01211433

Vision and Control of Industrial Robots

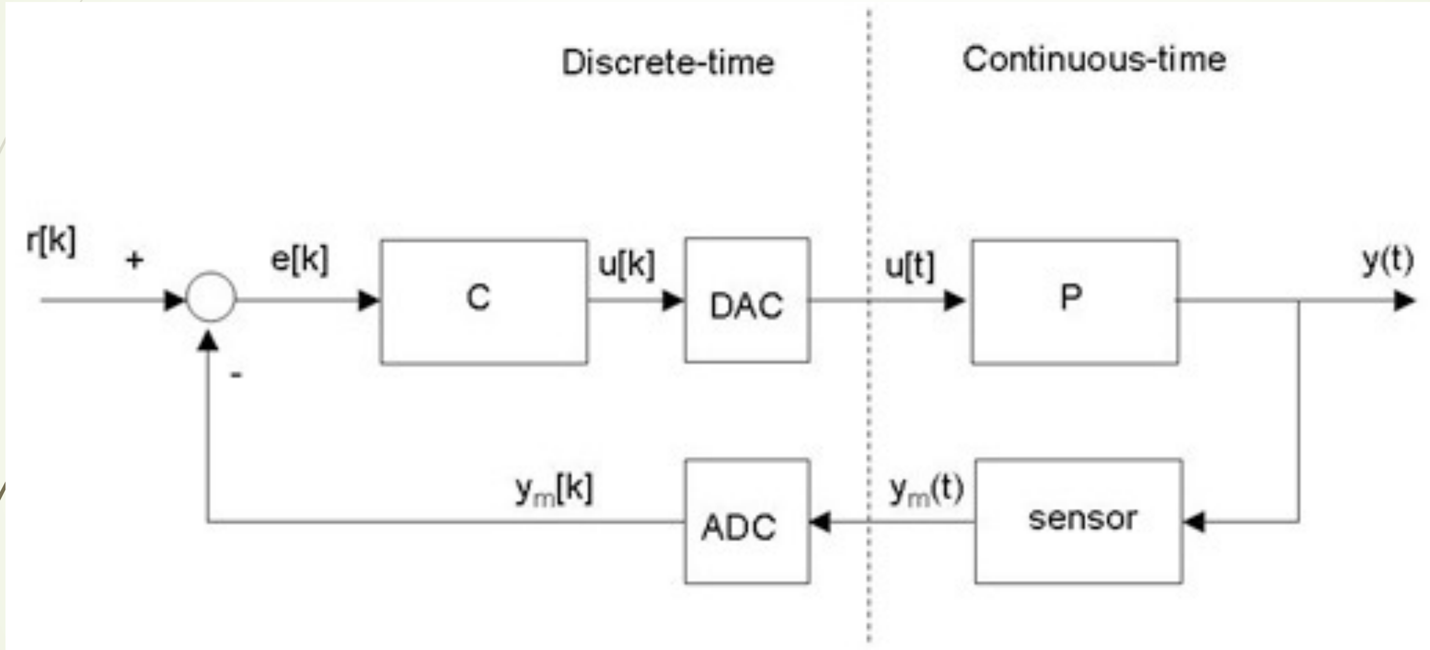
Controller Implementation

Dr.Varodom Toochinda
Dept. of Mechanical Engineering, Kasetsart University

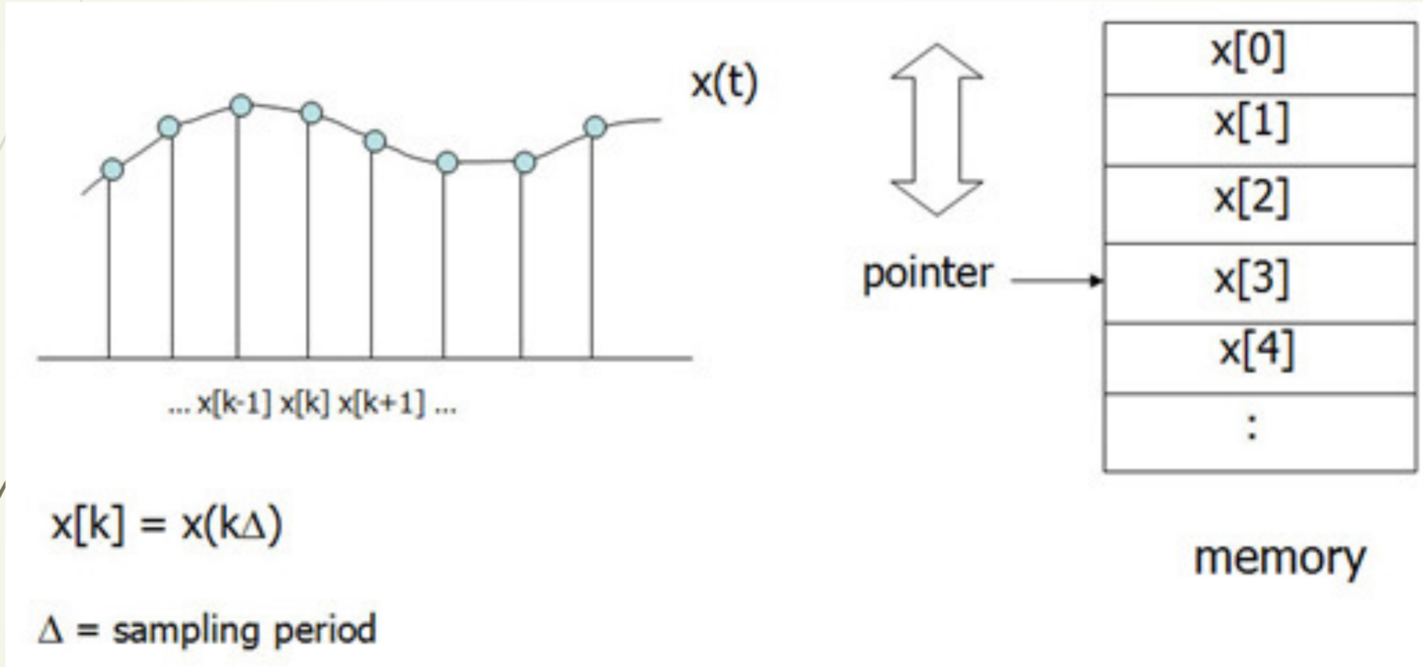
Topics

- hybrid systems
- Sampling of analog signal
  - aliasing
  - sampling theorem
- Discrete-time System Description
  - Approximation of continuous-time transfer function
    - forward difference
    - backward difference
    - bilinear transformation
  - Stability of discrete-time feedback system
  - Relationship between approximation and stability
- Discrete-time system implementation

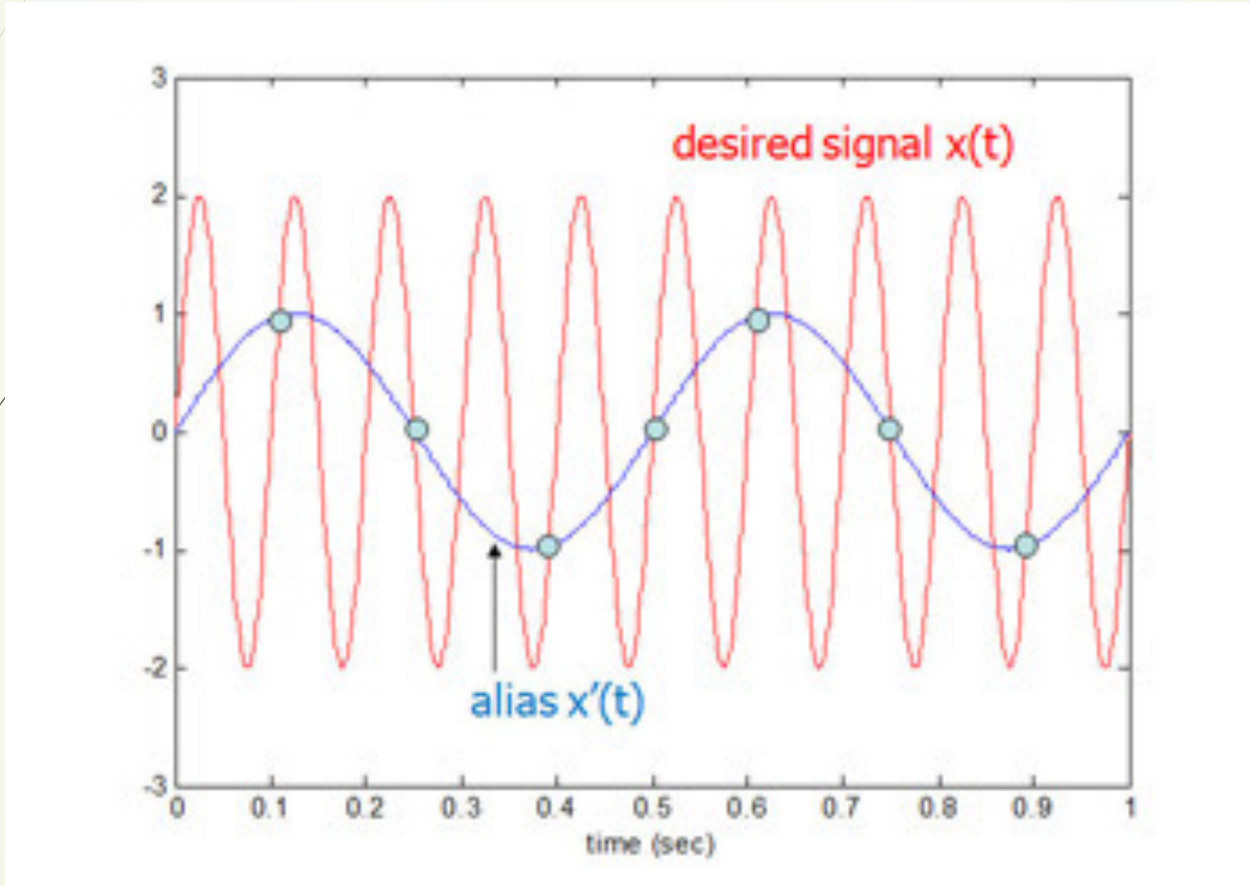
Hybrid Feedback Systems



Sampling of analog signal



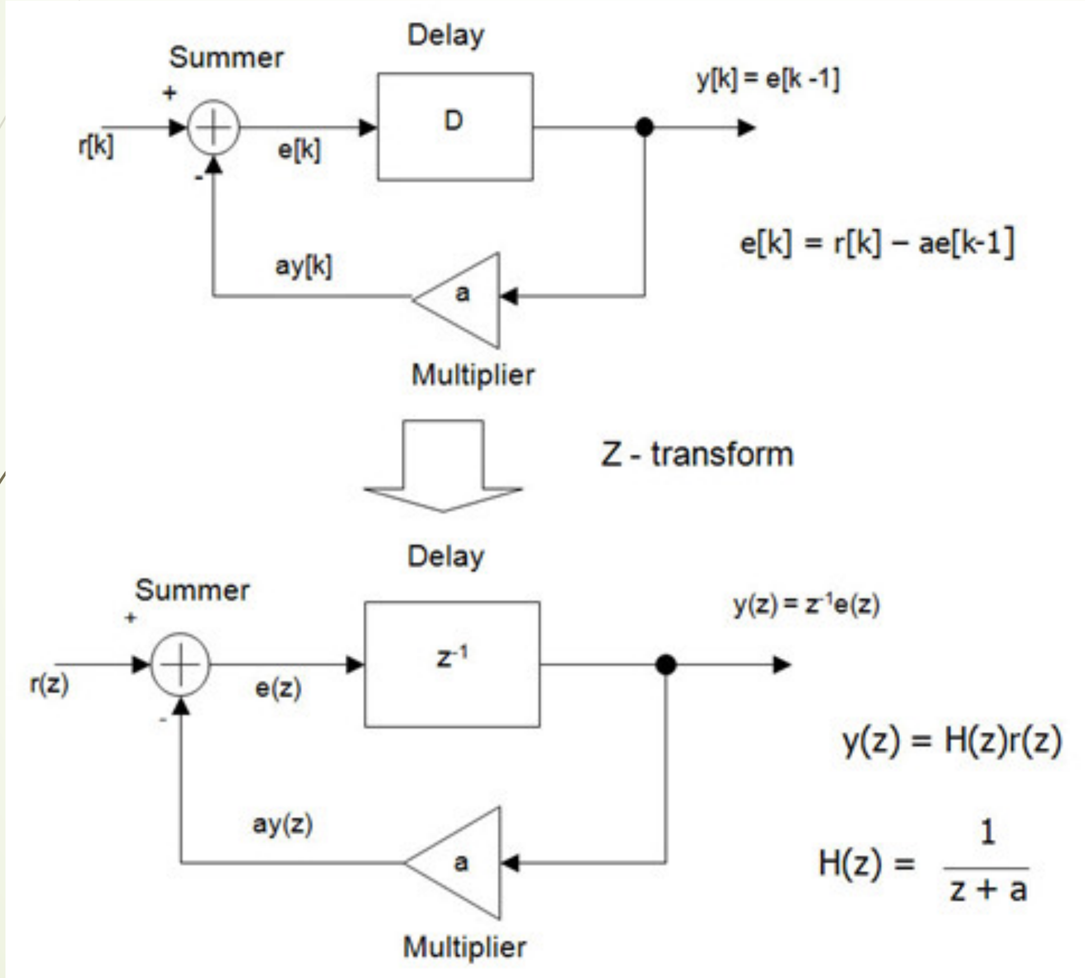
aliasing problem



Sampling Theorem

- Signal can be reconstructed without aliasing problem with sampling frequency twice the signal bandwidth, called Nyquist rate

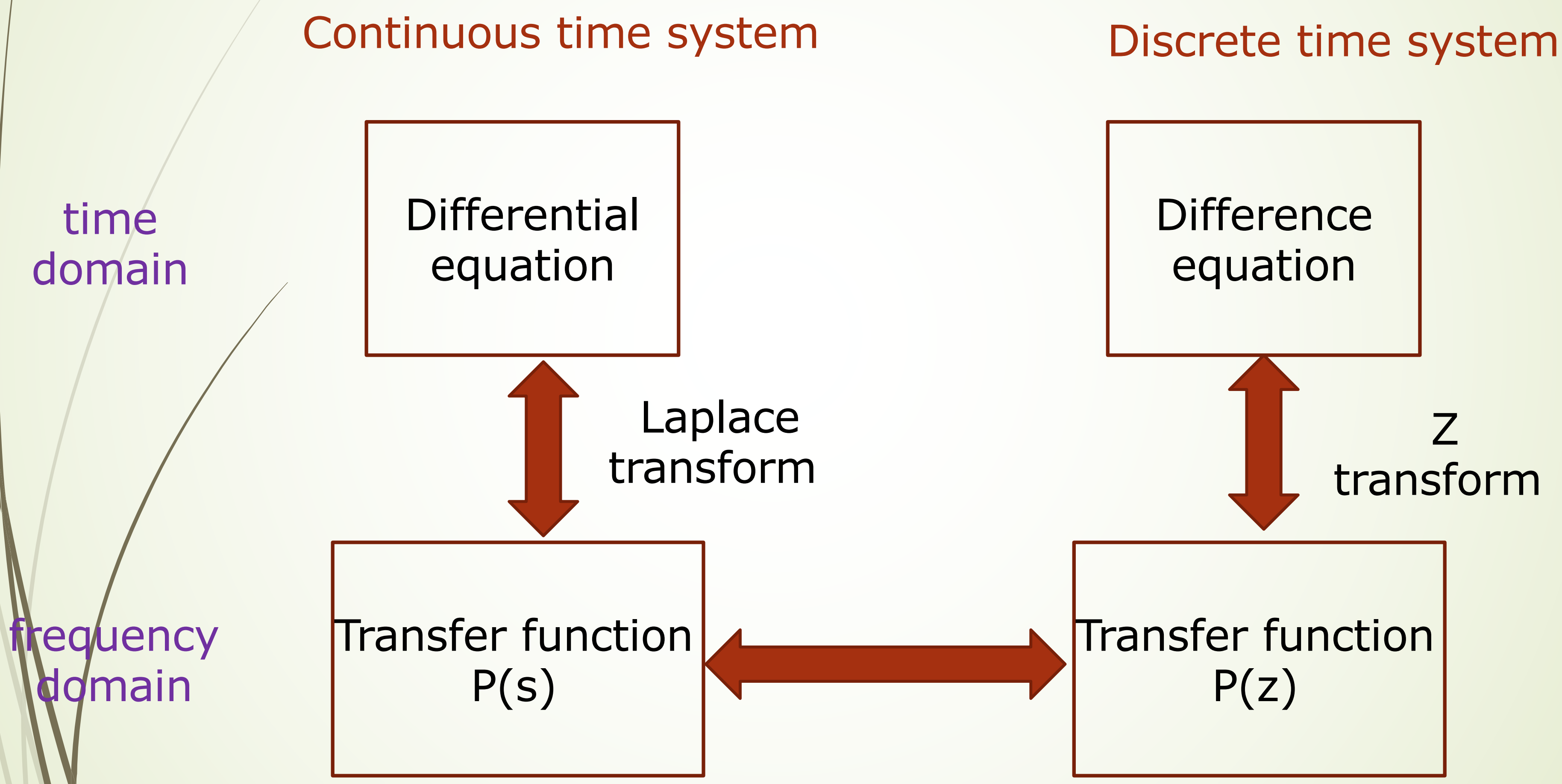
Discrete-time system description



Difference equation

Discrete-time
Transfer function

Continuous-discrete relationships



Approximation of continuous-time transfer function

Consider $$\dot{u}(t) = e(t)$$

$$C(s) = \frac{U(s)}{E(s)} = \frac{1}{s}$$

Solution $$u(t) = u(t_0) + \int_{t_0}^{t} e(\tau)d\tau$$

At sampling instant

$$u((k+1)T) = u(kT) + \int_{kT}^{(k+1)T} e(\tau)d\tau$$

3 methods of integrator approximation

$$u((k+1)T) = u(kT) + \int_{kT}^{(k+1)T} e(\tau)\,d\tau$$

Forward difference

$$u(k+1) \approx u(k) + e(k)T$$

Backward difference

$$u(k+1) \approx u(k) + e(k+1)T$$

Bilinear transform

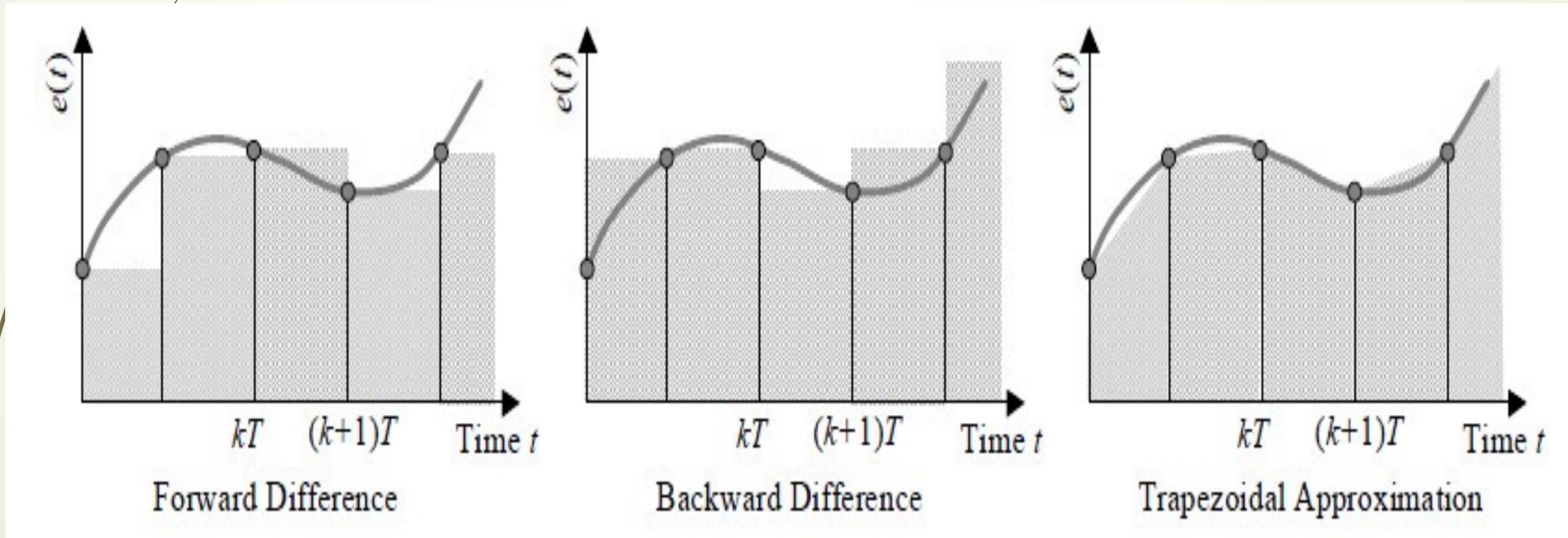
$$u(k+1) \approx u(k) + \frac{e(k+1)+e(k)}{2}T$$

3 methods of integrator approximation

Forward difference $$u(k+1) \approx u(k) + e(k)T$$

Backward difference $$u(k+1) \approx u(k) + e(k+1)T$$

Bilinear transform $$u(k+1) \approx u(k) + \frac{e(k+1)+e(k)}{2}T$$



Discrete-time Transfer Function

$$C(z) = U(z) / E(z)$$

Forward difference

$$C(z) = \frac{T}{z-1} = \frac{Tz^{-1}}{1-z^{-1}}$$

Backward difference

$$C(z) = \frac{Tz}{z-1} = \frac{T}{1-z^{-1}}$$

Bilinear transform

$$C(z) = \frac{T}{2}\frac{z+1}{z-1} = \frac{T}{2}\frac{1+z^{-1}}{1-z^{-1}}$$

Transformation of C(s) to C(z)

Forward difference

$$C(z) = C(s)\Big|_{s \to \frac{z-1}{T}}$$

Backward difference

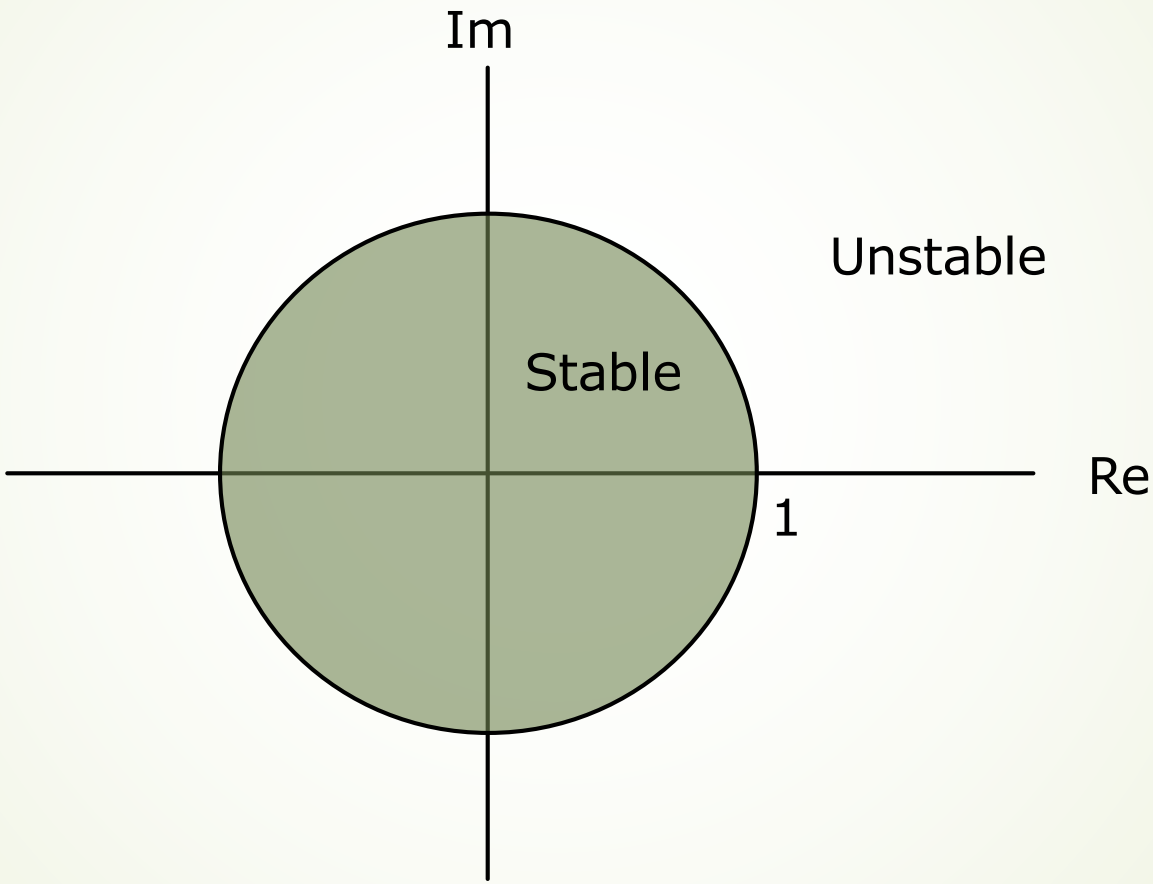
$$C(z) = C(s)\Big|_{s \to \frac{z-1}{Tz}}$$

Bilinear transform

$$C(z) = C(s)\Big|_{s \to \frac{2}{T}\frac{z-1}{z+1}}$$

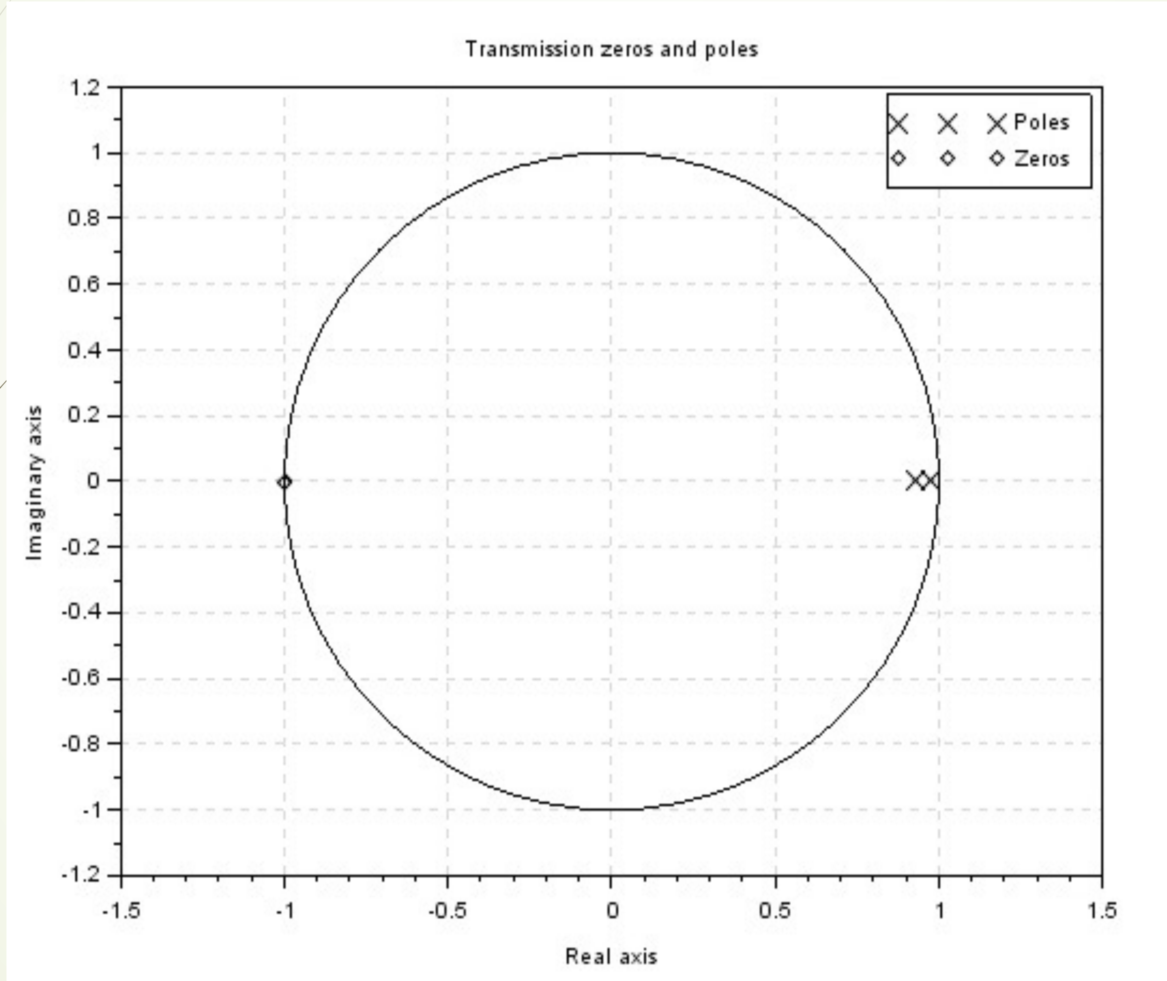
Scilab commands : cls2dls

Stability of discrete-time transfer function

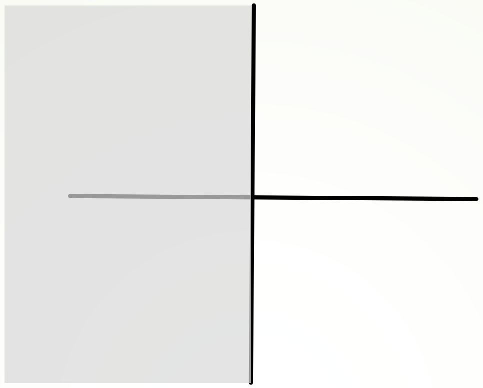


Closed-loop pole location

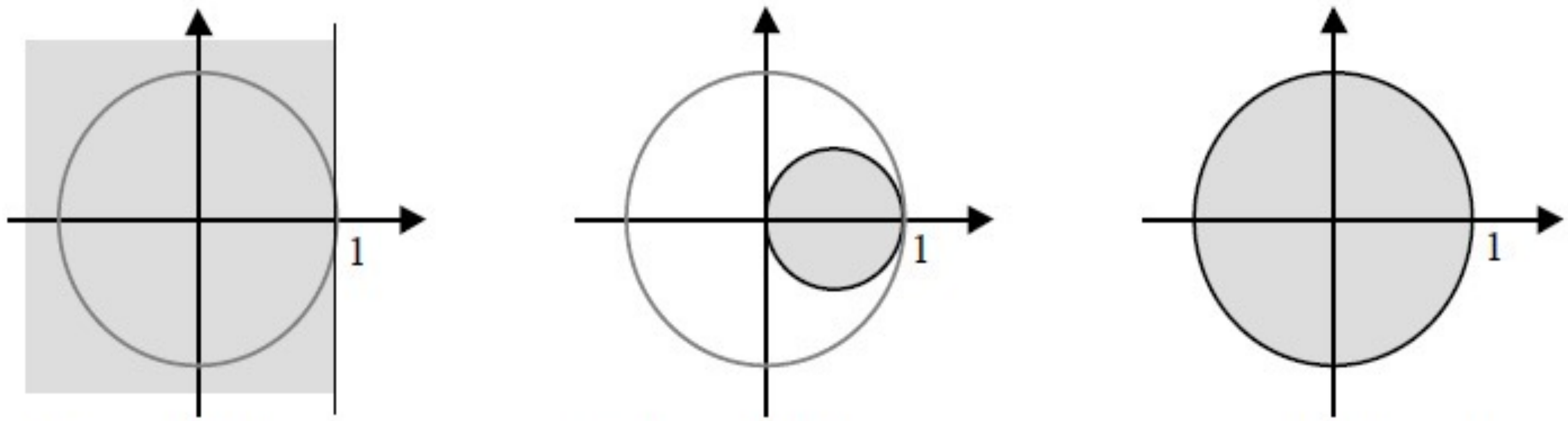
Pole/zero plot by plzr



Stability region relationship from approximations

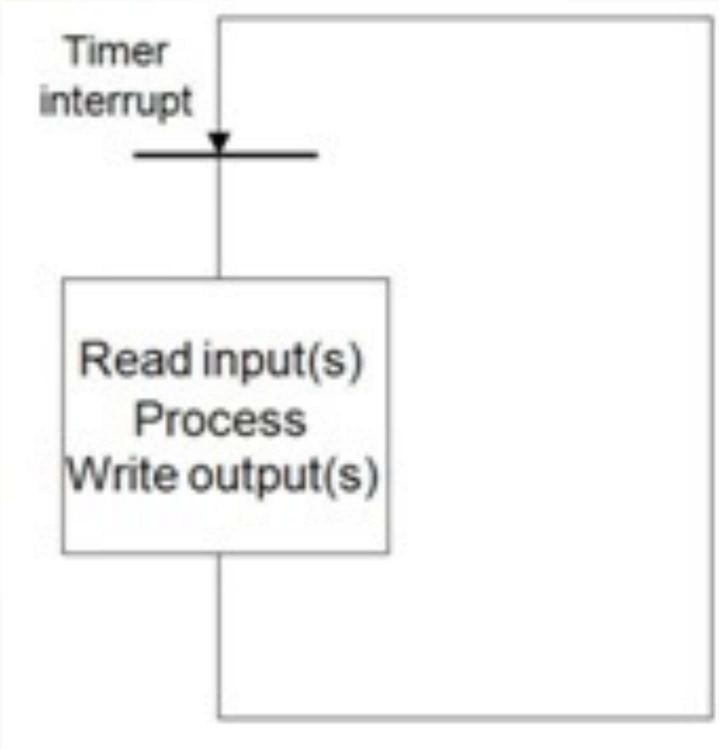


Continuous time

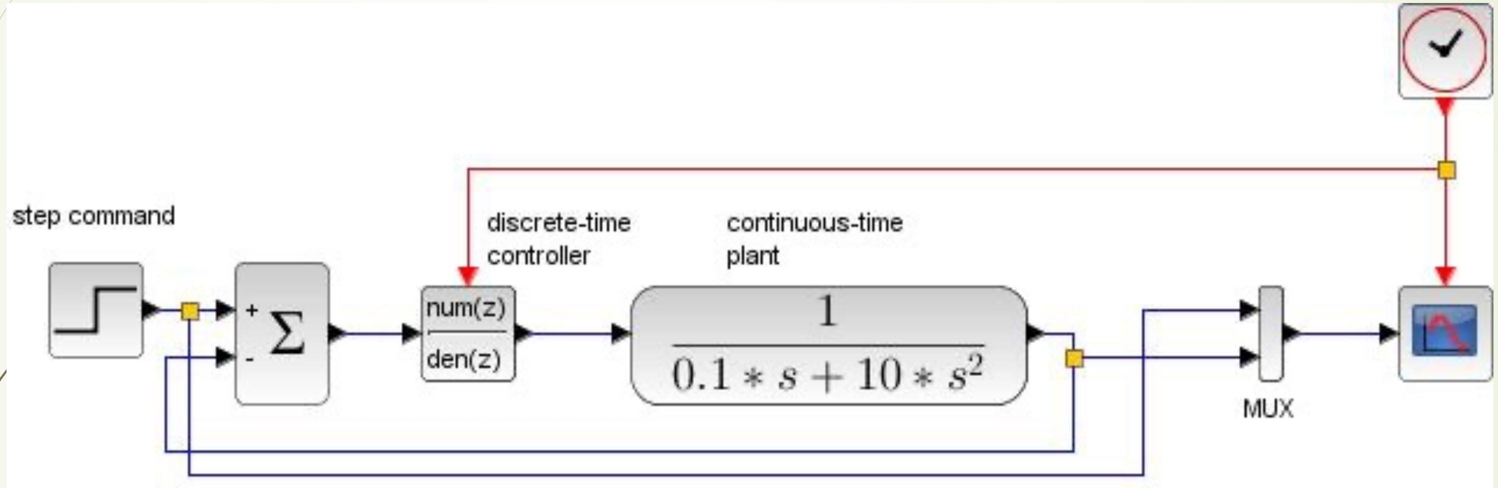


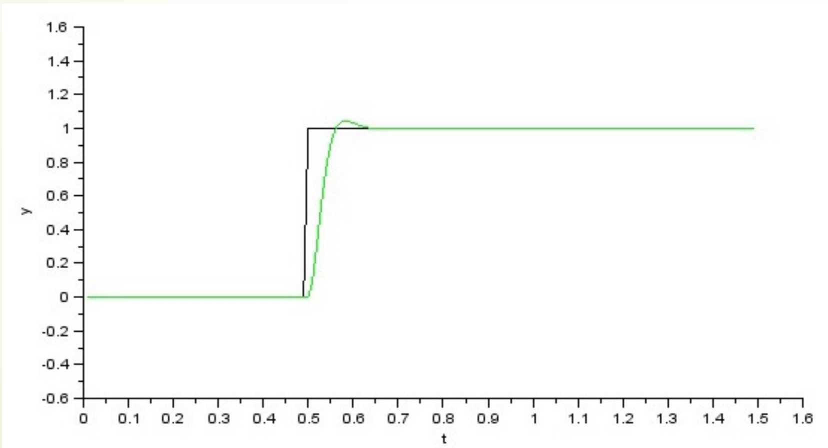
Forward Difference   Backward Difference   Trapezoidal Approximation

Discrete-time implementation



Hybrid system simulation





hybridsim.zcos

HW#4

Convert your controller from HW#3 to discrete-time, and simulate with the plant

$$P(s) = \frac{1}{s(7s+0.05)}$$

Compare the responses between continuous and discrete-time.
This homework can be done with either Python or Julia.
There is no Jupyter or Pluto notebook prepared for you.
Students must create your notebooks.