \qquad u = \hat{x} + r$$

Note: no differentiation of reference signal

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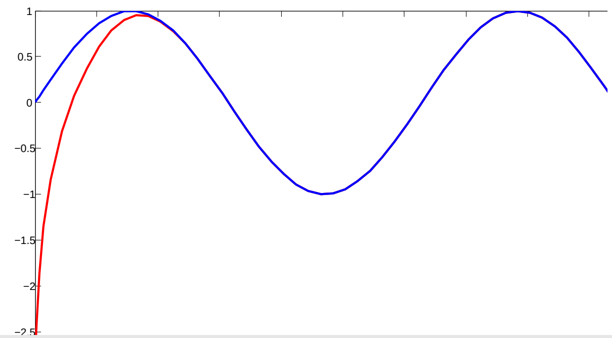
Series connection of inverse and original system

$$\dot{\hat{x}} = -g(\hat{x}) + r$$
$$\dot{x} = -x - g(x) + \hat{x} + r$$
$$y = -x + \hat{x} + r$$



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