Embedded Systems

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Modeling: Hybrid systems

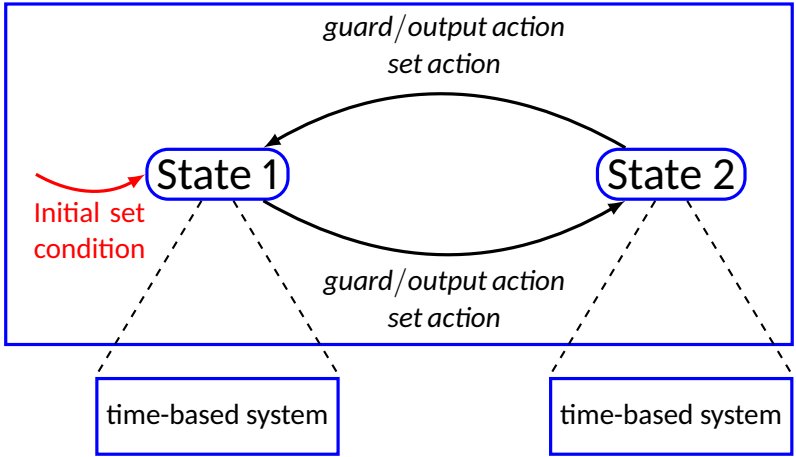
Introduction

- Most of the systems have both continuous and discrete behavior
- Continuous behavior can be modeled by ODE and discrete behavior by FSM
- Need to have separate modeling scheme to describe both the behavior
- Usually, states in discrete modelling are enhanced with time based behavior

Hybrid systems: example

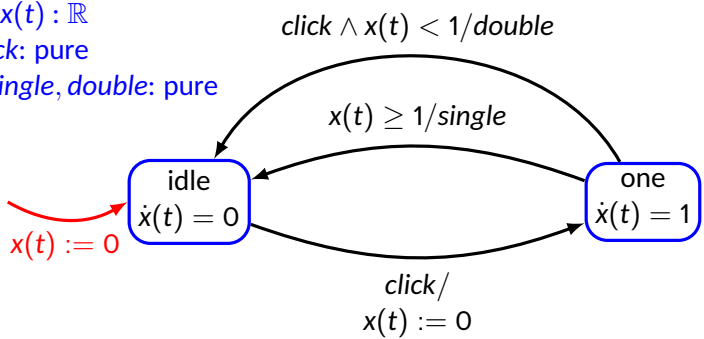
- Digital controller
  - Thermostat
  - Automatic cruise control
  - Aircraft autopilot
- Phased operation
  - Bouncing ball
  - Biological cell growth
- Multiagent systems
  - Interaction of robots
  - Ground and air transportation systems

Timed automata

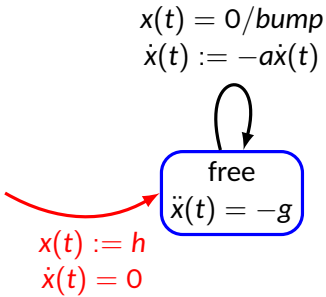


Double click detector

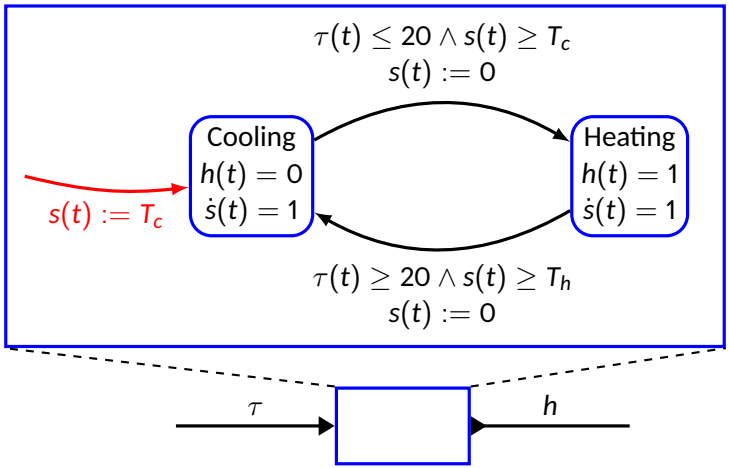
variable: $x(t) : \mathbb{R}$
input: *click*: pure
output: *single*, *double*: pure



Bouncing ball

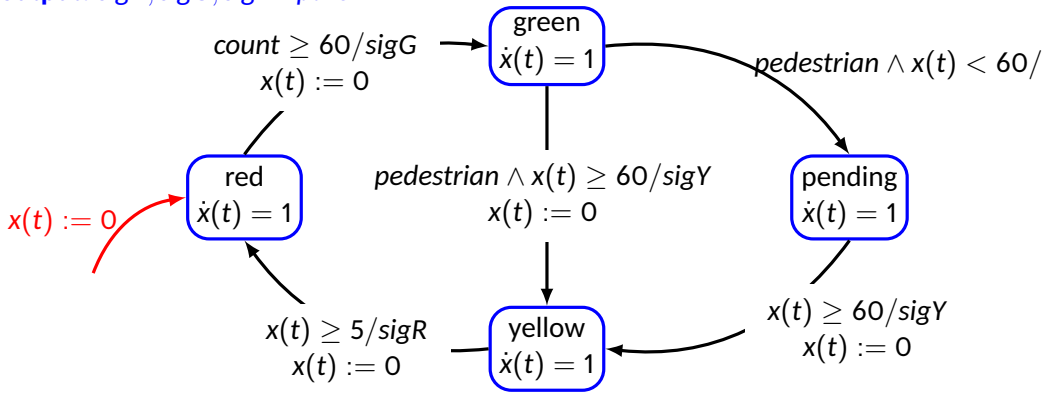


Thermostat

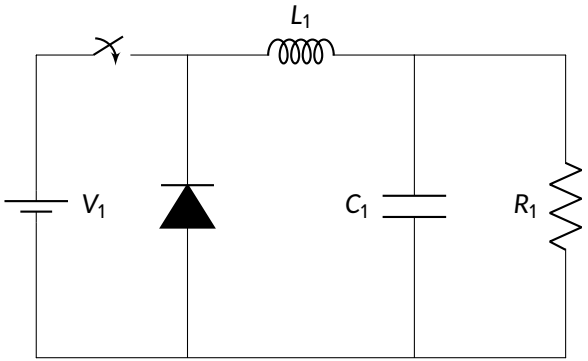

$\tau(t) \leq 20 \wedge s(t) \geq T_c$
$s(t) := 0$
Cooling
$h(t) = 0$
$\dot{s}(t) = 1$
Heating
$h(t) = 1$
$\dot{s}(t) = 1$
$s(t) := T_c$
$\tau(t) \geq 20 \wedge s(t) \geq T_h$
$s(t) := 0$
τ
h

Example: pedestrian crosswalk

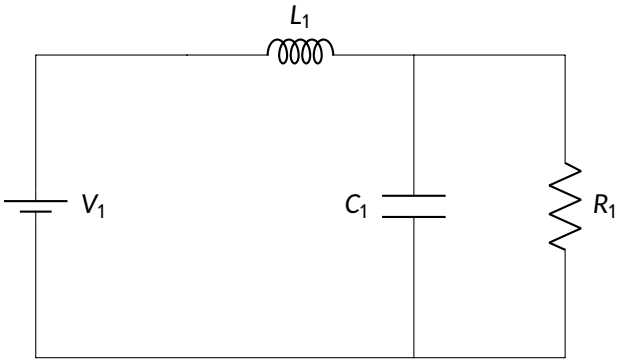
variable: $count : \{0, 1, \ldots, 60\}$
input: $pedestrian : pure$
output: $sigY, sigG, sigR : pure$



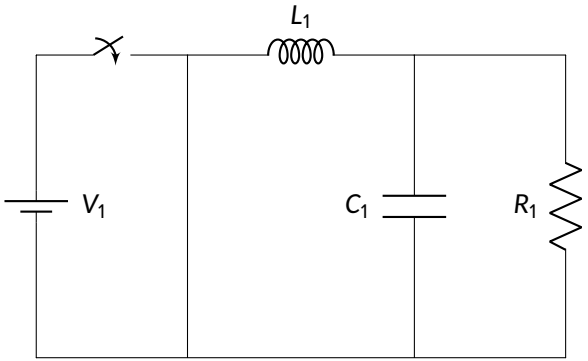
Buck converter



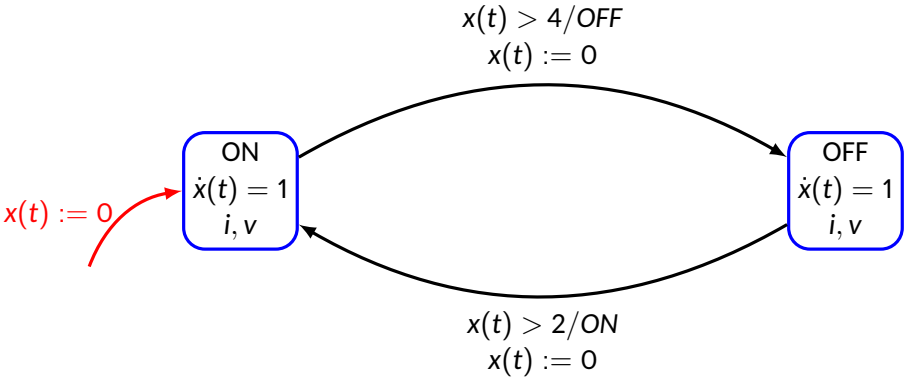
Buck converter: Mode 1



Buck converter: Mode 2



Buck converter: hybrid automata



Automatic cruise control

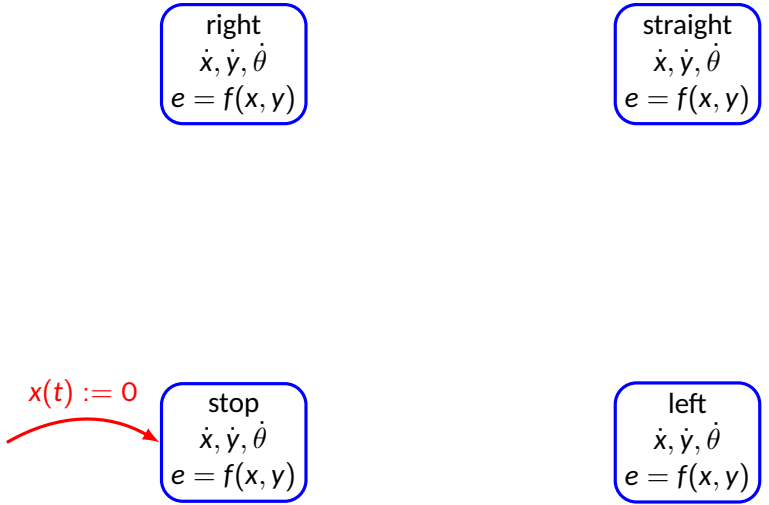
right
$\dot{x}, \dot{y}, \dot{\theta}$
$e = f(x, y)$

straight
$\dot{x}, \dot{y}, \dot{\theta}$
$e = f(x, y)$

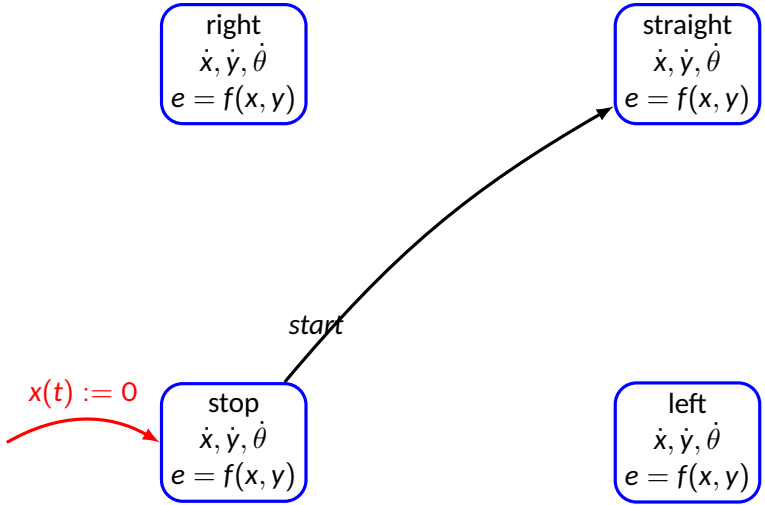
stop
$\dot{x}, \dot{y}, \dot{\theta}$
$e = f(x, y)$

left
$\dot{x}, \dot{y}, \dot{\theta}$
$e = f(x, y)$

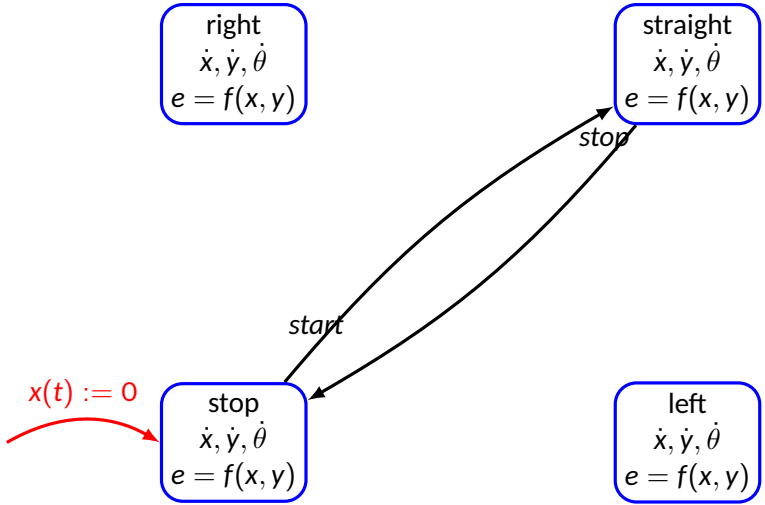
Automatic cruise control



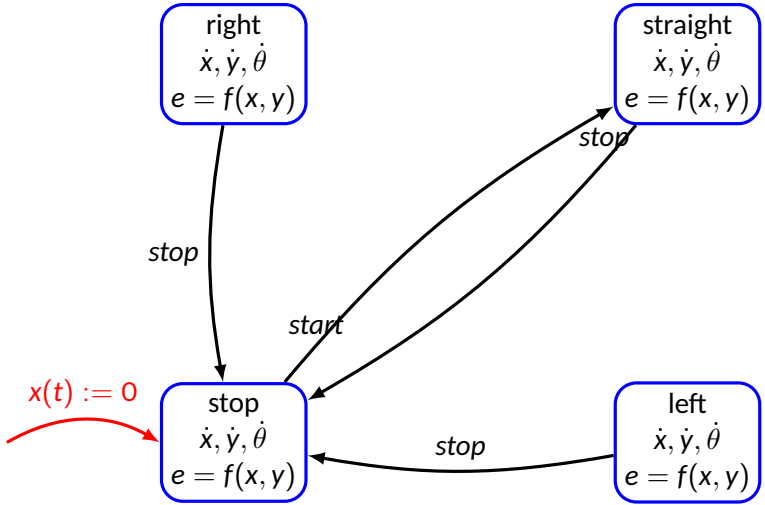
Automatic cruise control



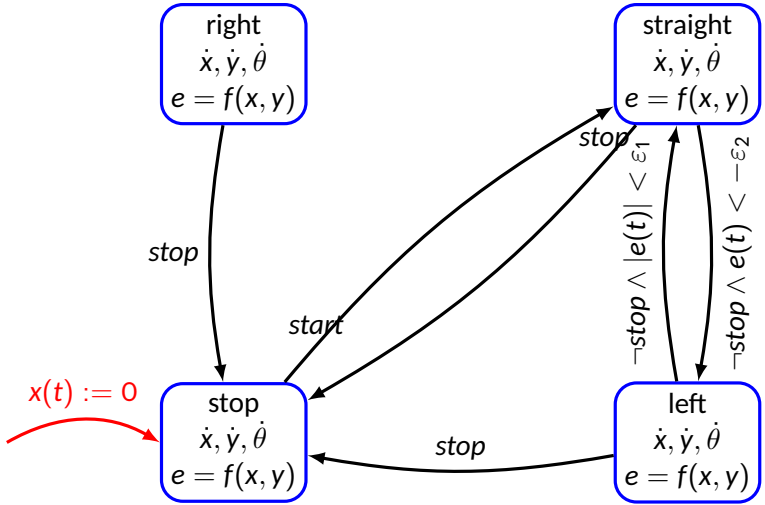
Automatic cruise control



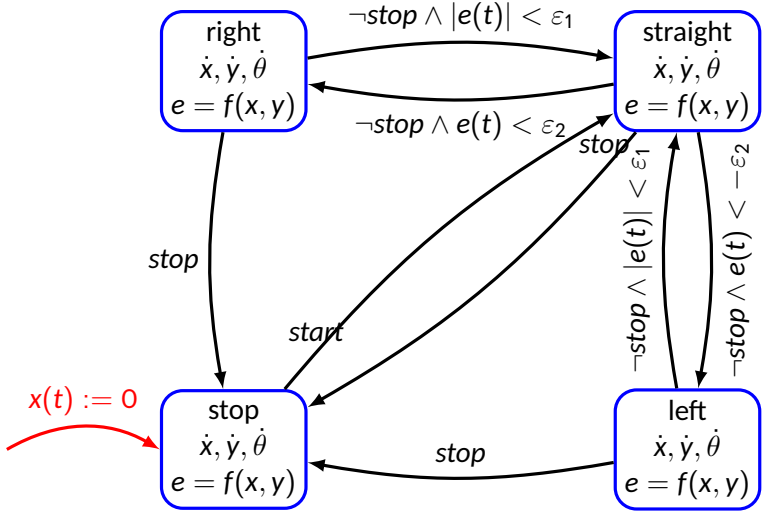
Automatic cruise control



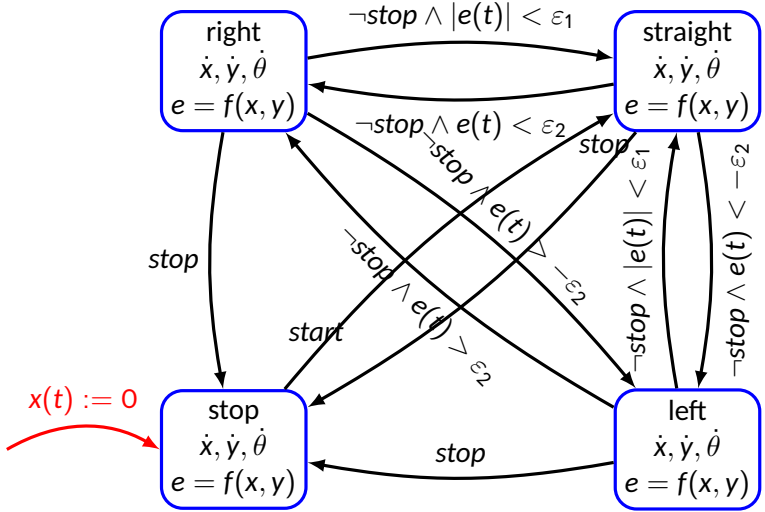
Automatic cruise control



Automatic cruise control



Automatic cruise control



Summary

- Hybrid systems provide a bridge between continuous and discrete dynamics
- Hierarchical description of the system
- Each mode is time-based operation, that is, refinement of state
- State machine to describe mode transition, refinement of state provides continuous dynamics