Report of PA3: Jacobian

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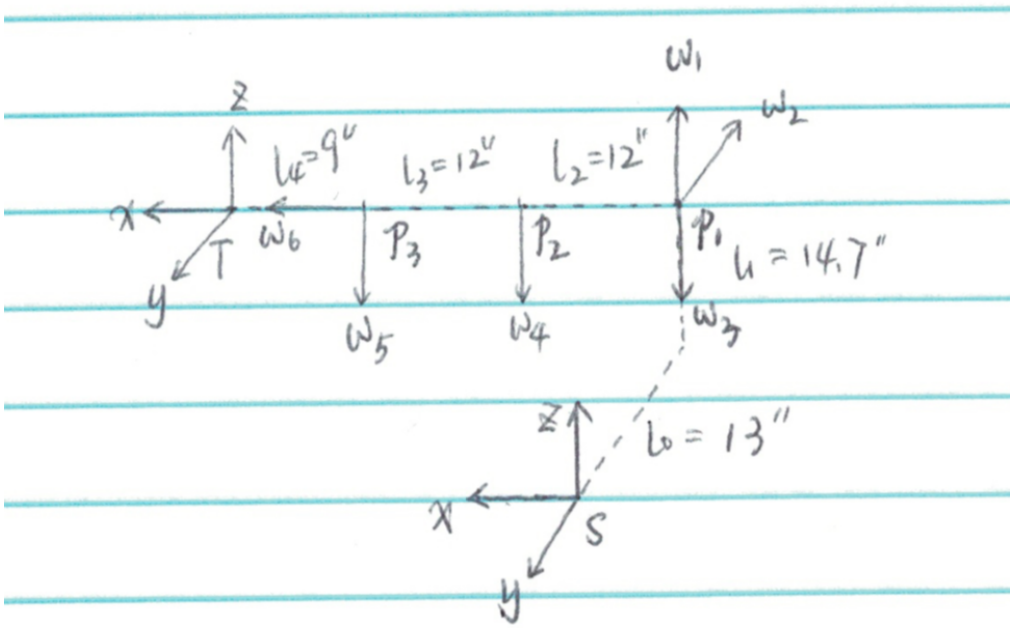
1. Graph of Frame



Graph of Frame
(As shown in the above graph, the number of the axes are renumbered based on 1.)

2. Theta List 1

θ = [0, π/3, 0, π/4, π/3, π/12]

Spatial Jacobian:

Jst_s =

-13.0000 14.7000 6.5000 6.5000 10.7426 36.1512

```
     0         0   12.7306   24.7306   33.2159   -1.9023
     0         0   11.2583   11.2583   18.6068  -12.6740
     0         0    0.8660    0.8660    0.8660   -0.1294
     0   -1.0000         0         0         0   -0.9659
1.0000         0   -0.5000   -0.5000   -0.5000   -0.2241
```

SVD:

U =

```
-0.4524    0.8679   -0.2008   -0.0010   -0.0018    0.0418
-0.7942   -0.2895    0.5335    0.0056    0.0164   -0.0229
-0.4043   -0.4026   -0.8184   -0.0391    0.0223    0.0510
-0.0261   -0.0108   -0.0247    0.0582   -0.9733   -0.2186
 0.0059   -0.0275    0.0236    0.6396   -0.1321    0.7564
 0.0183   -0.0064    0.0638   -0.7655   -0.1854    0.6125
```

S =

```
52.2288         0         0         0         0         0
     0   42.0495         0         0         0         0
     0         0    6.4430         0         0         0
     0         0         0    1.0136         0         0
     0         0         0         0    0.4277         0
     0         0         0         0         0    0.3160
```

V =

```
 0.1130   -0.2685    0.4150   -0.7429   -0.3784    0.2186
-0.1275    0.3041   -0.4618   -0.6449    0.2464   -0.4489
-0.3377   -0.0614   -0.5868    0.0580   -0.7069    0.1865
-0.5201   -0.1440    0.4069    0.1249   -0.2467   -0.6832
-0.7428   -0.1852    0.0438   -0.1152    0.4436    0.4494
-0.1862    0.8813    0.3206   -0.0036   -0.1967    0.2173
```

Body Jacobian:

Jst_b =

```
  -10.9917    0.0000   21.9834   10.3923    0.0000         0
    1.8940    4.6991  -11.4889  -14.4889   -8.6933         0
  -15.9094   17.5373    3.0784    3.8823    2.3294   -0.0000
   -0.2241    0.9659         0         0         0    1.0000
    0.9374    0.2500   -0.2588   -0.2588   -0.2588         0
    0.2665   -0.0670   -0.9659   -0.9659   -0.9659         0
```

SVD:

S =

```
   -0.7546    0.1810    0.6304   -0.0133   -0.0101   -0.0057
    0.4899   -0.4797    0.7233    0.0044   -0.0060   -0.0820
   -0.4338   -0.8575   -0.2727    0.0322   -0.0250    0.0223
   -0.0076   -0.0385   -0.0110   -0.9165    0.3978    0.0045
    0.0222    0.0040    0.0045   -0.3900   -0.8998    0.1942
    0.0423   -0.0202    0.0697    0.0813    0.1770    0.9772
```

V =

```
   33.9473         0         0         0         0         0
         0   22.3214         0         0         0         0
         0         0    9.9683         0         0         0
         0         0         0    1.1420         0         0
         0         0         0         0    0.6671         0
         0         0         0         0         0    0.3369
```

D =

```
    0.4760    0.4817   -0.1200   -0.4337   -0.5818   -0.0210
   -0.1564   -0.7762   -0.1402   -0.3533   -0.4777   -0.0172
   -0.6952    0.3077    0.4656   -0.1947   -0.2533   -0.3212
   -0.4911    0.2473   -0.5071   -0.0483   -0.0801    0.6571
   -0.1566    0.0982   -0.7014    0.0517    0.0839   -0.6813
   -0.0002   -0.0017   -0.0011   -0.8026    0.5964    0.0134
```

>>

Conclusion:

All the singulars are non zeros which proves it is not a singular configuration.

3. Theta List 2

θ = [π/3, 0, −π/4, π/3, 0, π/6]

Spatial Jacobian:

Jst_s =

```
 -13.0000    7.3500   13.0000    1.4089   -7.0764  -10.3945
       0   12.7306         0   -3.1058    5.3795   10.3945
       0   11.2583         0         0         0   -1.1999
       0    0.8660         0         0         0    0.7071
       0   -0.5000         0         0         0    0.7071
  1.0000         0   -1.0000   -1.0000   -1.0000         0
```

SVD:

U =

```
  -0.9766    0.0281   -0.2028   -0.0656    0.0080   -0.0000
   0.1236    0.8791   -0.4491   -0.0663    0.0762   -0.0000
  -0.1714    0.4726    0.8498    0.1201   -0.0618    0.0828
   0.0030    0.0539   -0.0138   -0.0718   -0.7705   -0.6309
   0.0208   -0.0066   -0.1025   -0.0716   -0.6235    0.7714
   0.0342   -0.0069    0.1561   -0.9832    0.0884   -0.0000
```

S =

```
  24.0207         0         0         0         0         0
       0   19.4515         0         0         0         0
       0         0    6.0795         0         0         0
       0         0         0    1.5780         0         0
       0         0         0         0    0.4590         0
```

```
        0         0         0         0         0    0.0000
```

V =

```
    0.5300   -0.0191    0.4592   -0.0826   -0.0327   -0.7071
   -0.3140    0.8621    0.3947   -0.0002   -0.0494    0.0000
   -0.5300    0.0191   -0.4592    0.0826    0.0327   -0.7071
   -0.0747   -0.1380    0.1568    0.6949   -0.6841    0.0000
    0.3140    0.2333   -0.1870    0.6913    0.5780   -0.0000
    0.4853    0.4274   -0.6024   -0.1599   -0.4397   -0.0000
```

Body Jacobian:

Jst_b =

```
  -10.3923   -0.0000   10.3923    0.0000    0.0000         0
   23.3827   14.3849  -23.3827  -18.1865   -7.7942         0
  -13.5000   24.9153   13.5000   10.5000    4.5000    0.0000
         0    0.2588         0         0         0    1.0000
    0.5000   -0.8365   -0.5000   -0.5000   -0.5000         0
    0.8660    0.4830   -0.8660   -0.8660   -0.8660         0
```

SVD:

S =

```
   -0.2793    0.0000   -0.9587   -0.0000    0.0533    0.0000
    0.8308   -0.4997   -0.2392    0.0045    0.0497   -0.0168
   -0.4797   -0.8655    0.1381    0.0078   -0.0287   -0.0291
   -0.0000   -0.0090    0.0000   -1.0000    0.0000    0.0000
    0.0202    0.0291   -0.0336   -0.0003   -0.4985   -0.8655
    0.0349   -0.0168   -0.0581    0.0002   -0.8634    0.4997
```

V =

```
   46.3345         0         0         0         0         0
         0   28.7871         0         0         0         0
         0         0    7.2692         0         0         0
```

```
         0         0         0    1.0000         0         0
         0         0         0         0    0.5236         0
         0         0         0         0         0    0.0000


D =

    0.6225   -0.0000    0.3353   -0.0000   -0.0013   -0.7071
         0   -1.0000    0.0000    0.0003   -0.0000         0
   -0.6225   -0.0000   -0.3353   -0.0000    0.0013   -0.7071
   -0.4357    0.0000    0.8073    0.0000   -0.3980   -0.0000
   -0.1872   -0.0000    0.3513    0.0000    0.9174   -0.0000
   -0.0000   -0.0003    0.0000   -1.0000   -0.0000    0.0000

>>
```

Conclusion:

There is one singular is zero which proves it is a singular configuration.

4. Theta List 3, my choice

θ = [π/3, π/2, 0, 0, 0, π/6]

When picking up joint 2=pi/2, and joint 3, 4, 5 equal 0, then joint 1 and joint 6 are align, namely robot has singularity.

Spatial Jacobian:

```
Jst_s =

   -13.0000    7.3500  -12.7306  -23.1229  -33.5152  -13.0000
         0   12.7306    7.3500   13.3500   19.3500    0.0000
         0   11.2583    6.5000    6.5000    6.5000    0.0000
         0    0.8660    0.5000    0.5000    0.5000    0.0000
         0   -0.5000    0.8660    0.8660    0.8660    0.0000
    1.0000         0   -0.0000   -0.0000   -0.0000    1.0000
```

SVD:

U =

-0.8698	-0.4776	0.1124	0.0147	0.0332	0.0380
0.4510	-0.6753	0.5679	0.1019	0.0576	0.0657
0.1979	-0.5595	-0.7874	-0.1111	-0.1224	-0.0234
0.0152	-0.0430	-0.0606	-0.0085	0.7452	-0.6624
0.0252	0.0117	0.0001	-0.6703	0.4885	0.5580
0.0081	0.0292	-0.2030	0.7264	0.4320	0.4935

S =

52.8645	0	0	0	0	0
0	20.6818	0	0	0	0
0	0	4.0488	0	0	0
0	0	0	1.2135	0	0
0	0	0	0	0.0000	0
0	0	0	0	0	0.0000

V =

0.2140	0.3016	-0.4110	0.4408	0.3275	-0.6267
0.0298	-0.8921	-0.2126	0.3977	0.0000	-0.0000
0.2970	-0.1224	-0.5939	-0.6143	0.3618	0.1891
0.5192	-0.0784	-0.0408	-0.2365	-0.7237	-0.3781
0.7414	-0.0343	0.5124	0.1413	0.3618	0.1891
0.2140	0.3016	-0.4110	0.4408	-0.3275	0.6267

Body Jacobian:

Jst_b =

0	0.0000	0.0000	0.0000	0.0000	0
0.0000	16.5000	-28.5788	-18.1865	-7.7942	0
-0.0000	28.5788	16.5000	10.5000	4.5000	0.0000
1.0000	0	0	0	0	1.0000
0.0000	-0.8660	-0.5000	-0.5000	-0.5000	0

```
    0.0000    0.5000   -0.8660   -0.8660   -0.8660         0
```

SVD:

S =

```
    0.0000   -0.0000         0   -0.0000   -0.4889   -0.8723
   -0.8654   -0.4998   -0.0000   -0.0339   -0.0132    0.0074
    0.4996   -0.8656    0.0000    0.0195   -0.0229    0.0128
   -0.0000   -0.0000    1.0000    0.0000         0         0
   -0.0195    0.0262    0.0000    0.4996   -0.7551    0.4232
   -0.0339   -0.0151   -0.0000    0.8654    0.4360   -0.2444
```

V =

```
   40.1680         0         0         0         0         0
         0   33.0151         0         0         0         0
         0         0    1.4142         0         0         0
         0         0         0    0.7318         0         0
         0         0         0         0    0.0000         0
         0         0         0         0         0    0.0000
```

D =

```
   -0.0000   -0.0000    0.7071   -0.0000    0.1147   -0.6977
   -0.0000   -1.0000   -0.0000    0.0000    0.0000    0.0000
    0.8219   -0.0000    0.0000    0.3973    0.4028    0.0662
    0.5234   -0.0000    0.0000   -0.2437   -0.8057   -0.1324
    0.2249   -0.0000    0.0000   -0.8847    0.4028    0.0662
    0.0000         0    0.7071    0.0000   -0.1147    0.6977
```