PID Air Levitation Control

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1. Components:

1. 12V DC fan
2. Arduino
3. ping ball
4. ultrasonic
5. adapter
6. LCD
7. H-Bridge

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2. Abstract about the project

This report explores the design, analysis, and implementation of a PID-controlled air levitation system, focusing on the conversion from the S Domain to the Z Domain and subsequent tuning.The system comprises a 12V DC fan, 12V adapter, an L298N Motor Driver, and an Ultrasonic sensor, controlled by an Arduino Uno.

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3. Methods to get Z transform

Bilinear (Tutsin) method:

1. **Start with the Continuous-Time Transfer Function:**
   - Begin with the continuous-time transfer function of system, represented in Laplace domain.
2. **Apply Bilinear Transformation:**
   - Use the bilinear transformation to convert the continuous-time transfer function to the discrete-time transfer function in the Z domain.
   - The bilinear transformation is given by the formula:

     where
     s is the Laplace variable and *T* is the sampling period.

$$s = \frac{2}{T}\frac{1 - z^{-}1}{1 + z^{-}1}$$

3. **Substitute Bilinear Transformation into Transfer Function:**

- Substitute the expression for *s* into the Laplace domain transfer function and simplify to obtain the Z-transform.

c2d (Zero-Order Hold) Method:

1. **Start with the Continuous-Time Transfer Function:**
   - Begin with the continuous-time transfer function of your system.
2. **Use c2d Function in MATLAB or Python:**
   - MATLAB: Use the `c2d` function to convert the continuous-time transfer function to a discrete-time transfer function using the Zero-Order Hold method.

When we try to get z trasfer function for PID with ZoH we found PID in s domain is improper because it has Zeros more than Poles.

Therefore, we used Tustin method that could be able to handle system better.

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4. Post tuning

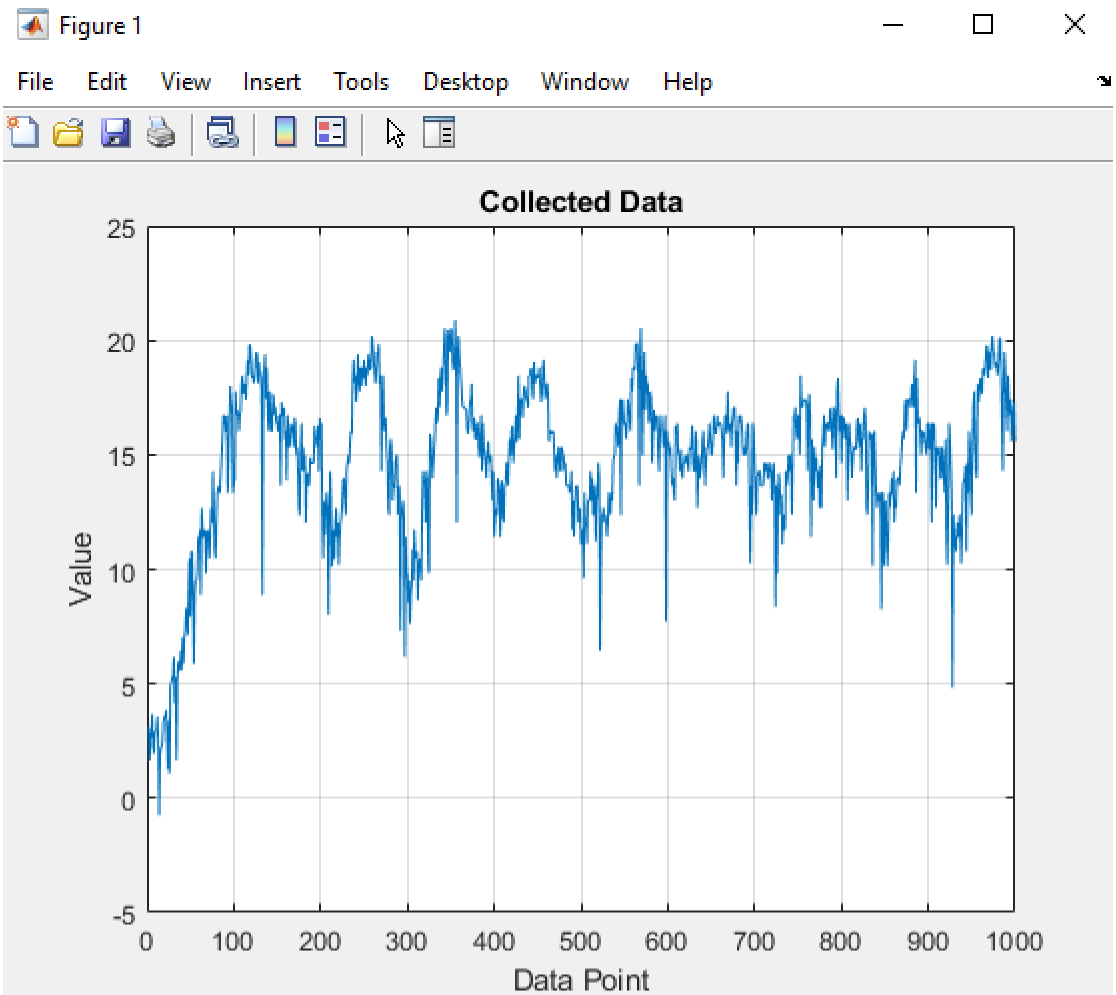
After tuning the PID controller with the selected values:

- K_p = 0.36962
- K_i = 0.50657
- K_d = 0.067425
- we observed a minor steady-state error of 0.026793 .

The transient response parameters following PID control are as follows:

1. **Rise Time:** 1.2000
   - This value indicates the time taken for the system response to transition from 10% to 90% of its final value. A value of 1.2000 signifies a rapid response of the system upon activation.
2. **Settling Time:** 7
   - The settling time is the duration required for the system response to remain within an accepted percentage (commonly 2%) of its final value. A settling time of 7 is considered acceptable.
3. **Overshoot:** 8.3744
   - The overshoot represents the percentage by which the system exceeds the setpoint. In this case, an overshoot of 8.3744% is acceptable as it allows for accelerated rise time without being excessively high.
4. **Undershoot:** 0
   - The absence of undershoot is positive, as it indicates the prevention of oscillation or vibration around the setpoint.
5. **Peak Time:** 2.3000
   - The peak time is the time taken for the system response to reach its peak amplitude. A value of 2.3000 is deemed acceptable, indicating efficient control without spending excessive time overshooting the final value.

Following a stability test, the system is observed to be on the brink of critical stability. The proximity of left poles and right poles to the unit circle suggests a delicate balance. Attempts were made to bring the left poles inside the circle, but doing so resulted in the right poles moving outside, and vice versa. This delicate equilibrium indicates the system's susceptibility to instability, requiring careful consideration during further tuning and control adjustments.



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5. Steady-State Error Analysis in Z Domain:

The investigation into the steady-state error within the Z domain revealed significant improvements after the implementation of PID control.

- **Steady-State Error Before PID in Z Domain:**
  The initial steady-state error in the system, prior to PID control, was measured at

12.504212.

- **Steady-State Error After PID in Z Domain:**
  Following the application of PID control, the steady-state error experienced a remarkable reduction, converging to a minimal value of 0.0267930.

This substantial decrease in steady-state error underscores the effectiveness of the PID control mechanism in enhancing the system's precision and ability to maintain a desired position. The successful reduction in steady-state error aligns with the objectives of the PID tuning process, indicating improved performance and stability in the controlled air levitation system.

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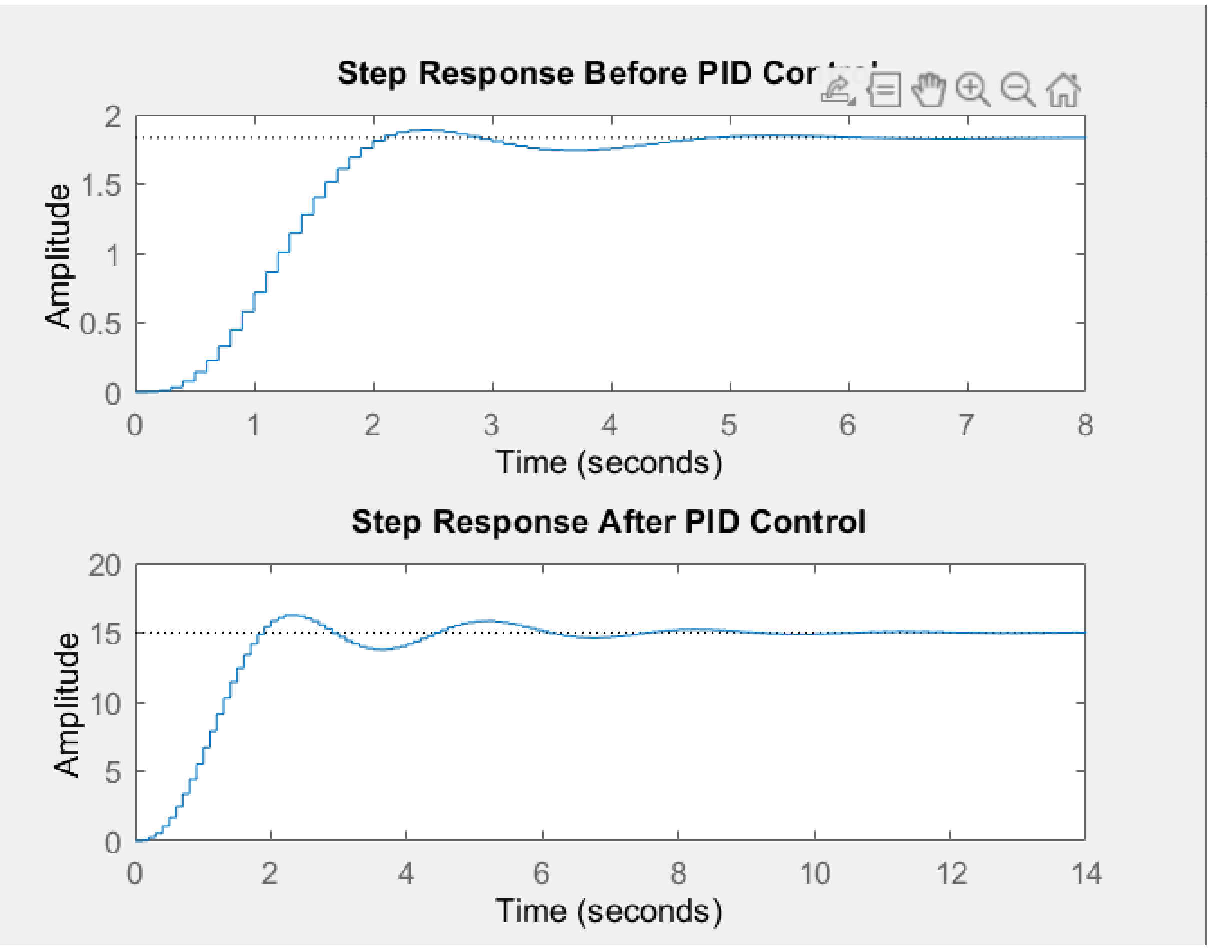
6. Transient Response Analysis in Z Domain:

The transient response parameters, indicative of the dynamic behavior of the system, were thoroughly examined both before and after the implementation of PID control.

- **Transient Response Parameters Before PID Control:**
  - **Rise Time:** 1.2000
  - **Settling Time:** 4.4000
  - **Settling Min:** 1.6933
  - **Settling Max:** 1.8902
  - **Overshoot:** 3.1544
  - **Undershoot:** 0
  - **Peak:** 1.8902
  - **Peak Time:** 2.4000
- **Transient Response Parameters After PID Control:**
  - **Rise Time:** 1.2000
  - **Settling Time:** 7
  - **Settling Min:** 13.7899

- **Settling Max:** 16.2562
- **Overshoot:** 8.3744
- **Undershoot:** 0
- **Peak:** 16.2562
- **Peak Time:** 2.3000

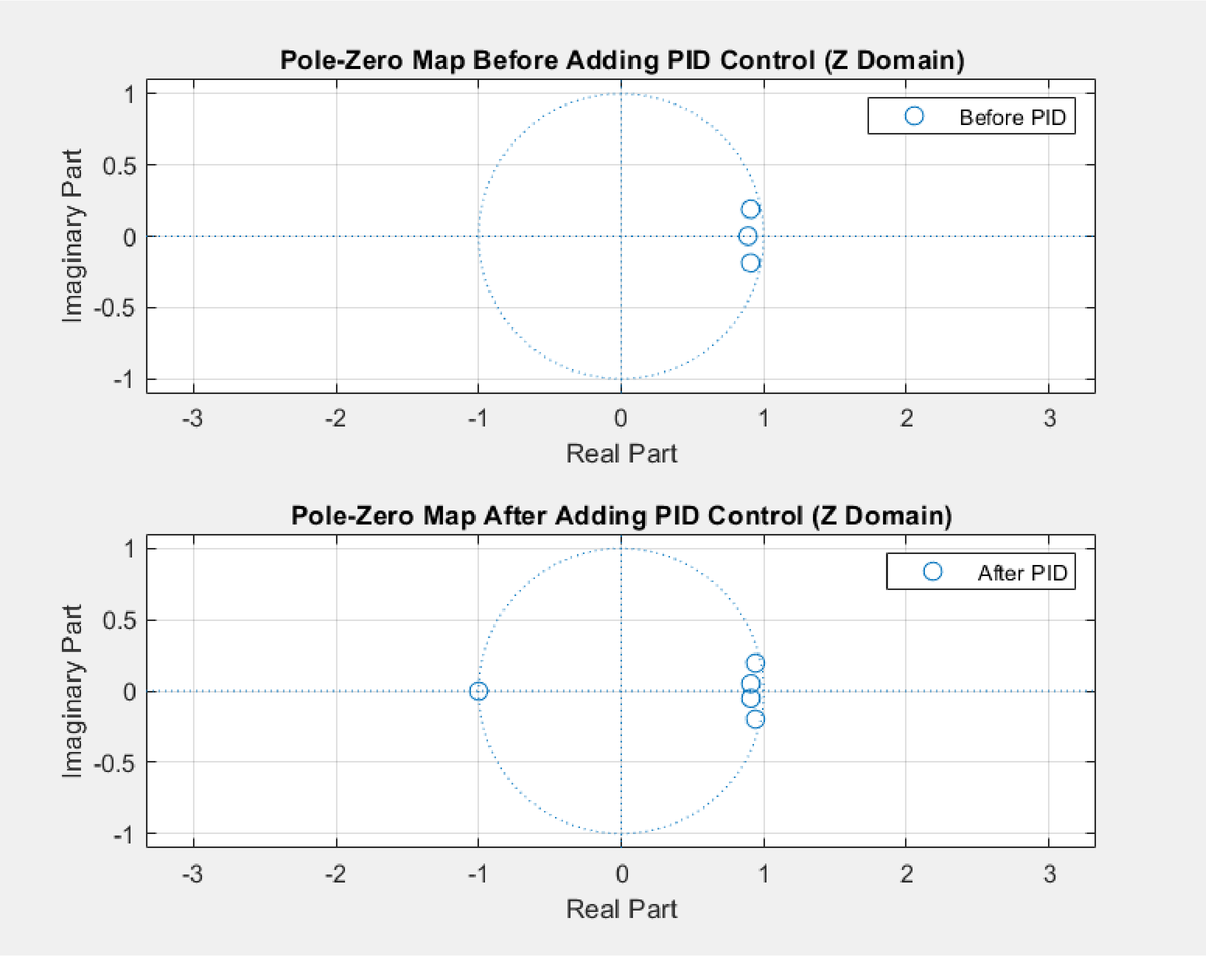
The comparison highlights the evolution in the transient response characteristics with the incorporation of PID control. While the rise time remained consistent, the settling time experienced an increase, indicative of the system's enhanced stability. However, this improvement is coupled with a higher overshoot and a notable increase in the peak response.



7. System Stability Analysis in Z Domain:

The stability of the system, a critical aspect in control system design, was rigorously examined both before and after the integration of PID control.

- **System Stability Before PID Control:**
  The system demonstrated stability in the absence of PID control, affirmed by the boolean result :
  true.
- **System Stability After PID Control:**
  Following the implementation of PID control, the system maintained its stability, as indicated by the boolean result:
  true.
- **Checking if the S Domain is Stable to Use ZOH:**
  The assessment of stability for ZOH discretization yielded a result of
  false. This finding suggests that the system may not be entirely suitable for discretization using ZOH.
- **Causal and Proper System Characteristics:**
  - **Is Causal:** false
  - **Is Proper:** false


Pole-Zero Map Before Adding PID Control (Z Domain)
Before PID
Imaginary Part
Real Part
1
0.5
0
-0.5
-1
-3
-2
-1
0
1
2
3
Pole-Zero Map After Adding PID Control (Z Domain)
After PID
Imaginary Part
Real Part