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ภาคผนวก

ภาคผนวก ก

ชุดคำสั่งในการคำนวณ

ชุดคำสั่ง MATLAB สำหรับหาผลเฉลยของสมการเคอร์เนล ด้วยวิธีการประมาณสืบเนื่อง หรือวิธีเชิงตัวเลข นอกจากนี้ยังมีชุดคำสั่งสำหรับจำลองพลวัตของคานตีโมเชนโค พลวัตของคานตีโมเชนโคลดรูป และผลตอบสนองของระบบวงวนปิดที่มีการป้อนกลับที่ขอบด้วยเทคนิคก้าวถอยหลัง

ก.1 การหาผลเฉลยของสมการเคอร์เนลด้วยวิธีการประมาณสืบเนื่อง

```
% initialize-----------------------------------
syms x y lambda mu tau eta xi s t;
syms a b c k q epsilon alpha positive;
N=101;
h=1/(N-1);
n=5;
q=inf;
epsilon=1;
A=c+b^2;
g=0;
f=b^3*sinh(b*(x-y));
G0=-(1/(4*epsilon))*int(subs(A,t,tau/2),tau,eta,xi)-...
   (1/(2*epsilon))*int(exp(q*(tau-eta))*(subs(A,t,tau/2)+2*subs(g,x,tau)),tau,0,eta)-...
   (1/(4*epsilon))*int(int(subs(subs(f,x,(s+tau)/2),y,(s-tau)/2),tau,0,eta),s,eta,xi)-...
   (1/(2*epsilon))*int(exp(q*(tau-eta))*int(subs(subs(f,x,(s+tau)/2),y,(s-tau)/2),s,0,tau),tau,0,eta)
G(1)=G0;

%calculate $n^{th}$ term of kernel------------------
for i=1:n
   G(i+1)=G0+...
   (1/(2*epsilon))*int(exp(q*(tau-eta))*int(subs(A,t,(tau-s)/2)
*subs(subs(G(i),xi,tau),eta,s),s,0,tau),tau,0,eta)+...
   (1/(4*epsilon))*int(int(subs(A,t,(tau-s)/2)*subs(subs(G(i),xi,tau),eta,s),s,0,eta),tau,eta,xi)+...
   (1/(2*epsilon))*int(int(exp(q*((tau+s)/2-eta))
*subs(g,x,(tau-s)/2)*subs(subs(G(i),xi,tau),eta,s),tau,s,2*eta-s),s,0,eta)+...
   (1/(4*epsilon))*int(int(int(subs(subs(f,x,(tau-s)/2),y,mu-(tau+s)/2)
*subs(subs(G(i),xi,tau),eta,s),tau,mu,mu+eta-s),s,0,eta),mu,eta,xi)+...
   (1/(2*epsilon))*int(exp(q*(mu-eta))*int(int(subs(subs(f,x,(tau-s)/2),y,mu-(tau+s)/2)
*subs(subs(G(i),xi,tau),eta,s),tau,mu,2*mu-s),s,0,mu),mu,0,eta);
end
```

ก.2 การหาผลเฉลยของสมการเคอร์เนลด้วยวิธีเชิงตัวเลข

```
% Initialize-----------------------------------
u(1,1)=0;
k(1,1)=0;
N=101;
h=1/(N-1);
epsilon=1;
c=10;
b=1;
d=0.1;
DN=0;

% Boundary conditions--------------------------
for i=1:N+1
   k(i,1)=0;
   k(i,i)=-(c+b^2)*h*(i-1)/2;
   k(i,i+1)=0;
end

%calculate the kernel--------------------------
for m=1:((N-1)/2)
   for n=2:(N-2*m+1)
      k(n+2*m-1,n)=(k(n+2*m-1,n+1)+k(n+2*m-1,n-1))/2;
      f=0;
  % integral term------------------------
      for l=1:m
         f=f+(k(n+2*m-1,n+l)*sinh(b*(l)*h)+k(n+2*m-1,n+l-1)*sinh(b*(l-1)*h));
      end
      k(n+2*m,n)=-k(n+2*m-2,n)+k(n+2*m-1,n+1)+k(n+2*m-1,n-1)...
+(c+b^2)*h^2*(k(n+2*m-1,n+1)+k(n+2*m-1,n-1))/2-b^3*h^2*sinh(b*(2*m-1)*h)+b^3*h^3*f/2;
   end
end
```

ก.3 การจำลองแบบพลวัตของคานตีโมเชนโคปลายยึดทั้งสองข้าง

```
% Initialize-----------------------------------
N=101;
h=1/(N-1);
epsilon=1;
c=10;
b=1;
d=0.1;
DN=0;
mu=0.001;
a=1;
C1=zeros(N);
C2=zeros(N);
C3=zeros(N);
C4=zeros(N);

%matrix C ------------------------------------
for i=1:N
   C1(i,i+1)=-1;
   C1(i,i)=2;
   C1(i+1,i)=-1;

   C2(i,i+1)=-h/2;
   C2(i+1,i)=h/2;

   C3(i,i+1)=a*h/2;
   C3(i+1,i)=-a*h/2;

   C4(i,i+1)=-epsilon;
   C4(i,i)=2*epsilon-a*h^2;
   C4(i+1,i)=-epsilon;
end

%matrix D ------------------------------------
for i=1:N
   D(i)=(-((i-1)*h)^2+(i-1)*h)*10;
end

% Boundary conditions--------------------------
C1(1,1)=0;
C1(N,N)=0;
C2(1,1)=0;
C2(N,N)=0;
C3(1,1)=0;
C3(N,N)=0;
C4(1,1)=0;
C4(N,N)=0;

iAC=[-(1/(epsilon*h^2))*C1(1:N,1:N) -(1/(epsilon*h^2))*C2(1:N,1:N);
-(1/(mu*epsilon*h^2))*C3(1:N,1:N) -(1/(mu*epsilon*h^2))*C4(1:N,1:N)];
iAB=d*iAC;

%matrix G ------------------------------------
G=[zeros(2*N) eye(2*N);iAC iAB];
G0=transpose([D zeros(1,3*N)]);

% zakian $I_{MN}$ recursion--------------------
```

```
[alpha,K,c] = imncoef1(3,4) ;
tf=8; % final time
ts = 0.05;  % step time
u = G0;
t=0:ts:tf;

K1 = K(1);
K2 = K(2) ;

a1 = alpha(1)/ts ;
a2 = alpha(2)/ts ;
II = eye(4*N) ;
CK1=inv(a1*II - G);
CK2=inv(a2*II - G);

for i = 2:length(t),
   X1 = CK1 * u(:,i-1) ;
   X2 = CK2 * u(:,i-1) ;
   u(:,i) = 2/ts*real( K1*X1 + K2*X2 ) ;
end
```

ก.4 การจำลองแบบพลวัตของคานตีโมเชนโคลดรูป

```
% Initialize-----------------------------------
cB=zeros(N);
cC=zeros(N);

% tridiagonal matrix C-------------------------
for i=1:N
   cC(i,i+1)=-1;
   cC(i,i)=2-b^2*h^2;
   cC(i+1,i)=-1-b^3*h^3*sinh(b*h);
end
%matrix L -------------------------------------
for m=4:N
   for n=0:N-m
      cC(m+n,2+n)=-b^3*h^3*sinh((m-2)*b*h);
   end
end

for l=3:N
   cC(l,1)=-b^3*h^3*sinh((l-1)*b*h)/2;
end

cC(2,1)=cC(2,1)+b^3*h^3*sinh(b*h)/2;

%matrix B -------------------------------------
cB=d*cC;

%matrix D -------------------------------------
for i=1:N
   cD(i)=(-((i-1)*h)^2+(i-1)*h)*10;
end

%matrix G -------------------------------------
cG=[zeros(N) eye(N);-(1/(epsilon*h^2))*cC(1:N,1:N) -(1/(epsilon*h^2))*cB(1:N,1:N)];
cG0=transpose([cD zeros(1,N)]);

% zakian $I_{MN}$ recursion--------------------
II = eye(2*N) ;
CK1=inv(a1*II - cG);
CK2=inv(a2*II - cG);

for i = 2:length(t),
   X1 = CK1 * u(:,i-1) ;
   X2 = CK2 * u(:,i-1) ;
   u(:,i) = 2/ts*real( K1*X1 + K2*X2 ) ;
end
```

ก.5 การจำลองแบบผลตอบสนองของระบบวงวนปิด

```
% Initialize-----------------------------------
A=epsilon*h^2*eye(N-2);
C=zeros(N-2);

% tridiagonal matrix C-------------------------
for i=1:N-2
   C(i,i+1)=-1;
   C(i,i)=2-b^2*h^2;
   C(i+1,i)=-1-b^3*h^3*sinh(b*h);
end

%matrix L --------------------------------------
for m=3:N-2
   for n=0:N-m-2
      C(m+n,1+n)=-b^3*h^3*sinh((m-1)*b*h);
   end
end

%matrix J --------------------------------------
for i=1:N-2
   C(N-2,i)=C(N-2,i)-h*k(N,i+1)/(1-h*k(N,N)/2);
end
B=d*C;

%matrix D --------------------------------------
for i=1:N-2
   D(i)=(-(i*h)^2+i*h)*1;
end

%matrix G --------------------------------------
G=[zeros(N-2) eye(N-2);-(1/(epsilon*h^2))*C(1:N-2,1:N-2) -(1/(epsilon*h^2))*B(1:N-2,1:N-2)];
G0=transpose([D zeros(1,N-2)]);

% zakian $I_{MN}$ recursion--------------------
[alpha,K,c] = imncoef1(3,4) ;
tf=10; % final time
ts = 0.05; % step time
u = G0;
t=0:ts:tf;

K1 = K(1);
K2 = K(2);

a1 = alpha(1)/ts ;
a2 = alpha(2)/ts ;
II = eye(2*(N-2)) ;
CK1=inv(a1*II - G);
CK2=inv(a2*II - G);

for i = 2:length(t),
   X1 = CK1 * u(:,i-1) ;
   X2 = CK2 * u(:,i-1) ;
   u(:,i) = 2/ts*real( K1*X1 + K2*X2 ) ;
   un(i)=(h*k(N,2:N-1)*u(1:N-2,i))/(1-h*k(N,N)/2); % control signal
   Ebc(i)=norm(u(:,i)); % ||u||_2
end
```

ประวัติผู้เขียนวิทยานิพนธ์

นายธีรเดช พิญญพงษ์ เกิดเมื่อวันที่ 28 สิงหาคม 2520 ที่จังหวัดพระนครศรีอยุธยาเป็นบุตร นายทองเล้ง และนางเซ็งเซี้ยม พิญญพงษ์ สำเร็จการศึกษาปริญญาวิศวกรรมศาสตรบัณฑิต สาขาวิชาวิศวกรรมไฟฟ้า จากภาควิชาวิศวกรรมไฟฟ้า คณะวิศวกรรมศาสตร์ สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหาร ลาดกระบัง ในปีการศึกษา 2541 เริ่มต้นทำงานที่ศูนย์อิเล็กทรอนิกส์และคอมพิวเตอร์แห่งชาติ จนถึงปัจจุบันได้ลาศึกษาต่อในหลักสูตรวิศวกรรมศาสตรมหาบัณฑิต ภาควิชาวิศวกรรมไฟฟ้า คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย สังกัดห้องปฏิบัติการวิจัยระบบควบคุม เมื่อปีการศึกษา 2548 โดยได้รับทุนการศึกษาจากโครงการทุนสถาบันบัณฑิตวิทยาศาสตร์และเทคโนโลยีไทย