Robotics – Symbolic Control

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Model 1: integrator model

Consider a mobile robot modeled as a unicycle with disturbances:

$$\begin{cases} x_1(t+1) &= x_1(t) + \tau\left(u_1(t) + w_1(t)\right) \\ x_2(t+1) &= x_2(t) + \tau\left(u_2(t) + w_2(t)\right) \end{cases}$$

where τ is the sampling period, with state and input constraints:

$$\mathbb{X} = [-10, 10] \times [-10, 10],\ \mathbb{U} = [-1, 1] \times [-1, 1].$$

and disturbances:

$$\mathbb{W} = [-0.05, 0.05] \times [-0.05, 0.05].$$

Model 2: unicycle model

Consider a mobile robot modeled as a unicycle with disturbances:

$$\begin{cases} x_1(t+1) &= x_1(t) + \tau\left(u_1(t)\cos(x_3(t)) + w_1(t)\right) \\ x_2(t+1) &= x_2(t) + \tau\left(u_1(t)\sin(x_3(t)) + w_2(t)\right) \\ x_3(t+1) &= x_3(t) + \tau\left(u_2(t) + w_3(t)\right)(\mathrm{mod}2\pi) \end{cases}$$

where τ is the sampling period, with state and input constraints:

$$\mathbb{X} = [0, 10] \times [0, 10] \times [-\pi, \pi],\ \mathbb{U} = [0.25, 1] \times [-1, 1].$$

and disturbances:

$$\mathbb{W} = [-0.05, 0.05] \times [-0.05, 0.05] \times [-0.05, 0.05].$$

Model 3: robotic manipulator

The model of a two-link planar robotic manipulator is given by

$$x(t+1) = x(t) + \tau f(x(t), u(t))$$

where

$$f(x(t), u(t)) = \begin{bmatrix} \dot{\theta}(t) \\ M(\theta(t))^{-1}\big(u(t) - c(\theta(t), \dot{\theta}(t)) - g(\theta(t))\big) \end{bmatrix}$$

with $x = [\theta, \dot{\theta}]$ with $\theta \in \mathbb{R}^2$ represents the joint angles, $u \in \mathbb{R}^2$ represents the joint torques and τ is the sampling period. The numerical values are given by:

$$m_1 = m_2 = 1.0 \text{ kg}, \quad \ell_1 = \ell_2 = 0.5 \text{ m}, \quad g = 9.81 \text{ m/s}^2.$$

Objectives

Objective 1: Control

- Create a scenario and define a control objective.
- Classical control: Reference trajectory.
- Symbolic control: Regular language or LTL specification.
- Reinforcement learning: Reward function.

Objective 2: Integration with Natural Language Specifications

- Input: User gives a command in Darija (e.g., "ŝır l l-yamin u tjanab l-haït" $\rightarrow$ "go to the right while avoiding the wall").
- Translation: Darija $\rightarrow$ English.
- Formalization: English $\rightarrow$ temporal logic specification (e.g., LTL).
- Controller synthesis.
- Execution: Simulate and visualize.

Objective 3: From model-based to data-driven

- Data-driven robots (adaptation of the proposed four control techniques to robots with unknown models) and comparison with

Deliverables

- Report, presentation and code.
- Theoretical analysis, implementation and visualization.