UNIVERSITÀ DEGLI STUDI DI VERONA

Robotics Programming & Control Module A Report

COMPUTER ENGINEERING FOR ROBOTICS AND SMART INDUSTRY

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Contents

1 Homework 1

1.1 Inertia and friction parameter identification

Description: Compute the inertial and frictions parameter of the motor model with no arm attached. For the homework the following motor model was assumed:

$$\tau_m = J\ddot{\theta} + d\dot{\theta} + fsign(\dot{\theta})$$

The data provided to the regressor were collected during experiments of 15 seconds, using as reference input a sinusoidal reference position $\theta_r = Asin(2\pi f_{req} t)$

Experiment	A	f_{req}
1	$\pi/4$	0.1
2	$\pi/4$	0.5
3	$\pi/2$	0.5
4	$\pi/2$	1

The parameter resulting from the least square regressor algorithm with no filtering were the following:

$$J = 0.0000 \quad d = 0.0006 \quad f = 0.0204$$

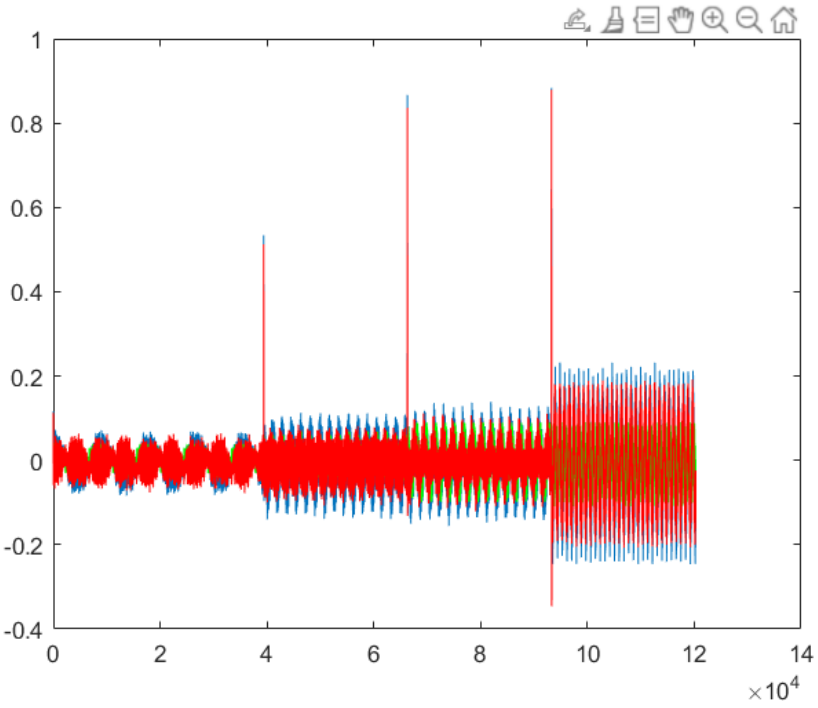

Figure 1: Motor model with no filtering

The parameter resulting from the least square regressor algorithm with data filter at 10Hz were the following:

$$J = 0.0005 \quad d = 0.001 \quad f = 0.0173$$

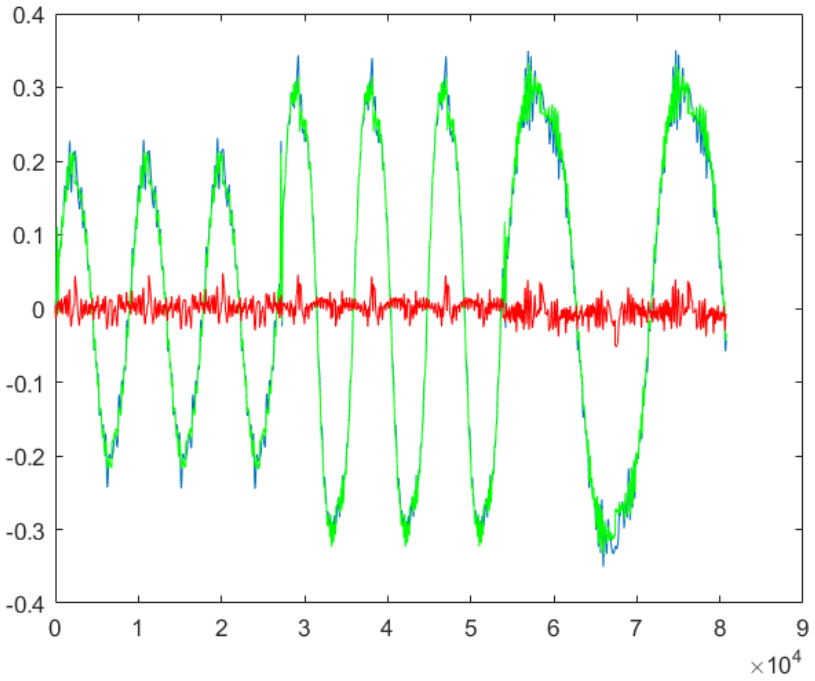

Figure 2: Motor model applying filtering at 10 Hz

1.2 Gravity term parameter identification

Description: Compute gravity term parameter of the motor model with an arm attached. For the homework the following motor model was assumed:

$$\tau_m = J\ddot{\theta} + d\dot{\theta} + fsign(\dot{\theta}) + mgbsin\theta$$

The data provided to the regressor were collected during experiments of 15 seconds, using as reference input a sinusoidal reference position $\theta_r = Asin(2\pi f_{req} t)$

Experiment	A	f_{req}
1	$\pi/4$	0.1
2	$\pi/2$	0.1
3	$\pi/2$	0.05

The parameter resulting from the least square regressor algorithm with no filtering were the following:

$$J = 0.0000 \quad d = -0.0156 \quad f = 0.0310 \quad mb = -0.0289 \quad v = 0.0036$$

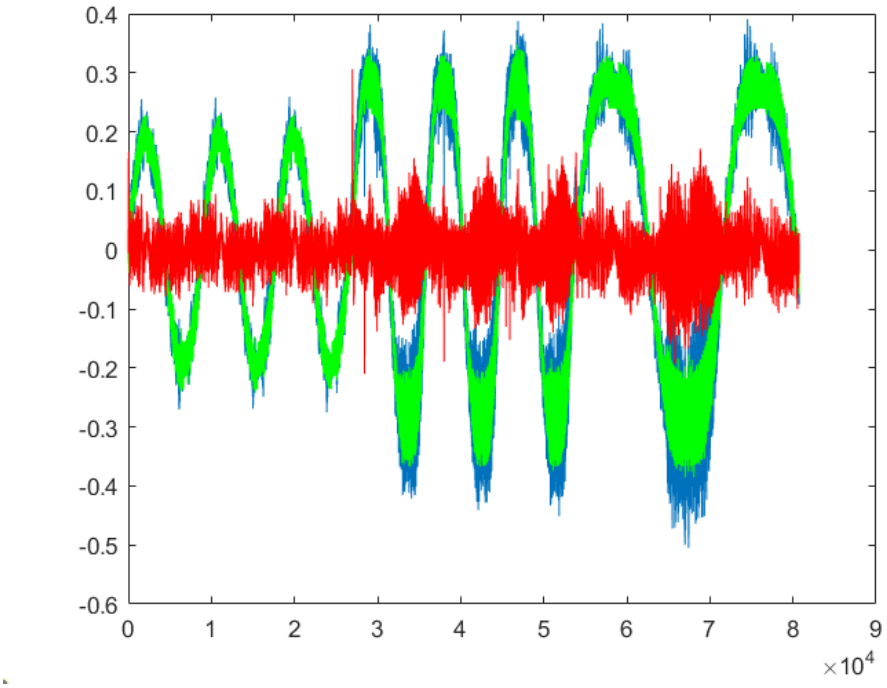

Figure 3: Motor model with no filtering

The parameter resulting from the least square regressor algorithm with data filter at 10Hz were the following:

$$J = 0.0038 \quad d = -0.0038 \quad f = 0.0176 \quad mb = -0.0296 \quad v = 0.0046$$

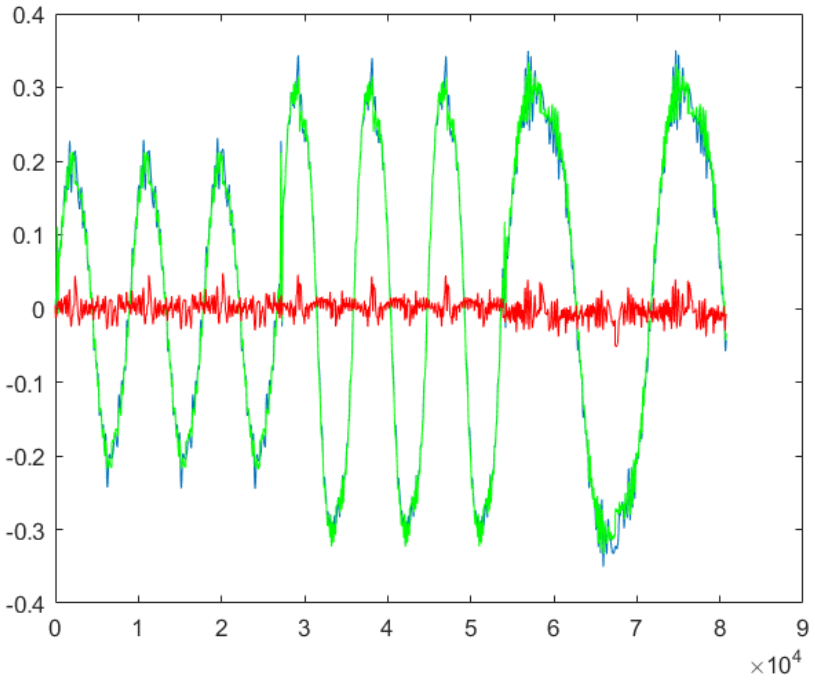

Figure 4: Motor model applying filtering at 10 Hz

2 Homework 2

2.1 Digital controller implementation

Description: Synthesize your best position controller using SISOTool and loop shaping techniques, convert your controller to digital domain using the c2d function, implement your controller, use the AnalogFilter classes and compare results

For the controllers design the following motor was assumed: $I = 0.000506, \quad F = 0.001$

$$M = \frac{1}{Is^2 + Fs} \quad M(s) = \frac{1976}{s^2 + 1.976s}$$

2.2 PD controller

$$PD(s) = \frac{25.64s + 300}{s + 1200}$$

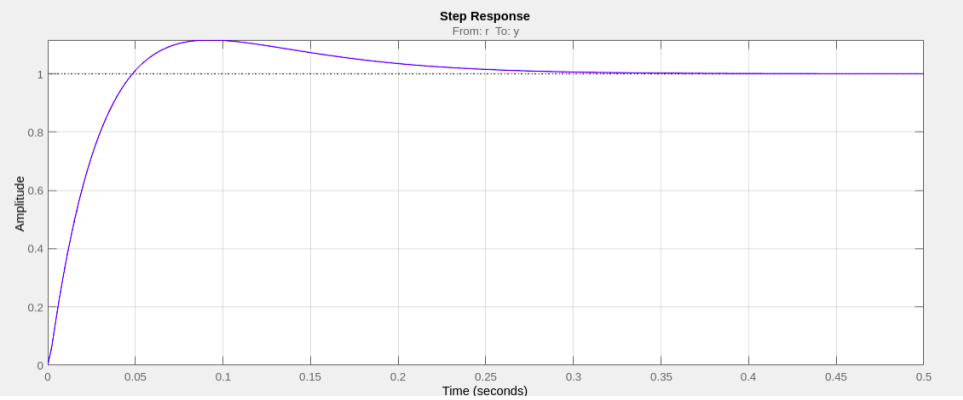

Figure 5: PD: Step response from SISOtool

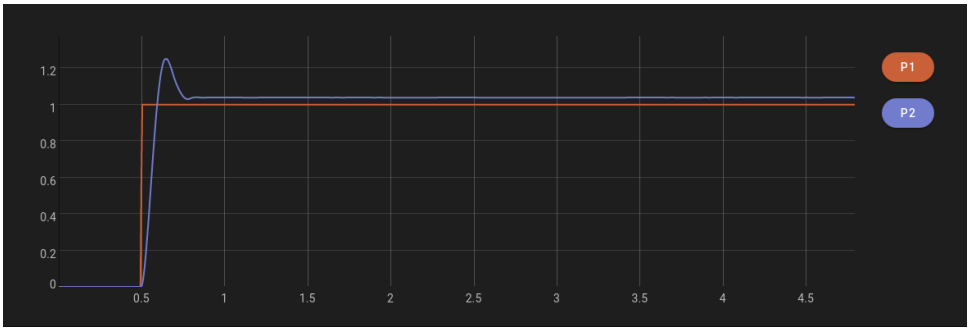

Figure 6: PD: Step response using AnalogFilter

Discretization using c2d, the method used was Tustin, sampling time 5 ms

$$PD(z) = \frac{19.78z - 19.67}{z - 0.5385}$$

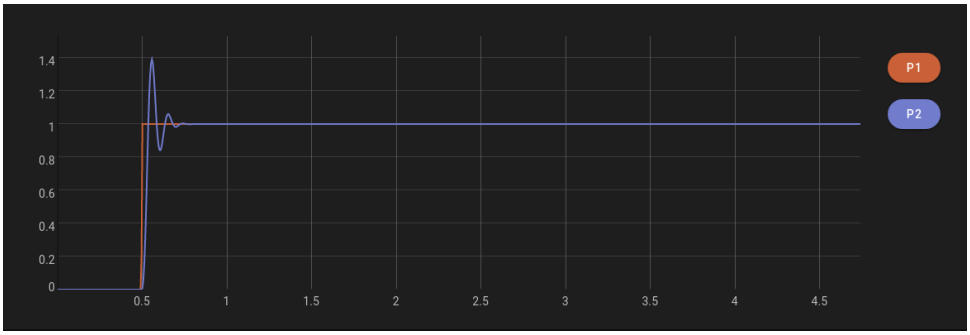

Figure 7: PD: Step response using DigitalFilter

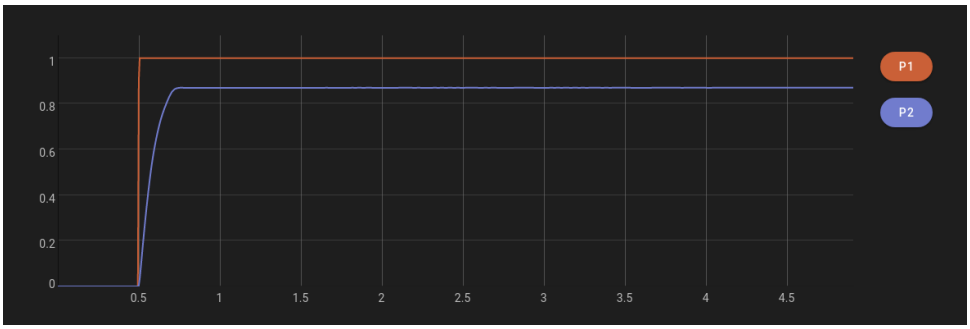

Figure 8: PD: Step response using difference equations

2.3 PID controller, hight disturbance du2y

$$PID_{HighDist}(s) = \frac{5.206s^2 + 75.93s + 55.09}{s^2 + 338.3s}$$

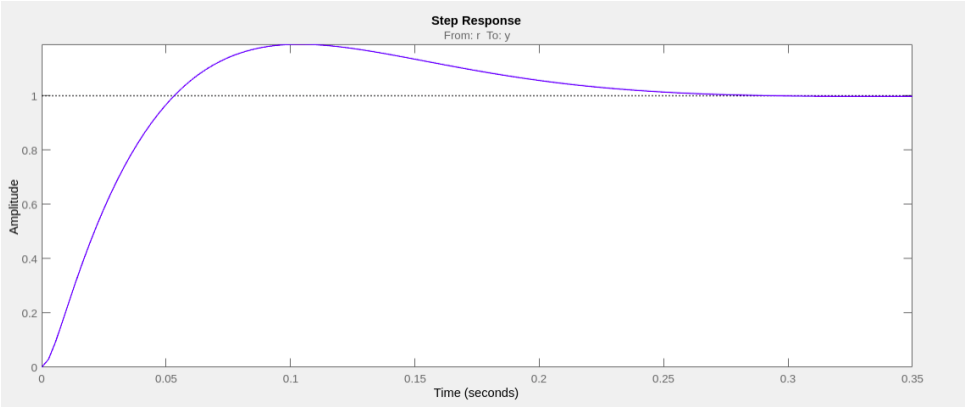

Figure 9: PID High Dist: Step response from SISOtool

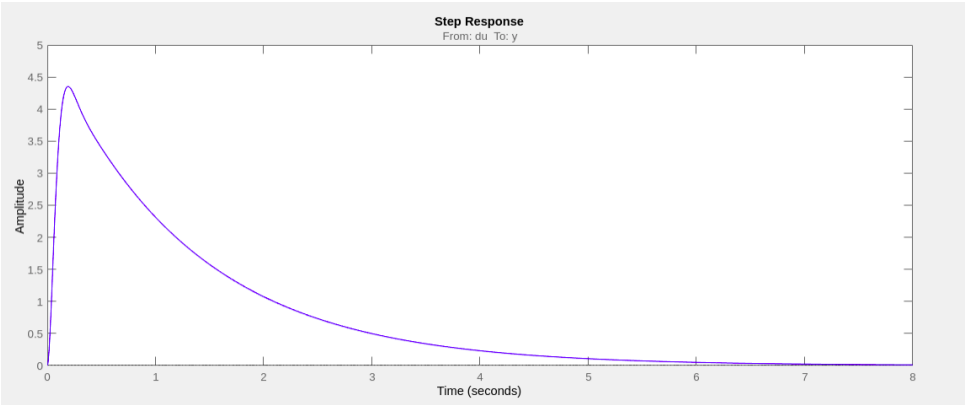

Figure 10: PID High Dist: step response du2y

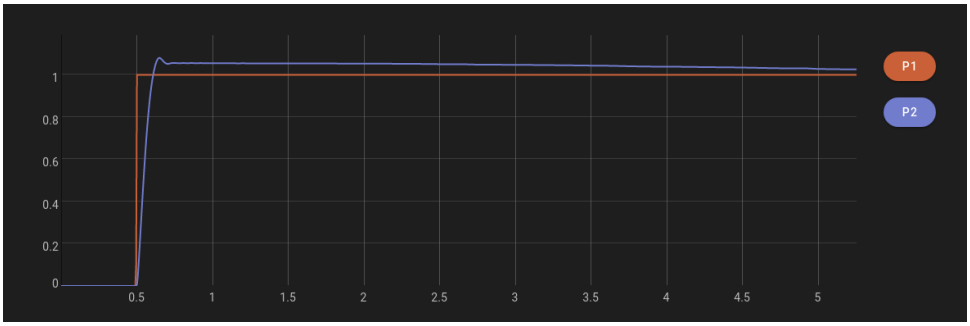

Figure 11: PID High Dist: Step response using AnalogFilter

Discretization using c2d, the method used was Tustin, sampling time 5 ms

$$PID_{HighDist}(z) = \frac{4.818z^2 - 9.6z + 4.783}{z^2 - 1.844z + 0.844}$$

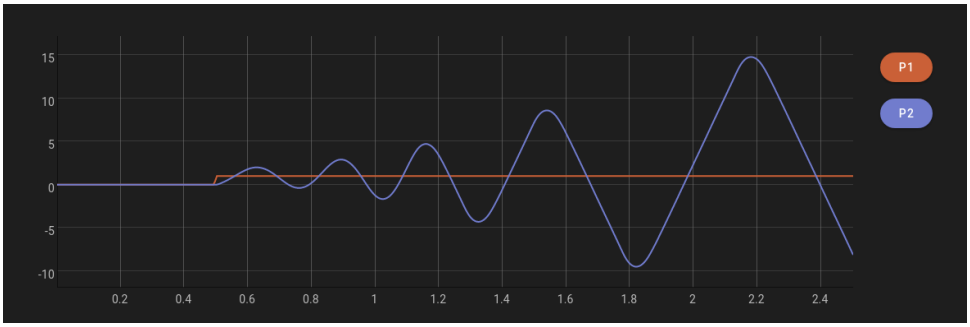

Figure 12: PID High Dist: Step response using DigitalFilter

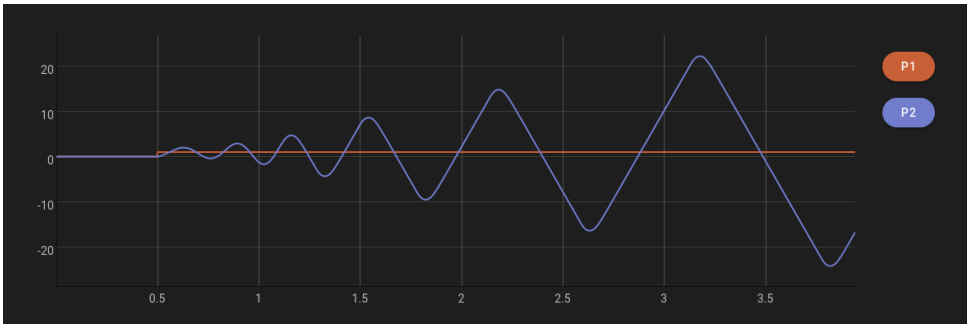

Figure 13: PID High Dist: Step response using difference equations

2.4 PID controller, low disturbance du2y

$$PID_{LowDist}(s) = \frac{24.64s^2 + 253.4s + 646.4}{s^2 + 800s}$$

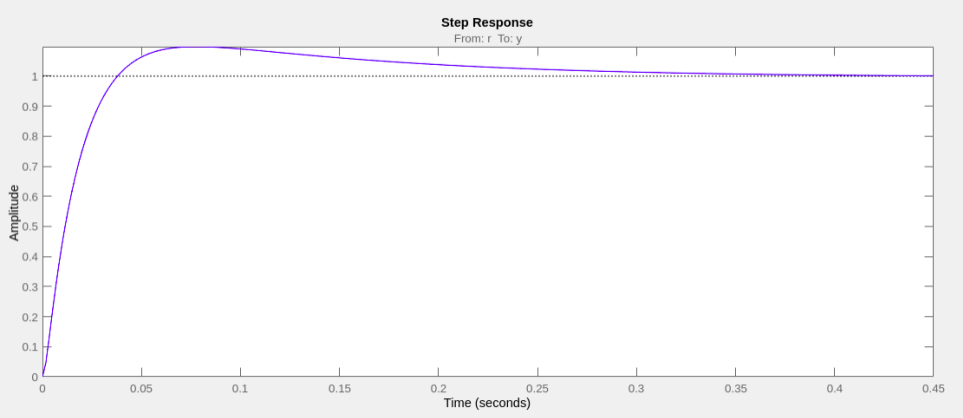

Figure 14: PID Low Dist: Step response from SISOtool

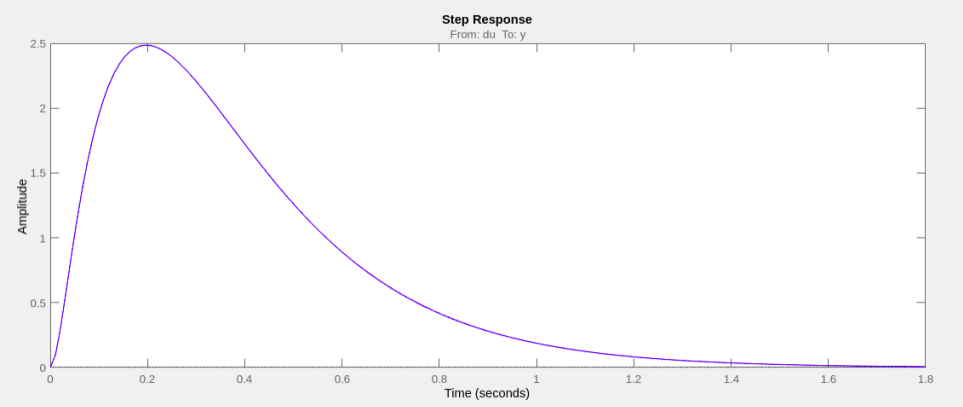

Figure 15: PID Low Dist: step response du2y

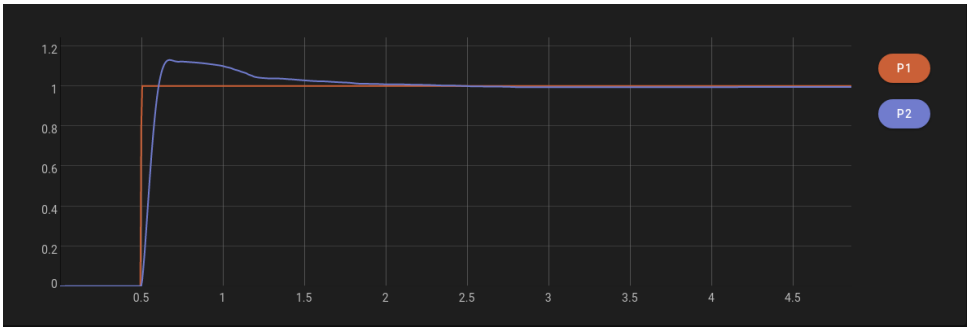

Figure 16: PID Low Dist: Step response using AnalogFilter

Discretization using c2d, the method used was Tustin, sampling time 5 ms

$$PID_{LowDist}(z) = \frac{20.58z^2 - 41.06z + 20.48}{z^2 - 1.667z + 0.6667}$$

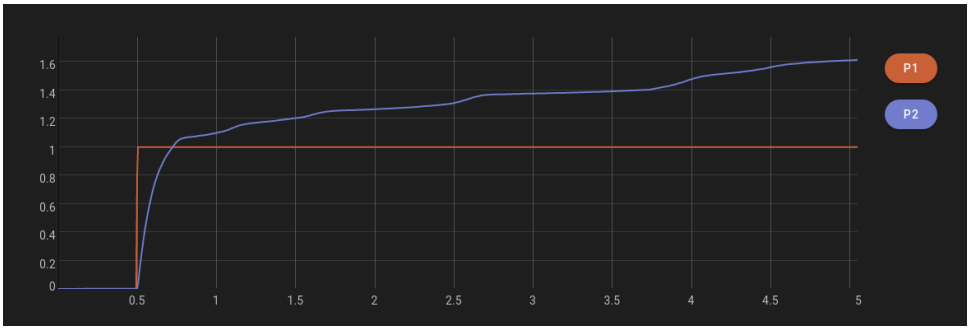

Figure 17: PID Low Dist: Step response using DigitalFilter

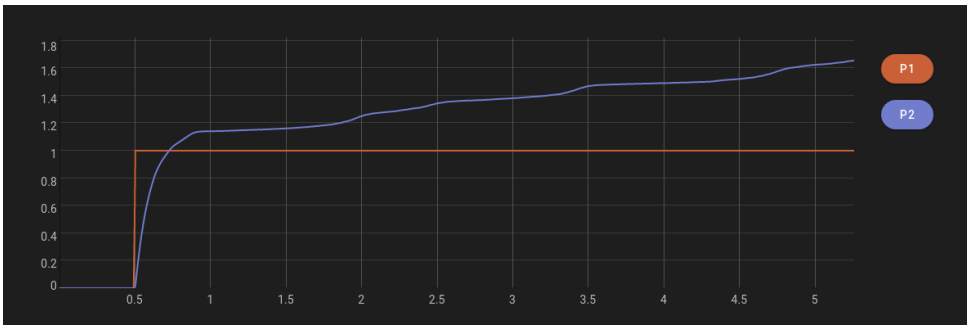

Figure 18: PID Low Dist: Step response using difference equations