



**POLITECNICO**  
MILANO 1863

# Networked Control: Project 10

Automatic Generation Control (AGC)

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$$\begin{cases} \dot{x} = Ax + B_1 u_1 + B_2 u_2 \\ y_i = C_i x, \quad i = 1, 2 \end{cases}$$

With  $x = [\Delta x_1^T, \Delta v_1, \Delta p_e, \Delta v_2, \Delta x_2]^T$

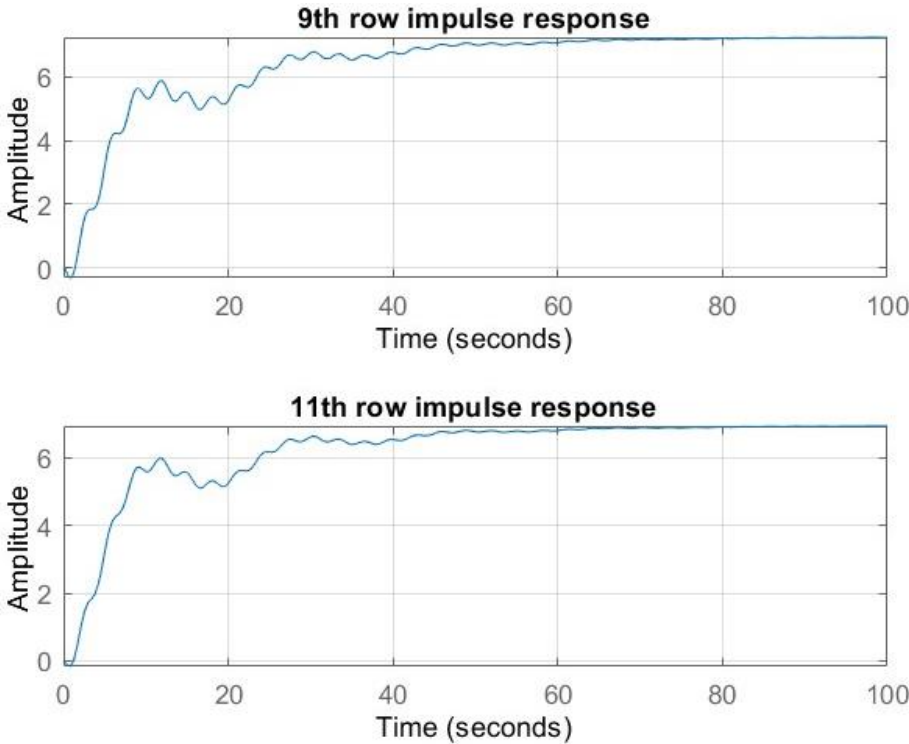
- $\Delta x_i$  is the deviation of the internal states of area  $i$  with respect to their nominal value,
- $\Delta v_i$  are variables introduced to achieve integral action,
- $\Delta p_e$  is the variation of the total power exchange between the areas with respect to its nominal value.



# Networked Control: Project 10

## Eigenvalues and Spectral abscissa

Simply stable eigenvalues



Continuous-time	Discrete-time
0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	1.0000 + 0.0000i
-0.0506 + 2.0380i	0.9744 + 0.2014i
-0.0506 - 2.0380i	0.9744 - 0.2014i
-4.3931 + 0.0000i	0.6445 + 0.0000i
-4.5326 + 0.0000i	0.6356 + 0.0000i
-5.0006 + 0.0000i	0.6065 + 0.0000i
-5.0010 + 0.0000i	0.6065 + 0.0000i
-1.9971 + 0.0000i	0.8190 + 0.0000i
-1.9933 + 0.0000i	0.8193 + 0.0000i
-0.0790 + 0.3331i	0.9916 + 0.0330i
-0.0790 - 0.3331i	0.9916 - 0.0330i
-0.3787 + 0.0000i	0.9628 + 0.0000i
-0.2182 + 0.0000i	0.9784 + 0.0000i
-0.1514 + 0.0000i	0.9850 + 0.0000i
-0.0721 + 0.0000i	0.9928 + 0.0000i
-0.0501 + 0.0000i	0.9950 + 0.0000i
-1.3885 + 0.0000i	0.8704 + 0.0000i
-1.3891 + 0.0000i	0.8703 + 0.0000i

The system is not open-loop asymptotically stable

Sampling time = 0,1s

Given the following information structure constraints:

*Centralized structure:*  $\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix};$

*Decentralized structure:*  $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix};$

*Distrubuted 1 structure:*  $\begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix};$

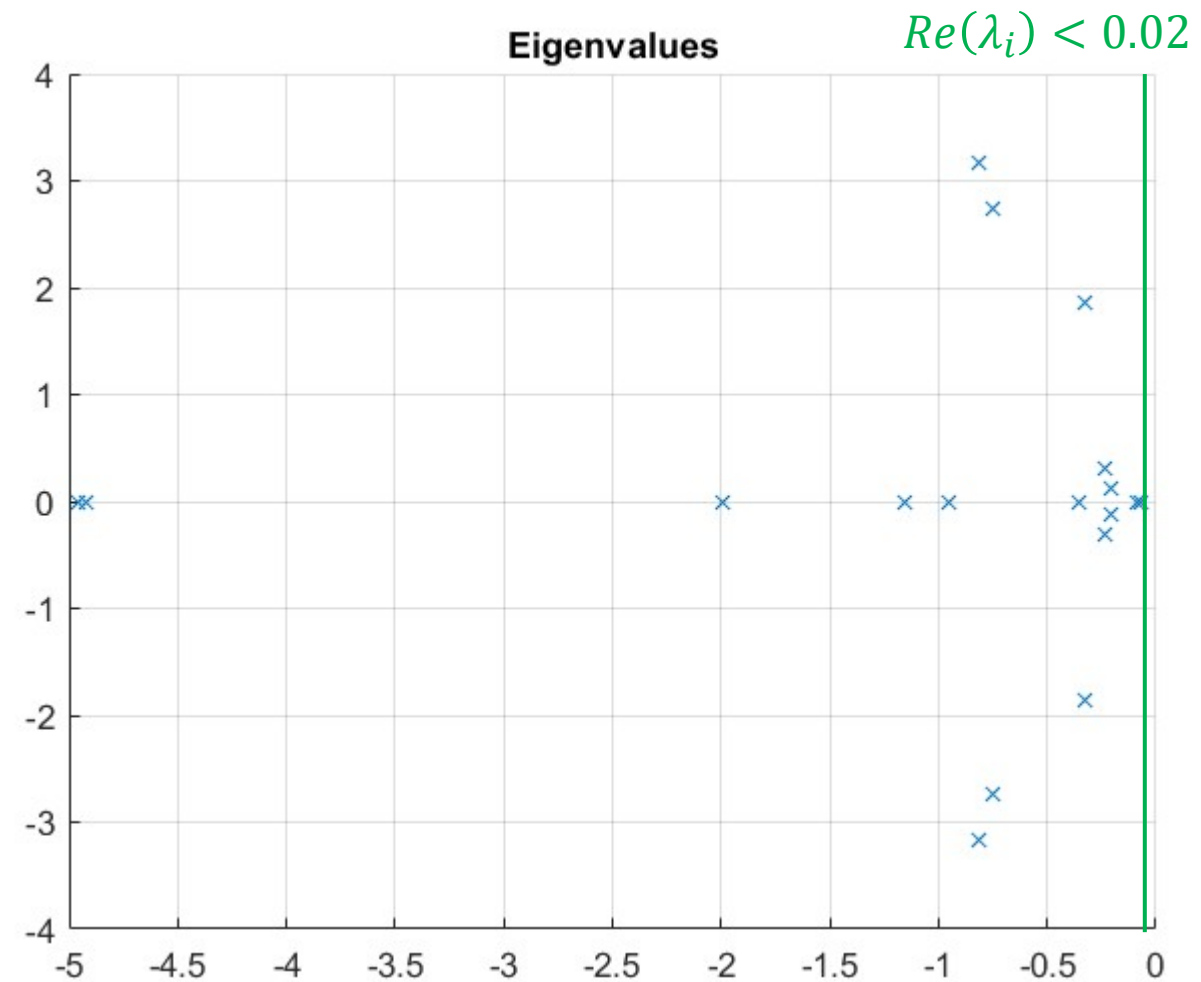
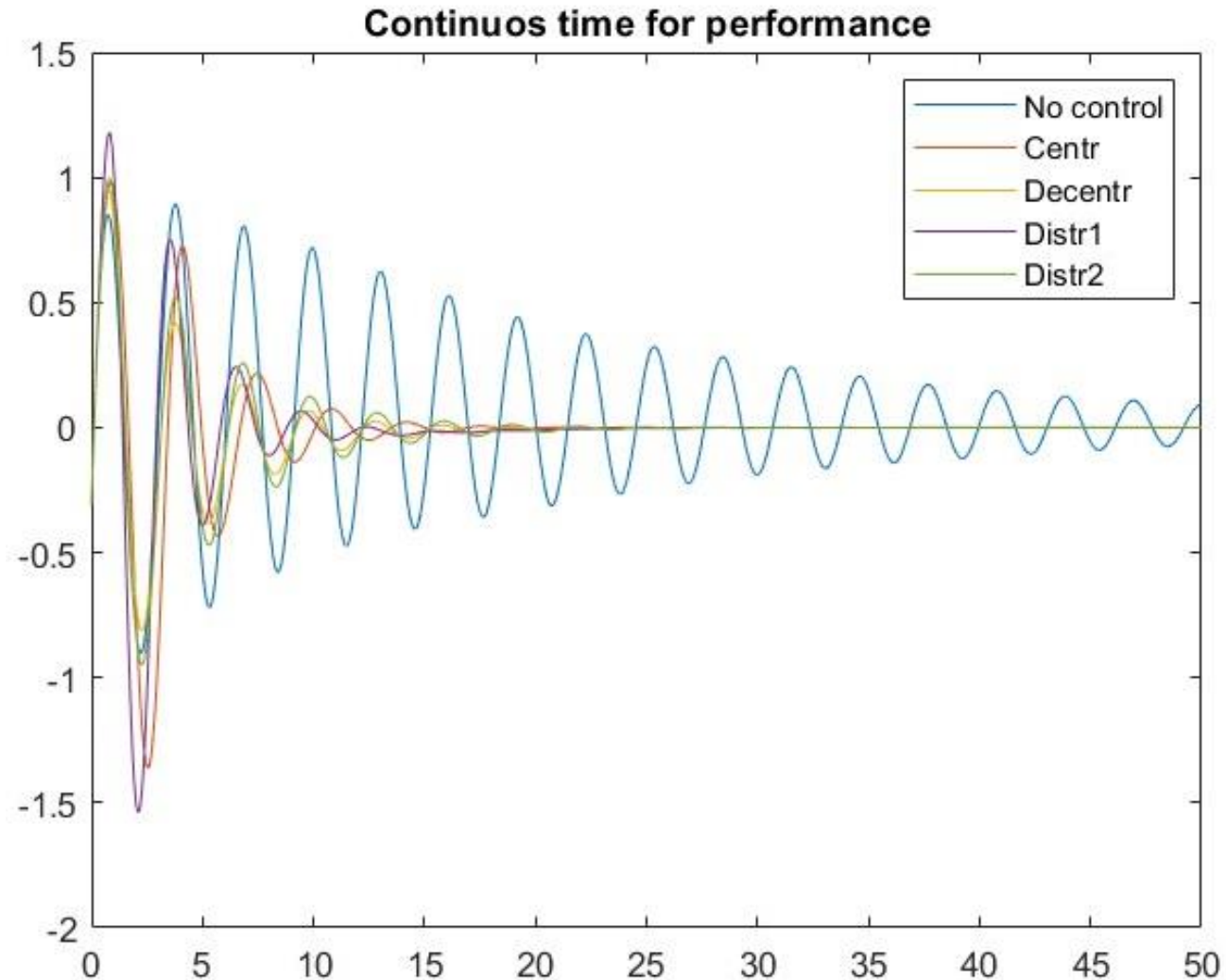
*Distributed 2 structure:*  $\begin{bmatrix} 1 & 0 \\ 1 & 1 \end{bmatrix};$

No Fixed Modes have been found for both continuous and discrete time and in different control structures

## CONTINUOUS TIME

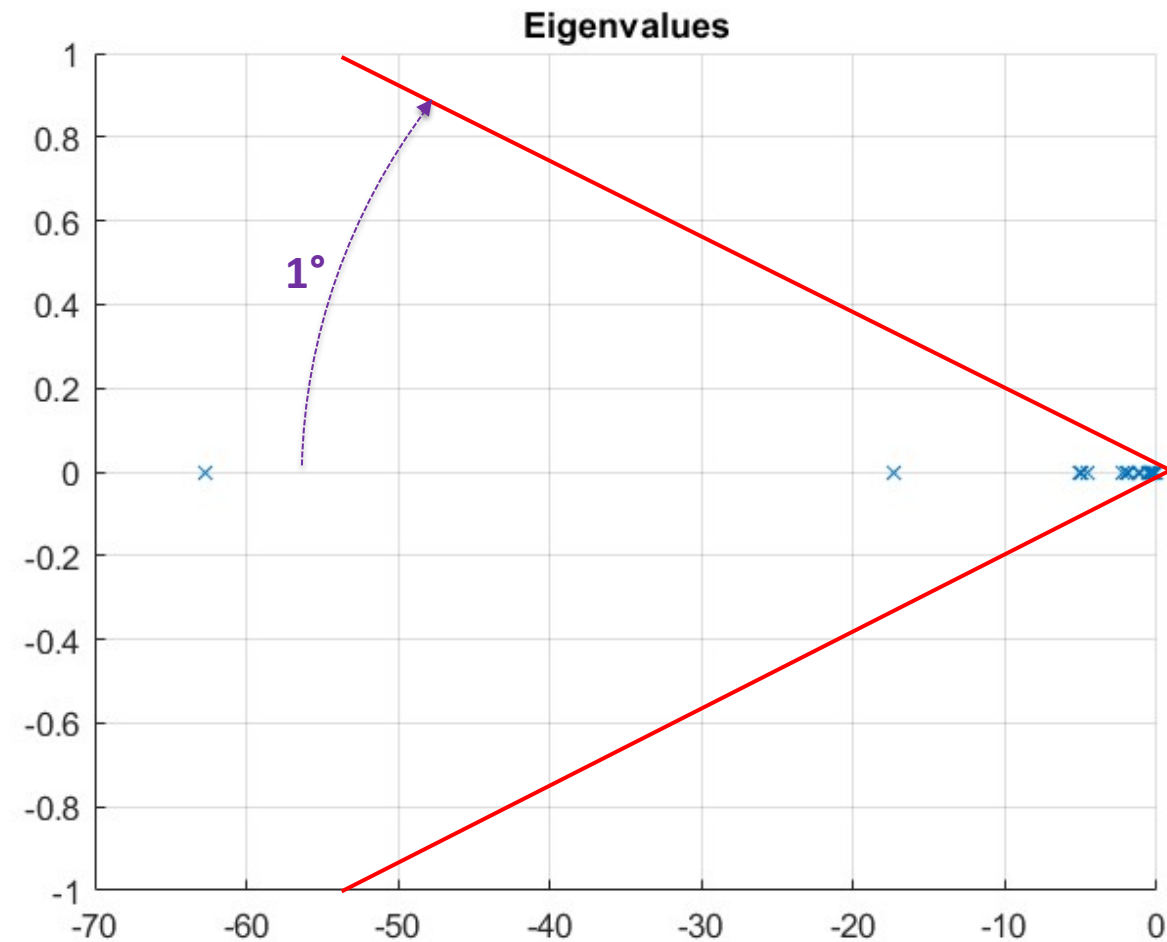
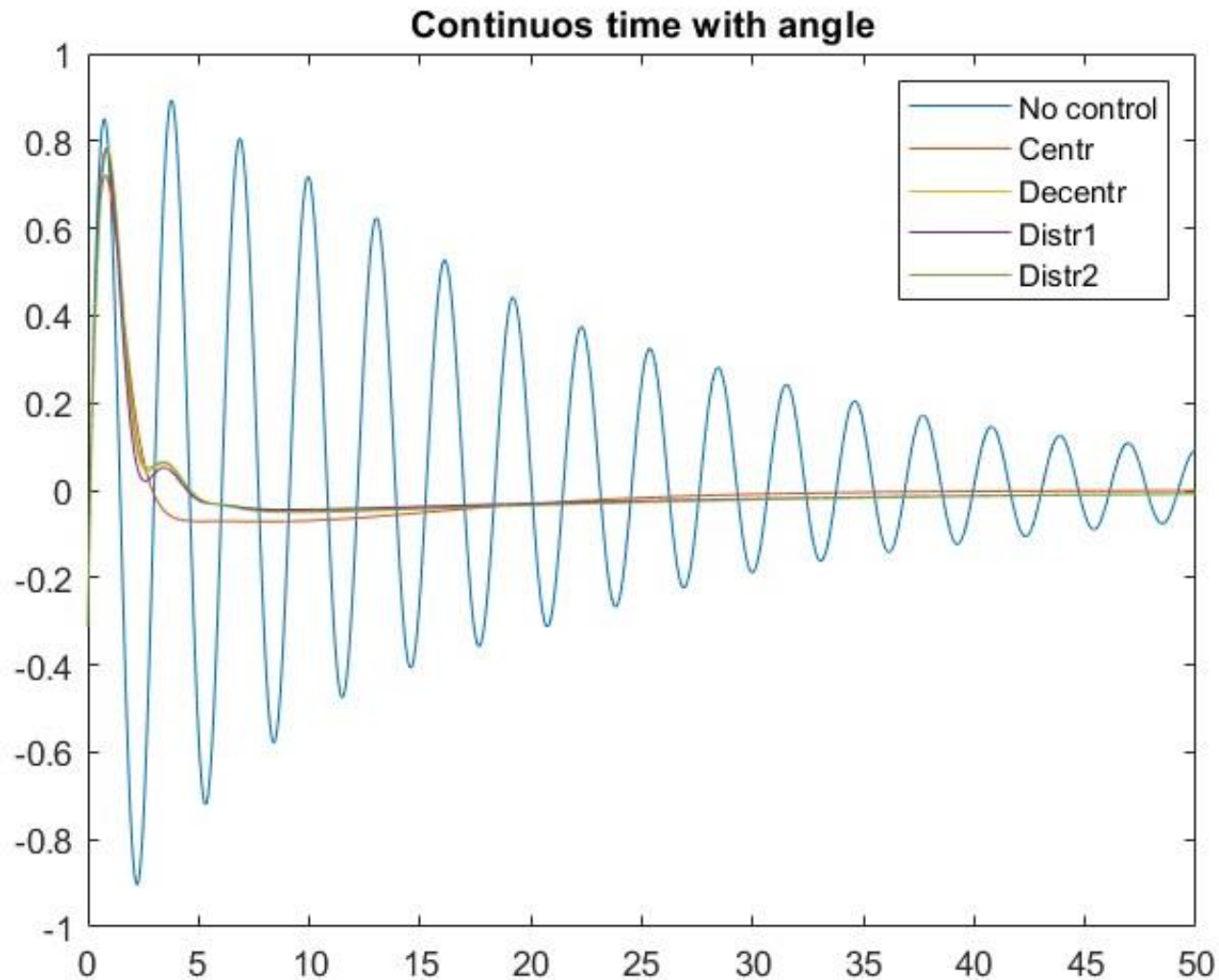
# Networked Control: Project 10

Continuous time – Spectral abscissa limitation



# Networked Control: Project 10

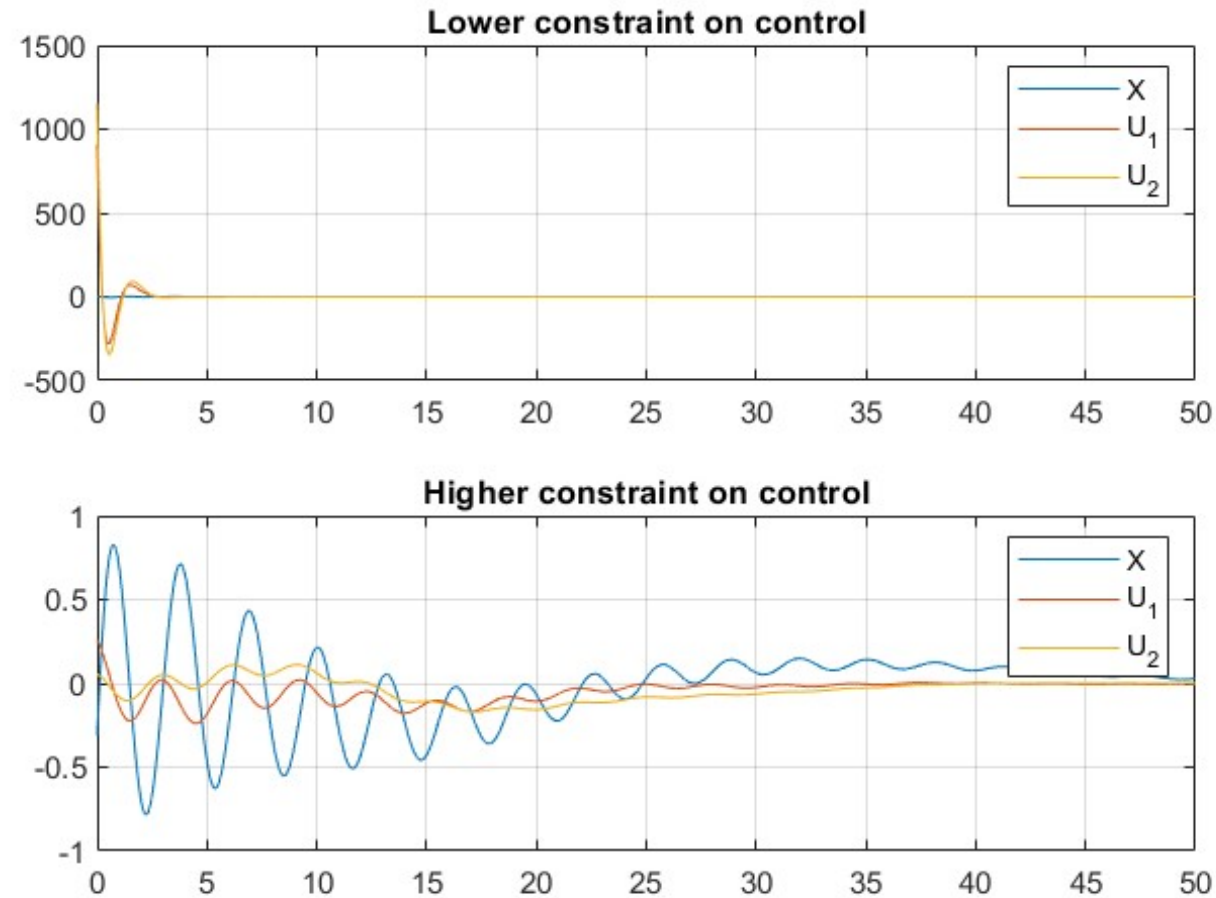
Continuous time – Angular region



# Networked Control: Project 10

Continuous time – Control effort limitation

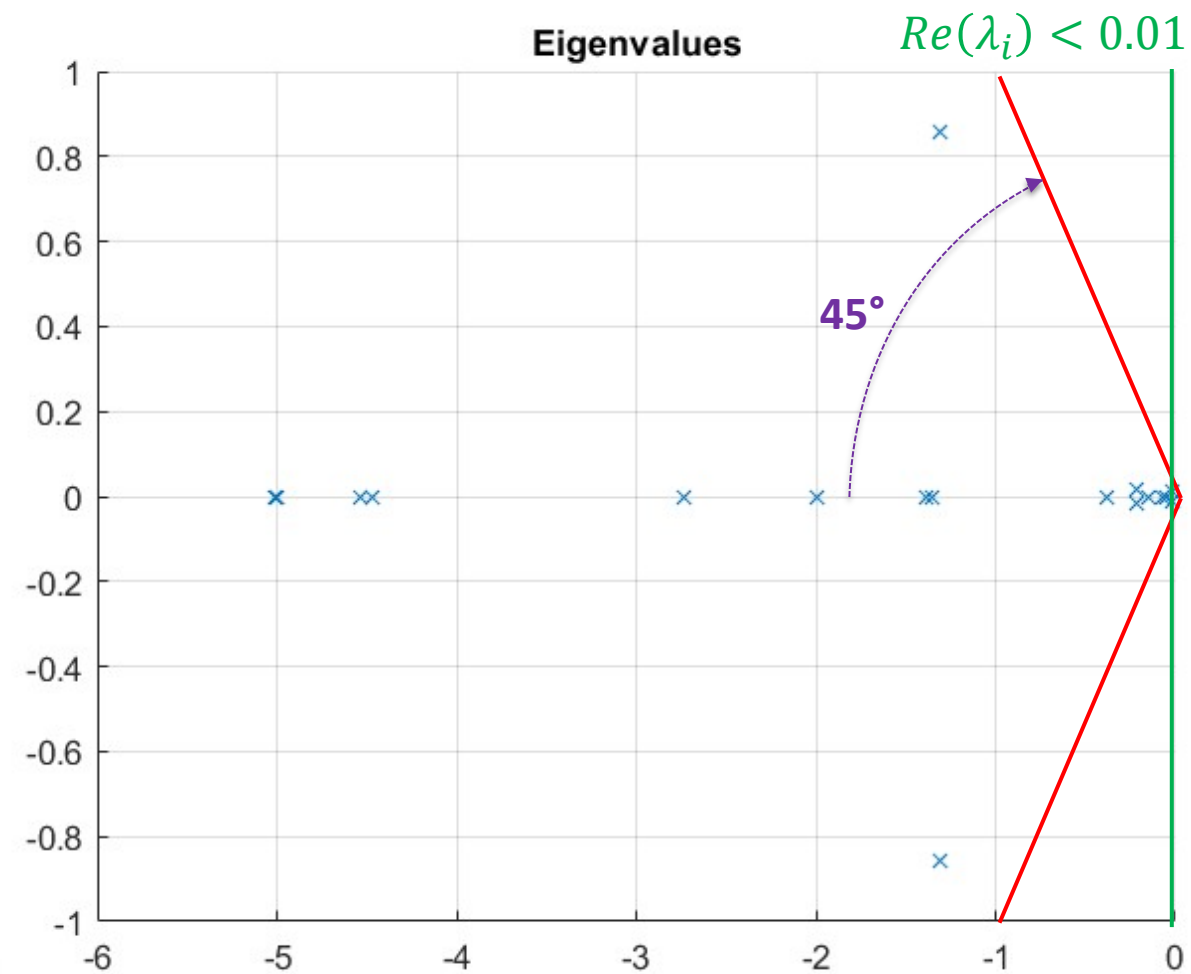
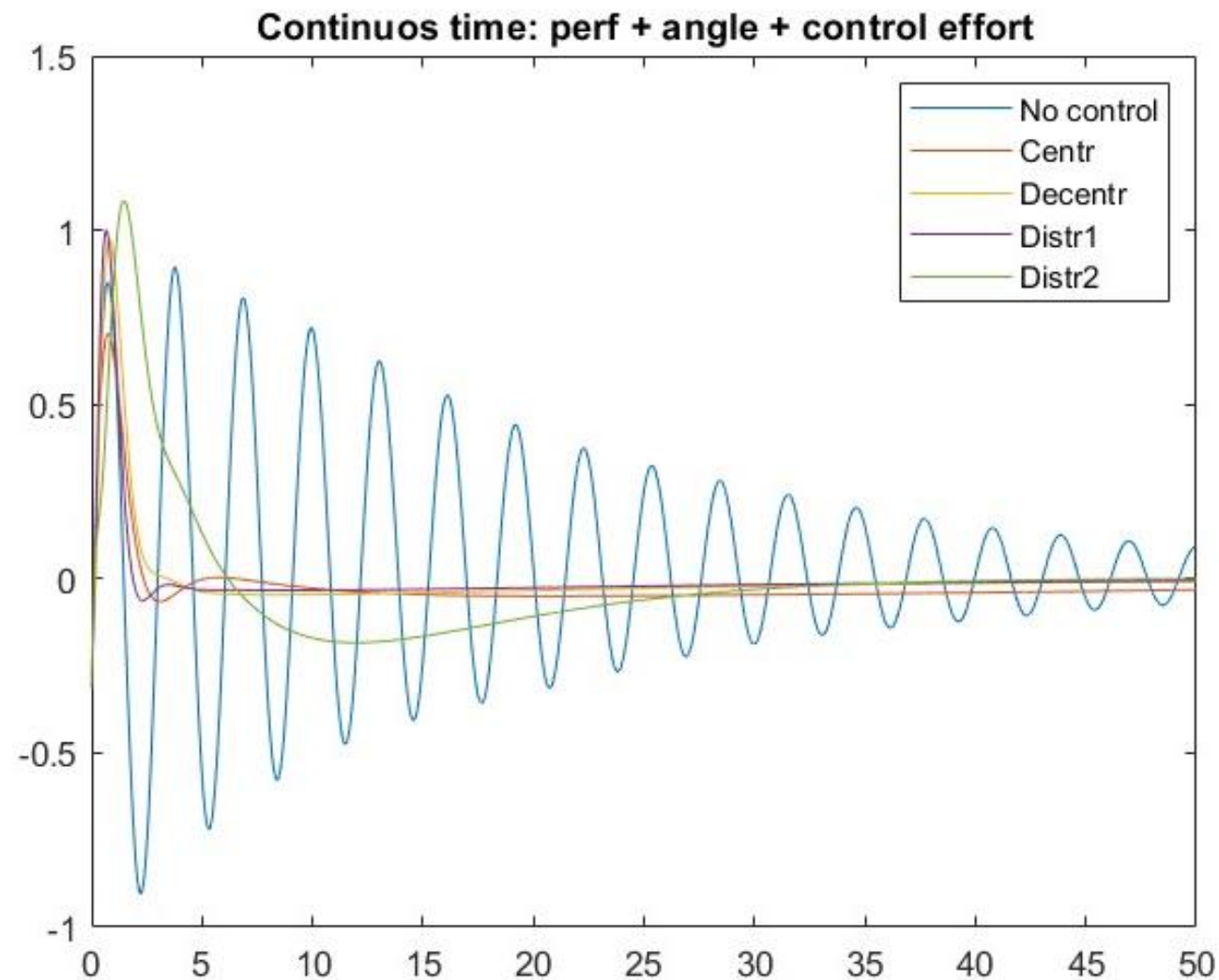
## Control effort comparison





# Networked Control: Project 10

Continuous time – Best mix of constraint



# Networked Control: Project 10

Continuous time – System model with noise

$$\begin{cases} \dot{x} = Ax + B_1 u_1 + B_2 u_2 + B_w w \\ z = H_w x + D_w u \end{cases}$$

## **Noise**

$w \sim U(0,1);$

## **Noise matrix**

$B_w = \text{eye}(19);$

## **Output weight**

$Q = \text{eye}(19);$   
 $Q(10,10) = 100;$

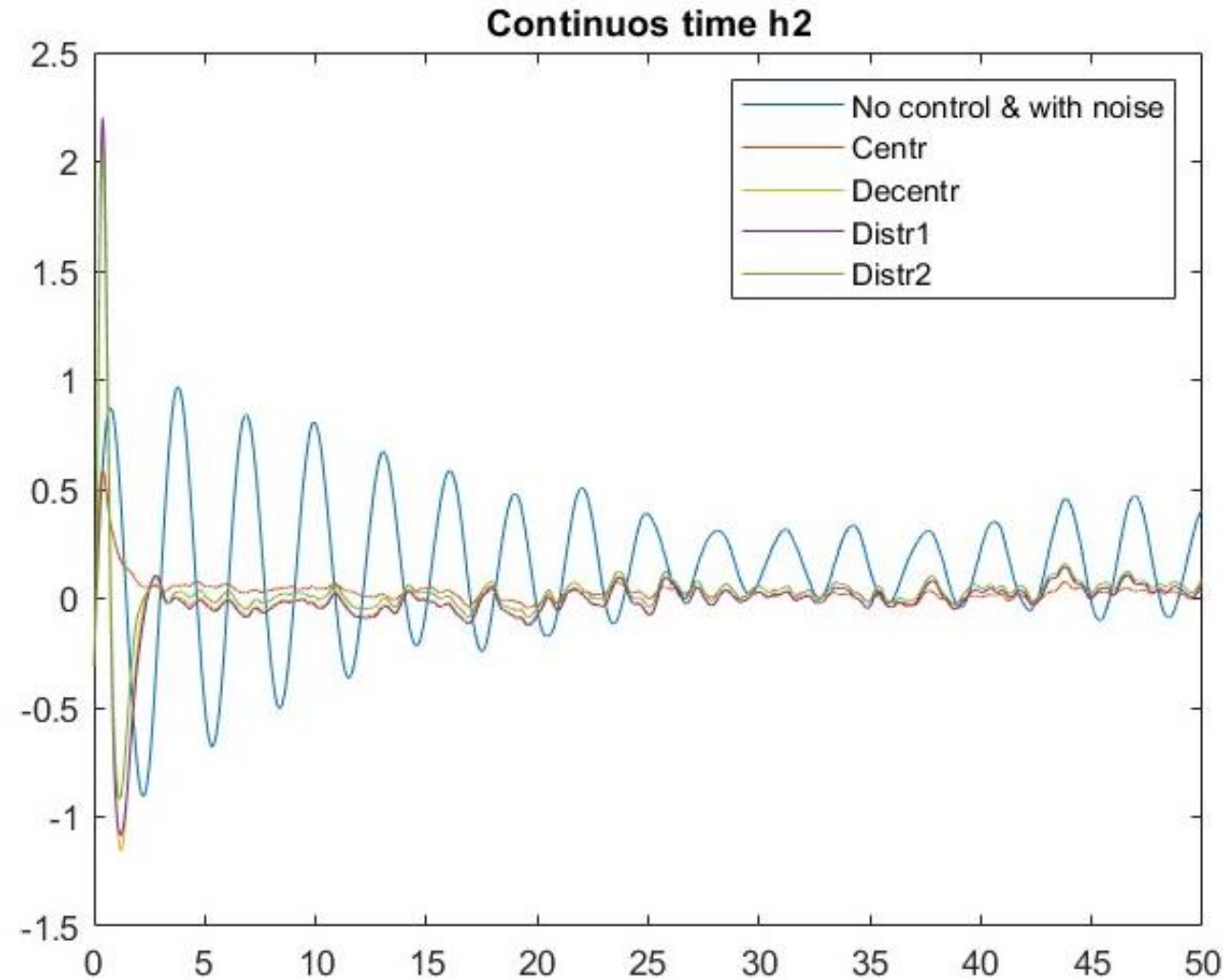
## **Weight matrices**

$H_w = \begin{bmatrix} Q; \\ \text{zeros}(2,19) \end{bmatrix};$

$D_w = \begin{bmatrix} \text{zeros}(19,2); \\ \text{eye}(2,2) \end{bmatrix};$

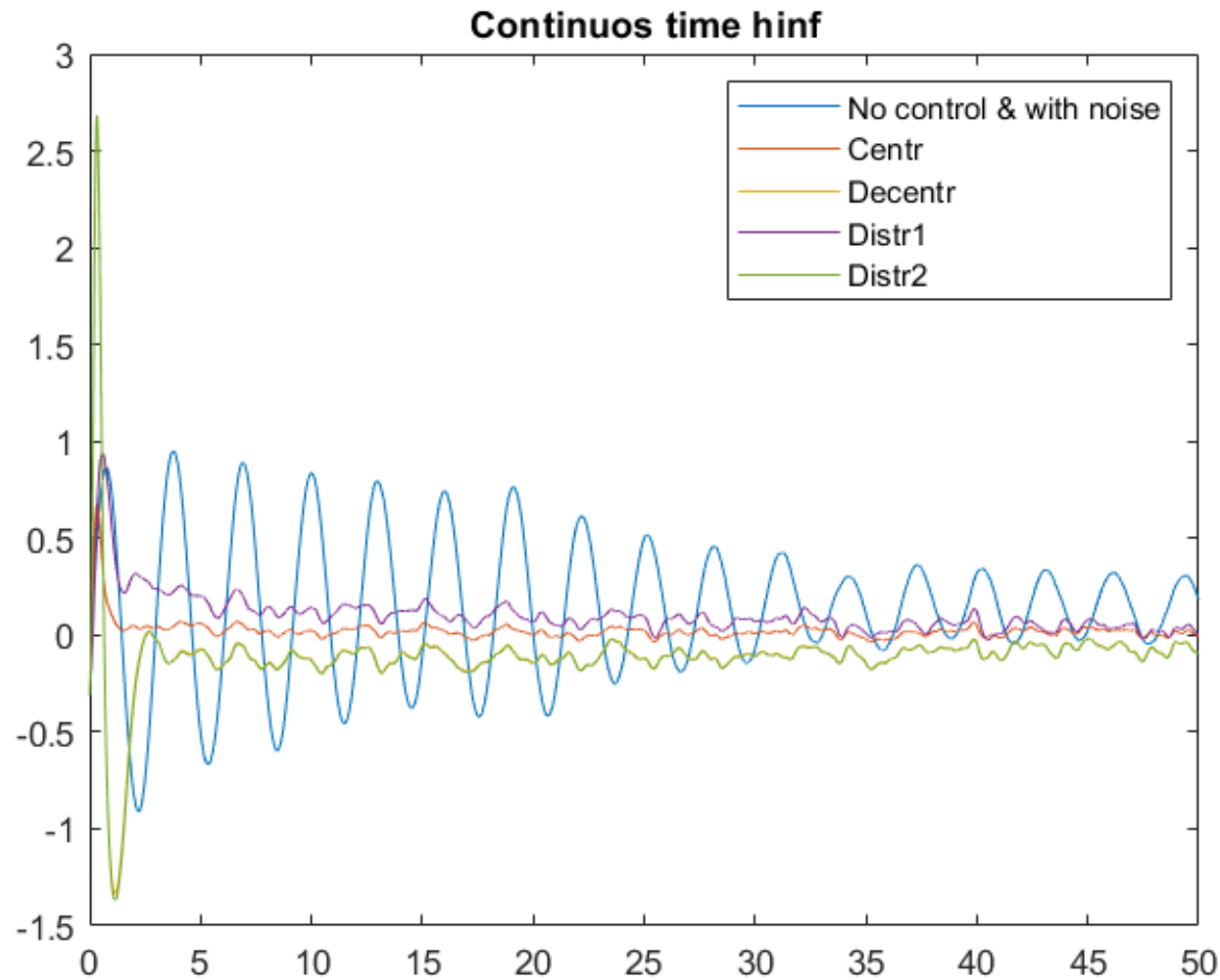
# Networked Control: Project 10

Continuous time with noise – H2 control



# Networked Control: Project 10

Continuous time with noise –  $H^\infty$  control

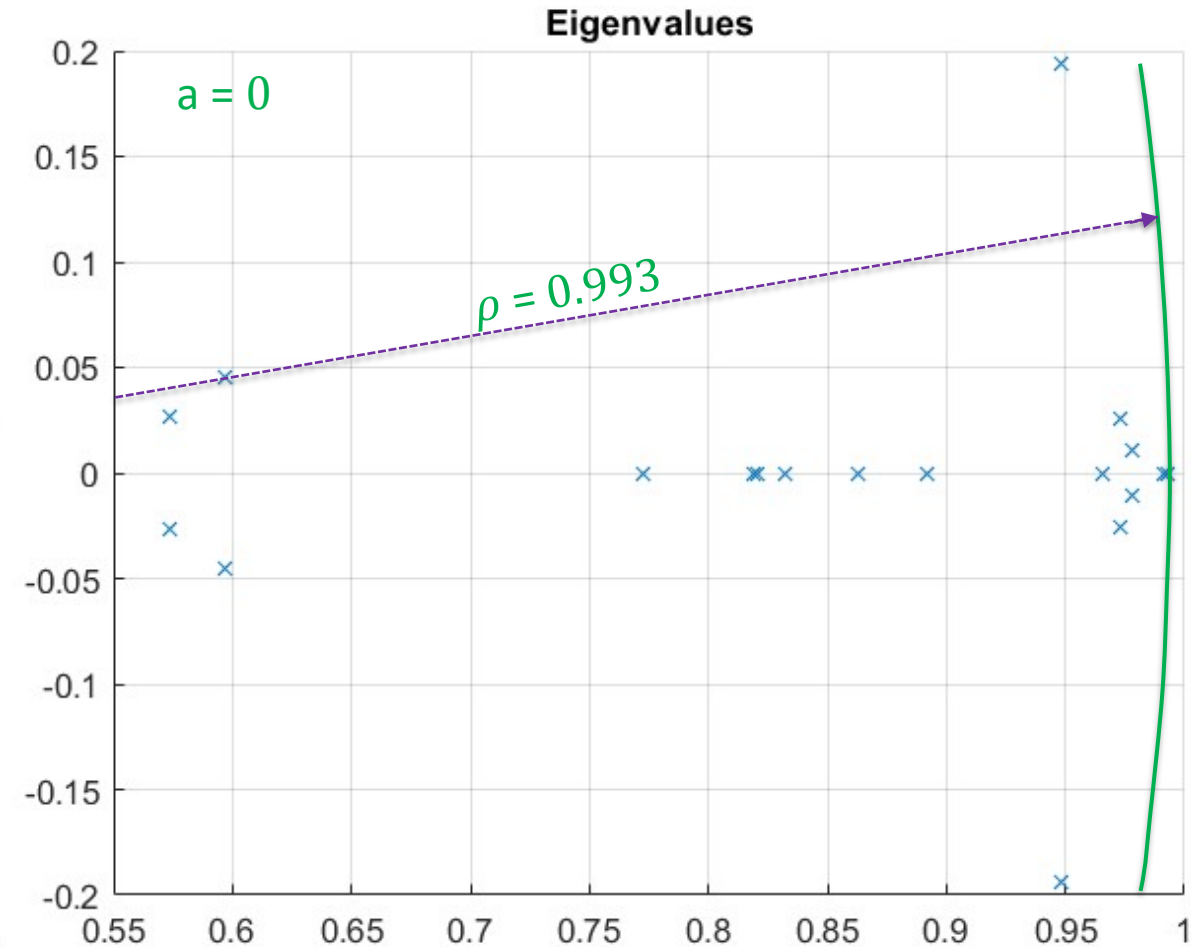
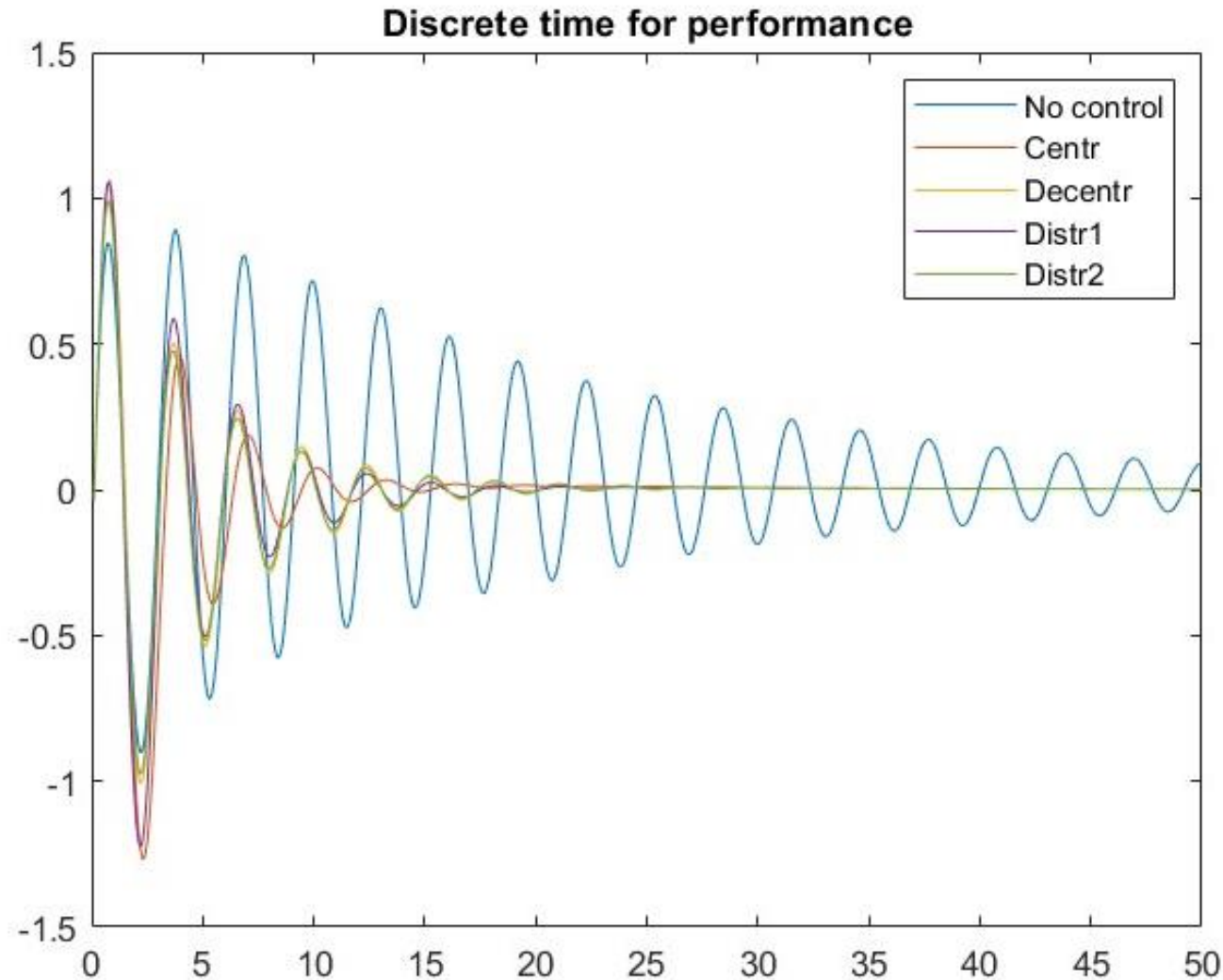




## DISCRETE TIME

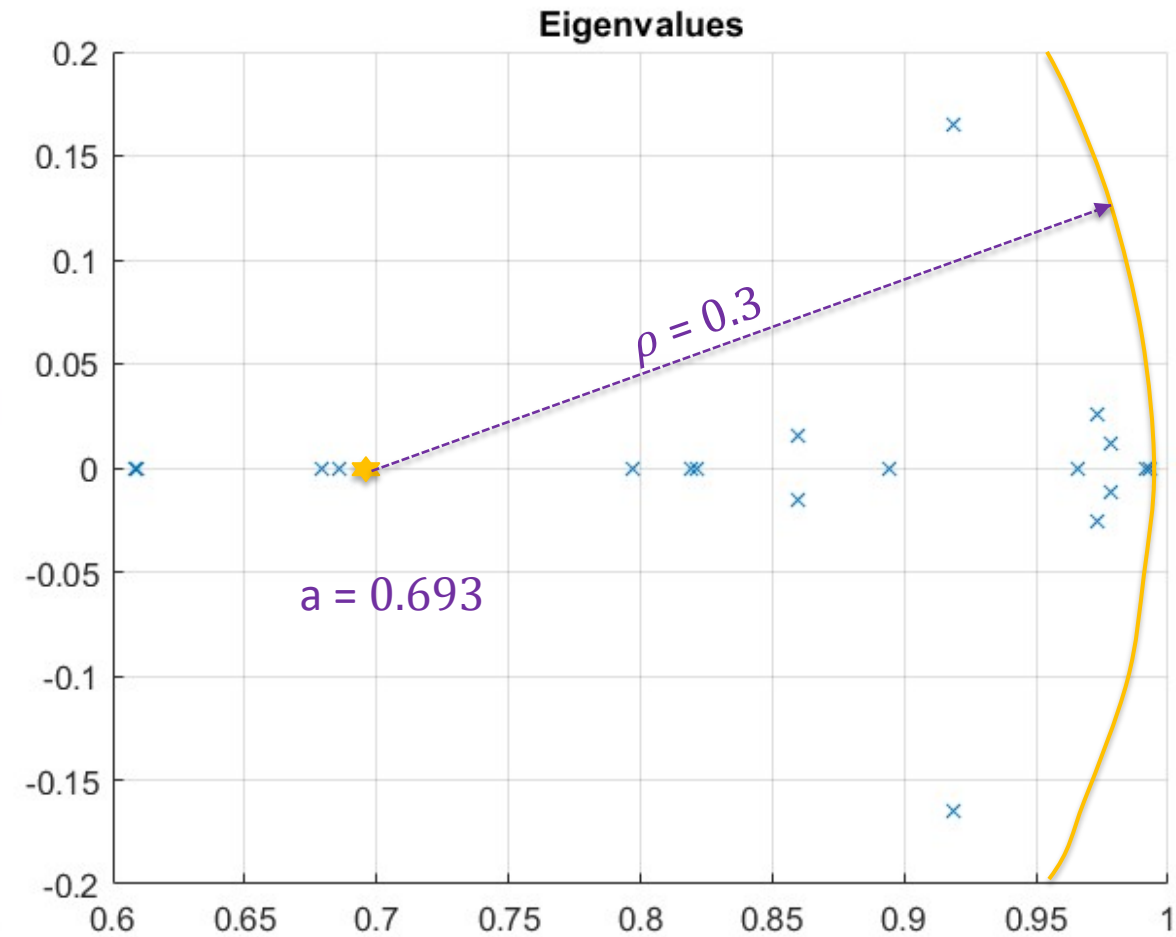
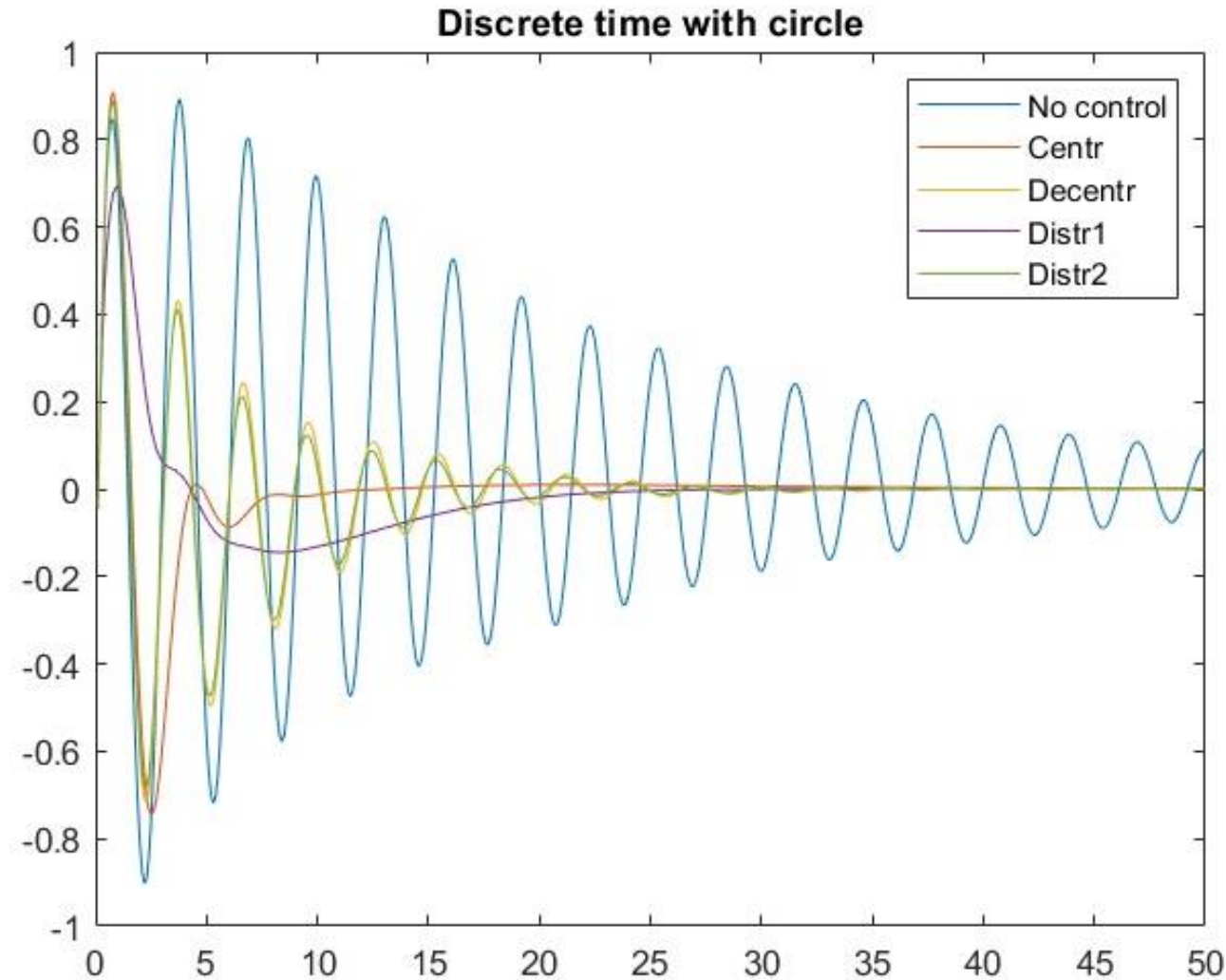
# Networked Control: Project 10

Discrete time – Spectral abscissa limitation



# Networked Control: Project 10

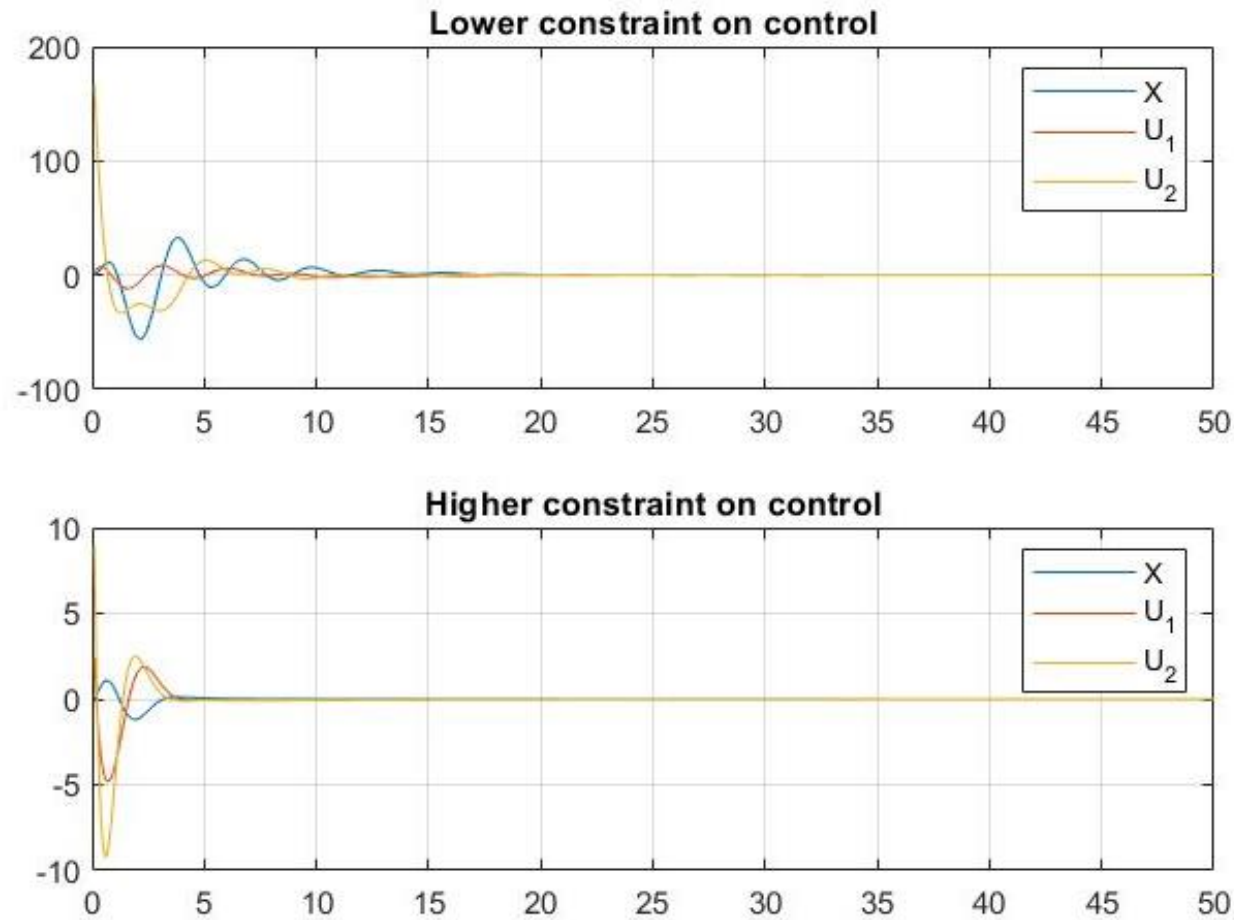
Discrete time – Circle region



# Networked Control: Project 10

Discrete time – Control effort limitation

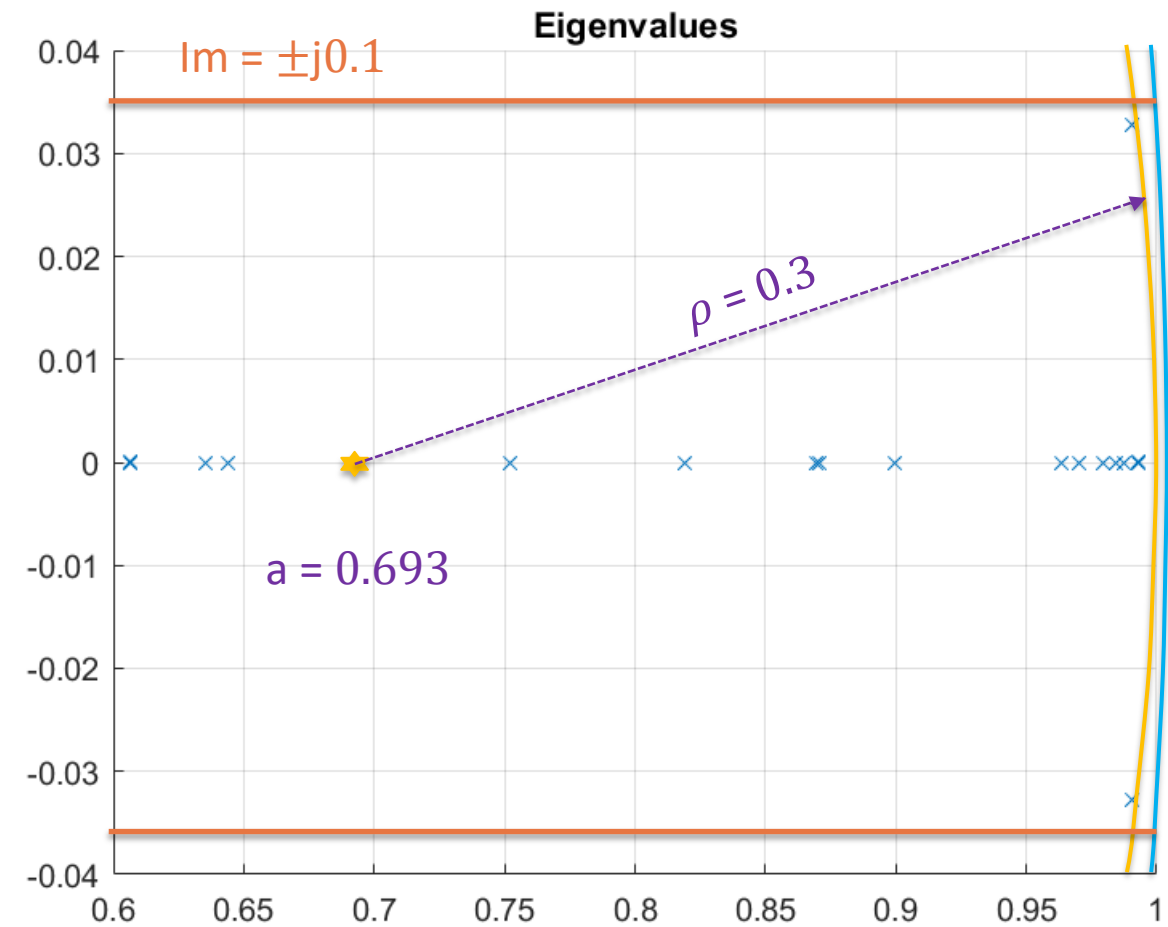
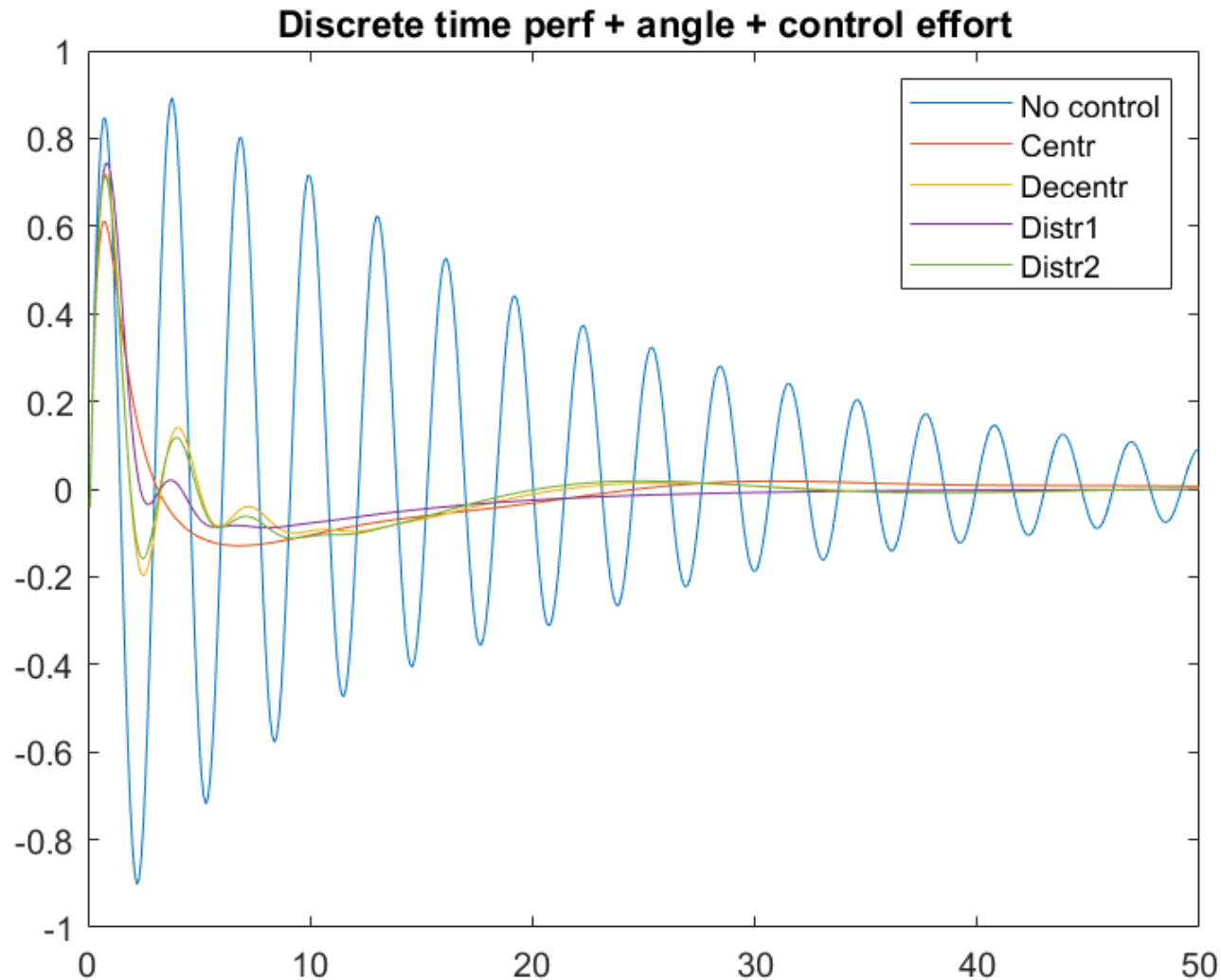
## Control effort comparison





# Networked Control: Project 10

Discrete time – Best mix of constraint



$$\begin{cases} x_{k+1} = Fx_k + Gu_k + G_w w_k \\ z_k = H_w x_k + D_w u_k \end{cases}$$

### ***System discretization***

```
sys2=ss(Atot,eye(19), eye(19),0);  
sys2d=c2d(sys2,Ts);  
[Nw,Gw,Tw]=ssdata(sys2d);
```

### ***Output weight***

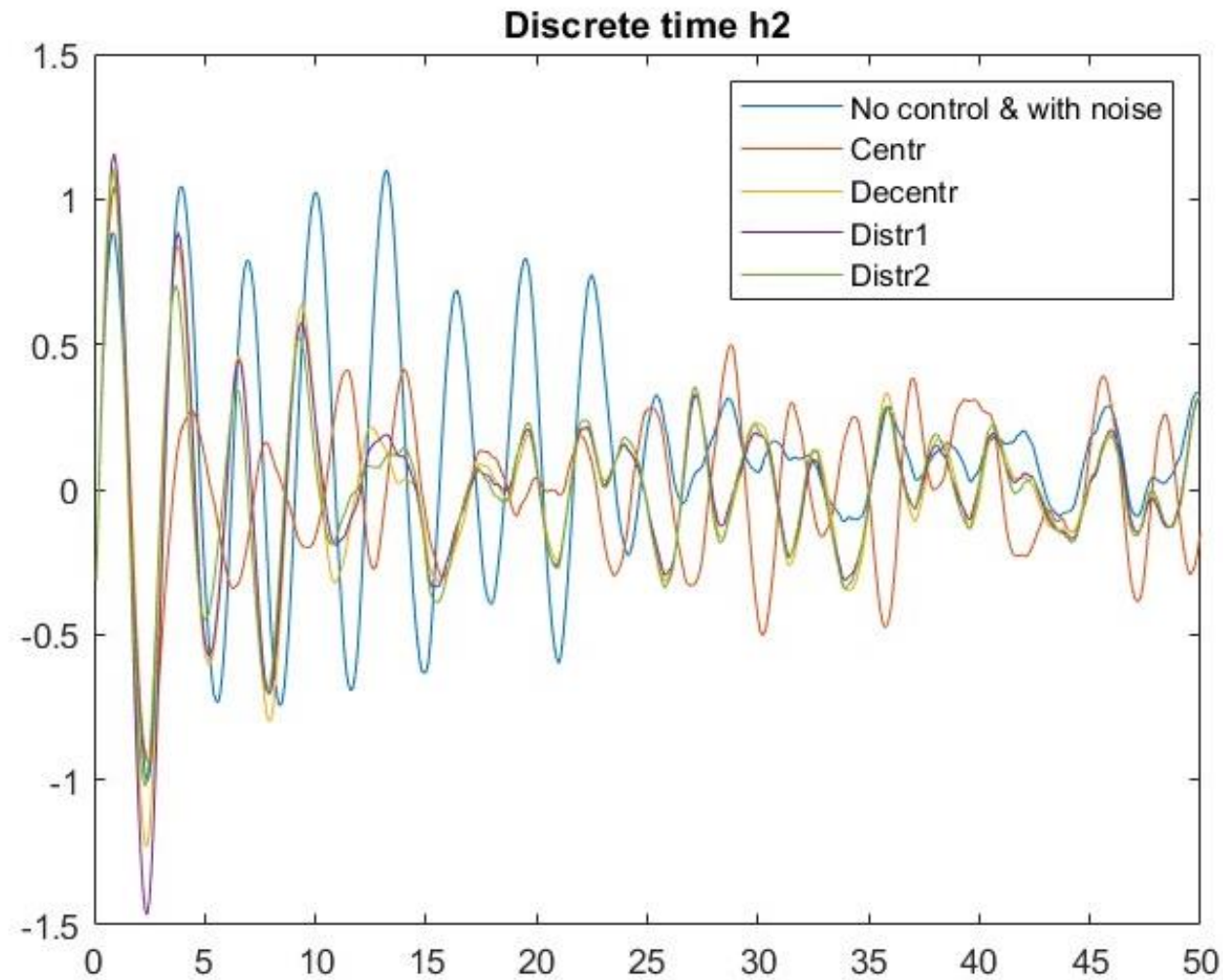
```
Q = eye(19);  
Q(10,10) = 100;
```

### ***Weight matrices***

```
Hw = [Q;  
      zeros(2,19)];  
  
Dw = [zeros(19,2);  
      eye(2,2)];
```

# Networked Control: Project 10

Discrete time with noise – H2 control



# Networked Control: Project 10

Discrete time with noise –  $H^\infty$  control

