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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. In one location the ball should be falling down, in the other location it should be going up.

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 $\sigma_0 \rightarrow \sigma_1 \rightarrow \dots$ by constraints over σ_i .
- (b) Consider the hybrid automaton from Example 10 on page 25 in the script.
 - (i) Instantiate the rules `Ruleediscrete` and `Ruleetime` (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).