```matlab
% ECE 4560 - Homework 12.3
% Caitlyn Caggia

l0 = 4.35; l1 = 4.725; l2 = l1; l3 = 5.12;
syms a1 a2 a3 a4 a5

%forward kinematics
g1 = SE3([0;0;l0], SE3.RotZ(a1));
g2 = SE3([0;0;0],SE3.RotX(a2));
g3 = SE3([0;0;l1], SE3.RotX(a3));
g4 = SE3([0;0;l2],SE3.RotX(a4));
g5 = SE3([0;0;0],SE3.RotZ(a5));
g6 = SE3([0;0;l3],eye(3));
ge = g1*g2*g3*g4*g5*g6;

%individual Jacobians
J1 = [0;0;0;0;0;1]
J2 = [0;0;0;1;0;0]
J3 = [0;0;0;1;0;0]
J4 = [0;0;0;1;0;0]
J5 = [0;0;0;0;0;1]

%inverted adjoints
g23456 = g2*g3*g4*g5*g6;
R1 = getRotationMatrix(g23456);
T1 = getTranslation(g23456);
ad1 = [transpose(R1) -transpose(R1)*SE3.hat(T1); zeros(3)
 transpose(R1)];
g3456 = g3*g4*g5*g6;
R2 = getRotationMatrix(g3456);
T2 = getTranslation(g3456);
ad2 = [transpose(R2) -transpose(R2)*SE3.hat(T2); zeros(3)
 transpose(R2)];
g456 = g4*g5*g6;
R3 = getRotationMatrix(g456);
T3 = getTranslation(g456);
ad3 = [transpose(R3) -transpose(R3)*SE3.hat(T3); zeros(3)
 transpose(R3)];
g56 = g5*g6;
R4 = getRotationMatrix(g56);
T4 = getTranslation(g56);
ad4 = [transpose(R4) -transpose(R4)*SE3.hat(T4); zeros(3)
 transpose(R4)];
R5 = getRotationMatrix(g6);
T5 = getTranslation(g6);
ad5 = [transpose(R5) -transpose(R5)*SE3.hat(T5); zeros(3)
 transpose(R5)];


%part a: body Jacobian
 --------------------------------------------------
Jb1 = simplify(ad1 * J1);
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```matlab
Jb2 = simplify(ad2 * J2);
Jb3 = simplify(ad3 * J3);
Jb4 = simplify(ad4 * J4);
Jb5 = ad5 * J5;
Jbody = [Jb1 Jb2 Jb3 Jb4 Jb5]

%part b
 --------------------------------------------------------------------
a = [-pi/3; -pi/6; pi/4; -pi/2; 0];
adot = [pi/10; -pi/20; pi/20; 0; -pi/16];

%forward kinematics
g1 = SE3([0;0;l0], SE3.RotZ(a(1)));
g2 = SE3([0;0;0],SE3.RotX(a(2)));
g3 = SE3([0;0;l1], SE3.RotX(a(3)));
g4 = SE3([0;0;l2],SE3.RotX(a(4)));
g5 = SE3([0;0;0],SE3.RotZ(a(5)));
g6 = SE3([0;0;l3],eye(3));
ge = g1*g2*g3*g4*g5*g6;

%inverted adjoints
g23456 = g2*g3*g4*g5*g6;
R1 = getRotationMatrix(g23456);
T1 = getTranslation(g23456);
ad1 = [transpose(R1) -transpose(R1)*SE3.hat(T1); zeros(3)
 transpose(R1)];
g3456 = g3*g4*g5*g6;
R2 = getRotationMatrix(g3456);
T2 = getTranslation(g3456);
ad2 = [transpose(R2) -transpose(R2)*SE3.hat(T2); zeros(3)
 transpose(R2)];
g456 = g4*g5*g6;
R3 = getRotationMatrix(g456);
T3 = getTranslation(g456);
ad3 = [transpose(R3) -transpose(R3)*SE3.hat(T3); zeros(3)
 transpose(R3)];
g56 = g5*g6;
R4 = getRotationMatrix(g56);
T4 = getTranslation(g56);
ad4 = [transpose(R4) -transpose(R4)*SE3.hat(T4); zeros(3)
 transpose(R4)];
R5 = getRotationMatrix(g6);
T5 = getTranslation(g6);
ad5 = [transpose(R5) -transpose(R5)*SE3.hat(T5); zeros(3)
 transpose(R5)];

%body jacobian
Jb1 = ad1 * J1;
Jb2 = ad2 * J2;
Jb3 = ad3 * J3;
Jb4 = ad4 * J4;
Jb5 = ad5 * J5;
Jbody = [Jb1 Jb2 Jb3 Jb4 Jb5];
```

```
%body velocity
vbody = Jbody*adot

%part c
 ---------------------------------------------------------------
Rc = getRotationMatrix(ge);
Tc = getTranslation(ge);
adj = [Rc SE3.hat(Tc)*Rc; zeros(3) Rc];

vspatial = adj*vbody
```

J1 =

        0
        0
        0
        0
        0
        1

J2 =

        0
        0
        0
        1
        0
        0

J3 =

        0
        0
        0
        1
        0
        0

J4 =

        0
        0
        0
        1
        0
        0

J5 =

```
        0
        0
        0
        0
        0
        1


Jbody =

[  cos(a5)*((189*sin(a2 + a3))/40 + (189*sin(a2))/40 + (128*sin(a2
 + a3 + a4))/25), -(sin(a5)*(945*cos(a3 + a4) + 945*cos(a4) +
 1024))/200, -(sin(a5)*(945*cos(a4) + 1024))/200, -(128*sin(a5))/25,
 0]
[ -sin(a5)*((189*sin(a2 + a3))/40 + (189*sin(a2))/40 + (128*sin(a2
 + a3 + a4))/25), -(cos(a5)*(945*cos(a3 + a4) + 945*cos(a4) +
 1024))/200, -(cos(a5)*(945*cos(a4) + 1024))/200, -(128*cos(a5))/25,
 0]
[
          0,                (189*sin(a3 + a4))/40 + (189*sin(a4))/40,
                  (189*sin(a4))/40,                    0, 0]
[
  sin(a5)*sin(a2 + a3 + a4),
      cos(a5),                                cos(a5),          cos(a5),
 0]
[
  cos(a5)*sin(a2 + a3 + a4),
     -sin(a5),                               -sin(a5),         -sin(a5),
 0]
[
  cos(a2 + a3 + a4),
     0,                                      0,                 0, 1]


vbody =

   -1.9117
    0.5248
    0.5248
         0
   -0.3035
   -0.1150


vspatial =

    1.7610
   -1.7647
   -0.3711
   -0.1642
   -0.0948
    0.2633
```

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