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ME449 Assignment 2

1. Run run.py to execute the code.
2. See full code output in Appendix 1

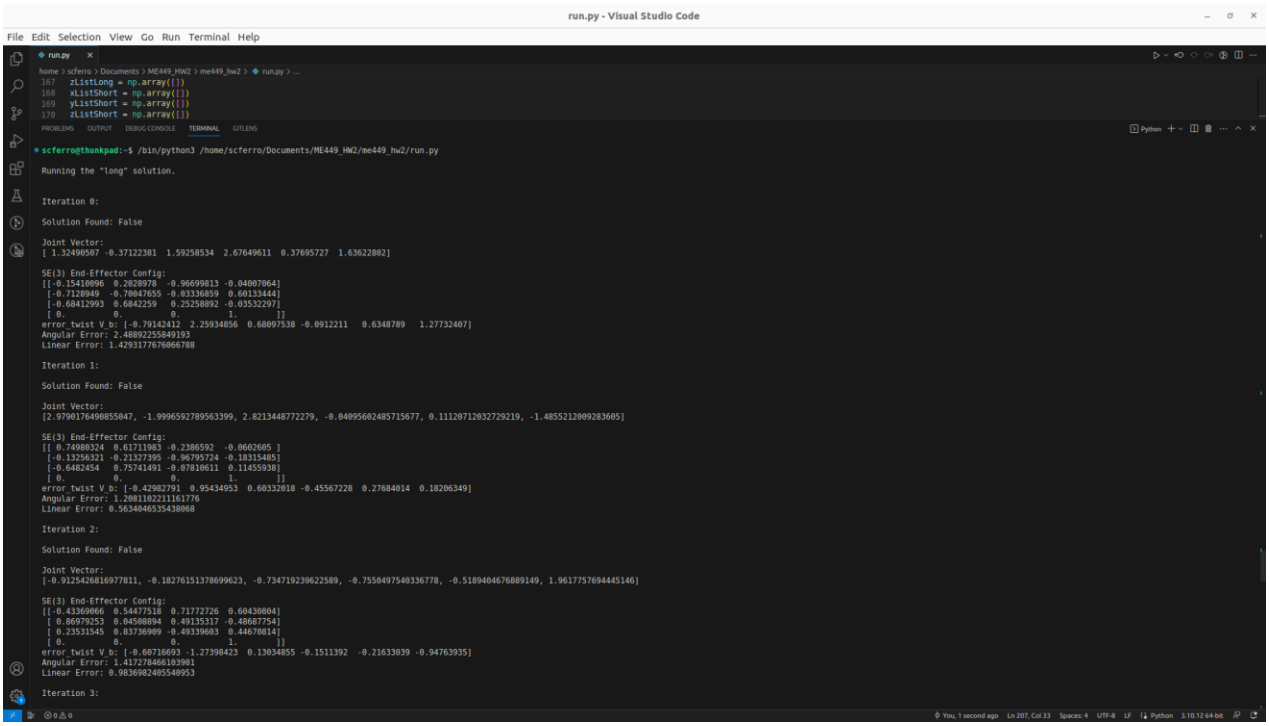


Fig. 1: “Long” Run Code Output

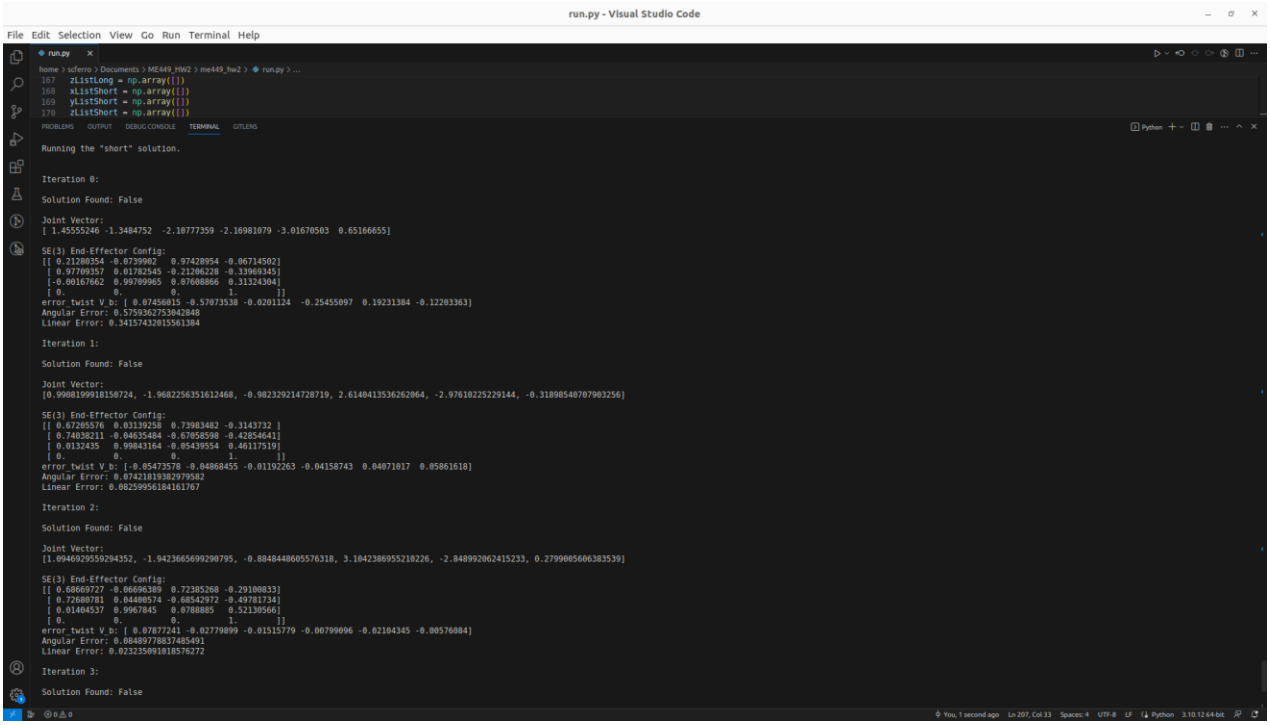


Fig. 2: “Short” Run Code Output

3.

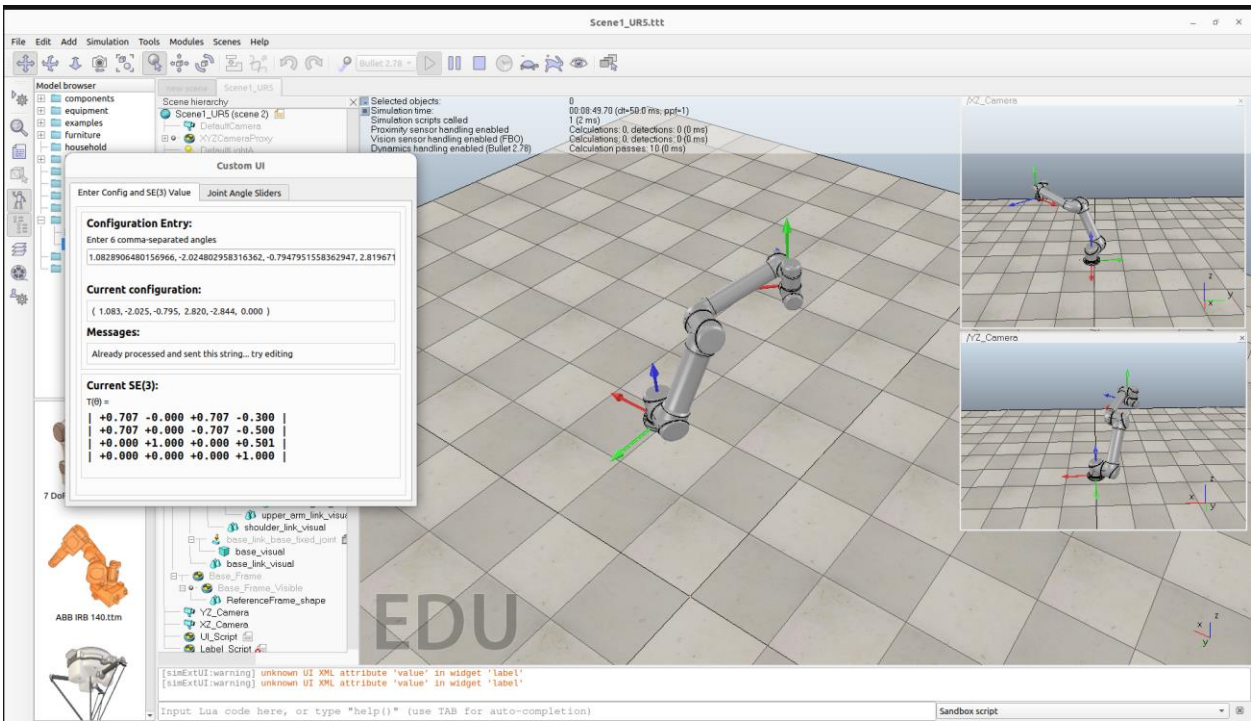
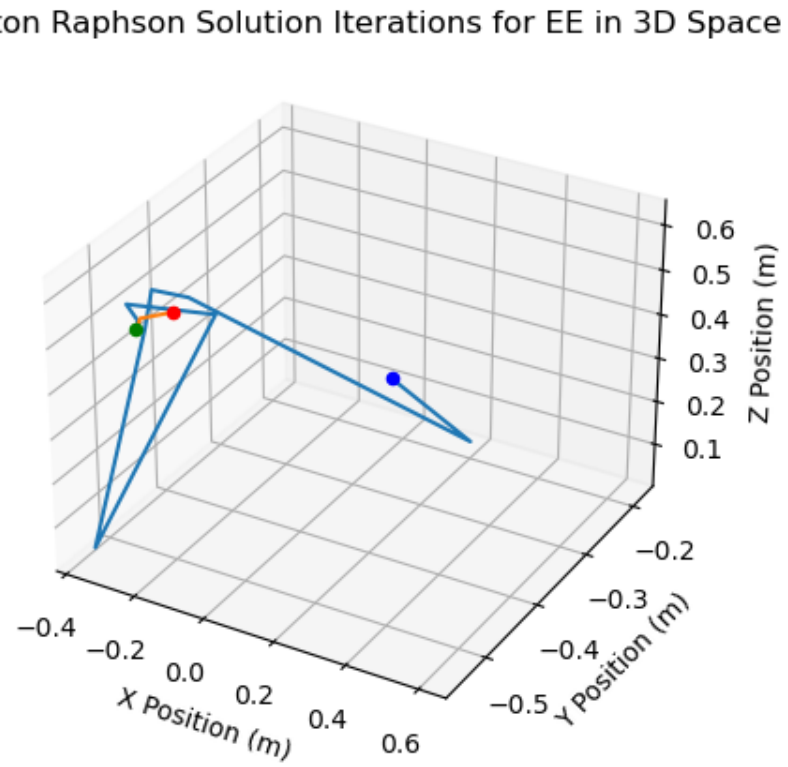


Fig. 3: CoppeliaSim Screenshot



4.

Fig. 4: Output Plot of EE Position

5.

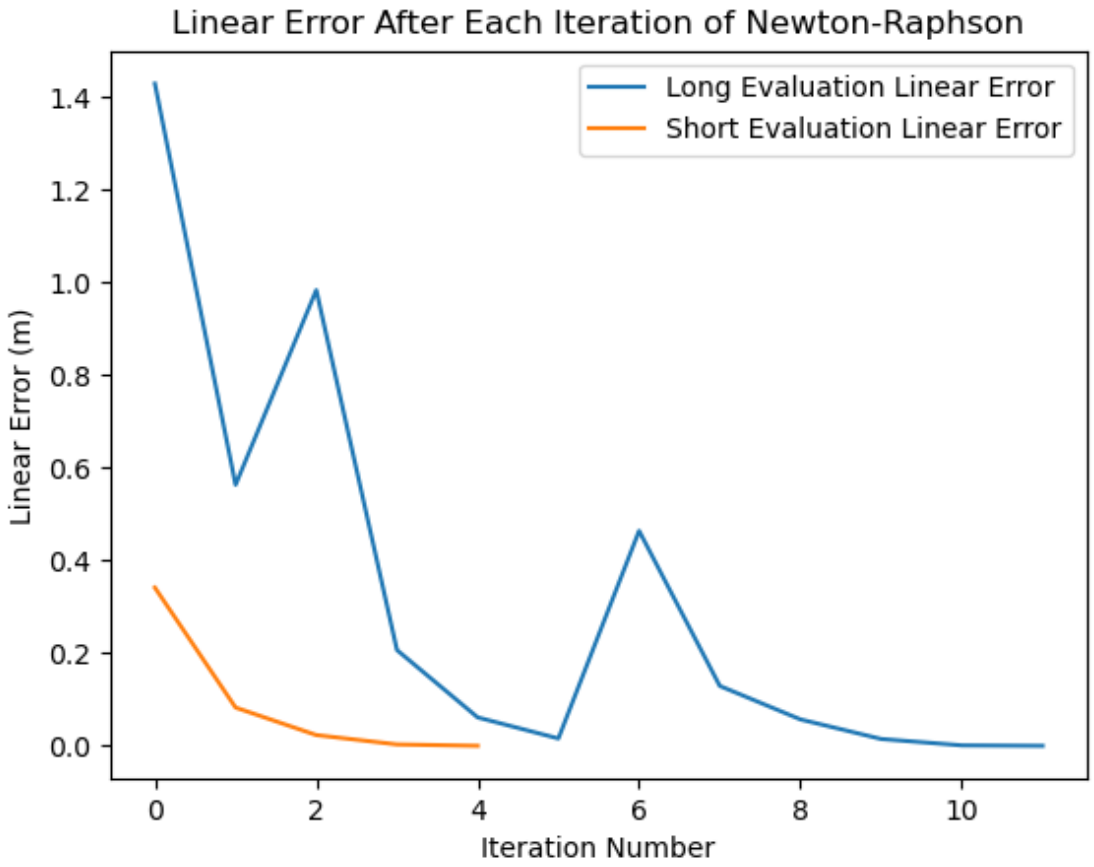


Fig. 5: Output Plot of Linear Error

6.

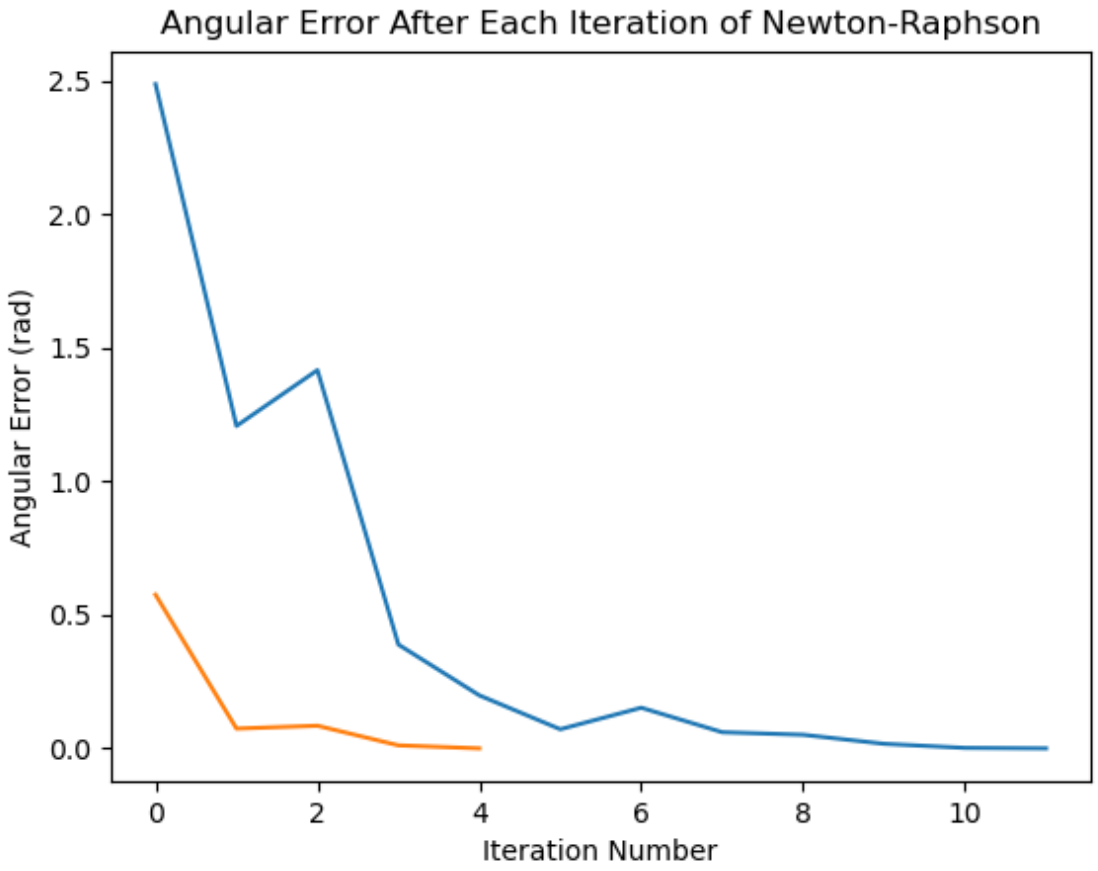


Fig. 6: Output Plot of Angular Error

7. Convergence is difficult from the "Long" guess because the end effector is further from the goal position and orientation. Because the goal is far away, more iterations are needed to get the joints in the correct orientation. As the current guess gets closer to the goal orientation with each iteration, the change in each joint angle in the next iteration decreases. This means that an initial guess that is closer to the solution may only need a handful of guesses to reach the goal, while a guess that is further away may make a few larger jumps and then several smaller ones to get to the correct configuration. This is exactly what can be seen in the attached CoppeliaSim videos, which show the "Long" iteration case starting further from the goal and taking longer to reach the correct location.

Appendix 1: Full Code Output

```
scferro@thunkpad:~$ /bin/python3 /home/scferro/Documents/ME449_HW2/me449_hw2/run.py

Running the "long" solution.


Iteration 0:

Solution Found: False

Joint Vector:
[ 1.32490507 -0.37122381  1.59258534  2.67649611  0.37695727  1.63622802]

SE(3) End-Effector Config:
[[-0.15410096  0.2028978  -0.96699813 -0.04007064]
[-0.7128949  -0.70047655 -0.03336859  0.60133444]
[-0.68412993  0.6842259   0.25258892 -0.03532297]
[ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.79142412  2.25934856  0.68097538 -0.0912211   0.6348789   1.27732407]
Angular Error: 2.48892255849193
Linear Error: 1.4293177676066788

Iteration 1:

Solution Found: False

Joint Vector:
[2.9790176490855047, -1.9996592789563399, 2.8213448772279, -0.04095602485715677,
0.11120712032729219, -1.4855212009283605]

SE(3) End-Effector Config:
[[ 0.74980324  0.61711983 -0.2386592  -0.0602605 ]
[-0.13256321 -0.21327395 -0.96795724 -0.18315485]
[-0.6482454   0.75741491 -0.07810611  0.11455938]
[ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.42982791  0.95434953  0.60332018 -0.45567228  0.27684014  0.18206349]
Angular Error: 1.2081102211161776
Linear Error: 0.5634046535438068

Iteration 2:

Solution Found: False

Joint Vector:
[-0.9125426816977811, -0.18276151378699623, -0.734719239622589, -0.7550497540336778, -
0.5189404676889149, 1.9617757694445146]

SE(3) End-Effector Config:
[[-0.43369066  0.54477518  0.71772726  0.60430804]
[ 0.86979253  0.04508894  0.49135317 -0.48687754]
[ 0.23531545  0.83736909 -0.49339603  0.44670814]
[ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.60716693 -1.27398423  0.13034855 -0.1511392  -0.21633039 -0.94763935]
Angular Error: 1.417278466103901
Linear Error: 0.9836982405540953

Iteration 3:

Solution Found: False
```

```
Joint Vector:
[-2.1829931680497063, -0.21030171179093637, -1.39055032832288, -0.7002505041884282, -
0.31407514299726147, 2.0111065684595246]

SE(3) End-Effector Config:
[[ 0.65043995  0.37607583  0.65992033 -0.12943548]
 [ 0.69716372  0.04925526 -0.71521791 -0.50971658]
 [-0.30148071  0.92527882 -0.23014884  0.61404591]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.23654446  0.00310912  0.30884916 -0.09463174 -0.14524812 -0.11253161]
Angular Error: 0.38903823802032034
Linear Error: 0.20667739214606626

Iteration 4:

Solution Found: False

Joint Vector:
[-2.5317594337043605, -0.05519122445585267, -1.4786174648949215, -0.28466064326351054,
0.1338939524799989, 1.7806635723008837]

SE(3) End-Effector Config:
[[ 0.80285495 -0.04555425  0.59443145 -0.32407168]
 [ 0.59485748  0.12744824 -0.79366336 -0.45852375]
 [-0.0396045   0.99079855  0.12942074  0.53807787]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [ 0.12670764  0.14492786  0.04907822 -0.00802404 -0.04124902  0.04465662]
Angular Error: 0.19866449319416615
Linear Error: 0.06131949252261684

Iteration 5:

Solution Found: False

Joint Vector:
[-2.4397739208333107, 0.12764929195618596, -1.5614434071681385, -0.9821879344664817,
0.017609168280137255, 2.4100016912971793]

SE(3) End-Effector Config:
[[ 0.75513061 -0.00308664  0.65556711 -0.28681831]
 [ 0.6555464   0.01279417 -0.75504651 -0.49256845]
 [-0.00605688  0.99991339  0.01168471  0.49525028]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [ 0.01146686  0.07043943  0.00646609 -0.01472795  0.0047247  -0.00352355]
Angular Error: 0.0716590056116241
Linear Error: 0.01586350691069262

Iteration 6:

Solution Found: False

Joint Vector:
[-2.4459453893471608, 0.5285564433673053, -1.2350584606152646, 1.184119110135228,
0.06698038573220462, -0.47758476357159907]

SE(3) End-Effector Config:
[[ 8.04376304e-01  1.89883634e-02  5.93816641e-01 -3.58541973e-01]
 [ 5.94119501e-01 -2.42226365e-02 -8.04011992e-01 -5.47912963e-01]
 [-8.83067178e-04  9.99526241e-01 -3.07654718e-02  4.22637173e-02]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [-0.03077905  0.14922814 -0.00141452  0.07584453  0.45773353 -0.0051675 ]
```

```
Angular Error: 0.15237581525031577
Linear Error: 0.46400331524379784

Iteration 7:

Solution Found: False

Joint Vector:
[-2.425625523315169, -0.13437449215801767, -1.2125775841728932, 2.301723252110412, -
0.061651486387227436, -0.9544582666077366]

SE(3) End-Effector Config:
[[ 7.30604154e-01 -3.39102652e-02  6.81958697e-01 -1.97443340e-01]
 [ 6.82801017e-01  3.71377192e-02 -7.29659894e-01 -4.24722494e-01]
 [-5.83430046e-04  9.98734641e-01  5.02869355e-02  4.77390516e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [ 0.05029343  0.03378634  0.00143366 -0.12607474  0.02298175 -0.01659118]
Angular Error: 0.06060528962044638
Linear Error: 0.12922178118791627

Iteration 8:

Solution Found: False

Joint Vector:
[-2.4565872318352193, -0.48081629669666337, -0.6756574494053273, 0.7825488327775081, -
0.058031778859299624, 0.3747041307615002]

SE(3) End-Effector Config:
[[ 0.73913729  0.0132709   0.67342405 -0.3167083 ]
 [ 0.67355345 -0.01656908 -0.73895279 -0.5052017 ]
 [ 0.00135144  0.99977465 -0.02118548  0.5542236 ]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.0211519   0.0463751  -0.00184259  0.01563309 -0.05415111  0.00834929]
Angular Error: 0.051004395555624214
Linear Error: 0.05697759796958888

Iteration 9:

Solution Found: False

Joint Vector:
[-2.4451518803763497, -0.4131021050439636, -0.6731524673055387, 1.2724661672544948, -
0.08280247255807793, -0.1860897905096256]

SE(3) End-Effector Config:
[[ 7.12451576e-01 -1.03876858e-02  7.01644389e-01 -2.97728877e-01]
 [ 7.01721099e-01  1.12611975e-02 -7.12362748e-01 -4.97581155e-01]
 [-5.01555630e-04  9.99882634e-01  1.53123162e-02  5.14391471e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [ 1.53109155e-02  7.58362958e-03  5.59636922e-04 -3.31200830e-03
 -1.43929495e-02  6.84649784e-06]
Angular Error: 0.017095284892116442
Linear Error: 0.014769104325099626

Iteration 10:

Solution Found: False

Joint Vector:
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```
[-2.444199968982057, -0.3555616666508364, -0.8003796843738553, 1.1453875458032463, -
0.08648692780890635, 0.010546519547360717]

SE(3) End-Effector Config:
[[ 7.08183147e-01  6.20850421e-04  7.06028501e-01 -2.99374977e-01]
 [ 7.06028773e-01 -6.68292545e-04 -7.08182833e-01 -4.99607147e-01]
 [ 3.21579742e-05  9.99999584e-01 -9.11611779e-04  5.00628759e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [-9.11585778e-04  1.52334835e-03 -3.28522723e-05 -7.19881667e-04
 -6.28822288e-04 -1.63334287e-04]
Angular Error: 0.0017755726085383688
Linear Error: 0.0009697036528770872

Iteration 11:

Solution Found: True

Joint Vector:
[-2.444362138237006, -0.35594141134571533, -0.7946583637936502, 1.1508044215010045, -
0.0881627377806128, -0.0002047206698903084]

SE(3) End-Effector Config:
[[ 7.07110255e-01 -1.21266053e-05  7.07103308e-01 -2.99999165e-01]
 [ 7.07103308e-01  1.33558480e-05 -7.07110254e-01 -4.99997900e-01]
 [-8.69117361e-07  1.00000000e+00  1.80188198e-05  5.00001912e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [ 1.80187889e-05  4.91207706e-06  8.69160226e-07 -2.07545822e-06
 -1.91190290e-06  8.94959629e-07]
Angular Error: 1.86965422885498e-05
Linear Error: 2.9603804230405444e-06
Running the "short" solution.


Iteration 0:

Solution Found: False

Joint Vector:
[ 1.45555246 -1.3484752  -2.10777359 -2.16981079 -3.01670503  0.65166655]

SE(3) End-Effector Config:
[[ 0.21280354 -0.0739902   0.97428954 -0.06714502]
 [ 0.97709357  0.01782545 -0.21206228 -0.33969345]
 [-0.00167662  0.99709965  0.07608866  0.31324304]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [ 0.07456015 -0.57073538 -0.0201124  -0.25455097  0.19231384 -0.12203363]
Angular Error: 0.5759362753042848
Linear Error: 0.34157432015561384

Iteration 1:

Solution Found: False

Joint Vector:
[0.9908199918150724, -1.9682256351612468, -0.982329214728719, 2.6140413536262064, -
2.97610225229144, -0.31898540707903256]

SE(3) End-Effector Config:
[[ 0.67205576  0.03139258  0.73983482 -0.3143732 ]
 [ 0.74038211 -0.04635484 -0.67058598 -0.42854641]
 [ 0.0132435   0.99843164 -0.05439554  0.46117519]
```

```
[ 0.          0.          0.          1.        ]]
error_twist V_b: [-0.05473578 -0.04868455 -0.01192263 -0.04158743  0.04071017  0.05861618]
Angular Error: 0.07421819382979582
Linear Error: 0.08259956184161767

Iteration 2:

Solution Found: False

Joint Vector:
[1.0946929559294352, -1.9423665699290795, -0.8848448605576318, 3.1042386955210226, -
2.848992062415233, 0.2799005606383539]

SE(3) End-Effector Config:
[[ 0.68669727 -0.06696389  0.72385268 -0.29100833]
 [ 0.72680781  0.04400574 -0.68542972 -0.49781734]
 [ 0.01404537  0.9967845   0.0788885   0.52130566]
 [ 0.          0.          0.          1.        ]]
error_twist V_b: [ 0.07877241 -0.02779899 -0.01515779 -0.00799096 -0.02104345 -0.00576084]
Angular Error: 0.08489778837485491
Linear Error: 0.023235091018576272

Iteration 3:

Solution Found: False

Joint Vector:
[1.0839581933965559, -2.023815616823114, -0.7906420968151749, 2.8121391462313357, -
2.8543620780253733, -0.0018831712765635666]

SE(3) End-Effector Config:
[[ 6.99050035e-01  2.31727533e-04  7.15072720e-01 -2.98286088e-01]
 [ 7.15072676e-01 -7.02584016e-04 -6.99049765e-01 -4.98619040e-01]
 [ 3.40409585e-04  9.99999726e-01 -6.56843409e-04  5.02038366e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [-0.00065876 -0.01133    -0.00033668 -0.00218739 -0.00203808 -0.00024716]
Angular Error: 0.011354128108740077
Linear Error: 0.0029999211986905657

Iteration 4:

Solution Found: True

Joint Vector:
[1.0828906480156966, -2.024802958316362, -0.7947951558362947, 2.819671821846522, -
2.844100881237256, 7.371176917507797e-05]

SE(3) End-Effector Config:
[[ 7.07106277e-01 -1.75695854e-05  7.07107285e-01 -2.99994746e-01]
 [ 7.07107285e-01  1.29850980e-05 -7.07106277e-01 -4.99999936e-01]
 [ 3.24170674e-06  1.00000000e+00  2.16054261e-05  5.00000068e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
error_twist V_b: [ 2.16053904e-05 -7.13057439e-07 -3.24170927e-06 -3.76045714e-06
 -6.80346686e-08 -3.67050481e-06]
Angular Error: 2.185886603760969e-05
Linear Error: 5.25530895673241e-06
```