Formal Method Mod. 2 (Model Checking)

Laboratory 12

Giuseppe Spallitta
giuseppe.spallitta@unitn.it

Università degli studi di Trento

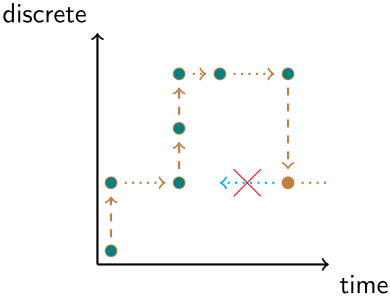
June 7, 2023

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.

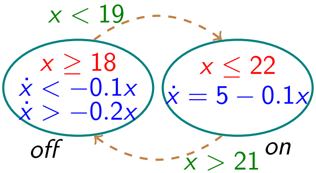
- in general model checking on hybrid systems is **undecidable**.
- many sub-classes
  - decidable: *rectangular*, *singular*;
  - undecidable: *linear*;



Hybrid systems: representation

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.



Outline

1. HyComp
2. Example
3. Homework

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 synchronization 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: input language [2/3]

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: input language [3/3]

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

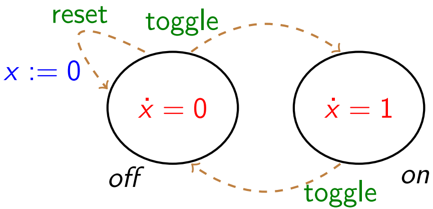
- `hycomp_check_invar_*`
- `hycomp_check_ltl*`

Outline

1. HyComp
2. Example
3. Homework

Example: stopwatch [1/3]

- 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.



Example: stopwatch [2/3]

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;
```

Example: stopwatch [3/3]

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;
```

Outline

1. HyComp

2. Example

3. Homework

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.