適應控制(HW4)_DIRECT STR

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OBJECTIVE-THE PROBLEM AND THE PURPOSE

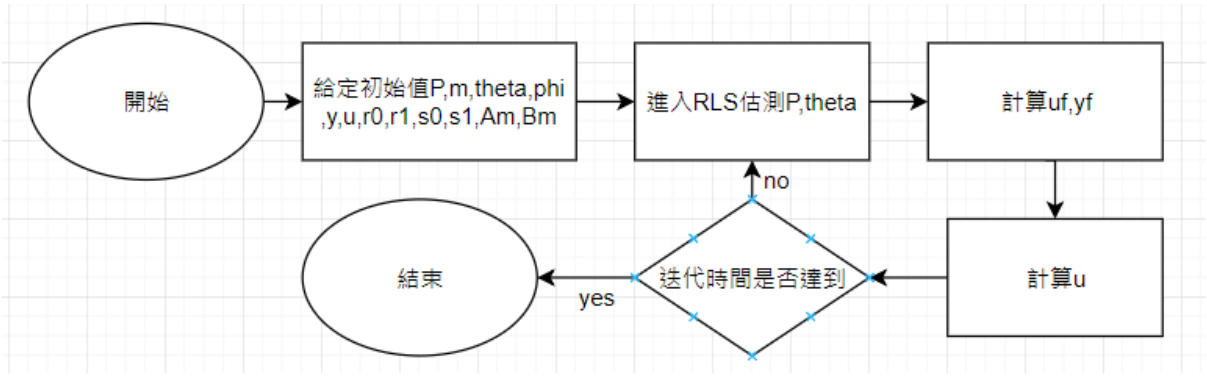
此次報告我們要模擬 Direct Self-Tuning Regulator，設計一個控制器去控制我們的馬達位置。

PROCEDURE

METHOD

首先我們以 RLS 的方法估測 Minimum-Phase Sysytems 的 R*(q)、S*(q)的係數，計算 uf,yf，並藉由 Contro; Law 找出控制訊號 u(t)，重複以上動作，直到 RLS 收斂。

PROGRAM FLOW CHART



EQUATION

RLS (EXPONENTIAL FORGETTING):

$$\theta(t) = \theta(t-1) + k(t)\big(y(t) - \varphi^{\top}(t)\theta(t-1)\big)$$

$$k(t) = P(t-1)\varphi(t)\big(\lambda I + \varphi^{T}(t)P(t-1)\varphi(t)\big)^{-1}$$

$$P(t) = \big(I - k(t)\varphi^{T}(t)\big)P(t-1)/\lambda$$

$$y(t) = \varphi^{T}(t-d0) * \theta$$

MPS (MINIMUM-PHASE SYSTEMS):

$y(t)=R^* u_f(t-do)+S^* y_f(t-do)$,

$u_f(t)*A_o*(q^{-1})*A_m*(q^{-1})=u(t)$ ， $y_f(t)*A_o*(q^{-1})*A_m*(q^{-1})=y(t)$

CONTROL LAW

$R^*u=T^*u_c-S^*y$

SIMULATION RESULTS

PROGRAM CODES

```
%%

%Direct STR,d0=1

clear,clc ;

format long;

m=100;%time(sec) ,sampling time=0.5(sec)

r0=-0.11;

r1=-0.11;

s0=-0.055;

s1=0;

theta(1,1)=r0;

theta(2,1)=r1;

theta(3,1)=s0;

theta(4,1)=s1;

phi(1,1)=0;

phi(1,2)=0;

phi(1,3)=0;

phi(1,4)=0;

uc(1:50)=1;

uc(51:99)=-1;

uc=[uc uc uc uc uc];

uc=[uc uc uc uc uc];

uc=[uc uc];

p=[100 0 0 0 ;0 100 0 0; 0 0 1 0; 0 0 0 1];

lambda=1;

%desired system:Am

am1=-1.3205;

am2=0.4966;

i=1;

y(1)=0;

u(1)=0.5;

t0=1+am1+am2;

for k=0:0.5:(m-0.5)

   %RLS:R,S

   [p ,theta(:,i+1)]=rls_forgetting(p,theta(:,i),phi(i,:),y(i),lambda) ;

   r0=theta(1,i+1);

   r1=theta(2,i+1);

   s0=theta(3,i+1);

   s1=theta(4,i+1);
```

```
    draw1(i)=r1/r0;
    draw2(i)=t0/r0;
    draw3(i)=s0/r0;
    draw4(i)=s1/r0;
    if i==1
        uf(i)=u(i)-am1*0-am2*0;
        yf(i)=y(i)-am1*0-am2*0;
        phi(i+1,1)=uf(i);
        phi(i+1,2)=0;
        phi(i+1,3)=yf(i);
        phi(i+1,4)=0;
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*0;
        y(i+1)=1.6065*y(i)-0.6065*0+0.1065*u(i)+0.0902*0; %measured y
    end
    if i==2
        uf(i)=u(i)-am1*uf(i-1)-am2*0;
        yf(i)=y(i)-am1*yf(i-1)-am2*0;
        phi(i+1,1)=uf(i);
        phi(i+1,2)=uf(i-1);
        phi(i+1,3)=yf(i);
        phi(i+1,4)=yf(i-1);
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    if i>=3
        uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
        yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
        phi(i+1,1)=uf(i);
        phi(i+1,2)=uf(i-1);
        phi(i+1,3)=yf(i);
        phi(i+1,4)=yf(i-1);
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    i=i+1;
end
figure(1)
subplot(211)
plot(0:0.5:m,y);
hold on
plot(0:0.5:m,uc(1:2*m+1));
```

```
title('Direct STR d0=1')
xlabel('Time')
text(51, -0.08197,' y')
text(21, -1,'uc')
axis([-inf, inf, -1.5, 1.5])
subplot(212)
stairs(0:0.5:m,u);
xlabel('Time')
text(65, 1,' u')
axis([-inf, inf, -4.5, 4.5])
figure(2)
o=90;
stairs(0:0.5:o,draw1(1:o*2+1)),hold on
stairs(0:0.5:o,draw2(1:2*o+1),'--'),hold on
stairs(0:0.5:o,draw3(1:2*o+1),'-.'),hold on
stairs(0:0.5:o,draw4(1:2*o+1),':')
title('estimated parameter'),xlabel('Time')
text(o-5, 0.85,' r1/r0'),text(o-5, 1.65,' t0/r0')
text(o-5, 2.68,'s0/r0'),text(o-5, -1.03,' s1/r0')
%%
%Direct STR,d0=2
clear,clc ;
format long;
m=100;%time(sec) ,sampling time=0.5(sec)
r0=-0.11;
r1=-0.11;
s0=-0.055;
s1=0;
theta(1,1)=r0;
theta(2,1)=r1;
theta(3,1)=s0;
theta(4,1)=s1;
phi(1,1)=0;
phi(1,2)=0;
phi(1,3)=0;
phi(1,4)=0;
uc(1:49)=1;
uc(50:99)=-1;
uc=[uc uc uc uc uc];
uc=[uc uc uc uc uc];
p=[100 0 0 0 ;0 100 0 0; 0 0 1 0; 0 0 0 1];
```

```
lambda=1;
%desired system:Am
am1=-1.3205;
am2=0.4966;
i=1;
y(1)=0;
u(1)=0.5;
t0=1+am1+am2;
for k=0:0.5:(m-0.5)
   %RLS:R,S
   [p ,theta(:,i+1)]=rls_forgetting(p,theta(:,i),phi(i,:),y(i),lambda) ;
   r0=theta(1,i+1);
   r1=theta(2,i+1);
   s0=theta(3,i+1);
   s1=theta(4,i+1);
   draw1(i)=r1/r0;
   draw2(i)=t0/r0;
   draw3(i)=s0/r0;
   draw4(i)=s1/r0;
   if i==1
      uf(i)=u(i)-am1*0-am2*0;
      yf(i)=y(i)-am1*0-am2*0;
      phi(i+1,1)=0;
      phi(i+1,2)=0;
      phi(i+1,3)=0;
      phi(i+1,4)=0;
      u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*0;
      y(i+1)=1.6065*y(i)-0.6065*0+0.1065*u(i)+0.0902*0; %measured y
   end
   if i==2
      uf(i)=u(i)-am1*uf(i-1)-am2*0;
      yf(i)=y(i)-am1*yf(i-1)-am2*0;
      phi(i+1,1)=uf(i-1);
      phi(i+1,2)=0;
      phi(i+1,3)=yf(i-1);
      phi(i+1,4)=0;
      u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
      y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
   end
   if i>=3
      uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
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```
        yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
        phi(i+1,1)=uf(i-1);
        phi(i+1,2)=uf(i-2);
        phi(i+1,3)=yf(i-1);
        phi(i+1,4)=yf(i-2);
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    i=i+1;
end
figure(3)
subplot(211)
plot(0:0.5:m,y);
title('Direct STR d0=2')
xlabel('Time')
text(51, -0.08197,' y')
hold on
plot(0:0.5:m,uc(1:2*m+1));
text(21, -1,'uc')
axis([-inf, inf, -1.5, 1.5])
subplot(212)
stairs(0:0.5:m,u);
xlabel('Time')
text(65, 1,' u')
axis([-inf, inf, -4.5, 4.5])
figure(4)
o=20;
stairs(0:0.5:o,draw1(1:o*2+1)),hold on
stairs(0:0.5:o,draw2(1:2*o+1),'--'),hold on
stairs(0:0.5:o,draw3(1:2*o+1),'-.'),hold on
stairs(0:0.5:o,draw4(1:2*o+1),':')
title('estimated parameter'),xlabel('Time')
text(o-5, -0.337,' r1/r0'),text(o-5, 0.52,' t0/r0')
text(o-5, 1.2,'s0/r0'),text(o-5, -0.67,' s1/r0')
%%
%Direct STR,d0=3
clear,clc ;
format long;
m=100;%time(sec) ,sampling time=0.5(sec)
r0=-0.11;
r1=-0.11;
```

```
s0=-0.055;

s1=0;

theta(1,1)=r0;

theta(2,1)=r1;

theta(3,1)=s0;

theta(4,1)=s1;

phi(1,1)=0;

phi(1,2)=0;

phi(1,3)=0;

phi(1,4)=0;

uc(1:49)=1;

uc(50:99)=-1;

uc=[uc uc uc uc uc];

uc=[uc uc uc uc uc];

p=[100 0 0 0 ;0 100 0 0; 0 0 1 0; 0 0 0 1];

lambda=1;

%desired system:Am

am1=-1.3205;

am2=0.4966;

i=1;

y(1)=0;

u(1)=0.5;

t0=1+am1+am2;

for k=0:0.5:(m-0.5)

   %RLS:R,S

   [p ,theta(:,i+1)]=rls_forgetting(p,theta(:,i),phi(i,:),y(i),lambda) ;

   r0=theta(1,i+1);

   r1=theta(2,i+1);

   s0=theta(3,i+1);

   s1=theta(4,i+1);

   draw1(i)=r1/r0;

   draw2(i)=t0/r0;

   draw3(i)=s0/r0;

   draw4(i)=s1/r0;

   if i==1

      uf(i)=u(i)-am1*0-am2*0;

      yf(i)=y(i)-am1*0-am2*0;

      phi(i+1,1)=0;

      phi(i+1,2)=0;

      phi(i+1,3)=0;

      phi(i+1,4)=0;
```

```
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*0;
        y(i+1)=1.6065*y(i)-0.6065*0+0.1065*u(i)+0.0902*0; %measured y
    end
    if i==2
        uf(i)=u(i)-am1*uf(i-1)-am2*0;
        yf(i)=y(i)-am1*yf(i-1)-am2*0;
        phi(i+1,1)=0;
        phi(i+1,2)=0;
        phi(i+1,3)=0;
        phi(i+1,4)=0;
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    if i==3
        uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
        yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
        phi(i+1,1)=uf(i-2);
        phi(i+1,2)=0;
        phi(i+1,3)=yf(i-2);
        phi(i+1,4)=0;
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    if i>=4
        uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
        yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
        phi(i+1,1)=uf(i-2);
        phi(i+1,2)=uf(i-3);
        phi(i+1,3)=yf(i-2);
        phi(i+1,4)=yf(i-3);
        u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
        y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
    end
    i=i+1;
end
figure(5)
subplot(211)
plot(0:0.5:m,y);
title('Direct STR d0=3')
xlabel('Time')
text(51, -0.08197,' y')
```

```
hold on

plot(0:0.5:m,uc(1:2*m+1));

text(21, -1,'uc')

axis([-inf, inf, -1.5, 1.5])

subplot(212)

stairs(0:0.5:m,u);

xlabel('Time')

text(65, 1,' u')

axis([-inf, inf, -4.5, 4.5])

figure(6)

o=20;

stairs(0:0.5:o,draw1(1:o*2+1)),hold on

stairs(0:0.5:o,draw2(1:2*o+1),'--'),hold on

stairs(0:0.5:o,draw3(1:2*o+1),'-.'),hold on

stairs(0:0.5:o,draw4(1:2*o+1),':')

title('estimated parameter'),xlabel('Time')

%%

%Direct STR,d0=4

clear,clc ;

format long;

m=100;%time(sec) ,sampling time=0.5(sec)

r0=-0.11;

r1=-0.11;

s0=-0.055;

s1=0;

theta(1,1)=r0;

theta(2,1)=r1;

theta(3,1)=s0;

theta(4,1)=s1;

phi(1,1)=0;

phi(1,2)=0;

phi(1,3)=0;

phi(1,4)=0;

uc(1:49)=1;

uc(50:99)=-1;

uc=[uc uc uc uc uc];

uc=[uc uc uc uc uc];

p=[100 0 0 0 ;0 100 0 0; 0 0 1 0; 0 0 0 1];

lambda=1;

%desired system:Am

am1=-1.3205;
```

```
am2=0.4966;
i=1;
y(1)=0;
u(1)=0.5;
t0=1+am1+am2;
for k=0:0.5:(m-0.5)
   %RLS:R,S
   [p ,theta(:,i+1)]=rls_forgetting(p,theta(:,i),phi(i,:),y(i),lambda) ;
   r0=theta(1,i+1);
   r1=theta(2,i+1);
   s0=theta(3,i+1);
   s1=theta(4,i+1);
   draw1(i)=r1/r0;
   draw2(i)=t0/r0;
   draw3(i)=s0/r0;
   draw4(i)=s1/r0;
   if i==1
      uf(i)=u(i)-am1*0-am2*0;
      yf(i)=y(i)-am1*0-am2*0;
      phi(i+1,1)=0;
      phi(i+1,2)=0;
      phi(i+1,3)=0;
      phi(i+1,4)=0;
      u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*0;
      y(i+1)=1.6065*y(i)-0.6065*0+0.1065*u(i)+0.0902*0; %measured y
   end
   if i==2
      uf(i)=u(i)-am1*uf(i-1)-am2*0;
      yf(i)=y(i)-am1*yf(i-1)-am2*0;
      phi(i+1,1)=0;
      phi(i+1,2)=0;
      phi(i+1,3)=0;
      phi(i+1,4)=0;
      u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
      y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
   end
   if i==3
      uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
      yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
      phi(i+1,1)=0;
      phi(i+1,2)=0;
```

```
    phi(i+1,3)=0;
    phi(i+1,4)=0;
    u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
    y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
  end
  if i==4
    uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
    yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
    phi(i+1,1)=uf(i-3);
    phi(i+1,2)=0;
    phi(i+1,3)=yf(i-3);
    phi(i+1,4)=0;
    u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
    y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
  end
  if i>=5
    uf(i)=u(i)-am1*uf(i-1)-am2*uf(i-2);
    yf(i)=y(i)-am1*yf(i-1)-am2*yf(i-2);
    phi(i+1,1)=uf(i-3);
    phi(i+1,2)=uf(i-4);
    phi(i+1,3)=yf(i-3);
    phi(i+1,4)=yf(i-4);
    u(i+1)=-r1/r0*u(i)+t0/r0*uc(i)-s0/r0*y(i)-s1/r0*y(i-1);
    y(i+1)=1.6065*y(i)-0.6065*y(i-1)+0.1065*u(i)+0.0902*u(i-1);  %measured y
  end
  i=i+1;
end
figure(7)
subplot(211)
plot(0:0.5:m,y);
title('Direct STR d0=4')
xlabel('Time')
text(51, -0.08197,' y')
hold on
plot(0:0.5:m,uc(1:2*m+1));
text(21, -1,'uc')
axis([-inf, inf, -1.5, 1.5])
subplot(212)
stairs(0:0.5:m,u);
xlabel('Time')
text(65, 1,' u')
```

```
axis([-inf, inf, -4.5, 4.5])

figure(8)

o=20;

stairs(0:0.5:o,draw1(1:o*2+1)),hold on

stairs(0:0.5:o,draw2(1:2*o+1),'--'),hold on

stairs(0:0.5:o,draw3(1:2*o+1),'-.'),hold on

stairs(0:0.5:o,draw4(1:2*o+1),':')

title('estimated parameter'),xlabel('Time')

function [ p,theta ] = rls_forgetting( p,theta,phi,y ,lambda)

   k = p *phi'./(lambda*1+phi*p*phi');

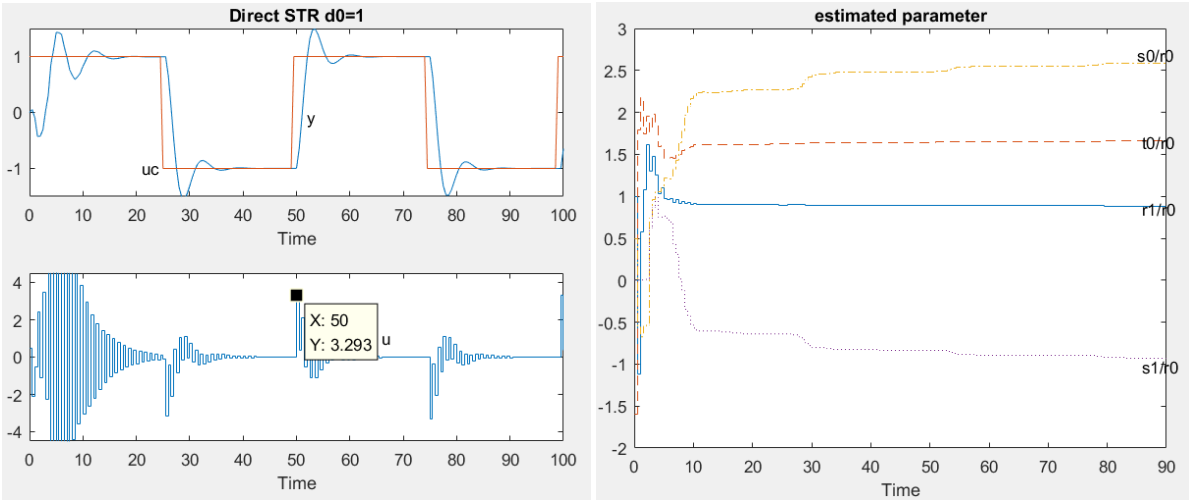
   p=p-k*phi*p/lambda;

   theta=theta+k*(y-phi*theta);

end
```

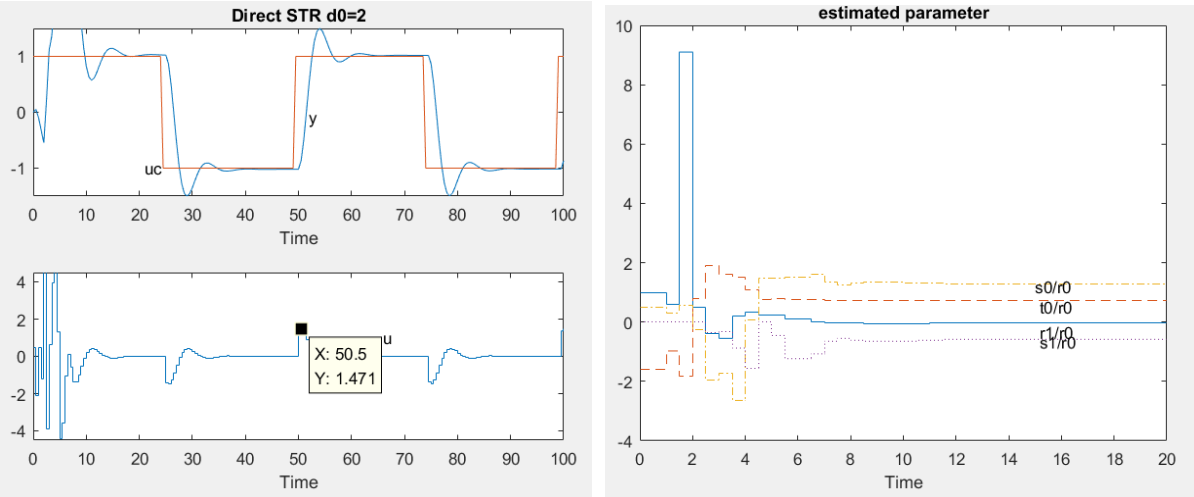
GRAPH

DIRECT STR WITH Do=1



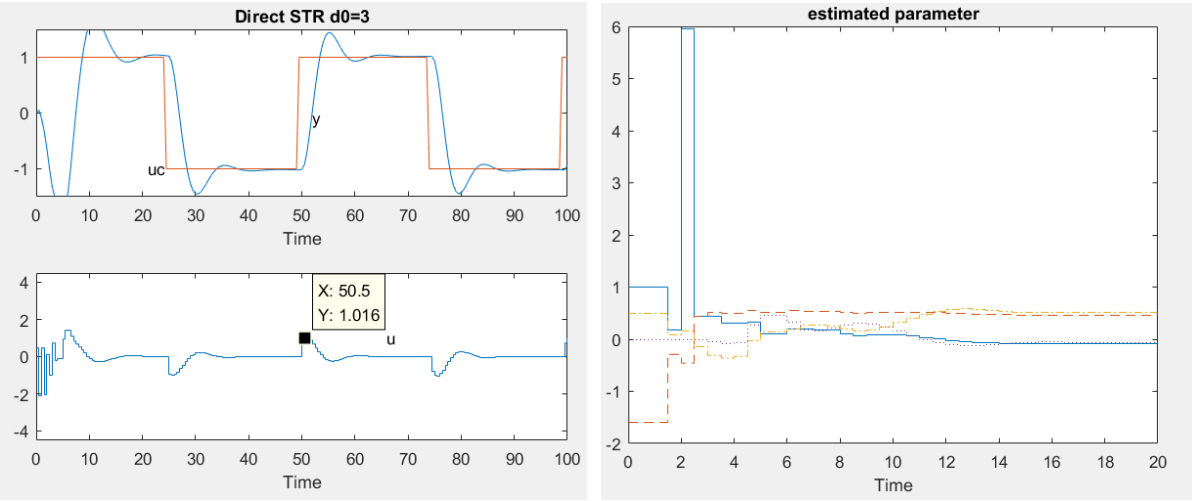
圖一

DIRECT STR WITH Do=2



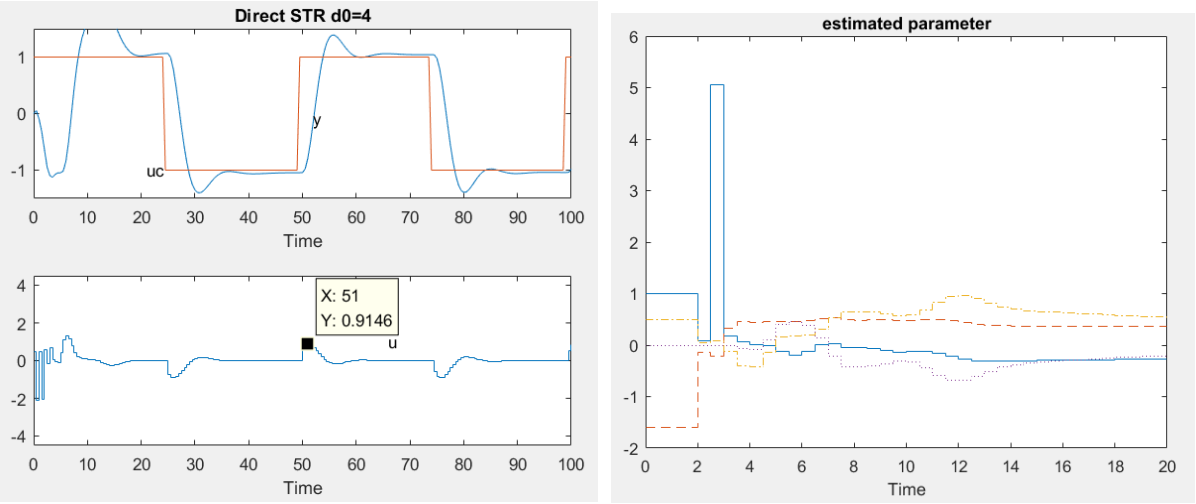
圖二

DIRECT STR WITH Do=3



圖三

DIRECT STR WITH Do=4



圖四

TABLE

t = 100	r1/r0	t0/r0	s0/r0	s1/r0
d0 = 1	0.884(0.8467)	1.658(1.653)	2.588(2.68)	-0.928(-1.032)
d0 = 2	-0.063(-0.337)	0.686(0.52)	1.241(1.2)	-0.565(-0.67)
d0 = 3	-0.366	0.369	0.702	-0.338
d0 = 4	-0.503	0.271	0.606	-0.344

表一

CONCLUSION-ANALYSIS

由圖一，do=1，我們可以看到 Control Signal (u)有"Ring"的現象產生，而如圖二，do=2，我們得到的 Control Signal (u) 較為穩定，耗能較小；由圖一至圖四，比較 do=1,2,3,4 時的結果，可以看到隨著 do 的增加，控制訊號 u(t)的最大值減少，越能降低運作時的耗能，而值得我們考慮的是，雖然 do 越大耗能越低，但是 do 代表的是延遲訊號，所以會導致整個系統輸出 y 的反應時間變慢。

Direct STR 的運算快於 Indirect STR，原因為 Direct STR 是直接估測 R*與 S*，而 Indirect STR 需先估出 A、B 後才去計算 R、S 係數，值得注意的是，當 do=1 時的 Dierect STR 控制訊號效果與消除零點方法之 Indirect STR 相似，而當 do=2,3,4 時之控制訊號效果與不消除零點之方 Indirect STR 同。