کنترل پیش بین
Model Predictive Control

ارائه کننده: امیرحسین نیکوفرد
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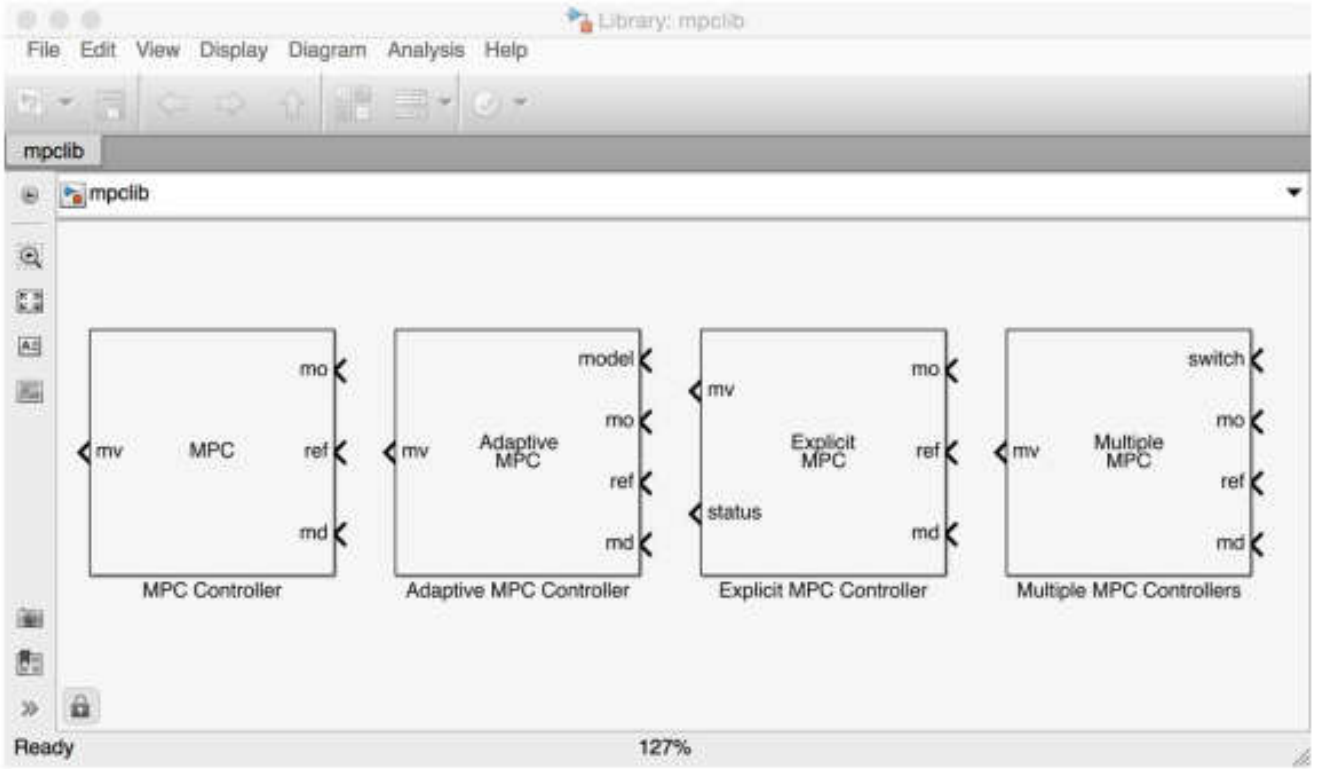
MPC

- 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

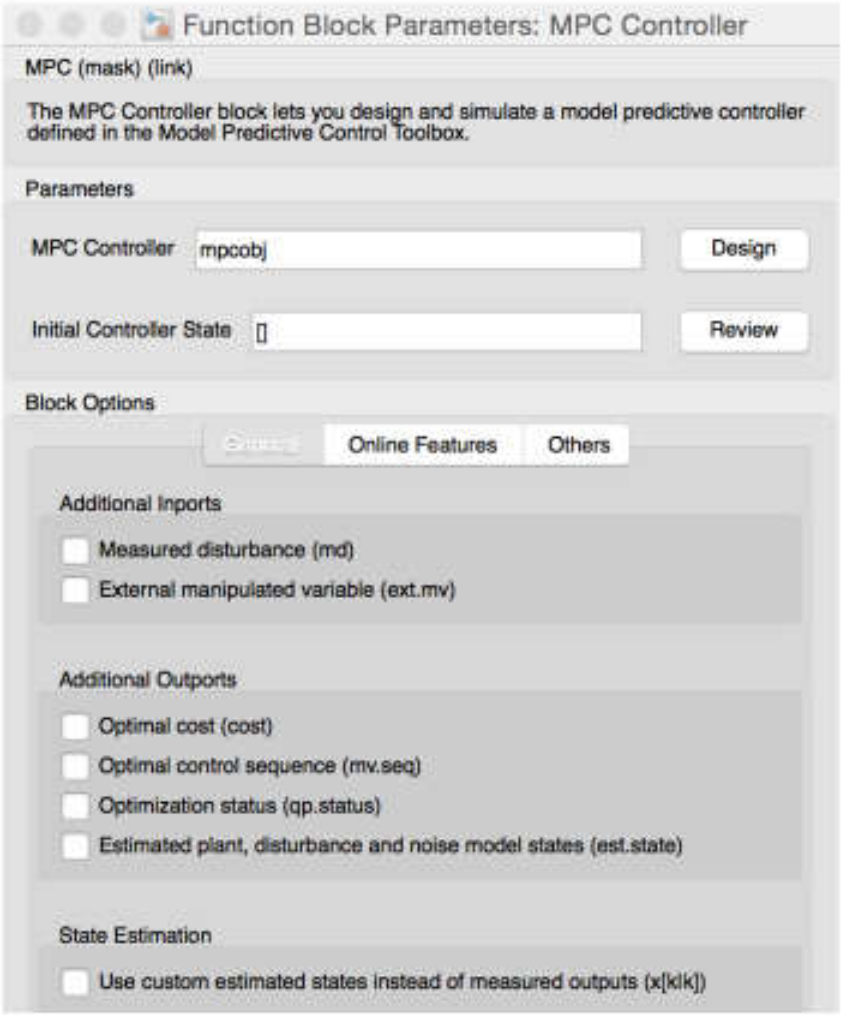
MPC Simulink Library

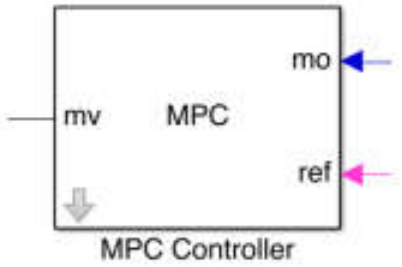



```
>> mpclib
```

MPC simulink

MPC Simulink Library





MPC simulink

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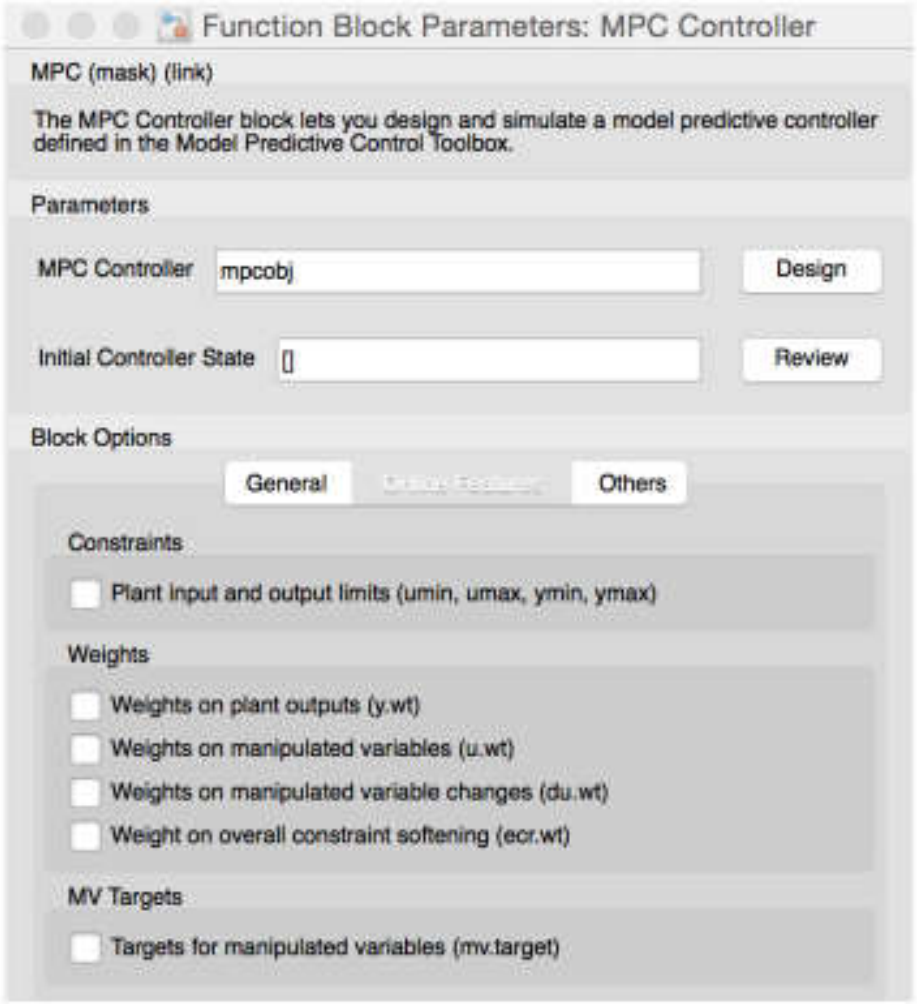

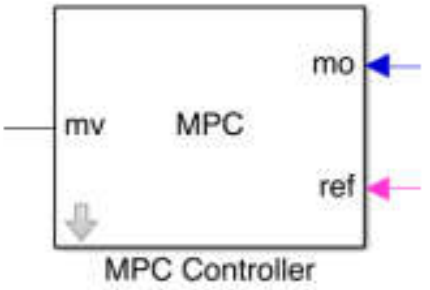

MPC simulink

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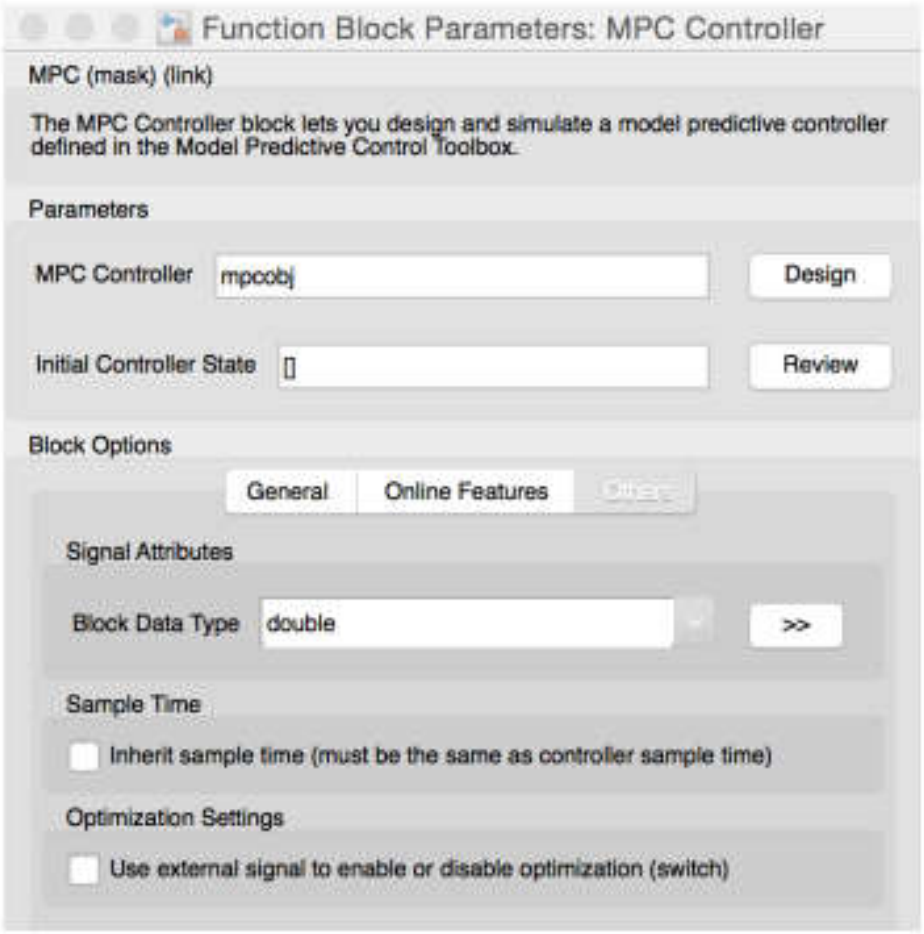
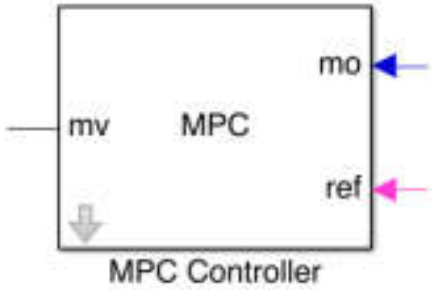
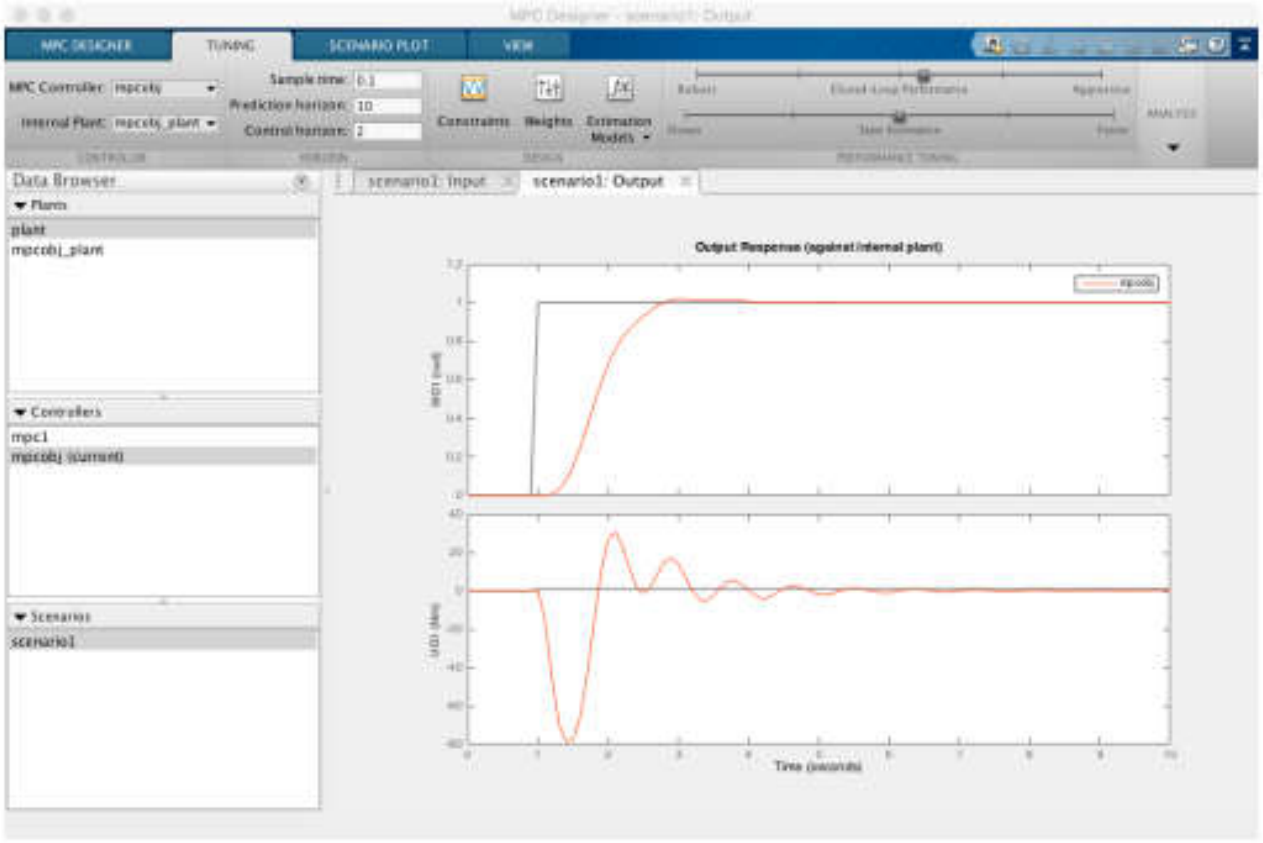




MPC simulink

MPC Graphical User Interface



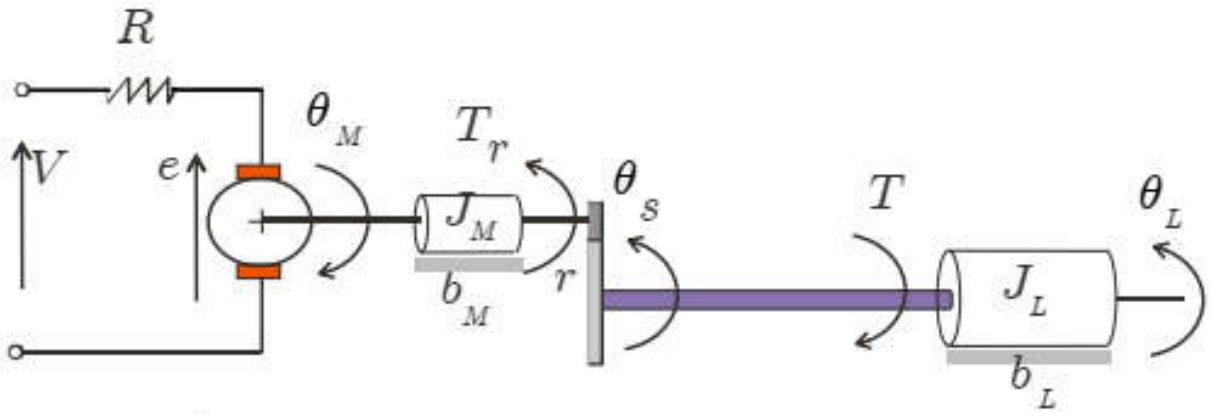

```
>> mpcDesigner
```

(old version: `>> mpctool`)

See video on Mathworks' web site (link)

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
β_M	0.1	motor viscous friction coefficient
R	20	resistance of armature
k_T	10	motor constant
ρ	20	gear ratio
k_θ	1280.2	torsional rigidity
J_L	$50.J_M$	nominal load inertia
β_L	25	load viscous friction coefficient
T_s	0.1	sampling time

```
>> mpcmotor
```

see also

`linear/dcmotor.m`

(Hybrid Toolbox)

MPC simulink

Example:

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

$$\theta_L = \begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix} x$$

$$T = \begin{bmatrix} k_\theta & 0 & -\frac{k_\theta}{\rho} & 0 \end{bmatrix} x$$

$$x = \begin{bmatrix} \theta_L \\ \dot{\theta}_L \\ \theta_M \\ \dot{\theta}_M \end{bmatrix}$$

$$y = \begin{bmatrix} \theta_L \\ T \end{bmatrix}$$

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

MPC simulink

Example:

- The input DC voltage V is bounded withing the range

$$|V| \leq 220\,V$$

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

$$|T| \leq 78.5398\,Nm$$

- Sampling time of model/controller: $T_s = 0.1s$

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

MPC simulink

Example:

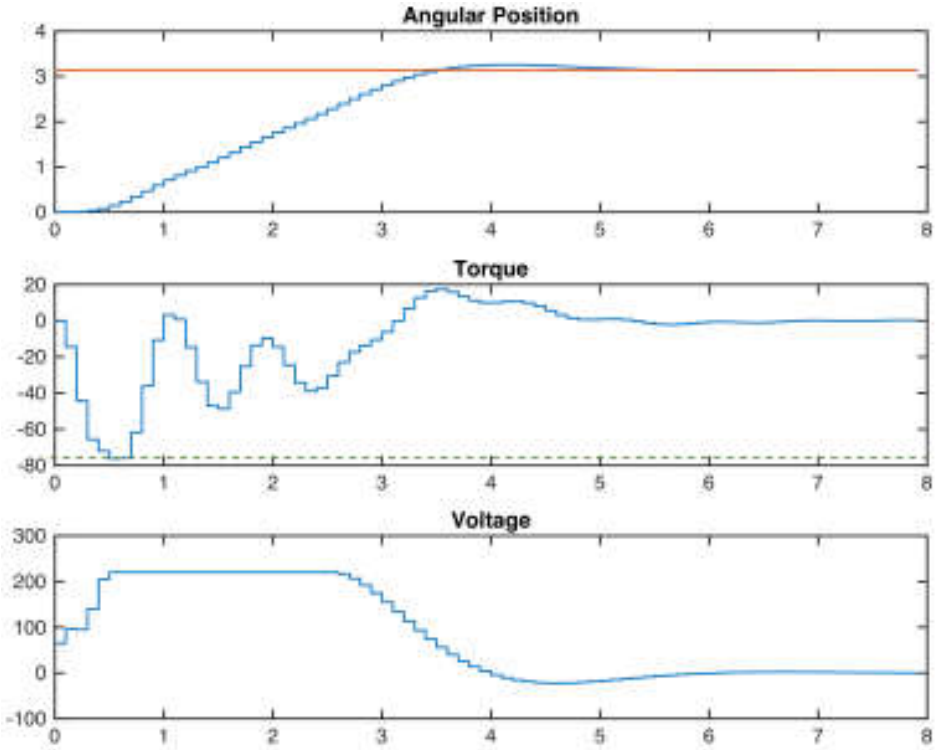
$$\min_{\Delta U} \quad \sum_{k=0}^{p-1} \|W^y(y_{k+1} - r(t))\|^2 + \|W^{\Delta u}\Delta u_k\|^2 + \rho_\epsilon \epsilon^2$$

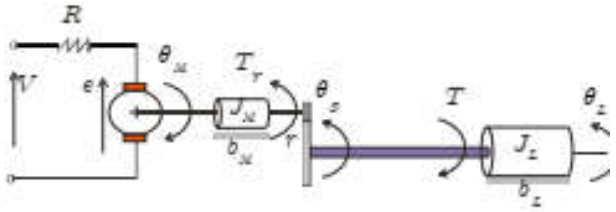
$$\begin{aligned}
\text{subj. to} \quad & \Delta u_{\min} \le \Delta u_k \le \Delta u_{\max},\ k = 0, \ldots, m-1 \\
& \Delta u_k = 0,\ k = m, \ldots, p-1 \\
& u_{\min} \le u_k \le u_{\max},\ k = 0, \ldots, m-1 \\
& y_{\min} - \epsilon V_{\min} \le y_k \le y_{\max} + \epsilon V_{\max},\ k = 1, \ldots, p
\end{aligned}$$

```
>> 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:



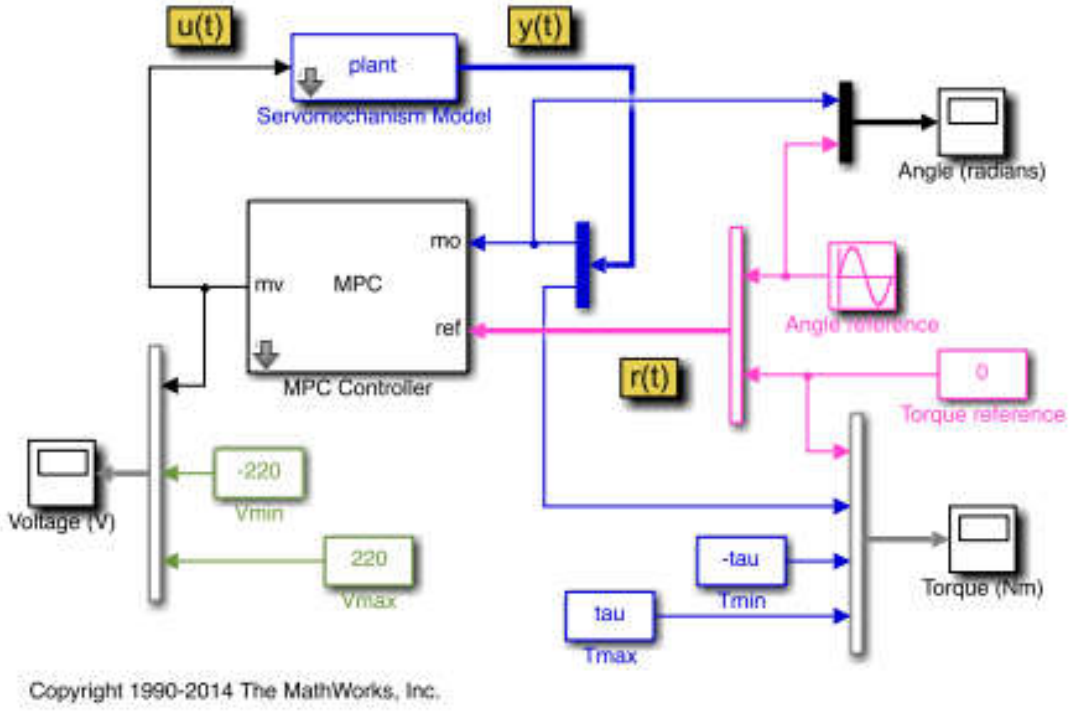


Closed-loop simulation using the `sim` command

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

MPC simulink

Example:



Closed-loop simulation in Simulink

```
>> mdl = 'mpc_motor';
>> open_system(mdl)
>> sim(mdl)
```