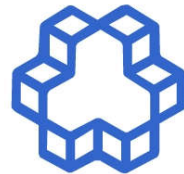


# کنترل پیش بین

## Model Predictive Control

ارائه کننده: امیرحسین نیکوفرد  
مهندسی برق و کامپیوتر دانشگاه خواجه نصیر



دانشگاه صنعتی خواجه نصیرالدین طوسی

# MPC



## Model Predictive Control Toolbox

Several linear MPC design features available:

explicit MPC

time-varying/adaptive models, weights, constraints

stability/frequency analysis of closed-loop (inactive constraints)

Graphical User Interface

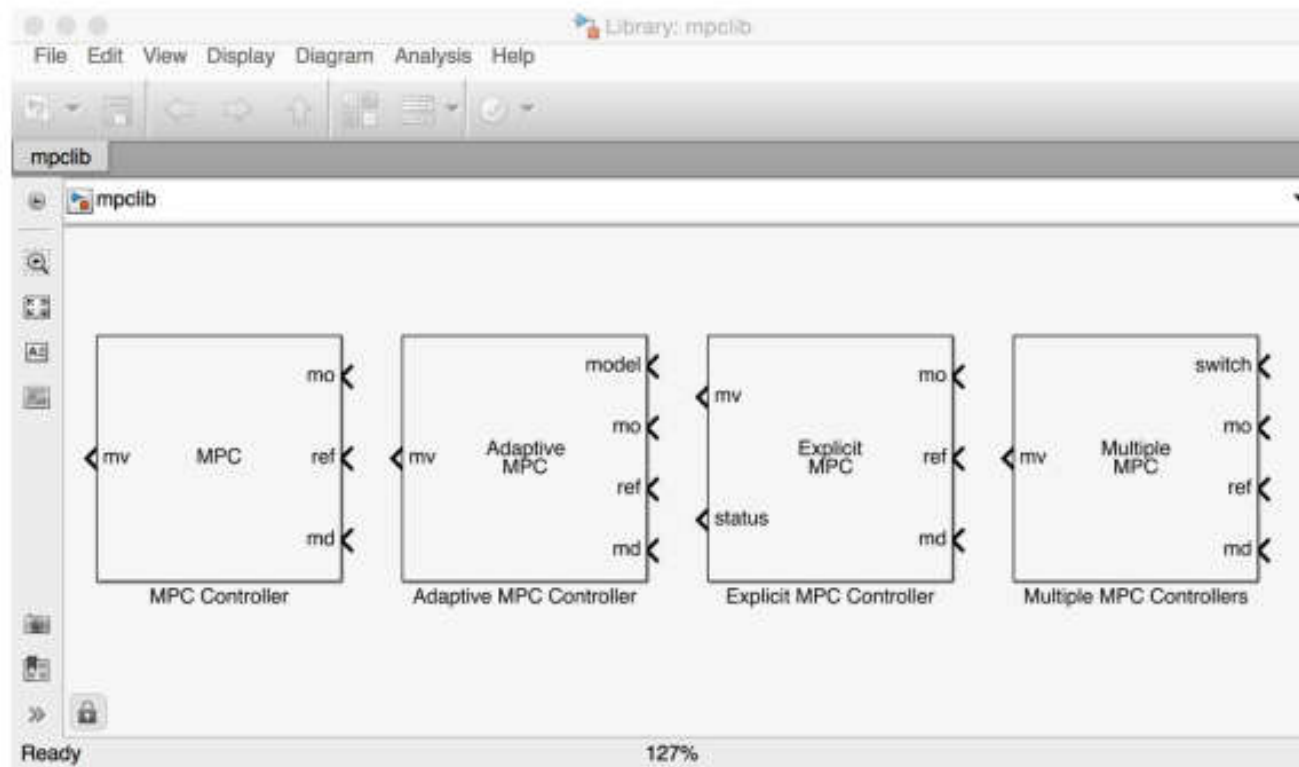
Simulink library

Yalmip Example

# MPC simulink



## MPC Simulink Library



```
>> mpclib
```

# MPC simulink

## MPC Simulink Library



Function Block Parameters: MPC Controller

MPC (mask) (link)

The MPC Controller block lets you design and simulate a model predictive controller defined in the Model Predictive Control Toolbox.

Parameters

MPC Controller:

Initial Controller State:

Block Options

Online  Online Features  Others

Additional Inputs

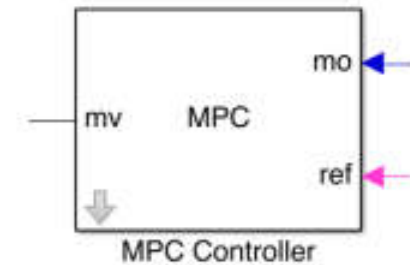
- Measured disturbance (md)
- External manipulated variable (ext.mv)

Additional Outputs

- Optimal cost (cost)
- Optimal control sequence (mv.seq)
- Optimization status (qp.status)
- Estimated plant, disturbance and noise model states (est.state)

State Estimation

- Use custom estimated states instead of measured outputs (x[k|k])



# MPC simulink

## MPC Simulink Library



Function Block Parameters: MPC Controller

MPC (mask) (link)

The MPC Controller block lets you design and simulate a model predictive controller defined in the Model Predictive Control Toolbox.

Parameters

MPC Controller

Initial Controller State

Block Options

Constraints

Plant input and output limits (umin, umax, ymin, ymax)

Weights

Weights on plant outputs (y.wt)

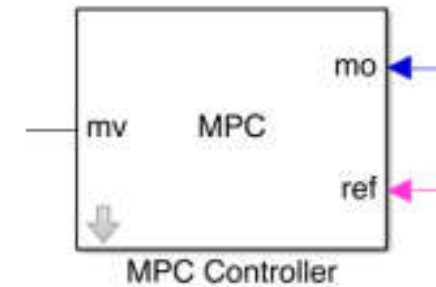
Weights on manipulated variables (u.wt)

Weights on manipulated variable changes (du.wt)

Weight on overall constraint softening (ecr.wt)

MV Targets

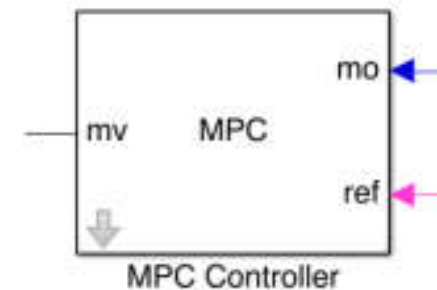
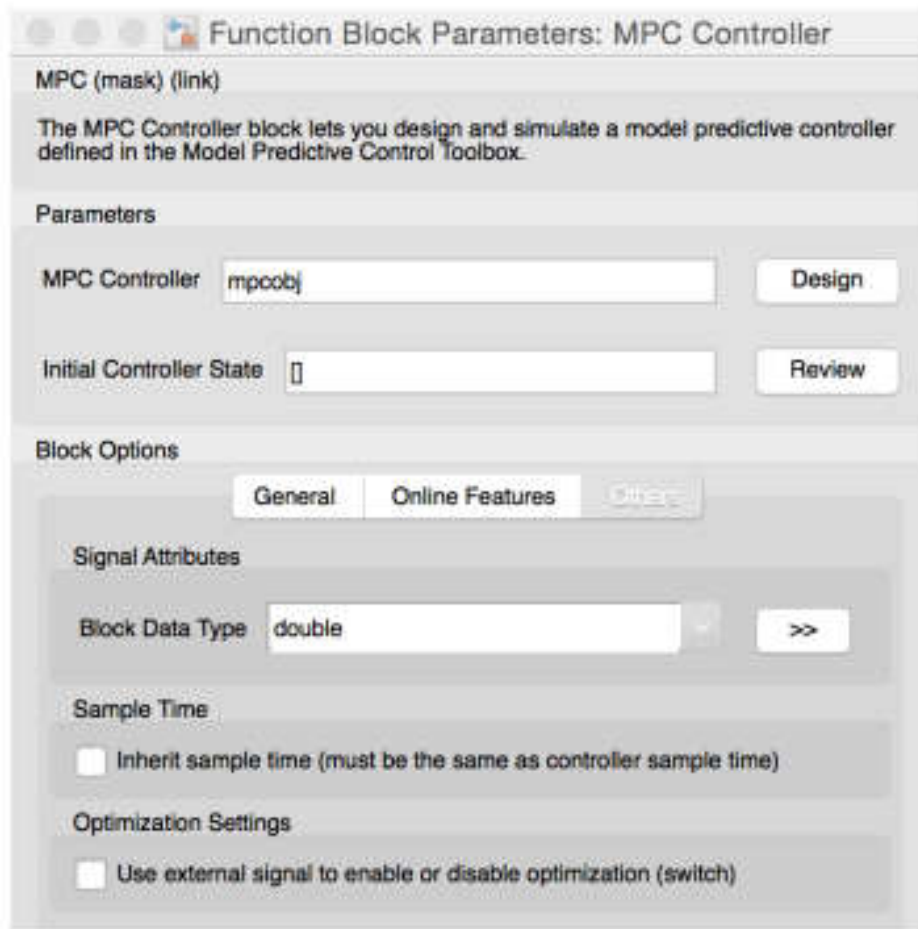
Targets for manipulated variables (mv.target)



# MPC simulink

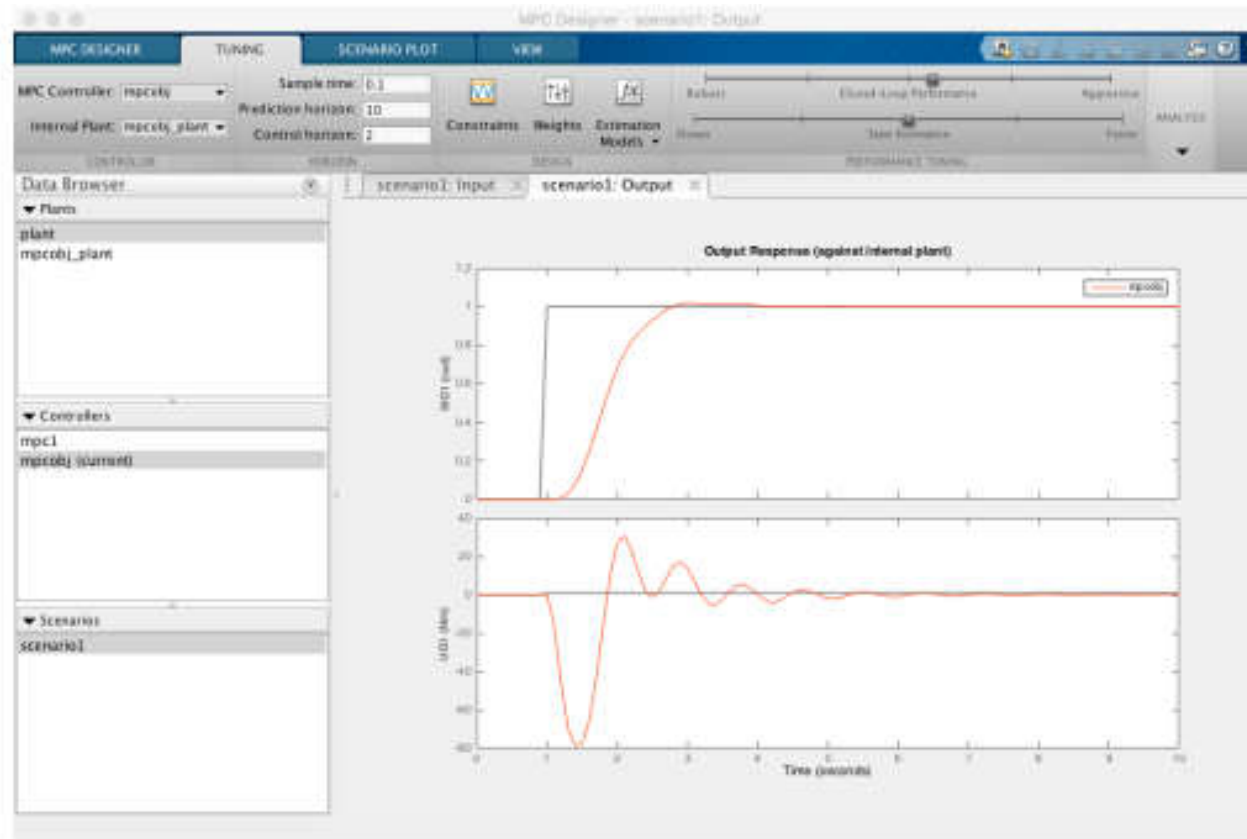


## MPC Simulink Library



# MPC simulink

## MPC Graphical User Interface



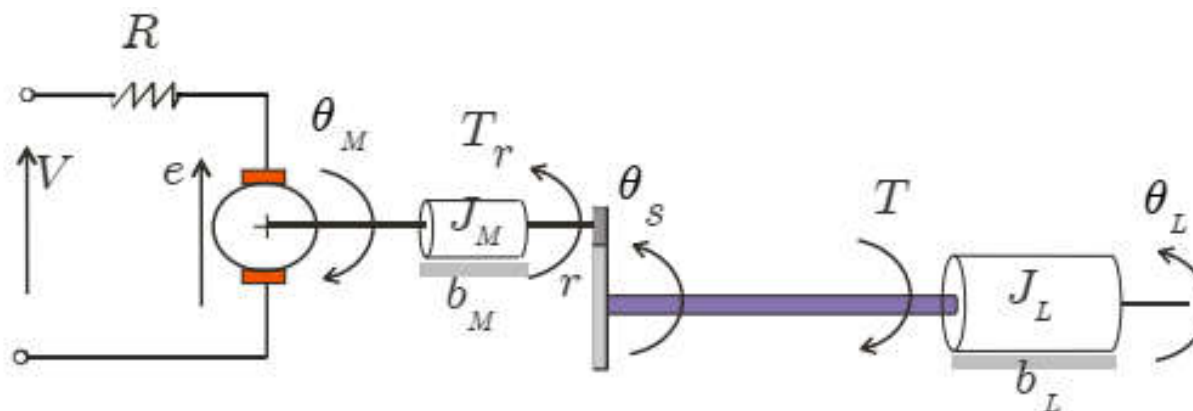
```
>> mpcDesigner
```

```
(old version: >> mpctool)
```

# MPC simulink



## Example:



Symbol	Value (MKS)	Meaning
$L_S$	1.0	shaft length
$d_S$	0.02	shaft diameter
$J_S$	negligible	shaft inertia
$J_M$	0.5	motor inertia
$\beta_M$	0.1	motor viscous friction coefficient
$R$	20	resistance of armature
$k_T$	10	motor constant
$\rho$	20	gear ratio
$k_\theta$	1280.2	torsional rigidity
$J_L$	$50J_M$	nominal load inertia
$\beta_L$	25	load viscous friction coefficient
$T_s$	0.1	sampling time

>> mpcmotor

see also  
linear/dcmotor.m  
(Hybrid Toolbox)



# MPC simulink



## Example:

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ -\frac{k_\theta}{J_L} & -\frac{\beta_L}{J_L} & \frac{k_\theta}{\rho J_L} & 0 \\ 0 & 0 & 0 & 1 \\ \frac{k_\theta}{\rho J_M} & 0 & -\frac{k_\theta}{\rho^2 J_M} & -\frac{\beta_M + k_T^2/R}{J_M} \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{k_T}{R J_M} \end{bmatrix} V$$
$$x = \begin{bmatrix} \theta_L \\ \dot{\theta}_L \\ \theta_M \\ \dot{\theta}_M \end{bmatrix}$$
$$\theta_L = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} x$$
$$T = \begin{bmatrix} k_\theta & 0 & -\frac{k_\theta}{\rho} & 0 \end{bmatrix} x$$
$$y = \begin{bmatrix} \theta_L \\ T \end{bmatrix}$$

```
>> [plant, tau] = mpcmotormodel;  
>> plant = setmpcsignals(plant, 'MV', 1, 'MO', 1, 'UO', 2);
```

# MPC simulink



## Example:

- The input DC voltage  $V$  is bounded within the range

$$|V| \leq 220 \text{ V}$$

- Finite shear strength  $\tau_{adm} = 50 \text{ N/mm}^2$  requires that the torsional torque  $T$  satisfies the constraint

$$|T| \leq 78.5398 \text{ Nm}$$

- Sampling time of model/controller:  $T_s = 0.1 \text{ s}$

```
>> MV = struct('Min', -220, 'Max', 220);  
>> OV = struct('Min', {-Inf, -78.5398}, 'Max', {Inf, 78.5398});  
>> Ts = 0.1;
```

# MPC simulink



## Example:

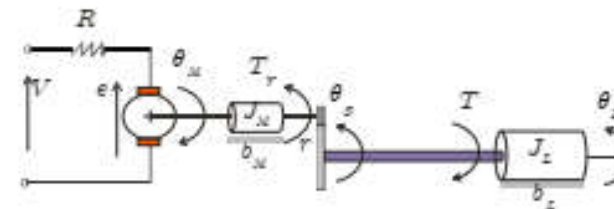
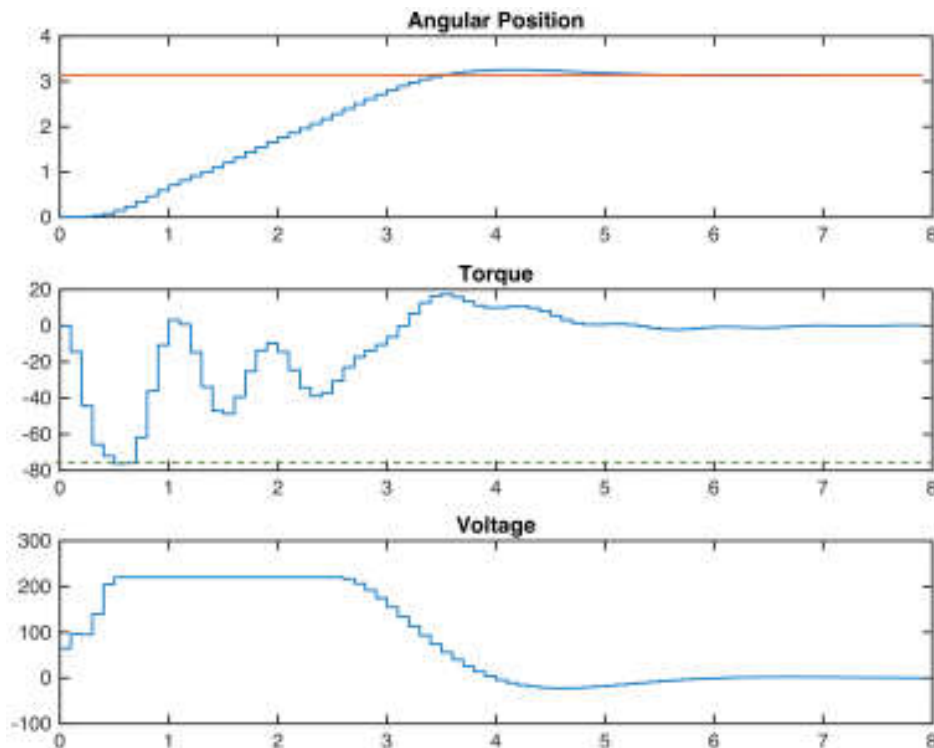
$$\begin{aligned} \min_{\Delta U} \quad & \sum_{k=0}^{p-1} \|W^y(y_{k+1} - r(t))\|^2 + \|W^{\Delta u} \Delta u_k\|^2 + \rho_\epsilon \epsilon^2 \\ \text{subj. to} \quad & \Delta u_{\min} \leq \Delta u_k \leq \Delta u_{\max}, k = 0, \dots, m-1 \\ & \Delta u_k = 0, k = m, \dots, p-1 \\ & u_{\min} \leq u_k \leq u_{\max}, k = 0, \dots, m-1 \\ & y_{\min} - \epsilon V_{\min} \leq y_k \leq y_{\max} + \epsilon V_{\max}, k = 1, \dots, p \end{aligned}$$

```
>> Weights = struct('MV',0,'MVRate',0.1,'OV',[0.1 0]);  
>> p = 10;  
>> m = 2;  
>> mpcobj = mpc(plant,Ts,p,m,Weights,MV,OV);
```

# MPC simulink



## Example:



Closed-loop simulation using  
the `sim` command

```
>> Tstop = 8; % seconds
>> Tf = round(Tstop/Ts); % simulation iterations
>> r = [pi*ones(Tf,1) zeros(Tf,1)];
>> [y1,t1,u1] = sim(mpcobj,Tf,r);
```

