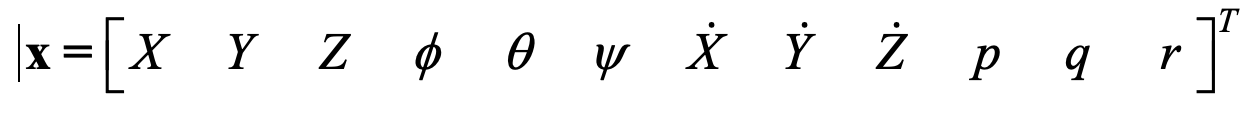
**Error Response with PID controller**

1. **Background**

**State space equation**

A picture containing logo

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A picture containing background pattern

Description automatically generated

A picture containing text

Description automatically generated

Y = C**x** + D**v**

Text

Description automatically generated with low confidence

Block diagram of system:

Diagram

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Referring to the above figure,

Text

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In the above equation, are parameters to find and G(s) will be obtained from ss2tf(A, B,C,D).

Plant transfer functions (G(s)) from MATLAB ss2tf function:

**For z position and psi**

For step input,

Where *a* is a constant.

For z position *a* is 1.25

For psi *a* is 58.82

**For x and y position**

Where *b* is a constant

For step input,

For x position *b* is

For y position *b* is -

1. **Error response for observed variables with controller**

Analysis: Take gain values (Kp, Ti and Td) as 1 and look at error response by taking inverse Laplace transform of equation 1 (for z and psi) or 2 (for x and y) on MATLAB.

1. **Proportional controller**

Gain values:

Kp = 1

Ti = 0

Td = 0

For z position

Unstable

For psi

Unstable

For y position

Unstable

For x position

Unstable

1. **Derivative controller**

Gain values:

Kp = 0

Ti = 0

Td = 1

For z position

stable

For psi

stable

For y position

Unstable

For x position

Unstable

1. **Integral controller**

Gain values:

Kp = 0

Ti = 1

Td = 0

For z position

Unstable

For psi

Unstable

For y position

Unstable

For x position

Unstable

1. **Proportional Derivative Controller**

Gain values:

Kp = 1

Ti = 0

Td = 1

For z position

stable

For psi

stable

For y position

Unstable

For x position

Unstable

1. **MATLAB code**

% Define TF for observed variables with PID control

Kp =1;

Ti = 0;

Td = 0;

a = 1.25;

b = -1897.48;

c = 1897.48;

d = 58.82;

EZsPID = s^2/(s^3 + a\*Td\*s^2 + a\*Kp\*s + a\*Ti);

EYsPID = s^4/(s^5 + b\*Td\*s^2 + b\*Kp\*s + b\*Ti);

EXsPID = s^4/(s^5 + c\*Td\*s^2 + c\*Kp\*s + c\*Ti);

EPsPID = s^2/(s^3 + d\*Td\*s^2 + d\*Kp\*s + d\*Ti);

% take inverse laplace transform and observe

disp("==========================");

disp("Z")

pretty(simplify(ilaplace(EZsPID)));

disp("Y")

pretty(simplify(ilaplace(EYsPID)));

disp("X")

pretty(simplify(ilaplace(EXsPID)));

disp("P")

pretty(simplify(ilaplace(EPsPID)));

disp("==========================");

1. **Simulation Result**

All simulations below use both LQR and PD controller. Effect of PD control on different variables has been analyzed. Blue line is the result of using standalone LQR control and red line is a combination of LQR and PD controllers.

**PD control on all 4 observed variables (x, y, z and psi)**

**Kp =1, Td = 1 for all 4 variables**

**Simulation time: 10 seconds**

A picture containing chart

Description automatically generated

**Kp =1, Td = 1 for all 4 variables**

**Simulation time: 100 seconds**

**Calendar

Description automatically generated**

**PD control only on z and psi**

**Kp =1, Td = 1 for all z and psi**

**Simulation time: 10 seconds**

A picture containing calendar

Description automatically generated

**Kp =1, Td = 1 for all z and psi**

**Simulation time: 100 seconds**

Calendar

Description automatically generated

**PD control only on all x and y**

**Kp =1, Td = 1 for all x and y**

**Simulation time: 10 seconds**

A picture containing chart

Description automatically generated

**Kp =1, Td = 1 for all x and y**

**Simulation time: 100 seconds**

Calendar

Description automatically generated