3. code 1 chương trình bài toán động học ngược

```
%********************main*************************%
close all; clear all; clc;
l1 = 0.25; l2 = 0.194; l3 = 0.265; a1 = 0.03;
% du doan nghiem dau
q=[0.7649928327;-0.3812343942;-0.3543431040];

% thoi gian chuyen dong
t = 1.1780972450:0.01:1.178097245*3.01;

for i=1:length(t)

    % phuong trinh Xe(q) - X(t)
    f1 =l3*cos(q(2) + q(3))*cos(q(1)) - cos(q(1))*(a1 - l2*cos(q(2))) - (0.25 +
0.09*cos(t(i)/0.75));

    f2= l3*cos(q(2) + q(3))*sin(q(1)) - sin(q(1))*(a1 - l2*cos(q(2))) - (0.15 +
0.09*sin(t(i)/0.75));

    f3= l1 + l2*sin(q(2)) + l3*sin(q(2) + q(3));

    k=1;
    while(norm([f1; f2; f3],2)>1e-12) %norm(lk,2) = norm(lk)
      % Jacobian
       J=zeros(3,3);
       J(1,1)= sin(q(1))*(a1 - l2*cos(q(2))) - l3*cos(q(2) + q(3))*sin(q(1));
       J(1,2)= -l2*cos(q(1))*sin(q(2)) - l3*sin(q(2) + q(3))*cos(q(1));
       J(1,3)= -l3*sin(q(2) + q(3))*cos(q(1));

       J(2,1)= l3*cos(q(2) + q(3))*cos(q(1)) - cos(q(1))*(a1 - l2*cos(q(2)));
       J(2,2)= -l2*sin(q(1))*sin(q(2)) - l3*sin(q(2) + q(3))*sin(q(1));
       J(2,3)= -l3*sin(q(2) + q(3))*sin(q(1));

       J(3,1)= 0;
       J(3,2)= l2*cos(q(2)) + l3*cos(q(2) + q(3));
       J(3,3)= l3*cos(q(2) + q(3));

       delta=-inv(J)*[f1;f2;f3];
       q=q+delta;

      % pt liên kết
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        f1= l3*cos(q(2) + q(3))*cos(q(1)) - cos(q(1))*(a1 - l2*cos(q(2))) - (0.25 +
0.09*cos(t(i)/0.75));
        f2= l3*cos(q(2) + q(3))*sin(q(1)) - sin(q(1))*(a1 - l2*cos(q(2))) - (0.15 +
0.09*sin(t(i)/0.75));
        f3= l1 + l2*sin(q(2)) + l3*sin(q(2) + q(3));

        k=k+1;
    end

    % xac dinh Vector toa do suy rong tai thoi diem t(i)
    q1(i)=q(1); q2(i)=q(2);q3(i)=q(3);
    % xac dinh Vector van toc suy rong tai thoi diem t(i)
    vEx= -0.12*sin(1.3*t(i));
    vEy= 0.12*cos(1.3*t(i));
    vEz= 0;
    dX=[vEx;vEy;vEz];

    dq=inv(J)*dX;
    dq1(i)=dq(1); dq2(i)=dq(2);dq3(i)=dq(3);

    % xac dinh Vector gia toc suy rong tai thoi diem t(i)
    d2xE= -0.16*cos(1.3*t(i));
    d2yE= -0.16*sin(1.3*t(i));
    d2zE= 0;
    d2X=[d2xE;d2yE;d2zE];
        % dao ham jacobian theo t(i)
    dJq=zeros(3,3);

    dJq(1,1)= cos(q1(i))*dq1(i)*(a1-
l2*cos(q2(i)))+sin(q1(i))*l2*sin(q2(i))*dq2(i)+l3*sin(q2(i)+q3(i))*(dq2(i)+dq3(i))*sin
(q1(i))-l3*cos(q2(i)+q3(i))*cos(q1(i))*dq1(i);
    dJq(1,2)= -
l3*cos(q2(i)+q3(i))*(dq2(i)+dq3(i))*cos(q1(i))+l3*sin(q2(i)+q3(i))*sin(q1(i))*dq1(i)+
l2*sin(q1(i))*dq1(i)*sin(q2(i))-l2*cos(q1(i))*cos(q2(i))*dq2(i);
    dJq(1,3)= -
l3*cos(q2(i)+q3(i))*(dq2(i)+dq3(i))*cos(q1(i))+l3*sin(q2(i)+q3(i))*sin(q1(i))*dq1(i);

    dJq(2,1)= -l3*sin(q2(i)+q3(i))*(dq2(i)+dq3(i))*cos(q1(i)) -
l3*cos(q2(i)+q3(i))*sin(q1(i))*dq1(i) + sin(q1(i))*dq1(i)*(a1-l2*cos(q2(i))) -
cos(q1(i))*l2*sin(q2(i))*dq2(i);
    dJq(2,2)= -l3*cos(q2(i)+q3(i))*(dq2(i)+dq3(i))*sin(q1(i)) -
l3*sin(q2(i)+q3(i))*cos(q1(i))*dq1(i) - l2*cos(q1(i))*dq1(i)*sin(q2(i))-
l2*sin(q1(i))*cos(q2(i))*dq2(i);
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```
   dJq(2,3)= -l3*cos(q2(i)+q3(i))*(dq2(i)+dq3(i))*sin(q1(i)) -
l3*sin(q2(i)+q3(i))*cos(q1(i))*dq1(i);

   dJq(3,1)=0;
   dJq(3,2)= -l3*sin(q2(i)+q3(i))*(dq2(i)+dq3(i))-l2*sin(q2(i))*dq2(i);
   dJq(3,3)= -l3*sin(q2(i)+q3(i))*(dq2(i)+dq3(i));

   d2q=inv(J) * (d2X - dJq * dq);
   d2q1(i)=d2q(1); d2q2(i)=d2q(2);d2q3(i)=d2q(3);

   % tim To

   % Ma tran Cq
   Cq = zeros(3,3);
   Cq(1,1) = (-0.1*cos(q2(i))*sin(q2(i))+0.1e-1*sin(q2(i))-0.2e-
1*cos(q2(i)+q3(i))*sin(q2(i)+q3(i))+0.3e-2*sin(q2(i)+q3(i))-0.2e-
1*sin(q2(i)+q3(i))*cos(q2(i))-0.2e-1*cos(q2(i)+q3(i))*sin(q2(i)))*dq2(i)-0.2e-
1*sin(q2(i)+q3(i))*(cos(q2(i)+q3(i))-0.2+cos(q2(i)))*dq3(i);
   Cq(1,2) = -0.4e-2*cos(q1(i))*sin(q1(i))*dq3(i);
   Cq(1,3) = -0.4e-2*cos(q1(i))*sin(q1(i))*dq2(i)-0.4e-2*cos(q1(i))*sin(q1(i))*dq3(i);

   Cq(2,1) = -(0.5*(-0.1*cos(q2(i))*sin(q2(i))+0.1e-1*sin(q2(i))-0.2e-
1*cos(q2(i)+q3(i))*sin(q2(i)+q3(i))+0.3e-2*sin(q2(i)+q3(i))-0.2e-
1*sin(q2(i)+q3(i))*cos(q2(i))-0.2e-1*cos(q2(i)+q3(i))*sin(q2(i))))*dq1(i);
   Cq(2,2) = (0.2e-1*cos(q2(i)+q3(i))*sin(q2(i))-0.2e-
1*sin(q2(i)+q3(i))*cos(q2(i)))*dq3(i);
   Cq(2,3) = 0.8e-2*cos(q1(i))*sin(q1(i))*dq1(i)+(0.9e-2*cos(q2(i)+q3(i))*sin(q2(i))-
0.9e-2*sin(q2(i)+q3(i))*cos(q2(i)))*dq3(i);

   Cq(3,1) = 0.1e-1*sin(q2(i)+q3(i))*(cos(q2(i)+q3(i))-0.2+cos(q2(i)))*dq1(i);
   Cq(3,2) = 0.8e-2*cos(q1(i))*sin(q1(i))*dq1(i)+(0.8e-2*cos(q2(i)+q3(i))*sin(q2(i))-
0.8e-2*sin(q2(i)+q3(i))*cos(q2(i)))*dq3(i)-(0.5*(0.2e-1*cos(q2(i)+q3(i))*sin(q2(i))-
0.2e-1*sin(q2(i)+q3(i))*cos(q2(i))))*dq2(i)-(0.5*(0.9e-2*cos(q2(i)+q3(i))*sin(q2(i))-
0.9e-2*sin(q2(i)+q3(i))*cos(q2(i))))*dq3(i);
   Cq(3,3) = 0.8e-2*cos(q1(i))*sin(q1(i))*dq1(i)-(0.5*(0.8e-
2*cos(q2(i)+q3(i))*sin(q2(i))-0.8e-2*sin(q2(i)+q3(i))*cos(q2(i))))*dq2(i);

   %ma tran Mq
   Mq = zeros(3,3);
   Mq(1,1) = 0.147e-2+0.52e-1*cos(q2(i))^2-0.135e-1*cos(q2(i))+0.1e-
1*cos(q2(i)+q3(i))^2-0.3e-2*cos(q2(i)+q3(i))+0.2e-1*cos(q2(i)+q3(i))*cos(q2(i));
   Mq(1,2) = 0;
   Mq(1,3) = 0;
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    Mq(2,1) = 0;
    Mq(2,2) = 0.62e-1+0.2e-1*sin(q2(i)+q3(i))*sin(q2(i))+0.2e-
1*cos(q2(i)+q3(i))*cos(q2(i));
    Mq(2,3) = 0.1e-1-0.4e-2*cos(q1(i))^2+0.9e-2*sin(q2(i)+q3(i))*sin(q2(i))+0.9e-
2*cos(q2(i)+q3(i))*cos(q2(i));

    Mq(3,1) = 0;
    Mq(3,2) = 0.1e-1-0.4e-2*cos(q1(i))^2+0.8e-2*sin(q2(i)+q3(i))*sin(q2(i))+0.8e-
2*cos(q2(i)+q3(i))*cos(q2(i));
    Mq(3,3) = 0.1e-1-0.4e-2*cos(q1(i))^2;

    %ma tran Gq
    Gq = zeros(3,1);
    Gq(1,1) = 0;
    Gq(2,1) = 1.9*cos(q2(i))+0.41*cos(q2(i)+q3(i));
    Gq(3,1) = 0.41*cos(q2(i)+q3(i));

    %tinh momen dan dong
    tau = Mq*d2q + Cq*dq + Gq;
    tau1(i) = tau(1); tau2(i) = tau(2); tau3(i) = tau(3);
end

% Ve do thi toa do suy rong
figure(1)
plot(t,q1,'k-',t,q2,'r-.',t,q3,'b--','linewidth',1);grid on;
hold on
xlabel('t[s]');ylabel('q[rad]');
title('Do thi cac toa do suy rong');
legend('q_1','q_2','q_3');

% Ve do thi cac van toc suy rong
figure(2)
plot(t,dq1,'k-',t,dq2,'r-.',t,dq3,'b--','linewidth',1);grid on;
xlabel('t[s]');ylabel('dq/dt[rad/s]');
title('Do thi cac van toc suy rong');
legend('dq_1/dt','dq_2/dt','dq_3/dt');

% Ve do thi cac gia toc suy rong
figure(3)
plot(t,d2q1,'k-',t,d2q2,'r-.',t,d2q3,'b--','linewidth',1);grid on;
xlabel('t[s]');ylabel('dq^2/dt[rad/s^2]');
title('Do thi cac gia toc suy rong');
```

```
legend('dq_1^2/dt','dq_2^2/dt','dq_3^2/dt');

% Ve do thi toa do suy rong q1
figure(4)
plot(t,q1,'k-',t,dq1,'r-.',t,d2q1,'b--','linewidth',1);grid on;
xlabel('t[s]');ylabel('q[rad],dq/dt[rad/s],dq^2/dt[rad/s^2]');
title('Do thi toa do suy rong q_1');
legend('q_1','dq_1/dt','dq_1^2/dt');

% Ve do thi toa do suy rong q2
figure(5)
plot(t,q2,'k-',t,dq2,'r-.',t,d2q2,'b--','linewidth',1);grid on;
xlabel('t[s]');ylabel('q[rad],dq/dt[rad/s],dq^2/dt[rad/s^2]');
title('Do thi toa do suy rong q_2');
legend('q_2','dq_2/dt','dq_2^2/dt');

% Ve do thi toa do suy rong q3
figure(6)
plot(t,q3,'k-',t,dq3,'r-.',t,d2q3,'b--','linewidth',1);grid on;
xlabel('t[s]');ylabel('q[rad],dq/dt[rad/s],dq^2/dt[rad/s^2]');
title('Do thi toa do suy rong q_3');
legend('q_3','dq_3/dt','dq_3^2/dt');


% Ve cau hinh cua robot
x0=0; y0=0; z0=0; z1=l1;
OAx= [x0,-a1]; OAy=[y0,y0]; OAz=[z0,z1];

j = 1.1780972450:0.01:1.178097245*3.01;
ABx = 0.250 + 0.090.*cos(j./0.750);
ABy = 0.150 + 0.090.*sin(j./0.750);
ABz = zeros(1, length(ABy));

figure(7);
hold on;
plot3(x0,y0,z0,'ob','linewidth',2,'Markersize',6);grid on
plot3(ABx,ABy,ABz,'r-','linewidth',1);
for i=1:13:length(t)
    qq1=[q1(i);q2(i);q3(i)];

    %RO3
    O3x= -cos(qq1(1))*(a1 - l2*cos(qq1(2)));
    O3y= -sin(qq1(1))*(a1 - l2*cos(qq1(2)));
```

```
    O3z= l1 + l2*sin(qq1(2));
    RO3=[O3x;O3y;O3z];

    %RO2
    O2x=-a1*cos(qq1(1));
    O2y=-a1*sin(qq1(1));
    O2z=l1;
    RO2=[O2x;O2y;O2z];

    %RE
    Ex = l3*cos(qq1(2) + qq1(3))*cos(qq1(1)) - cos(qq1(1))*(a1 - l2*cos(qq1(2)));
    Ey = l3*cos(qq1(2) + qq1(3))*sin(qq1(1)) - sin(qq1(1))*(a1 - l2*cos(qq1(2)));
    Ez = l1 + l2*sin(qq1(2)) + l3*sin(qq1(2) + qq1(3));
    RE=[Ex;Ey;Ez];

    AEx=[0,RO2(1),RO3(1),RE(1)];
    AEy=[0,RO2(2),RO3(2),RE(2)];
    AEz=[0,RO2(3),RO3(3),RE(3)];
    plot3(AEx,AEy,AEz,'k-','linewidth',1);
    plot3(RO2(1),RO2(2),RO2(3),'ob-','linewidth',1);
    plot3(RO3(1),RO3(2),RO3(3),'ob-','linewidth',1);
    plot3(RE(1),RE(2),RE(3),'or-','linewidth',1);
    axis equal
end


figure(9)
plot(t,tau1,'k-',t,tau2,'b--',t,tau3,'r-.','linewidth',1); grid on
xlabel('t[s]'); ylabel('tau[Nm]');
title('Do thi cac momen dan dong');
legend('tau_1','tau_2','tau_3');


% Gia tri lon nhat cua cac momen dan dong
Tau1Max = max(tau1)
Tau2Max = max(tau2)
Tau3Max = max(tau3)
```