# HyComp: model checking hybrid systems

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Hybrid systems

Cyber-physical systems

- Discrete controller with some modes: (in)finite state automaton; e.g. electronic controller.
- `continuous` variables with some behaviour w.r.t. time, physical phenomena e.g. braking car, water pump, temperature.

- in general model checking on hybrid systems is **undecidable**.
- many sub-classes
  - decidable: *rectangular*, *singular*;
  - undecidable: *linear*;

discrete

time
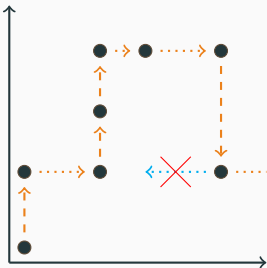
Hybrid Automata

- Explicit graph representation of discrete states/modes (nodes) and transitions (edges);

- Symbolic representation of linear temporal aspects via polytopes (N dimensional polyhedron);

- location invariants,

- transition guards,

- flow: derivative w.r.t time.

HyComp

HyComp introduction
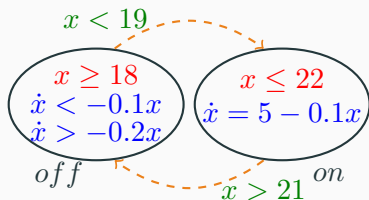
- HYCOMP has been developed in Embedded Systems (FBK) as part of Sergio Mover's PhD.
- Supports the modelling and verification of a network of hybrid automata;
- Supports invariant and LTL properties;
- It encodes the Hybrid model into a "standard" NUXMV model.

HyComp: input language [1/3]

The input language of HYCOMP is called HYDI (Hybrid automata with Discrete interaction).

Overview

- `main` module contains description of the network of automata: processes are `MODULE` instances;
- `main` module contains synchronisation constraints: `EVENT`;
- Symbolic description of infinite transition system using: `INIT`, `INVAR` and `TRANS` to specify initial, invariant and transition conditions.
- `continuous` type variables with `FLOW` conditions,

HyComp adds

- `continuous` variable type;
- all `continuous` vars increase accordingly to their FLOW conditions in timed transitions;
- `time`: built-in `continuous` symbol with flow condition: `der(time) = 1`, can not be used in properties;
- URGENT: freeze time: when one of the URGENT conditions is satisfied only discrete transitions are allowed;

HyComp updates

- `TRANS` constrain the discrete behaviour only,
- `INVAR`: `continuous` allowed in invariants with shape:
  `no_continuous_expr -> convex_continuous_expr`.

HyComp: commands

read and rewrite model

1. hycomp_read_model
2. hycomp_compile_model
3. hycomp_untime_network
4. hycomp_async2sync_network
5. hycomp_net2mono

check specifications

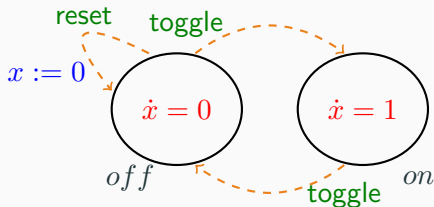- hycomp_check_invar_*
- hycomp_check_ltl*

Example

- write a HYDI model that represents the hybrid automaton in the picture.
- add an asynchronous process that controls the stop-watch using the `toggle` and `reset` commands.

Stopwatch module

```
MODULE StopWatch
DEFINE
  on  := mode = _on;
  off := mode = _off;

VAR
  mode : {_on, _off};
  c : continuous;

EVENT toggle, reset;
FLOW on -> der(c) = 1;
FLOW off -> der(c) = 0;

TRANS EVENT = reset -> next(c) = 0;
TRANS EVENT != reset -> next(c) = c;
TRANS EVENT = toggle -> next(mode) != mode;
```

Controller module

```
MODULE Controller
EVENT toggle, reset;
```

main module

```
MODULE main
VAR
  stopWatch : StopWatch;
  controller : Controller;

SYNC controller, stopWatch EVENTS toggle, toggle;
SYNC controller, stopWatch EVENTS reset, reset;
```

Exercises

Hybrid thermostat

- a thermostat has 2 states: *on* and *off*;
    - if the temperature is below 18 degrees the thermostat switches *on*.
    - if the temperature is above 18 degrees the thermostat switches *off*.
- at every time unit the temperature increases (if *on*) or decreases (if *off*) by 1;
- the thermostat measures the temperature at most ($<$) every max_dt time units.
- the temperature initially is in $[18 - max\_dt; 18 + max\_dt]$.

Verify that the temperature is always in
$[18 - max\_dt; 18 + max\_dt]$

Bouncing ball

- A ball is initially at height 10.
- We let the ball fall and bounce.
- Every time the ball bounces half its speed is lost.
- The gravitational acceleration is 9.8.