Title

Table of Contents

ME537 - Adv Robotics Lab1 Evan Justin Taylor Jae Lee Mark Peterson

Part 1

```
% dh = [THETA D A ALPHA SIGMA OFFSET] where OFFSET is a constant
% displacement between the user joint angle vector and the true
 kinematic solution.
% SIGMA=0 for a revolute and 1 for
% a prismatic joint, OFFSET is zero
clear;
clc;
close all;

baxter(1) = Link([0, 0.27035,   0.069, -pi/2, 0, 0]);
baxter(2) = Link([0, 0,         0, pi/2,    0, pi/2    ]);
baxter(3) = Link([0, 0.36435,   0.069, -pi/2,  0, 0 ]);
baxter(4) = Link([0, 0,         0, pi/2,  0, 0]);
baxter(5) = Link([0, 0.37429,   0.01, -pi/2, 0, 0]);
baxter(6) = Link([0, 0,         0, pi/2, 0, 0]);
baxter(7) = Link([0, 0.22952,   0, 0,     0, 0]);

leftArm = SerialLink(baxter, 'name', 'Baxter Left');
leftArm.base = transl(0.064614, 0.25858, 0.130)*rpy2tr(0, 0, pi/4);

q = zeros(4,7);
leftArm.plot(q(1,:));
view(45,30);
q(1,:) = [ 0.03298059 -0.29260684  0.20977187  0.15416507  0.31791752
 -0.21935925  0.17487381];
q(2,:) = [-0.91501954 -0.68760689  0.18829614  1.62640313 -1.24290793
 1.17502928  0.15071361];
q(3,:) = [ 0.57179134 -0.97100984  0.57102435 -0.05062137  1.69734974
 -1.57386429  0.50161172];
q(4,:) = [ 0.52423793 -1.4216167   0.66996611  0.03950001 -2.58207316
 0.54417968 -2.85397126];

pose_estimated = zeros(4,4,4);
pose_actual = zeros(4,4,4);
error = zeros(4,1);
string1 = 'data/Data';
string2 = '.mat';
for i = 1:4
    str = ['pose',num2str(i)];
```

```
    pose_estimated(:,:,i) = leftArm.fkine(q(i,:));
    pose_temp = load([string1,num2str(i),string2]);
    pose_actual(:,:,i) = [pose_temp.R, pose_temp.position'; 0 0 0 1];
    error(i) = sum(sum(abs(pose_actual(:,:,i)-
pose_estimated(:,:,i))))');
end

pose_estimated
pose_actual
% Error is the sum of every element error in the transformation
 matricies between
% pose estimaged and pose actual.
error

% Discussion
% Each of the seven rotary joints inacurately measure the joint angle.
% The robot may command a specific angle, but the actual joint angle
 may not
% be exactly on the commanded angle because of encoder resolution.
```

pose_estimated(:,:,1) =

-0.2634	-0.6627	0.7010	0.7553
0.6537	0.4118	0.6349	1.0161
-0.7095	0.6255	0.3247	0.5596
0	0	0	1.0000

pose_estimated(:,:,2) =

-0.7613	-0.6482	-0.0151	0.6746
-0.3850	0.4707	-0.7939	0.0706
0.5217	-0.5985	-0.6079	0.1395
0	0	0	1.0000

pose_estimated(:,:,3) =

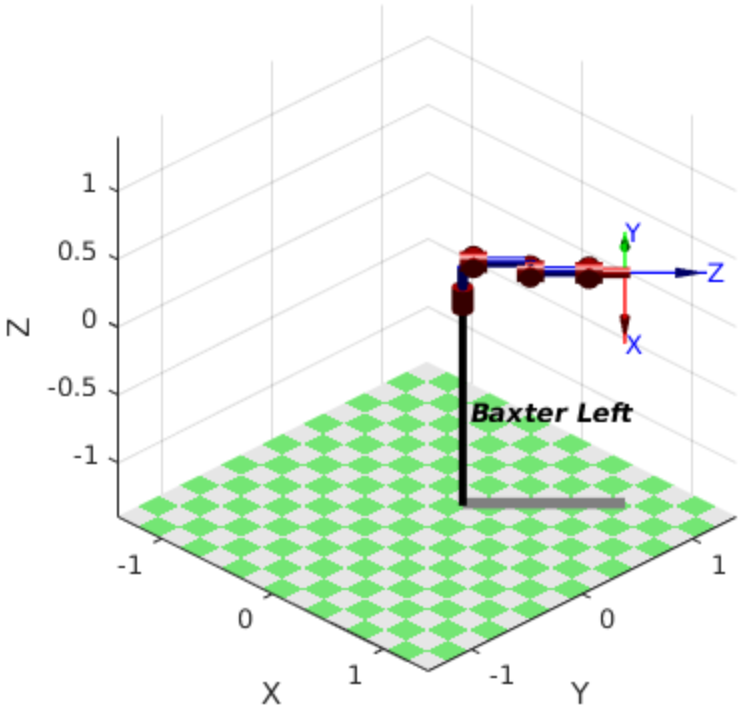
0.3583	0.3591	0.8618	0.3377
0.0732	-0.9310	0.3576	0.8514
0.9307	-0.0650	-0.3598	0.9069
0	0	0	1.0000

pose_estimated(:,:,4) =

-0.8262	-0.3431	0.4469	0.1881
0.3167	-0.9388	-0.1353	0.4708
0.4660	0.0298	0.8843	1.3245
0	0	0	1.0000

pose_actual(:,:,1) =

```
   -0.2659   -0.6629    0.6999    0.7533
    0.6520    0.4111    0.6371    1.0184
   -0.7101    0.6257    0.3229    0.5461
         0         0         0    1.0000


pose_actual(:,:,2) =

   -0.7597   -0.6501   -0.0140    0.6743
   -0.3861    0.4682   -0.7948    0.0720
    0.5233   -0.5984   -0.6068    0.1274
         0         0         0    1.0000


pose_actual(:,:,3) =

    0.3593    0.3613    0.8604    0.3365
    0.0755   -0.9302    0.3591    0.8531
    0.9302   -0.0641   -0.3615    0.8941
         0         0         0    1.0000


pose_actual(:,:,4) =

   -0.8268   -0.3402    0.4480    0.1881
    0.3152   -0.9398   -0.1319    0.4729
    0.4659    0.0322    0.8842    1.3126
         0         0         0    1.0000


error =

    0.0289
    0.0257
    0.0279
    0.0269
```



Part 2

z1 = [0.878 0.877 0.88 0.878 0.879 0.879 0.88 0.883 0.882 0.875]; z2 = [0.53 0.529 0.527 0.527 0.528];

```
z1 = [87.8 87.7 88 87.8 87.9 87.9 88 88.3 88.2 87.5];
z2 = [53 52.9 52.7 52.7 52.8];

variance_1 = var(z1)
variance_2 = var(z2)

q_actual = [-.9, -.2, 0, 1, -1.7, 0.3, -3];
pose_estimated2 = leftArm.fkine(q_actual);

string1 = 'data/part2b_data_';
string2 = '.mat';
pose_actual2 = zeros(4,4,10);
error2 = zeros(10,1);
for i = 1:10
    str = ['pose',num2str(i)];
    pose_temp = load([string1,num2str(i-1),string2]);
    pose_actual2(:,:,i) = [pose_temp.R, pose_temp.position'; 0 0 0 1];
    error2(i) = sum(sum(abs(pose_actual2(:,:,i)-pose_estimated2))');
end
error2

q_actual =[0.4, 0.85, -0.36, -0.27, 0.92, 0.19, 0.22];
```

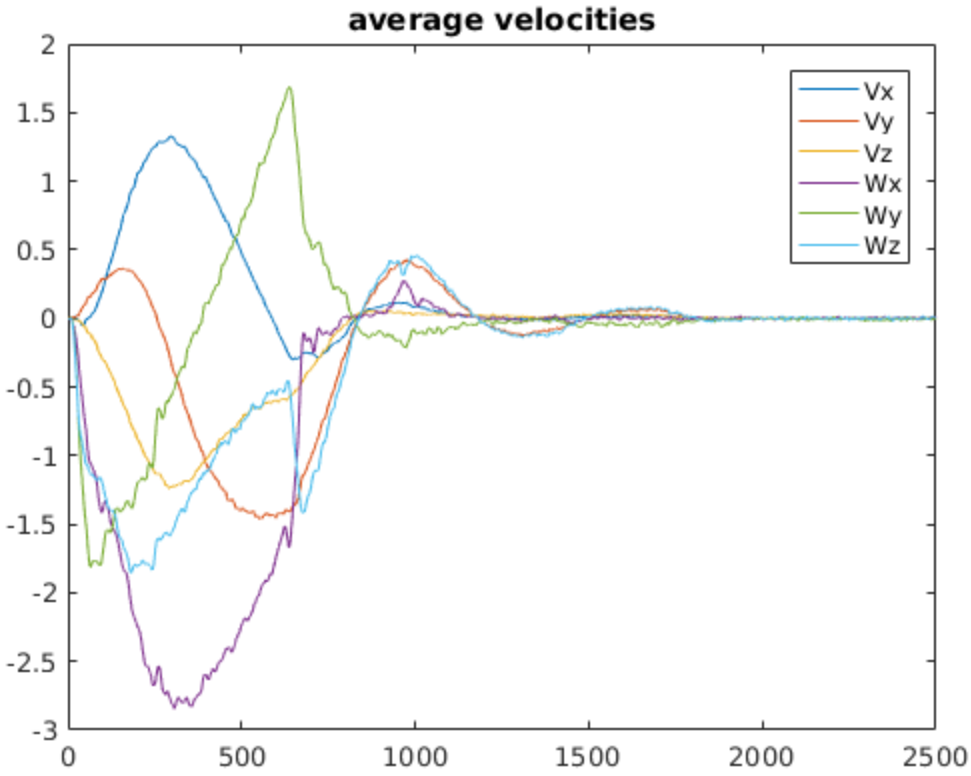
```
pose_estimated3 = leftArm.fkine(q_actual);

string1 = 'data/part2b_data_';
string2 = '_second.mat';
pose_actual3 = zeros(4,4,5);
error3 = zeros(5,1);
for i = 1:5
    str = ['pose',num2str(i)];
    pose_temp = load([string1,num2str(i-1),string2]);
    pose_actual3(:,:,i) = [pose_temp.R, pose_temp.position'; 0 0 0 1];
    error3(i) = sum(sum(abs(pose_actual3(:,:,i)-pose_estimated3))');
end
error3

% Discussion
% For the first 10 times, the commanded joint angle and the recorded
 joint
% angles are really close within 10^-3 range. However, the second 5
 times
% showed somewhat greater error. One potential reason for the greater
 error
% on the second trial is the our observation of a significant
 difference
% between commanded and measured joint angles for the initial pose of
 the
% robot.  The inability of the robot to initially achieve the
 commanded
% joint angles created greater error.

% We expected the repeatability of the first test of 10 in the case
 there
% was some accumulation of error over the repeated robot movement.
% However, we observed greater error in the test of 5.  A possible
% explanation for the greater error in the second test is the effect
 of
% different poses on repeatability.  Depending on the arm's
 orientation,
% gravity, flexibility, and other characteristics could affect the
 final
% position of the end effector.


variance_1 =

    0.0543


variance_2 =

    0.0170


error2 =
```

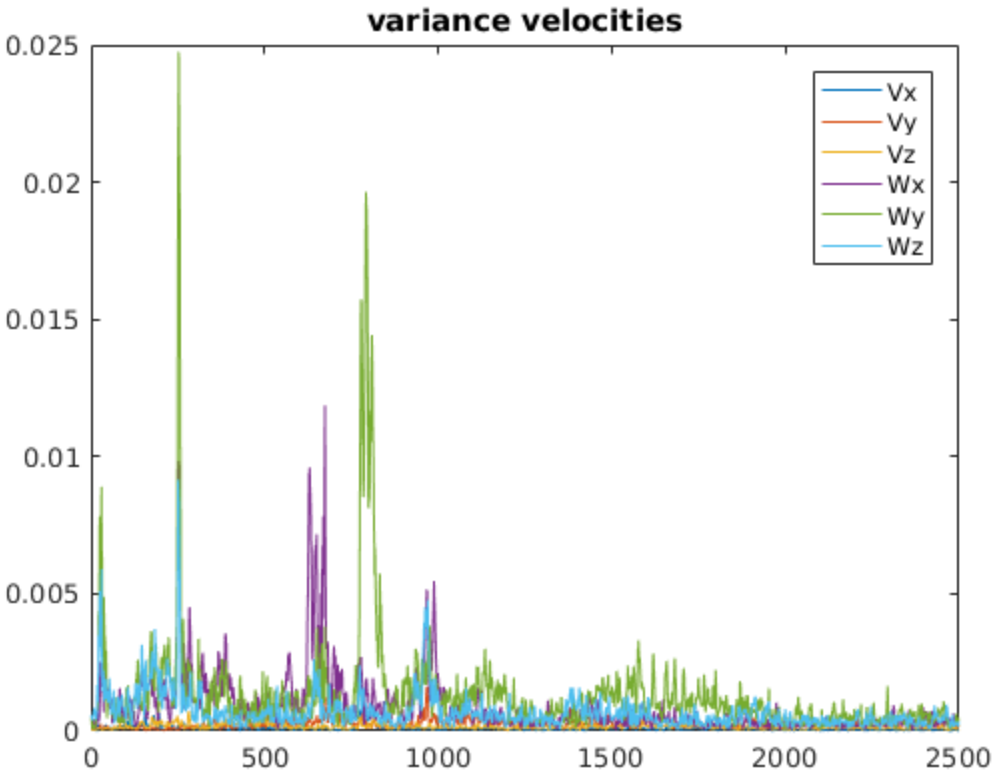
```
    0.0482
    0.0458
    0.0441
    0.0489
    0.0484
    0.0458
    0.0485
    0.0403
    0.0472
    0.0564


error3 =

    0.7282
    0.7355
    0.7285
    0.7225
    0.7344
```

Part 3

```
string1 = 'data/part3_trial0';
string2 = '.mat';
a = load('data/part3_trial00.mat');
v = zeros(6,length(a.q),10);
q = zeros(7,length(a.q),10);
q_dot = zeros(7,length(a.q),10);

for i = 1:10

    a = load([string1,num2str(i-1),string2]);
    for j = 1:length(a.q)
        q(:,j,i) = a.q(j,:);
        q_dot(:,j,i) = a.q_dot(j,:)';
        J = leftArm.jacob0(q(:,j,i));
        v(:,j,i) = J*q_dot(:,j,i);
    end

end

figure(2), clf;
avg = sum(v,3)'/10;
plot(avg);
title('average velocities');
legend('Vx','Vy','Vz','Wx','Wy','Wz');

var3 = zeros(6,2499);
for i = 1:6
    for j=1:2499
        var3(i,j) = var(v(i,j,:));
    end
```

```
end
figure(3)
plot(1:2499, var3);
title('variance velocities');
legend('Vx','Vy','Vz','Wx','Wy','Wz');

% Discussion
% The variation in the velocity and angular velocities in the base
 frame at
% each time step is difficult to maintain exactly due to the
 gravitational
% compensation of each joint.  The robot arm can hang out more than a
% meter, in addition to moving the robot to correct location, at a
 certain
% velocity, it is necessary to support the arm as it moves.  The
 change in
% torque of one joint of necesity requires a change of torque in all
 of the
% other joints.  The controller certainly is affected by various
% measurments and to perfectly reinact a motion is all but impossible
 due
% to the various inputs and disturbances.
```





Published with MATLAB® R2016a