Advanced Control Engineering I

2. Exercise

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Task 1

- **Objective**: 2DoF Control for a linear crane
- **System Specification**: The mathematical nonlinear model of the crane is calculated in the slides and is given by:

$$\begin{aligned} M\,\ddot{D}(t) &= F(t)\,\sin(\theta(t)) + u(t) \\ m\,(\ddot{y}_1(t) - g) &= -F(t)\,\cos(\theta(t)) \\ m\,\ddot{y}_2(t) &= -F(t)\,\sin(\theta(t)) \\ y_1(t) &= \ell\,\cos(\theta(t)) \\ y_2(t) &= D(t) + \ell\,\sin(\theta(t)) \end{aligned}$$

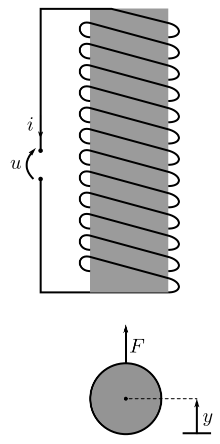
  Furthermore, the linearized model for trajectory planning can be used from the slides:

$$\begin{aligned} M\,\ddot{D}(t) &= m\,g\,\theta(t) + u(t) \\ m\,\ddot{y}(t) &= -m\,g\,\theta(t) \\ y(t) &= D(t) + \ell\,\theta(t) \end{aligned}$$

- **Tasks**:
  - Simulate the linearized system in Matlab/Simulink
  - Implement a PID-Controller to control the system
  - Create a 2DoF control structure and use a pre-filter with all its poles at -2 to satisfy the smoothness of the reference trajectory
  - Use a polynomial trajectory instead of the pre-filter by the flatness based approach

Task 2

- **Objective**: Magnetic levitation



- **System Specification**: The mathematical nonlinear model of the test rig is given by:
  Model: Neglect of the electrical subsystem

  $$m\ddot{y} = F(t) = \lambda \frac{i^2}{(y - s_0)^2} - mg$$

  Parameter:

  - m . . . mass
  - g . . . acceleration due to gravity
  - s_0 . . . nominal air gap
  - λ . . . proportionality factor

  Variables:

  - y . . . ball displacement
  - i . . . coil current (control variable)
  - $F(t)$ . . . total force on ball

- **Tasks**:
  - Simulate the nonlinear system in Matlab/Simulink
  - Implement a PID-Controller to control the system
  - Use a polynomial trajectory by the flatness based approach

- **Note**: The flat output can also be found for the nonlinear model pretty easily

Task 3

- **Objective**: Ball-in-Tube
- **System Specification**: The mathematical nonlinear model of the test rig is given by:
  Model: Neglect of the electrical subsystem

$$
\begin{aligned}
m\ddot{y} &= k_L \left(\frac{K_V\,\omega - A_B\,\dot{y}}{A_{AG}} \right)^2 - m\,g \\
T\,\dot{\omega} &= -\omega + k_F\,u
\end{aligned}
$$

  Parameter:

  - $m \ldots$ mass of the ball
  - $g \ldots$ acceleration due to gravity
  - $k_L \ldots$ proportionality between the air's flow rate and the fan speed
  - $k_V \ldots$ linear correlation between fan speed to air flow
  - $A_B \ldots$ cross-sectional area of the ball
  - $A_T \ldots$ cross-sectional area of the tube
  - $A_{AG} = A_T - A_B \ldots$ rest area at the ball position
  - $T \ldots$ Time constant to describe PT1 behavior of fan
  - $k_F \ldots$ proportionality between duty cycle and fan speed

  Variables:

  - $y \ldots$ ball displacement
  - $\omega \ldots$ fan speed
  - $u \ldots$ duty cycle as control input $u \in [0, 1]$

- **Tasks**:
  - Simulate the nonlinear system in Matlab/Simulink
  - Implement a PID-Controller to control the system
  - Use a polynomial trajectory by the flatness based approach
- **Note**: The flat output can also be found for the nonlinear model pretty easily