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Tutorial for Cyber-Physical Systems - Hybrid Models

Exercise Sheet 1

Exercise 1: Terminology

In your own words, *shortly* describe what the following terms mean. In particular, state the difference.

(a) cyber-physical system

(b) embedded system

(c) dynamical system

(d) hybrid system

(e) transition system

(f) system model

Exercise 2: Formal approach

The lecture follows a formal approach for modeling and analyzing hybrid systems. *Shortly* describe typical advantages and disadvantages of formal approaches.

In particular, comment on the following statement.

> "With a formal model of a system and a positive formal verification result that the specification holds, the system is guaranteed to be safe."

Exercise 3: Bouncing ball

Consider the bouncing ball model from Figure 2.9 on page 28. Provide an *equivalent* hybrid automaton model for the bouncing ball with two locations/modes. In one location, the ball should be falling, in the other location it should be rising.

Exercise 4: State reachability

Use the rules given in Definition 8 on page 23 in the script to reason about the reachable states of the following examples.

(a) Consider the hybrid automaton from Example 9 on page 23 in the script.

(i) Provide the set of reachable states at the time point $t = 1.5$.

(ii) Provide the set of reachable states at the time point $t = 6$.

(iii) Show the reachability of a state where $x = 0$ at the time point $t = 1.5$.

(iv) Provide a run where a state with $x = 4$ occurs at exactly 20 time points.
Hint: Describe a run $\sigma_0 \to \sigma_1 \to \cdots$ by constraints over σ_i.

(b) Consider the hybrid automaton from Example 10 on page 25 in the script.

(i) Instantiate the rules $\texttt{Rule}_{\texttt{discrete}}$ and $\texttt{Rule}_{\texttt{time}}$ (as for Example 9 on page 24).

(ii) Provide the set of reachable states at the time point $t = 4$.

(iii) Show the reachability of a state with $x = 2, y = 2$.
It is sufficient to show a run (no inference proof required).

Exercise 5: (optional[1]) Initial states of NFA
Show that having only one initial state is no restriction for an NFA.

[1]The exercise is not closely related to the course. It should be regarded with low priority.