

ME 449 Assignment 2

Part 1

Log of Output for 'good' guess (short iterations)

```
redhaidredyn@tokyo:~/Documents/academics/ME449/code
g-24.1 pillow-11.0.0 pyrsnmp-3.2.0 python-dateutil-2.9.0.post0 six-1.16.0
(code) redhaidredyn@tokyo:~/Documents/academics/ME449/code$ 1
asst1.py include/ long_itr.csv quiz3_3_to_3_4.py quiz_5.py share/
asst2.py lib/ output.csv quiz3_to_3_2.py quiz_6.py short_itr.csv
bin/ lib448 pyenv/cfg quiz2_4.py quiz_8_1.py
(code) redhaidredyn@tokyo:~/Documents/academics/ME449/code$ python3 asst2.py

Iteration 0
joint_vector:
[ 0.735 -1.323 2.442 0.722 -1.591 1.396]

SE(3) end-effector config:
[[ 0.99961696 0.00437112 0.02732804 0.2475526 ]
 [ 0.0034853 0.99946961 -0.03237816 0.38047945]
 [-0.02745507 0.03227051 0.99910201 0.4503143]
 [ 0. 0. 0. 1. ]]

error twist V_b: [-0.0232341 -0.02739983 0.00392939 0.05313503 -0.0010575 -0.04959817]
angular error ||omega_b||: 0.0425638070614101
linear_error ||v_b||: 0.072696052726433

Iteration 1
joint_vector:
[ 0.60714999 -1.33095193 1.67929845 1.22642457 -1.61299174 0.95980022]

SE(3) end-effector config:
[[ 0.99999519 -0.00000031 0.00310102 0.29765204]
 [ 0.00000047 0.99999762 0.00210347 0.29585926]
 [-0.00310101 -0.00218348 0.99999281 0.39731723]
 [ 0. 0. 0. 1. ]]

error twist V_b: [ 0.00218348 -0.00310102 0.00000308 0.00234379 0.00413781 0.00269093]
angular error ||omega_b||: 0.003792615899743626
linear_error ||v_b||: 0.005464061552853852

Iteration 2
joint_vector:
[ 0.51957016 -1.21527329 1.67082461 1.11902891 -1.57044068 1.05122242]

SE(3) end-effector config:
[[ 1. -0.00000071 0.00001336 0.29959599]
 [ 0.00000071 1. -0.00001874 0.30000082]
 [-0.00001336 0.00001874 1. 0.39999164]
 [ 0. 0. 0. 1. ]]

error twist V_b: [-0.00001874 -0.00001336 -0.00000071 0.00004001 -0.00000842 0.00000036]
angular error ||omega_b||: 2.30251728752383e-05
linear_error ||v_b||: 4.173545818132742e-05
Joint Angle Matrix: [[ 0.735 -1.323 2.442 0.722 -1.591 1.396 ]
 [ 0.60714999 -1.33095193 1.67929845 1.22642457 -1.61299174 0.95980022]
 [ 0.51957016 -1.21527329 1.67082461 1.11902891 -1.57044068 1.05122242]]
(code) redhaidredyn@tokyo:~/Documents/academics/ME449/code$
```

Log of output for 'bad' guess (long iterations)

```
redhaidredyn@tokyo:~/Documents/academics/ME449/code
[[ 0.99994669 0.00244714 -0.01003165 0.28097516]
 [-0.00217384 0.99962862 0.02716436 0.29688957]
 [ 0.0100944 -0.0271411 0.99958064 0.39449226]
 [ 0. 0. 0. 1. ]]

error twist V_b: [0.02715655 0.01006444 0.00231082 0.0190449 0.00305788 0.00545398]
angular error ||omega_b||: 0.02905358752395643
linear_error ||v_b||: 0.0204586336271691

Iteration 14
joint_vector:
[ 0.53707361 0.37490444 -2.19731778 0.25699781 1.54232017 -2.11025611]

SE(3) end-effector config:
[[ 0.99999993 -0.00000068 -0.00035838 0.30010849]
 [ 0.00000064 0.99999959 -0.00012779 0.29989153]
 [ 0.00035839 -0.00012776 0.99999993 0.39964450]
 [ 0. 0. 0. 1. ]]

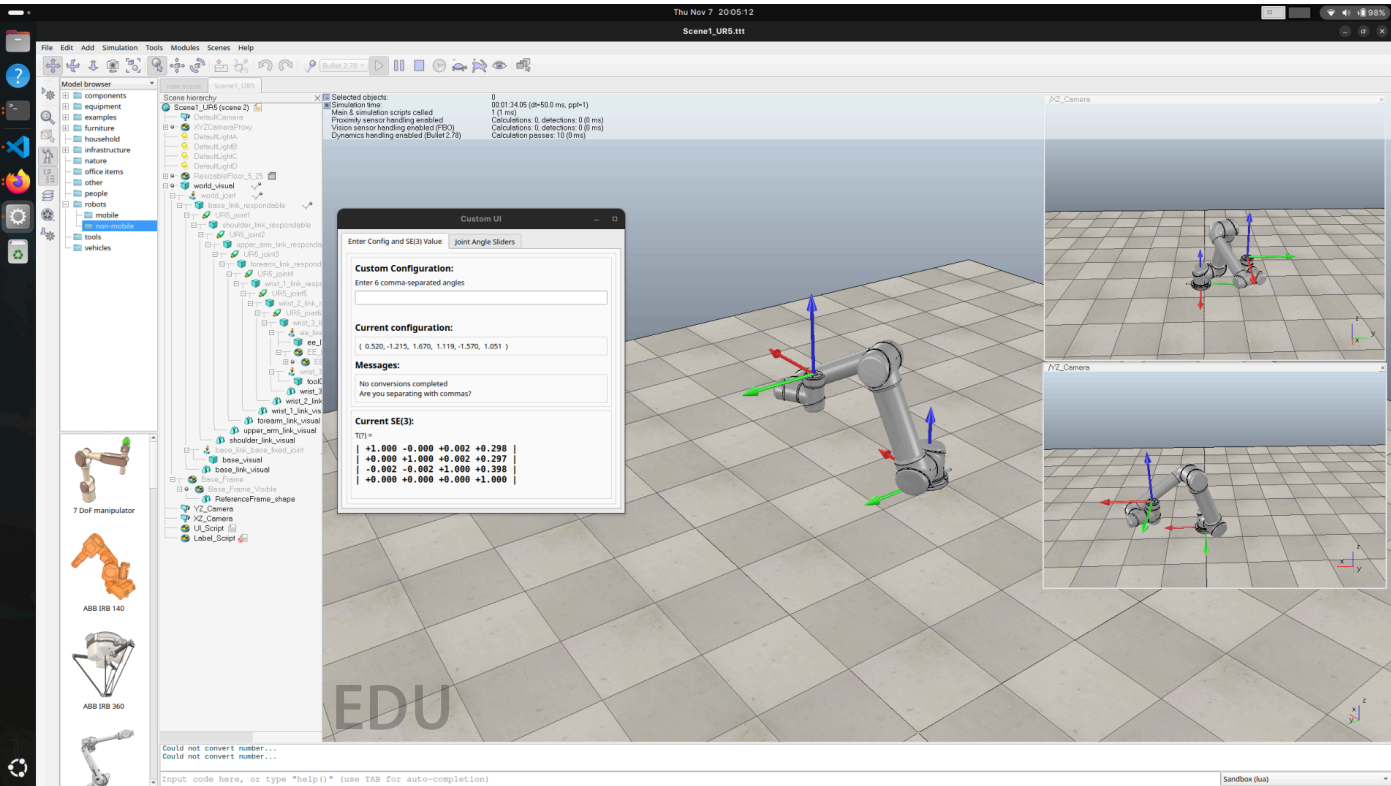
error twist V_b: [-0.00012778 0.00035839 -0.00000066 -0.00010842 0.0001085 0.00035543]
angular error ||omega_b||: 0.00038894039536588575
linear_error ||v_b||: 0.0003911682138257426

Iteration 15
joint_vector:
[ 0.52519359 0.37331577 -2.15139678 0.26691053 1.57072721 -2.09590924]

SE(3) end-effector config:
[[ 1. 0.00000001 -0.00000005 0.29999971]
 [-0.00000001 1. -0.00000015 0.29999964]
 [ 0.00000005 -0.00000015 1. 0.40000002]
 [ 0. 0. 0. 1. ]]

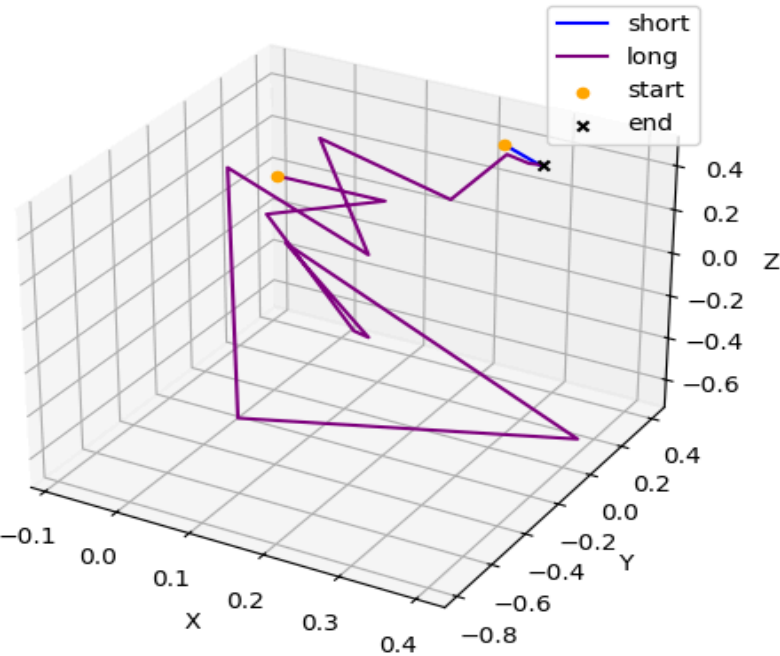
error twist V_b: [ 0.00000005 0.00000005 0.00000001 0.00000029 0.00000016 -0.00000002]
angular error ||omega_b||: 1.58699734744823e-07
linear_error ||v_b||: 3.32485262123815e-07
Joint Angle Matrix: [[ 0.7359816 0. -3.14159265 -0.76539816 1.57079633 0.05 ]
 [-2.32872429 0.15425889 -2.5261075 -0.59534155 1.24665608 3.0900056]
 [-0.01471638 -2.48993154 2.76098293 -2.50102744 -2.48942883 1.8498172 ]
 [ 0.81696478 1.09680219 -2.89482479 0.03063959 -2.91957536 0.98853145]
 [-0.46860502 2.18238791 1.52390326 -1.42515626 0.4472521 -0.09168914]
 [-1.49632993 0.27089048 2.85980107 -1.76378091 -1.24187805 2.25621847]
 [ 2.79127875 -0.48928168 3.10927104 -0.39707253 1.68416968 0.44592802]
 [ 0.11304218 1.58146071 -0.81156947 -1.92621935 -2.64286017 2.76428902]
 [-1.53328026 0.20113375 0.62065395 -2.7706555 1.4624981 -2.31663753]
 [ 0.24342362 -1.70358146 -2.72837947 2.98697259 1.5964592 -1.8038144 ]
 [-1.30670955 -0.34427483 2.98481501 2.11115654 1.37697889 -0.27743546]
 [ 0.59151088 -0.48708937 -2.47086642 1.76580915 1.44810315 -2.13924052]
 [ 0.15868142 0.68975042 -2.76191902 0.61170036 1.40932027 -1.77178485]
 [ 0.81242296 0.52834371 -2.15558247 0.15099726 1.8594228 -2.38860011]
 [ 0.53707361 0.37490444 -2.19731778 0.25699781 1.54232017 -2.11025611]
 [ 0.52519359 0.37331577 -2.15139678 0.26691053 1.57072721 -2.09590924]]
(code) redhaidredyn@tokyo:~/Documents/academics/ME449/code$
```

Final configuration and joint angles of the UR5 Robot after the short iterations

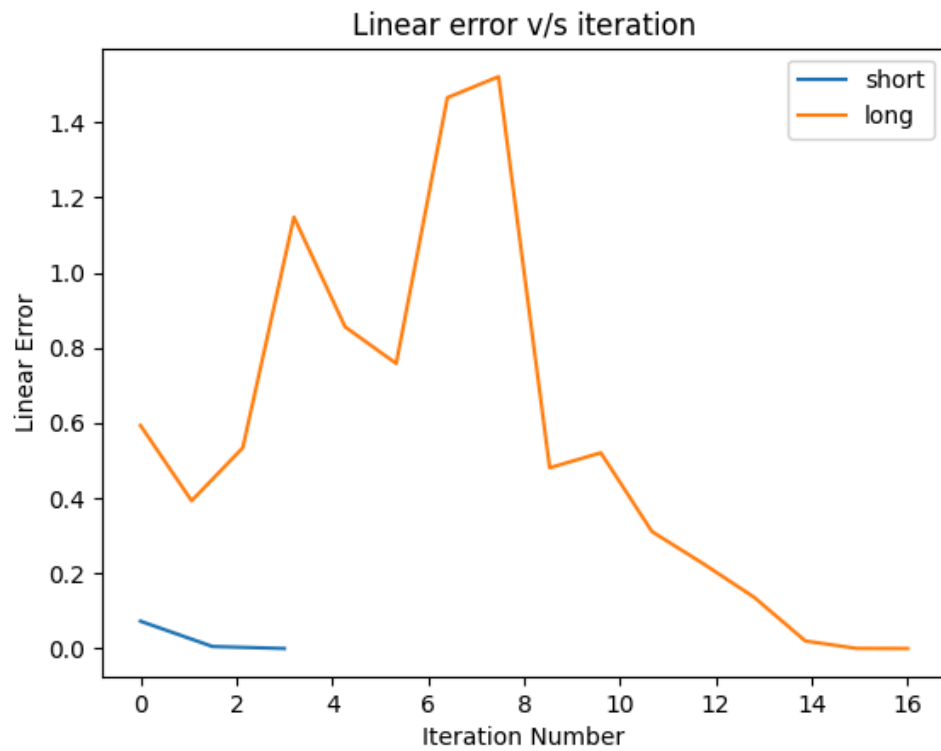


End effector pose variation over each iteration

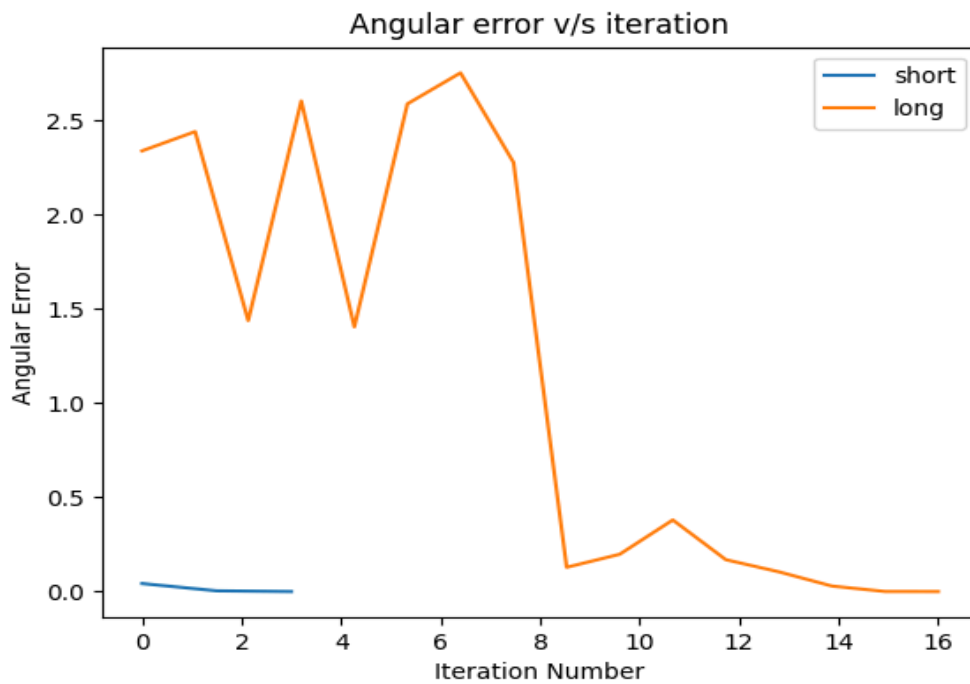
ee poses from start to end



Linear error variation with each iteration



Angular error variation over each iteration



Why is convergence difficult from the long_iterates initial guess?

Ans: The Newton Raphson iterative method involves using the first order terms of the Taylor Expansion to compute the next configuration from the current configuration. During this process, if the initial guess is too far off from the desired configuration, i.e. it does not lie in the **basin of attraction** of the solution, the consequent iteration values also do not lie in the basin of the solution and so the process does not converge. Therefore, in our case convergence from the long_iterates initial guess is difficult.

Part 2

(a) The constant joint speed at which we command the joints is given by:

$$\dot{\theta} = (\theta^* - \theta^0)/t_f$$

(b) The commanded joint speed vector at time 0 and at time $t_f/2$ is given by:

$$\dot{\theta}(0) = J_b(\theta(0))^{-1}vec([V])$$

$$\dot{\theta}(t_f/2) = J_b(\theta(t_f/2))^{-1}vec([V])$$

(c) The advantage of (a) over (b) is that the joint speeds are constant and the body Jacobian is not needed to be computed at each instant making it simpler and more straightforward.