1. S模糊模型与状态反馈控制及Matlab仿真

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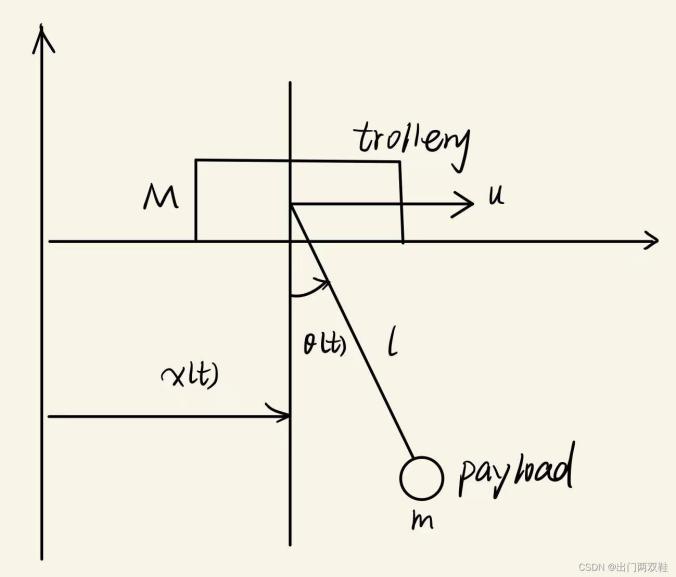
[6. trolly\_affine\_ctrl\_m 6](#_Toc4513)

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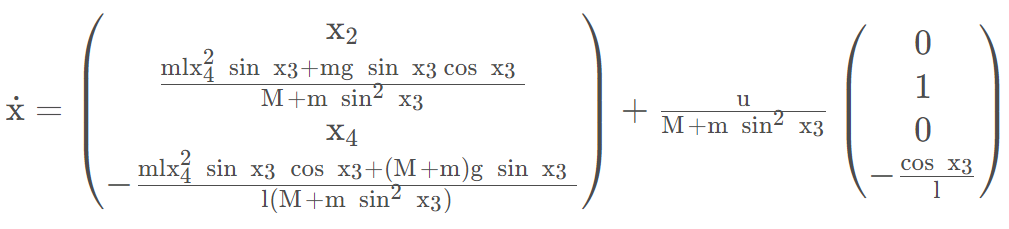
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# 仿射非线性系统建模

以overhead crane system为例，

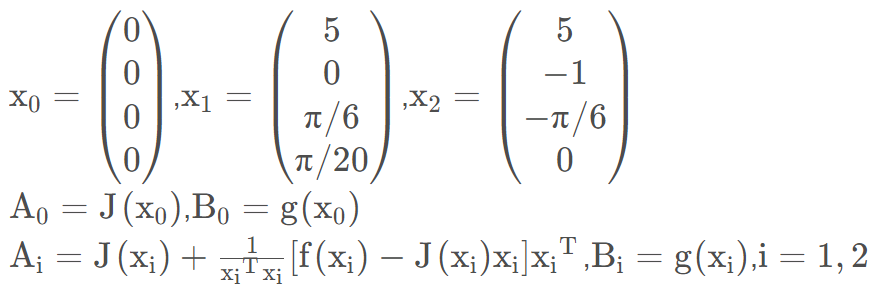


忽略摩擦，我们可以得到如下的状态空间方程，

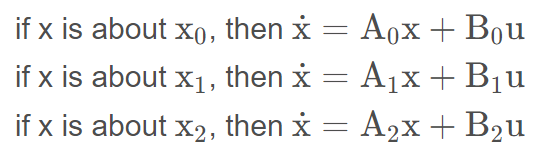


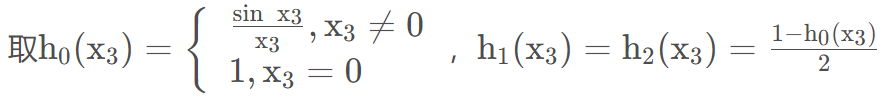
# 计算T-S模糊模型子系统

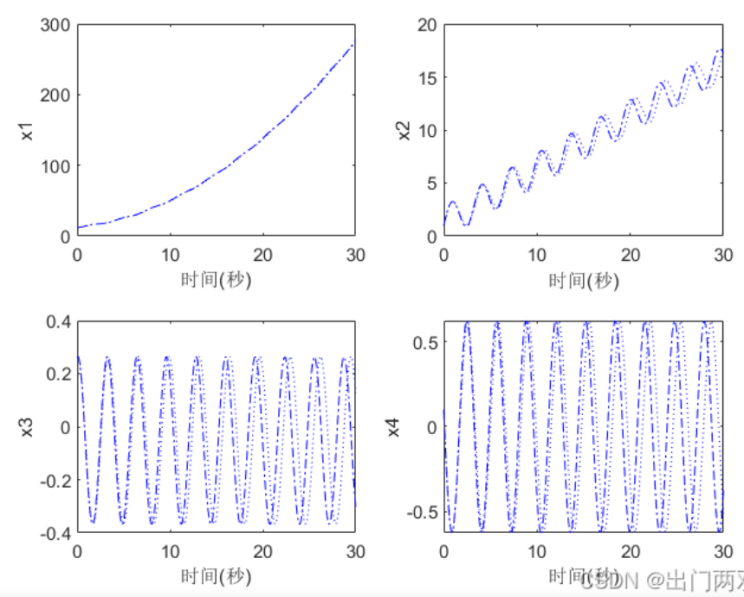
取工作点。一般地，我们会选取平衡点。



# **建立推理，验证开环特性**

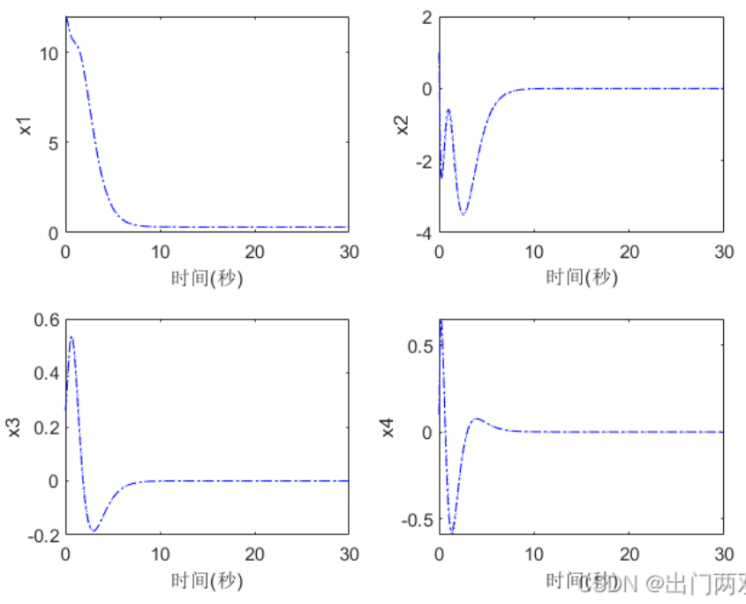






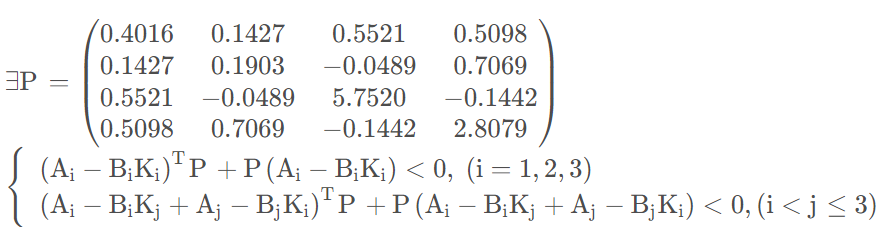
# 极点配置，验证闭环特性

选取极点p0 = (−1.1 −1.5 −1.8 −2.1 ), p1 = (−1.3 −1.6 −1.9 −2.2 ), p2 = (−1.5 −1.6 −1.8 −1.9)



# 使用LMI验证稳定性

## 理论分析



## Matlab代码

clear all;close all;

M=100;m=100;l=5;g=9.82;u=100;

syms x1 x2 x3 x4;

x00=[0 0 0 0]';x01=[5 0 pi/6 pi/20]';x02=[5 -1 -pi/6 0]';

x=[x1;x2;x3;x4];

f=[x2;(m\*l\*x4^2\*sin(x3)+m\*g\*sin(x3)\*cos(x3))/(M+m\*sin(x3)\*sin(x3));x4;-(m\*l\*x4^2\*sin(x3)\*cos(x3)+(M+m)\*g\*sin(x3))/l/(M+m\*sin(x3)\*sin(x3))];

gx=1/(M+m\*sin(x3)\*sin(x3))\*[0;1;0;-cos(x3)/l];

J=jacobian(f,x);

Ai=J+(f-J\*x)\*x'/(x'\*x);

A0=double(subs(J,x,x00));B0=double(subs(gx,x,x00));

A1=double(subs(Ai,x,x01));B1=double(subs(gx,x,x01));

A2=double(subs(Ai,x,x02));B2=double(subs(gx,x,x02));

a0=[-1.1 -1.5 -1.8 -2.1];

a1=[-1.3 -1.6 -1.9 -2.2];

a2=[-1.5 -1.6 -1.8 -1.9];

K0=place(A0,B0,a0);K1=place(A1,B1,a1);K2=place(A2,B2,a2);

setlmis([]);

P=lmivar(1,[4,1]);

lmiterm([1 1 1 P],1,A0-B0\*K0,'s');

lmiterm([2 1 1 P],1,A1-B1\*K1,'s');

lmiterm([3 1 1 P],1,A2-B2\*K2,'s');

lmiterm([4 1 1 P],1,A0-B0\*K1+A1-B1\*K0,'s');

lmiterm([5 1 1 P],1,A1-B1\*K2+A2-B2\*K1,'s');

lmiterm([6 1 1 P],1,A2-B2\*K0+A0-B0\*K2,'s');

lmiterm([-7 1 1 P],1,1);

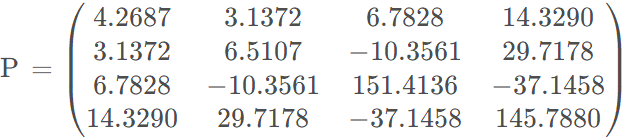
lmisys=getlmis;

[tmin,xfeas]=feasp(lmisys);

tmin

pmat=dec2mat(lmisys,xfeas,P)

tmin =−0.0163



下载链接

https://download.csdn.net/download/qq\_29710939/84993530

## trolly\_sim\_m

clear all;close all;

t0=0;tf=30;step=0.1;

x0(1:4)=[10 1 pi/10 0.1]';

global M m l u g;

global A0 A1 A2 B0 B1 B2 x3 K0 K1 K2;

M=100;m=50;l=4;g=9.81;u=100;

syms x1 x2 x3 x4;

x00=[0 0 0 0]';x01=[5 0 pi/6 pi/20]';x02=[5 -1 -pi/6 0]';

x=[x1;x2;x3;x4];

f=[x2;(m\*l\*x4^2\*sin(x3)+m\*g\*sin(x3)\*cos(x3))/(M+m\*sin(x3)\*sin(x3));x4;-(m\*l\*x4^2\*sin(x3)\*cos(x3)+(M+m)\*g\*sin(x3))/l/(M+m\*sin(x3)\*sin(x3))];

gx=1/(M+m\*sin(x3)\*sin(x3))\*[0;1;0;-cos(x3)/l];

J=jacobian(f,x);

Ai=J+(f-J\*x)\*x'/(x'\*x);

A0=double(subs(J,x,x00));B0=double(subs(gx,x,x00));

A1=double(subs(Ai,x,x01));B1=double(subs(gx,x,x01));

A2=double(subs(Ai,x,x02));B2=double(subs(gx,x,x02));

[t,x\_fuzzy]=ode45('trolly\_fuzzy',[t0:step:tf], x0);

[t,x\_affine]=ode45('trolly\_affine',[t0:step:tf], x0);

figure(1);

subplot(2,2,1);plot(t, x\_fuzzy(:,1),'b-.',t,x\_affine(:,1),'b:');xlabel('时间(秒)');ylabel('x1');

subplot(2,2,2);plot(t, x\_fuzzy(:,2),'b-.',t,x\_affine(:,2),'b:');xlabel('时间(秒)');ylabel('x2');

subplot(2,2,3);plot(t, x\_fuzzy(:,3),'b-.',t,x\_affine(:,3),'b:');xlabel('时间(秒)');ylabel('x3');

subplot(2,2,4);plot(t, x\_fuzzy(:,4),'b-.',t,x\_affine(:,4),'b:');xlabel('时间(秒)');ylabel('x4');

a0=[-1.1 -1.5 -1.8 -2.1];

a1=[-1.3 -1.6 -1.9 -2.2];

a2=[-1.5 -1.6 -1.8 -1.9];

K0=place(A0,B0,a0);K1=place(A1,B1,a1);K2=place(A2,B2,a2);

[t,x\_fuzzy\_ctrl]=ode45('trolly\_fuzzy\_ctrl',[t0:step:tf], x0);

[t,x\_affine\_ctrl]=ode45('trolly\_affine\_ctrl',[t0:step:tf], x0);

figure(2);

subplot(2,2,1);plot(t, x\_fuzzy\_ctrl(:,1),'b-.',t,x\_affine\_ctrl(:,1),'b:');xlabel('时间(秒)');ylabel('x1');

subplot(2,2,2);plot(t, x\_fuzzy\_ctrl(:,2),'b-.',t,x\_affine\_ctrl(:,2),'b:');xlabel('时间(秒)');ylabel('x2');

subplot(2,2,3);plot(t, x\_fuzzy\_ctrl(:,3),'b-.',t,x\_affine\_ctrl(:,3),'b:');xlabel('时间(秒)');ylabel('x3');

subplot(2,2,4);plot(t, x\_fuzzy\_ctrl(:,4),'b-.',t,x\_affine\_ctrl(:,4),'b:');xlabel('时间(秒)');ylabel('x4');

## trolly\_affine\_m

function xdot = trolly\_affine(t, x);

global M m l u g;

f=[x(2);(m\*l\*x(4)^2\*sin(x(3))+m\*g\*sin(x(3))\*cos(x(3)))/(M+m\*sin(x(3))\*sin(x(3)));x(4);-(m\*l\*x(4)^2\*sin(x(3))\*cos(x(3))+(M+m)\*g\*sin(x(3)))/l/(M+m\*sin(x(3))\*sin(x(3)))];

gx=1/(M+m\*sin(x(3))\*sin(x(3)))\*[0;1;0;-cos(x(3))/l];

xdot=f+gx\*u;

## trolly\_fuzzy\_m

function xdot = trolly\_fuzzy(t, x);

global A0 A1 A2 B0 B1 B2 u M m;

if(x(3)==0)

h0=1;

else

h0=sin(x(3))/x(3);

end

h1=(1-h0)/2;h2=h1;

xdot=h0\*(A0\*x+B0\*u)+h1\*(A1\*x+B1\*u)+h2\*(A2\*x+B2\*u);

## trolly\_affine\_ctrl\_m

function xdot = trolly\_affine\_ctrl(t, x);

global M m l u g K0 K1 K2;

f=[x(2);(m\*l\*x(4)^2\*sin(x(3))+m\*g\*sin(x(3))\*cos(x(3)))/(M+m\*sin(x(3))\*sin(x(3)));x(4);-(m\*l\*x(4)^2\*sin(x(3))\*cos(x(3))+(M+m)\*g\*sin(x(3)))/l/(M+m\*sin(x(3))\*sin(x(3)))];

gx=1/(M+m\*sin(x(3))\*sin(x(3)))\*[0;1;0;-cos(x(3))/l];

h0=M\*(sin(x(3)))^2/(M+m\*sin(x(3))\*sin(x(3)));

h1=M\*(cos(x(3)))^2/(M+m\*sin(x(3))\*sin(x(3)));

h2=m\*(sin(x(3)))^2/(M+m\*sin(x(3))\*sin(x(3)));

xdot=f+gx\*(u-h0\*K0\*x-h1\*K1\*x-h2\*K2\*x);

## trolly\_fuzzy\_ctrl\_m

function xdot = trolly\_fuzzy\_ctrl(t, x);

global A0 A1 A2 B0 B1 B2 u M m K0 K1 K2;

if(x(3)==0)

h0=1;

else

h0=sin(x(3))/x(3);

end

h1=(1-h0)/2;h2=h1;

u0=u-h0\*K0\*x-h1\*K1\*x-h2\*K2\*x;

xdot=h0\*(A0\*x+B0\*u0)+h1\*(A1\*x+B1\*u0)+h2\*(A2\*x+B2\*u0);

# 参考文献

<https://blog.csdn.net/qq_29710939/article/details/121828964>