ROB501 - Assignment 4: Image-Based Visual Servoing
Part 4: Performance Evaluation

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Experimental Setup

The following initial camera pose was used for the performance evaluation:

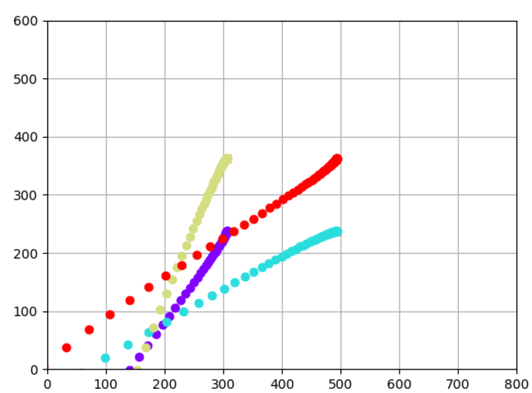
(x, y, z, roll, pitch, yaw) = (-0.8, 0.8, -5.0, π/1.3, -π/8, -π/6)

It was initialized in the simulation code as follows:

```
C_init = dcm_from_rpy([np.pi/1.3, -np.pi/8, -np.pi/6])
t_init = np.array([[-0.8, 0.8, -5.0]]).T
```

This initial camera pose was specifically selected to ensure a large difference in feature alignment. All the tracked points are initially located outside of the image plane and appear after a few iterations in the simulation. As well, the trajectory of the polygon defined by the points involved a substantial rotation to converge to the correct location.

From Figure 1, we can see the trajectory of the points as they converge to the end pose in both the case with exact feature depths and estimated feature depths for the default gain of 0.1. It is interesting to note that while the number of iterations was the same for both cases, a slightly different trajectory was taken in each case.



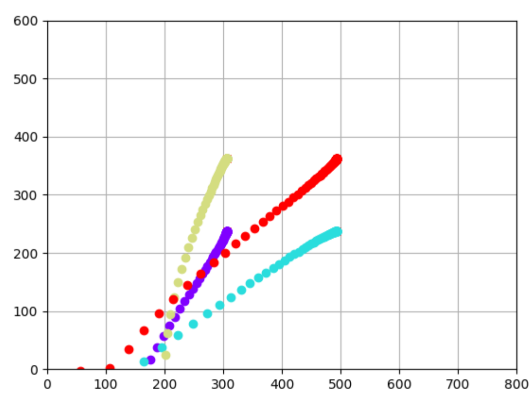


Figure 1. *Trajectory with gain of 0.1.* ***Left.*** *Trajectory with exact feature depths.* ***Right.*** *Trajectory with estimated feature depths.*

Optimal Gain Values

The optimal gain value was determined as the gain value that resulted in the smallest number of iterations until convergence. Control gain values ranging from 0.02 to 2.0 (in 0.02 increments) were evaluated. The findings, summarized in Table 1, show the optimal gains for scenarios with known and estimated feature depths.

Feature Depth	Optimal Gain	Number of Iterations
Exact Depths	1.06	11
Estimated Depths	0.78	14

Table 1. *Optimal gain value for known feature depths and estimated feature depths.*

Performance Evaluation

To compare the performances between using known and estimated depths, the number of iterations against each gain value (from 0.02 to 2.0, in 0.02 increments) was plotted, as illustrated in Figures 2 and 3. In the cases where a singularity was reached during the computation of the pseudoinverse of the Jacobian matrix due to the problem becoming numerically ill-conditioned, the iteration at which the singularity occurred is plotted.

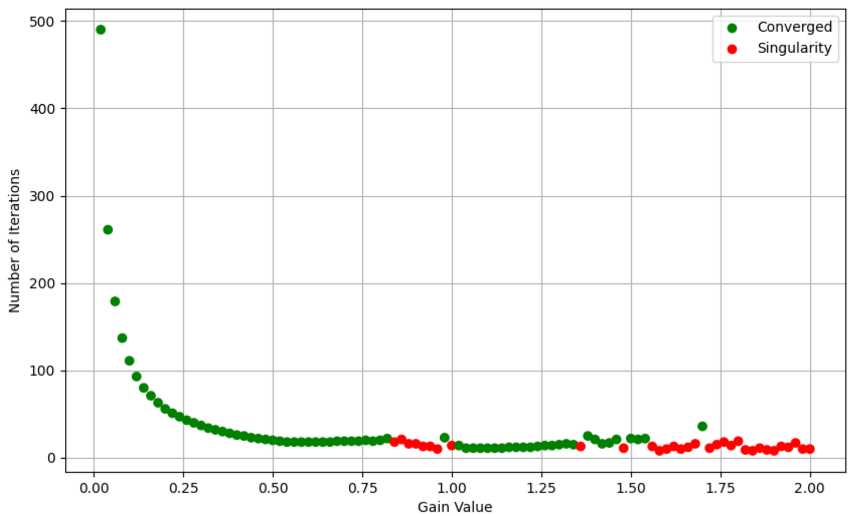


Figure 2. *Number of iterations until convergence for each control gain for exact depths setup.*

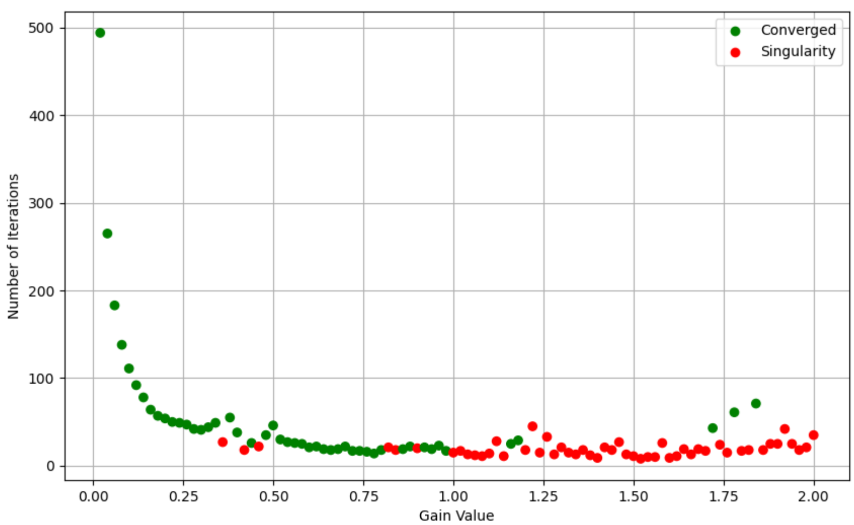


Figure 3. *Number of iterations until convergence for each control gain for estimated depths setup.*

The analysis reveals a noticeable performance decline when using estimated feature depths compared to exact depths. Convergence was typically slower for equivalent gain values with estimated depths. This discrepancy was more pronounced at higher gain values, with differences exceeding 30% in some cases. Furthermore, singularities occurred much more frequently and earlier in the estimated depths setup, emphasizing the importance of accurate feature depth values. This signifies that having accurate feature depth values is important for numerical stability and allowing the use of more aggressive control strategies.