Plots

Two plots were made to analyze the performance of the IBVS system when feature depths are known exactly and when feature depths are estimated. Two initial poses were used, categorized as an easy initial pose and a hard initial pose based on their deviation from the final desired pose. The easy initial pose was taken from the camera pose provided in the starter code, while the hard initial pose was created by choosing an initial rotation and position that resulted in a large deviation from the desired final pose.

Easy Initial Pose:

For the easy initial condition, the number of iterations required to converge to the final pose (within a norm of 1×10^{-4}) was determined for both known and estimated feature depths, using gains ranging from 0.01 to 1.25. It was observed that for gains beyond 1.25, both cases exhibited unstable behavior. The performance for the easy initial camera pose is illustrated in Figure 1 below.

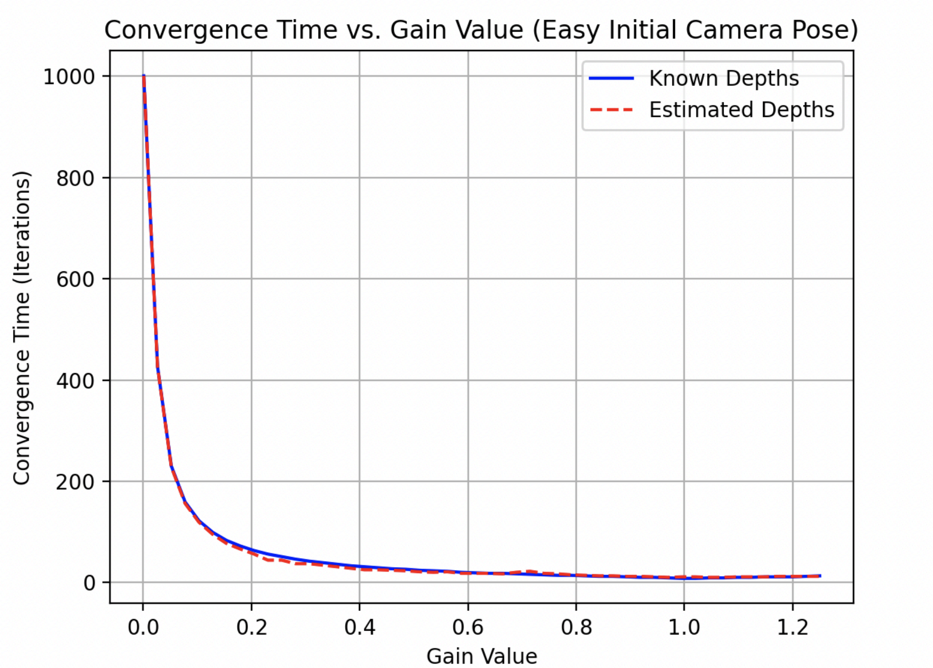

Figure 1: Easy Initial Camera Pose Performance

It was observed that both the IBVS system with known depth and the one with estimated depth had optimal gains of approximately 1. With a gain of 1, the IBVS system with known depth achieved convergence in 8 iterations, while the system with estimated depth took 10 iterations to converge. Overall, with the easy initial pose, both IBVS systems demonstrated very similar performance with similar stable gain ranges.

Hard Initial Pose:

For the hard initial pose, the convergence time was plotted for gain values between 0.01 and 1.25 for both the IBVS system with known and estimated depths. The performance of both systems can be observed in Figure 2 below.

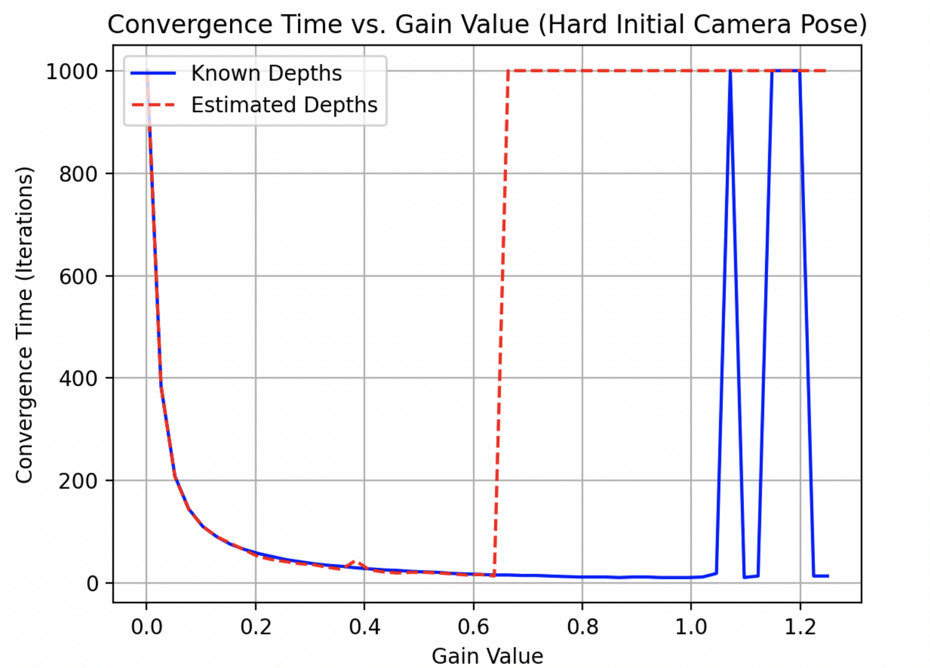

Figure 2: Hard Initial Camera Pose Performance

As illustrated in Figure 2 above, the range of gains for which the known depth was able to converge was approximately 1, while the IBVS system with estimated depth was only able to converge for gains less than 0.6. Prior to gains of 0.6, both systems perform similarly. Overall, the IBVS system with known depths achieved optimal convergence at a gain of 0.87, converging in 10 iterations, while the system with estimated depths achieved optimal performance at a gain of 0.64, converging in 14 iterations.

Discussion Questions

What is the optimal gain value (experimentally) for the case where feature depths are known exactly? That is, what gain value leads to the fastest convergence?

As observed in Figures 1 and 2, the IBVS system with known depth was able to converge for gains up to 1. When using an easy initial camera pose, an optimal gain was found to be **1**, resulting in convergence in **8 iterations**. For the hard initial camera pose, the optimal gain was found to be **0.87**, with convergence achieved in **10 iterations**. Thus, the optimal gain value when feature depths are known seems to be approximately **1**.

<u>What is the optimal gain value (experimentally) for the case where feature depths are estimated? That is,what gain value leads to the fastest convergence?</u>

For the IBVS system with estimated feature depths, it was observed that the optimal gain for the easy initial pose was **0.97**, with **10 iterations** needed to converge. For the hard initial camera pose, the optimal gain was **0.64**, requiring **14 iterations** to converge. For gains beyond **0.6**, the IBVS system was unable to converge with the hard initial pose. Therefore, the optimal gain for the case where feature depths are estimated is approximately **0.6** to ensure convergence.

The overall summary of optimal gains and performance can be found in Table 1 below.

Feature Depth	Camera Pose Difficulty	Optimal Gain	Convergence Iterations
Known	Easy	1.00	8
	Hard	0.87	10
Estimated	Easy	0.97	10
	Hard	0.64	14

Table 1: Optimal Gains and Performance for IBVS Systems

<u>How much worse is the performance with estimated depths compared to with known depths? Is the difference significant?</u>

Overall, the performance of the IBVS system with estimated depths is similar to that with known depths, as observed from Table 1 above. The major difference is that for initial poses that deviate significantly from the final pose, there is more instability in convergence when using estimated depths. As such, for IBVS systems with estimated depths, it would be wise to choose a smaller gain (closer to **0.6**), which results in slower convergence but increased stability.