Homework 2:

In this pdf I have attached the screen logs for my runs, as well as the plots, screenshots, and explanations of convergence.

As far as the attached code, I felt it was easy to just give the whole things, though the function can be easily identified with the commented “#” lines that indicate where to look.

My code was called using the command: /usr/bin/python3 /home/sags/modern_robotics/HW2.py
Which was done by VScode.

Screen Logs:

Log 1 - short iteration:

Iteration number: 1
Joint Vector: [3.83700136 5.18472113 1.38891757 2.44630404 0.06473925 3.54647222]
SE(3) Config:
 [[7.28334809e-01 1.68755688e-02 6.85013592e-01 -2.82091860e-01]
 [6.85220958e-01 -1.91084806e-02 -7.28084545e-01 -4.83938776e-01]
 [8.02728142e-04 9.99674988e-01 -2.54808650e-02 4.40434504e-01]
 [0.00000000e+00 0.00000000e+00 0.00000000e+00 1.00000000e+00]]
Error Twist Vb: [-0.02546938 0.03047876 -0.00119113 -0.02400639 0.0595615 -0.00169853]
Angular Error: 0.039737419089052414
Linear Error: 0.06423989490344827
Iteration number: 2
Joint Vector: [3.83953325 5.11390531 1.39616451 3.04192912 0.08039397 3.01440398]
SE(3) Config:
 [[7.12540522e-01 -6.88248874e-03 7.01597204e-01 -3.01554022e-01]
 [7.01630861e-01 7.52277379e-03 -7.12500907e-01 -5.01882821e-01]
 [-3.74177581e-04 9.99948018e-01 1.01892477e-02 4.87089626e-01]
 [0.00000000e+00 0.00000000e+00 0.00000000e+00 1.00000000e+00]]
Error Twist Vb: [0.01018791 0.00771235 0.00041347 0.00242672 0.01291196 -0.00017609]
Angular Error: 0.012784557018631314
Linear Error: 0.013139208872938079
Iteration number: 3
Joint Vector: [3.83871465 5.13365683 1.3362361 2.94279843 0.0875637 3.15368343]
SE(3) Config:
 [[7.07614922e-01 7.11129182e-04 7.06597917e-01 -2.99763235e-01]
 [7.06598273e-01 -7.83598946e-04 -7.07614490e-01 -4.99727967e-01]
 [5.04840691e-05 9.99999440e-01 -1.05696896e-03 4.98984256e-01]
 [0.00000000e+00 0.00000000e+00 0.00000000e+00 1.00000000e+00]]

```
Error Twist Vb: [-1.05694928e-03  7.18848071e-04 -5.08638958e-05 -3.59739996e-04
  1.01576666e-03  2.45311237e-05]
Angular Error: 0.0012792464410914643
Linear Error: 0.0010778666627332787
Iteration number: 4
Joint Vector: [3.83882585 5.13151303 1.3369715  2.95637611 0.08815853 3.14151004]
SE(3) Config:
 [[ 7.07111334e-01 -4.96142703e-06  7.07102228e-01 -2.99999567e-01]
 [ 7.07102228e-01  5.33214832e-06 -7.07111334e-01 -5.00000205e-01]
 [-2.62092672e-07  1.00000000e+00  7.27865862e-06  4.99992720e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
Error Twist Vb: [ 7.27864615e-06  6.43850009e-06  2.62115685e-07 -1.60617184e-07
  7.28046908e-06 -4.51164381e-07]
Angular Error: 9.721197343117593e-06
Linear Error: 7.296202930462472e-06
(array([3.83882585, 5.13151303, 1.3369715 , 2.95637611, 0.08815853,
       3.14151004]), True)
```

Log 2 - long iteration:

```
Iteration number: 1
Joint Vector: [-2.33759943 -1.69211207  4.14514241 -0.35370722  0.86860525 -1.89120568]
SE(3) Config:
 [[ 0.46669097  0.4960191   0.73223261  0.44115921]
 [ 0.83092348 -0.52948468 -0.17091559  0.22444756]
 [ 0.30292855  0.68819403 -0.65925964  0.25563427]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-0.79511367 -0.37588086 -0.18757516 -0.98972984  0.29684954 -0.31456901]
Angular Error: 0.8992644829429922
Linear Error: 1.0801103983621017
Iteration number: 2
Joint Vector: [-2.78522663e+00  4.75774230e-01  1.81014766e+00  1.16323936e-03
  2.21293299e-01 -2.49515736e+00]
SE(3) Config:
 [[ 0.8438548   0.2487577   0.47542474  0.03099096]
 [ 0.50108524 -0.04847065 -0.86403946 -0.19013454]
 [-0.19189232  0.96735216 -0.165551   -0.35282481]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-0.19218862  0.26453825  0.1705995  -0.52770599  0.8098992  -0.03236178]
Angular Error: 0.36881044083888553
Linear Error: 0.9671905799313381
Iteration number: 3
Joint Vector: [ 0.67011191 -4.64450722  5.65632928 -2.77716818 -1.9520474   0.49951412]
SE(3) Config:
```

```
 [[-0.91898139 -0.30947934  0.2443271   0.16711792]
 [-0.37257515  0.88439427 -0.28113079  0.23257585]
 [-0.12907732 -0.34938418 -0.9280462  -0.74172983]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-0.36199045 -1.5554792   2.3120226  -1.73905554 -0.47547325 -1.10707893]
Angular Error: 2.809982406866833
Linear Error: 2.1156589341710648
Iteration number: 4
Joint Vector: [ 6.18079998 -4.83602317  1.13511605  3.64255743 -1.47858356  1.46147969]
SE(3) Config:
 [[ 0.06337264  0.19152482 -0.97943971 -0.34205283]
 [ 0.56792737  0.80008289  0.19319902  0.15230838]
 [ 0.82063537 -0.56849415 -0.05806883 -0.64035321]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [ 2.47755561  1.32569431 -0.79516011  0.72163905 -0.24505648  1.77417737]
Angular Error: 2.920278553345487
Linear Error: 1.9309378351331747
Iteration number: 5
Joint Vector: [ 5.9791567  -1.7247127   0.03714742  2.68225445 -4.28728246  0.55764432]
SE(3) Config:
 [[ 0.83671604  0.42115254  0.35005257 -0.12042042]
 [ 0.54761256 -0.63739954 -0.54207223  0.11657805]
 [-0.00517175  0.64525372 -0.76395084  0.78390982]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-0.86680598  0.19497417 -0.08466966 -0.53674676 -0.1003582   0.46323947]
Angular Error: 0.8924889256697659
Linear Error: 0.7160723823838983
Iteration number: 6
Joint Vector: [ 2.48535529 -0.58860229  5.0135645  -0.83847966 -2.46216332  2.68176511]
SE(3) Config:
 [[-0.42482691  0.60732376  0.671327   -0.50130317]
 [-0.3865931  -0.79226244  0.47208686  0.31222803]
 [ 0.81857674 -0.05897518  0.57136158  0.39552092]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-0.75762606 -1.51338909 -1.71951782 -0.57658361  0.84018735  0.1328573 ]
Angular Error: 2.412692546318661
Linear Error: 1.027625667921509
Iteration number: 7
Joint Vector: [ 1.98693253 -1.83363063  1.76740046 -5.55741446 -3.03222034 -1.05119675]
SE(3) Config:
 [[ 0.2952963  -0.23384922  0.92634477 -0.08669338]
 [-0.53409347  0.76352667  0.36300301  0.1281569 ]
 [-0.79217691 -0.60194814  0.10056926  0.30171093]
 [ 0.          0.          0.          1.        ]]
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Error Twist Vb: [1.28900551 -0.52025843 1.86630966 -0.59823693 -0.62932938 0.06486243]
Angular Error: 2.3270831079253305
Linear Error: 0.870718110788954
Iteration number: 8
Joint Vector: [2.0554682 -3.13693402 0.79142589 -5.38693037 -1.60085305 -1.28566451]
SE(3) Config:
 [[-0.19551004 0.97717841 0.08305532 0.19220008]
 [0.97474145 0.20294654 -0.09322984 -0.59366602]
 [-0.10795798 0.06273009 -0.99217439 0.27823551]
 [0.   0.   0.   1.   ]]
Error Twist Vb: [-1.32157231 -0.70411104 0.80894687 -0.14033289 -0.21493836 -0.56325828]
Angular Error: 1.701975545115132
Linear Error: 0.618992493626164
Iteration number: 9
Joint Vector: [1.47642938 -1.67647951 -0.5815563 -4.44379087 -2.74121623 -1.02025298]
SE(3) Config:
 [[0.27711965 0.37822293 0.8832622 -0.06010593]
 [0.76391052 0.47084851 -0.44129627 -0.27968092]
 [-0.58279106 0.79702515 -0.1584471   0.71485625]
 [0.   0.   0.   1.   ]]
Error Twist Vb: [-0.05107494 -0.36085613 0.650127   -0.23824051 -0.31353761 -0.06176683]
Angular Error: 0.745312631410777
Linear Error: 0.398596933740028
Iteration number: 10
Joint Vector: [0.67232013 -2.32371403 -0.29437545 -3.99850142 -3.3306304 -0.41903989]
SE(3) Config:
 [[0.66057359 0.01393894 0.75063189 -0.47498897]
 [0.74524348 0.10882233 -0.65785245 -0.3417318]
 [-0.09085528 0.99396348 0.06149725 0.51036286]
 [0.   0.   0.   1.   ]]
Error Twist Vb: [0.06446712 -0.06290551 0.08906819 0.00497756 -0.01753574 0.23553739]
Angular Error: 0.1266738147216591
Linear Error: 0.23624169652937485
Iteration number: 11
Joint Vector: [1.05718326 -1.92060621 -1.08250272 -4.0946252 -2.88326686 -0.82621164]
SE(3) Config:
 [[0.63449458 0.16112425 0.75594683 -0.26131675]
 [0.77241929 -0.0967256 -0.62770422 -0.40274477]
 [-0.02801896 0.98218284 -0.18582735 0.46194685]
 [0.   0.   0.   1.   ]]
Error Twist Vb: [-0.18545739 -0.0948094   0.03705352 -0.09867627 0.03984622 0.03322536]
Angular Error: 0.2115566781559602
Linear Error: 0.11148386337526642
Iteration number: 12

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Joint Vector: [ 1.10239588 -2.03663952 -0.71165357 -3.46009126 -2.92437265  0.0790839 ]
SE(3) Config:
 [[ 0.63261092 -0.01629     0.77429843 -0.2866163 ]
 [ 0.77444626  0.00551686 -0.63261564 -0.50241115]
 [ 0.00603361  0.99985209  0.01610576  0.525529  ]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [ 0.01579004 -0.10041176 -0.00683749 -0.00727528 -0.02541328 -0.01175151]
Angular Error: 0.10187540152064448
Linear Error: 0.028928577314525097
Iteration number: 13
Joint Vector: [ 1.08300761 -2.03197944 -0.78385515 -3.49582995 -2.84485623 -0.02829446]
SE(3) Config:
 [[ 0.7064023   0.0066416   0.7077794  -0.29967915]
 [ 0.70780977 -0.00513197 -0.70638445 -0.4995891 ]
 [-0.00105922  0.99996478 -0.00832623  0.4994052 ]
 [ 0.          0.          0.          1.        ]]
Error Twist Vb: [-8.32578487e-03 -9.90811799e-04  1.06335482e-03 -5.17767225e-04
  5.94782319e-04  6.09429725e-05]
Angular Error: 0.008451693625004619
Linear Error: 0.0007909253769445142
Iteration number: 14
Joint Vector: [ 1.08288205e+00 -2.02482585e+00 -7.94680671e-01 -3.46361137e+00
 -2.84422686e+00  6.68939985e-05]
SE(3) Config:
 [[ 7.07023268e-01 -1.56917714e-05  7.07190284e-01 -2.99990230e-01]
 [ 7.07190285e-01  1.22431059e-05 -7.07023268e-01 -4.99987210e-01]
 [ 2.43624199e-06  1.00000000e+00  1.97532290e-05  5.00029708e-01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.00000000e+00]]
Error Twist Vb: [ 1.97530536e-05 -1.18097795e-04 -2.43740450e-06 -1.59523822e-05
 -2.97080314e-05  2.13426672e-06]
Angular Error: 0.00011976315517662045
Linear Error: 3.3787582419949935e-05
(array([ 1.08288205e+00, -2.02482585e+00, -7.94680671e-01, -3.46361137e+00,
        -2.84422686e+00,  6.68939985e-05]), True)
```
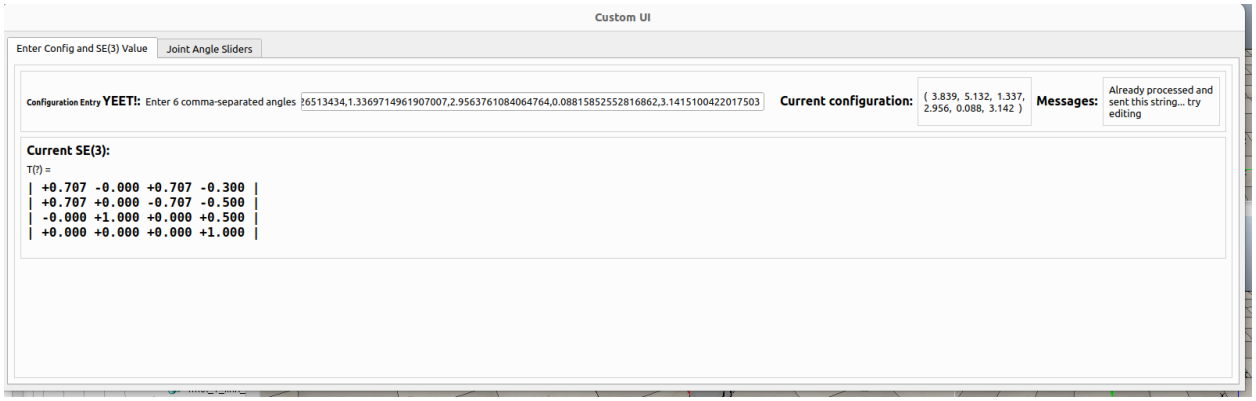
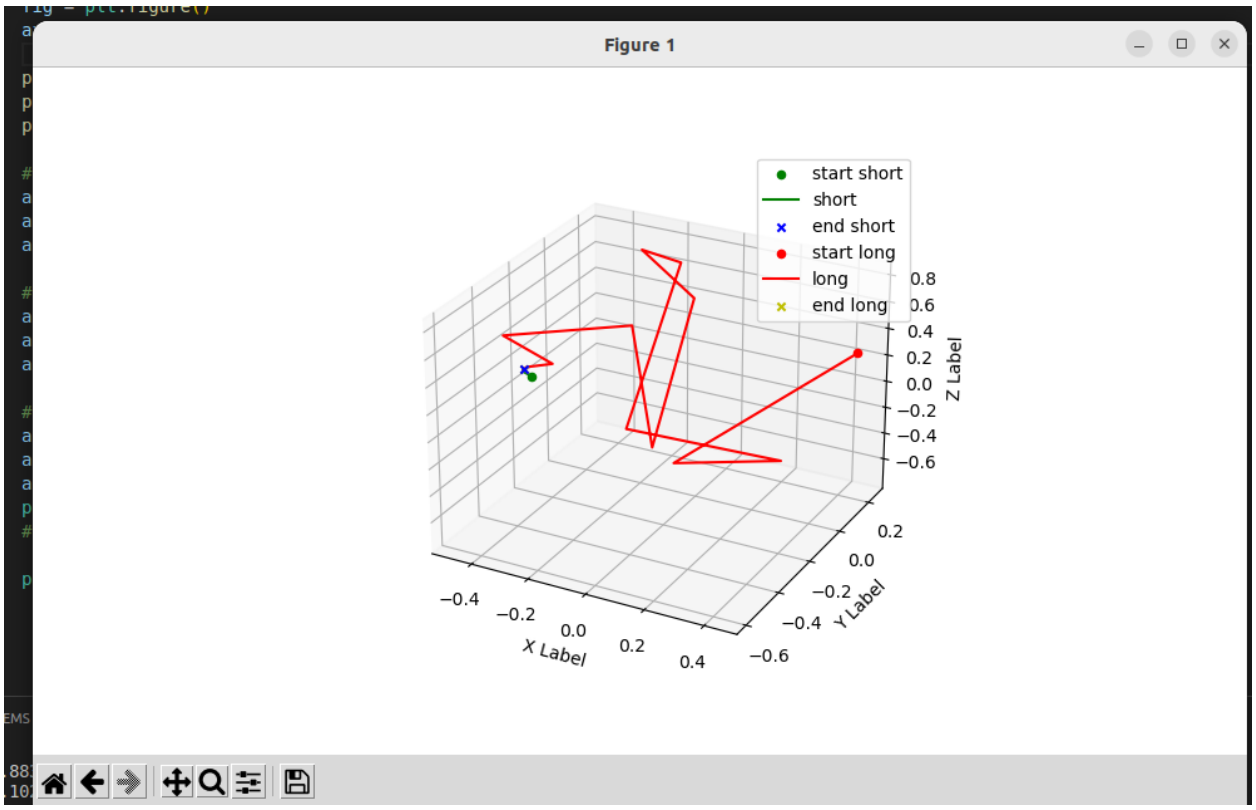
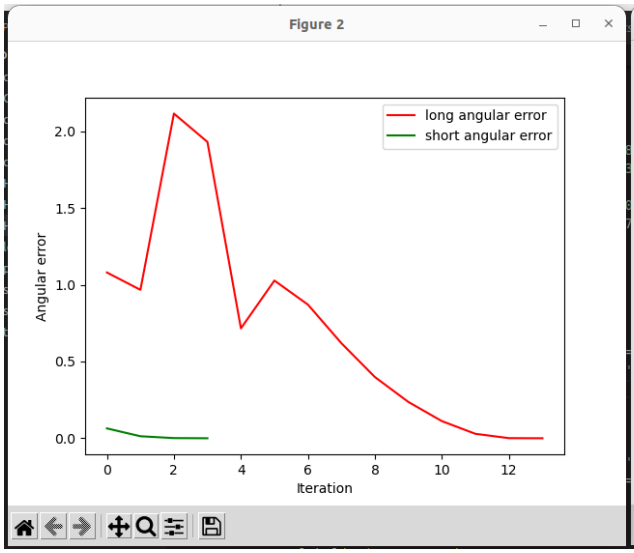

CoppeliaSim:

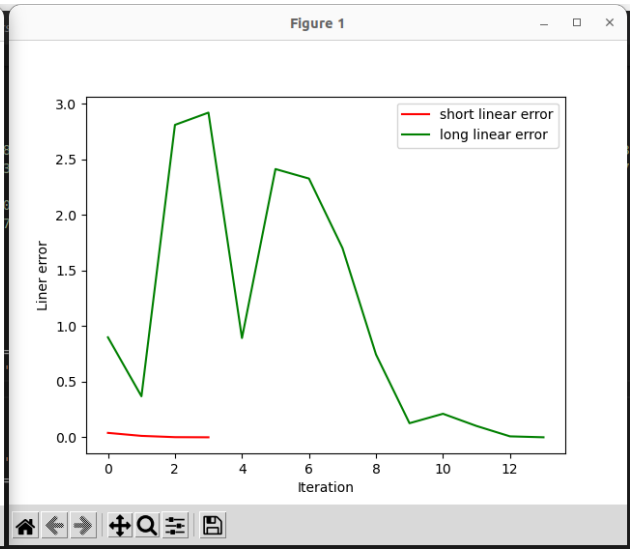


Above is a screenshot showing that my short iterations converged quite nicely to the Tsb value.

Plots:







Convergence Explanation:

In the long version, I chose something that was far away from the goal, and since the math for Newton-Raphson can overshoot the intended goal, the position bounces around the plot until it

eventually converges closer and closer to the goal. This bouncing around is something that is inefficient and leads to potential error that grows because the slope at a certain point can send it farther away.