Advanced Control Engineering I

3. Exercise

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Task 1

- **Objective**: Design a PID-controller.
- **System Specification**: Use a linear drive with mass $m = 1$ with the force $F(t)$ as input and the position of the cart $y(t)$ as output. The system can be described as:

$$G(s) = \frac{1}{s^2}$$

- **Tasks**:
  - Use the Matlab PID-tuner

```
>> pidTuner(G)
```

    to get an appropriate PID controller to control the system (find out the difference of an agressive and an robust controller)
  - Use a prefilter to design to smooth an input step and use the smooth trajectory as a feed-forward. What impact do the eigenvalues have?

Task 2

- **Objective**: Design a PID-controller.
- **System Specification**: Now we use a system $q \neq 0$:

$$G(s) = \frac{s+1}{s^2}$$

- **Tasks**:
  - Use the Matlab PID-tuner

```
>> pidTuner(G)
```

    to get an appropriate PID controller to control the system
  - Use a prefilter to design to smooth an input step and use the smooth trajectory as a feed-forward.
  - Use the flatness based approach to calculate the reference signals u_{ref} and w_{ref} by means of the flat output η and its derivatives.
  - Use a trajectory generator and a feed-forward to go from $y_0 = 0$ to $y_T = 3$ within $T = 2$.

Task 3

- **Objective**: Design a PID-controller.
- **System Specification**: Now we use a not phase-minimal system (i.e. the inverse is not stable):

$$G(s) = \frac{10\,(-s+3)}{(s+1)\,(s+2)\,(s+5)}$$

- **Tasks**:
  - Use the Matlab PID-tuner

```
>> pidTuner(G)
```

    to get an appropriate PID controller to control the system
  - Use the flatness based approach to calculate the reference signals u_{ref} and w_{ref} by means of the flat output η and its derivatives.
  - Use a trajectory generator and a feed-forward to go from $y_0 = 0$ to $y_T = 3$ within $T = 2$.

Task 4

- **Objective**: Trajectory design
- **System Specification**: Now we use a system which is not stable:

$$G(s) = \frac{10\,(s+3)}{(s+1)\,(s+2)\,(s-5)}$$

- **Tasks**:
  - Use the Matlab PID-tuner

```
>> pidTuner(G)
```

    to get an appropriate PID controller to control the system
  - Use the flatness based approach to calculate the reference signals u_{ref} and w_{ref} by means of the flat output η and its derivatives.
  - Use a trajectory generator and a feed-forward to go from $y_0 = 0$ to $y_T = 1$ within $T = 0.5$.

Task 5

- **Objective**: Trajectory design

- **System Specification**: The nonlinear dynamic of a Ball-in-Tube experiment:

$$m\,\ddot{x} = k_L \left(\frac{k_V}{A_{SP}}\,\omega - \frac{A_B}{A_{SP}}\,\dot{x} \right)^2 - m\,g$$
$$u = \frac{1}{k_F}\left(T_F\,\dot{\omega} + \omega\right)$$

  The parameters are given by:

$$\begin{aligned} k_L &= 2 \cdot 10^{-5}; & k_V &= 1.27 \cdot 10^{-4}; \\ m &= 2.7 \cdot 10^{-3}; & A_B &= 0.0013; \\ A_T &= 0.0015; & A_{SP} &= A_T - A_B; \\ T_F &= 1.6; & k_F &= 140; \\ g &= 9.81; \end{aligned}$$

- **Tasks**:
  - Implement the nonlinear model in Matlab/Simulink.
  - Tune a PID-Controller to stabalize the ball
  - Use a trajectory generator and a feed-forward to change the height of the ball in the tube.
- **Note**: The position x is a flat output and can be used to compute the feed forward.