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% MatLab codes for the influence of r_2 value change on the system
clear all
close all
clc
warning ('on')

k0 = [0.05 0.05 5000 5000  0.005 0.005 0.005];
lb = [0.05 0.02 0 0       0.00025 0.00025 0.00108];
ub = [0.12 0.09 70000  70000  0.05 0.05 0.07];
x0 = [26908.3   15482.6];
load('data.mat')
load('test.mat')
yexp = data;

[k,fval,flag] =
fmincon(@ObjFunc4Fmincon,k0,[],[],[],[],lb,ub,[],[],x0,yexp);
fprintf('\tr1 = %.9f\n',k(1))
fprintf('\tr2 = %.9f\n',k(2))
fprintf('\tk1 = %.9f\n',k(3))
fprintf('\tk2 = %.9f\n',k(4))
fprintf('\td1 = %.9f\n',k(5))
fprintf('\td2 = %.9f\n',k(6))
fprintf('\tm = %.9f\n',k(7))

fprintf('The sum of the squares is: %.1e\n\n',fval)
k_fmincon = k;

fprintf('\tr1 = %.9f\n',k(1))
fprintf('\tr2 = %.9f\n',k(2))
fprintf('\tk1 = %.9f\n',k(3))
fprintf('\tk2 = %.9f\n',k(4))
fprintf('\td1 = %.9f\n',k(5))
fprintf('\td2 = %.9f\n',k(6))
fprintf('\tm = %.9f\n',k(7))

k0 = k_fmincon;
[k,resnorm,residual,exitflag,output,lambda,jacobian] = ...
   lsqnonlin(@ObjFunc4LNL,k0,lb,ub,[],x0,yexp);
ci = nlparci(k,residual,jacobian);

fprintf('\tr1 = %.9f\n',k(1))
fprintf('\tr2 = %.9f\n',k(2))
fprintf('\tk1 = %.9f\n',k(3))
fprintf('\tk2 = %.9f\n',k(4))
fprintf('\td1 = %.9f\n',k(5))
fprintf('\td2 = %.9f\n',k(6))
fprintf('\tm = %.9f\n',k(7))
tspan1=0:1:81;
tspan = 0:1:88;
[t,uu] = ode45(@KineticEqs,tspan,x0,[],k);
tspan=0:1:81;

r1=k(1);
%r2=k(2);
k1=k(3);
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k2=k(4);
d1=k(5);
d2=k(6);
m=k(7);

DyDtAnony = @(r2)@(t,x,k)[ ( r1.*x(1).*(1-x(1)./k1)-m.*x(1)-d1.*x(1) )
   ( r2.*x(2).*(1-x(2)./k2)+m.*x(1)-d2.*x(2) )];

figure(1);h1 = axes;hold on;
figure(2);h2 = axes;hold on;
tspan1 =0:1:90;
for r2 = [0.0610 0.0810 0.1010];
    [t,u] = ode45(DyDtAnony(r2),tspan1,x0,k);
    if r2==0.0610
    plot(h1,t,u(:,1),'--r','linewidth',1);
    plot(h2,t,u(:,2),'--b','linewidth',1);
    elseif r2==0.0810
    plot(h1,t,u(:,1),'-r','linewidth',1);
    plot(h2,t,u(:,2),'-b','linewidth',1);
    elseif r2==0.1010
    plot(h1,t,u(:,1),':r','linewidth',1);
    plot(h2,t,u(:,2),':b','linewidth',1);
    end
end
ylabel(h1,'x(t)')
xlabel(h1,'t');
legend(h1,'{\itr_2}=0.0610','{\itr_2}=0.0810','{\itr_2}=0.1010');
ylabel(h2,'y(t)')
xlabel(h2,'t');
legend(h2,'{\itr_2}=0.0610','{\itr_2}=0.0810','{\itr_2}=0.1010');

%% ---------------------------------------------------------------------
function f = ObjFunc4Fmincon(k,x0,yexp)
tspan =0:1:81;
[t x] = ode45(@KineticEqs,tspan,x0,[],k);
y = x;
f = sum((y(:,1)-yexp(:,1)).^2) + sum((y(:,2)-yexp(:,2)).^2) ;
end

% ---------------------------------------------------------------------
function f = ObjFunc4LNL(k,x0,yexp)
tspan =0:1:81;
[t x] = ode45(@KineticEqs,tspan,x0,[],k);
y = x;
f1 = y(:,1) - yexp(:,1);
f2 = y(:,2) - yexp(:,2);
f = [f1; f2];
end
% ---------------------------------------------------------------------
function dxdt = KineticEqs(t,x,k)
r1=k(1);
r2=k(2);
k1=k(3);
k2=k(4);
d1=k(5);
d2=k(6);
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```
m=k(7);

dxdt =  ...
 [  ( r1.*x(1).*(1-x(1)./k1)-m.*x(1)-d1.*x(1) )
    ( r2.*x(2).*(1-x(2)./k2)+m.*x(1)-d2.*x(2) )
];
end
```