Information Systems Analysis

Temporal Logic and Timed Automata

(5)

UPPAAL timed automata

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version 2.3

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Tools for automatic verification of a system

- Which tool to choose?

Tools for automatic verification of a system

Which tool to choose?

tool	description of the system's model	temporal logic
Kronos	language ET-LOTOS	CTL (TCTL)
NuSMV	language SMV	LTL, CTL, RTCTL
Spin	language PROMELA	LTL
UPPAAL	**graphic**	**CTL (TCTL)**
Verus	language Verus	LTL, CTL, RTCTL, PRTCTL

UPPAAL

- What does UPPAAL serve for?
- UPPAAL editor, simulator and verifier
- Declarations in the editor

UPPAAL

What does UPPAAL serve for?

Goal:

- modelling and analysis of real-time systems, including concurrent programs.

Possibilities:

- graphic modelling a system as finite state automata,
- using timed automata (automata with clocks),
- graphic simulating possible runs of the automata,
- specifying some properties of the system as CTL formulas (temporal operators F and G only, without nesting thereof),
- verifying some properties of the model.

UPPAAL

UPPAAL editor, simulator and verifier

Step 1. **Modelling**

— build a model of a system as an automaton or automata.

Step 2. **Simulating**

— check, step by step, whether the model behaves correctly.

Step 3. Write properties of the system as logic CTL formulas.

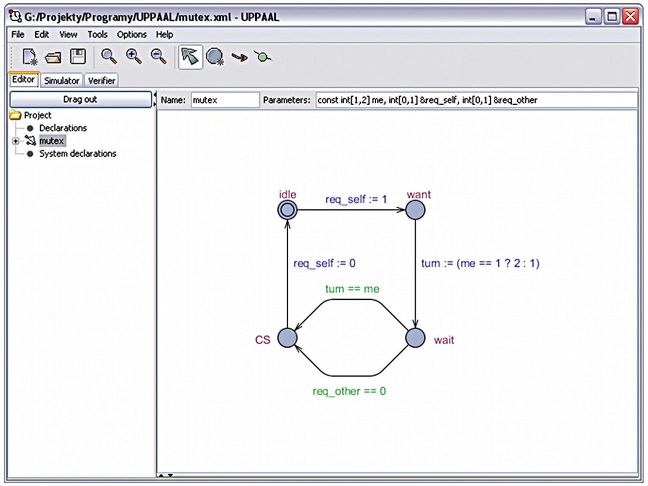
Step 4. **Verifying**

— automatically verify truth of these formulas.

UPPAAL

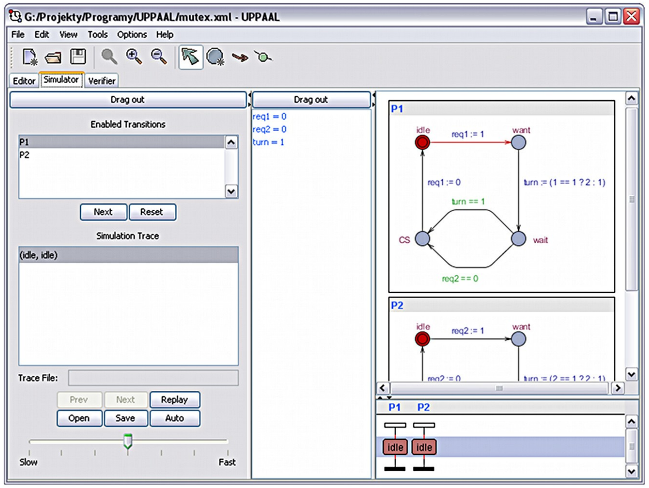
UPPAAL editor, simulator and verifier

Work order in UPPAAL:


G:/Projekty/Programy/UPPAAL/mutex.xml - UPPAAL

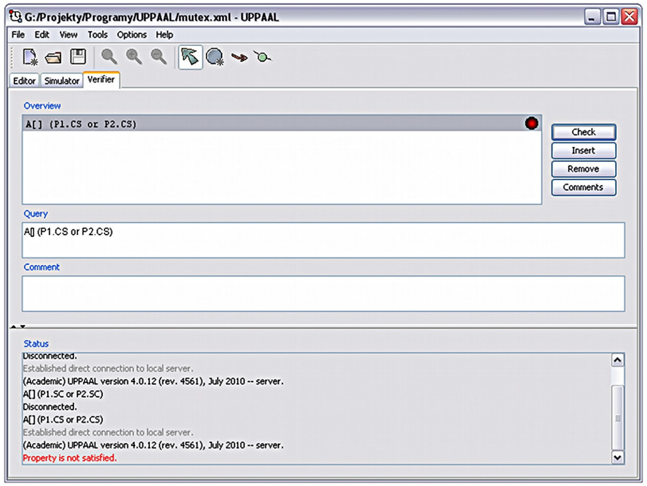
Name: mutex

Parameters: const int[1,2] me, int[0,1] &req_self, int[0,1] &req_other


G:/Projekty/Programy/UPPAAL/mutex.xml - UPPAAL

```
req1 = 0
req2 = 0
turn = 1
```

Simulation Trace: (idle, idle)


G:/Projekty/Programy/UPPAAL/mutex.xml - UPPAAL

Overview: A[] (P1.CS or P2.CS)

Query: A[] (P1.CS or P2.CS)

Status:

```
Disconnected.
Established direct connection to local server.
(Academic) UPPAAL version 4.0.12 (rev. 4561), July 2010 -- server.
A[] (P1.SC or P2.SC)
Disconnected.
A[] (P1.CS or P2.CS)
Established direct connection to local server.
(Academic) UPPAAL version 4.0.12 (rev. 4561), July 2010 -- server.
Property is not satisfied.
```

1) Editor

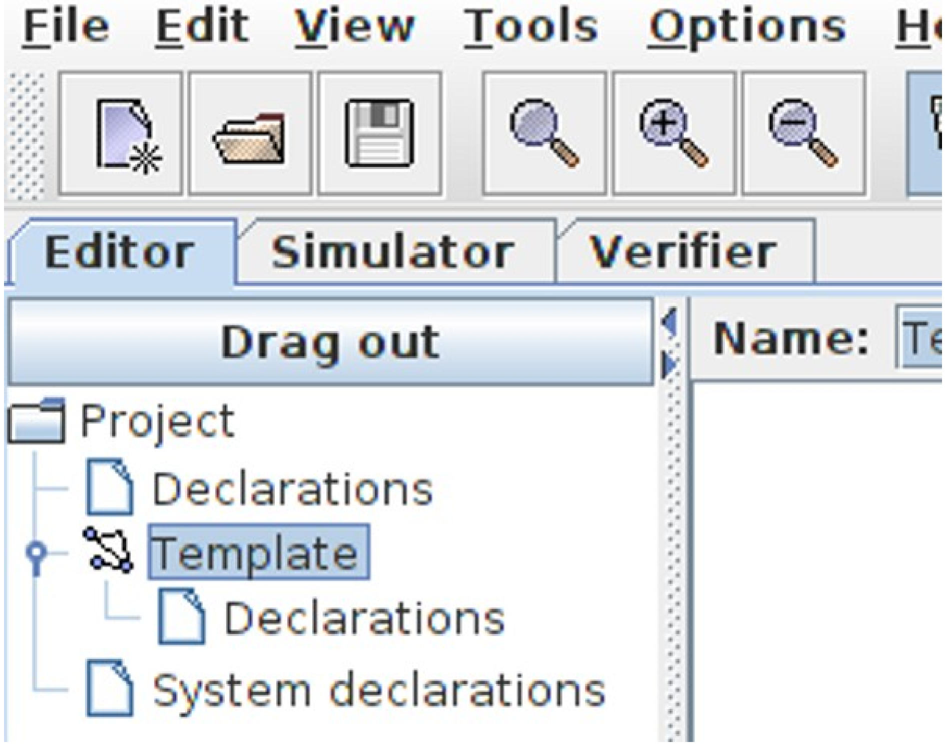
2)Simulator

3) Verifier

Automata in UPPAAL

Declarations in the editor

- Instances of automata are declared in the *System declarations*.
- Global variables are declared in the “upper” *Declarations.*
- Local variables (for one automaton) are declared in the *Declarations* “bellow” this automaton's *template*.



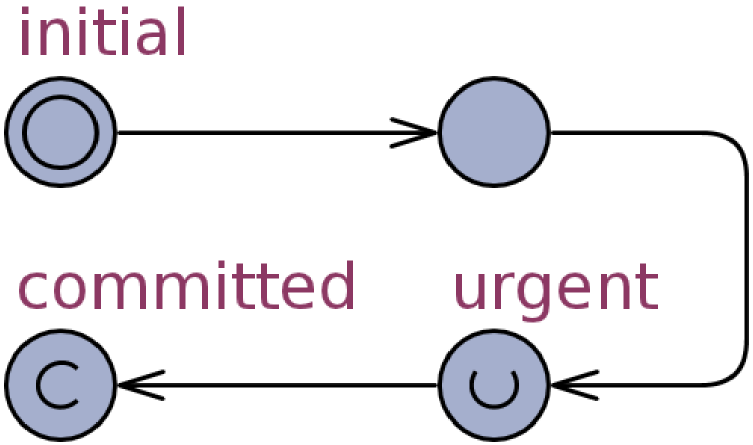
Automata in UPPAAL

- States of the automaton
- Numeric variables and constants
- Description of the automaton's transition
- Channels and synchronisation
- Clock variables

Automata in UPPAAL

States of the automaton:

- normal,
- *initial*,
- *urgent:*
  - time of being in it equals zero (it is left immediately),
- *committed:*
  - time of being in it equals zero (it is left immediately),
  - leaving it has a higher priority than leaving the *urgent* state.



If more than one *committed* state is active, the order of leaving them is random.

Automata in UPPAAL

Numeric variables and constants

Declarations of variables:

- int name;   *//an int variable (range from -32768 to 32768)*
- int [0,9] name;   *//an int variable (range from 0 to 9)*
- int name[3] = {1,2,3}; *//a table of 3 int variables and their values*
- bool name;   *//a logic variable*

Declaration of a constant:

- const int name = 3;   *//an int constant and its value*

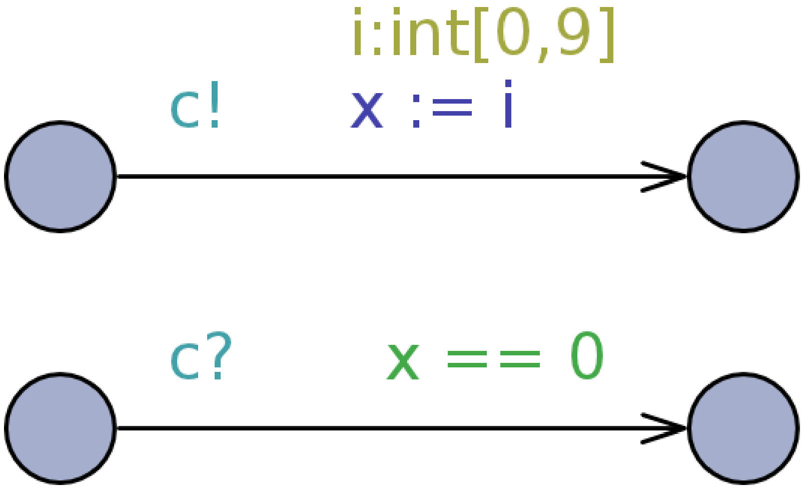
Declaration of a type:

- typedef int [0,9] name;   *//a definition of a type int[0,9]*

Automata in UPPAAL

Description of the automaton's transition:

- *select* – a selection of a variable's value from a given range,
- *guard* – a condition to take the transition,
- *sync* – a synchronisation through a channel,
- *update* – a change of values of variables and an execution of functions.



Automata in UPPAAL

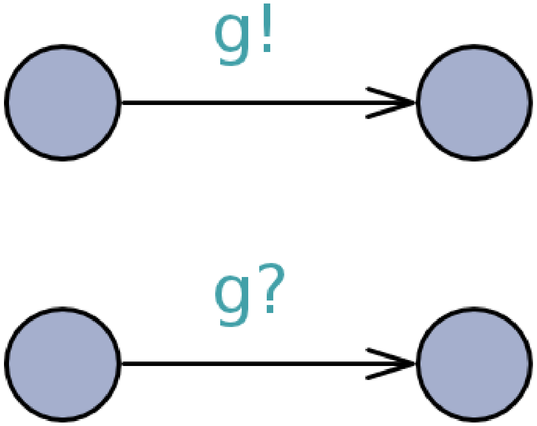
Channels and synchronisation

Binary channel

- Synchronisation between two automata.
- Lack of a receiver blocks the sender.
- For many available receivers 1 of them is chosen randomly.

Declaration of a channel:

- chan name;



Automata in UPPAAL

Channels and synchronisation

Binary urgent channel

- Synchronisation between two automata.
- Lack of a receiver blocks the sender.
- For many available receivers 1 of them is chosen randomly.
- Instant synchronisation (waiting time equals 0).
- Any guard with clock variables on a transition with the channel is forbidden.

Declaration of a channel:

- urgent chan name;

Automata in UPPAAL

Channels and synchronisation

Broadcast channel

- Synchronisation between one automaton and one or many at once.
- Lack of a receiver does not block the sender.
- Synchronisation applies to available receivers only.

Declaration of a channel:

- broadcast chan name;

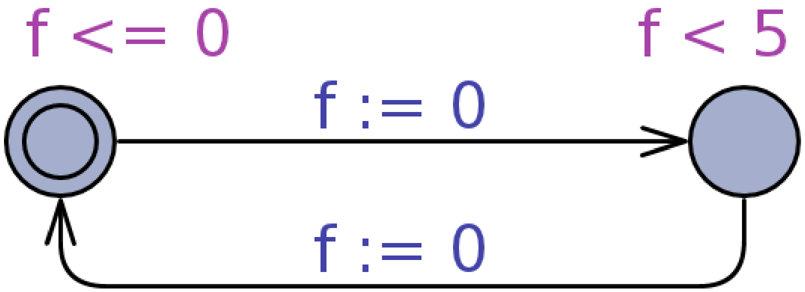
Automata in UPPAAL

Clock variables

Declaration of a clock variable:

- clock name;

A clock variable, as a state's *invariant*, makes the state to be left.



Verification in UPPAAL

- Syntax of the language of formulas
- Verification of reachability, liveness and safety
- What is possible?
- What is not possible?

Verification in UPPAAL

Syntax of the language of formulas

formula ::= 'A[]' expression | 'E<>' expression | 'E[]' expression | A<> expression | expression --> expression

expression ::= ID | NAT | expression '[' expression ']' | '(' expression ')' | expression '++' | '++' expression | expression '--' | '--' expression | expression assign expression | unary expression | expression binary expression | expression '?' expression ':' expression | expression '.' ID | expression '(' arguments ')' | 'forall' '(' ID ':' type ')' expression | 'exists' '(' ID ':' type ')' expression | 'deadlock' | 'true' | 'false'

arguments ::= [expression (',' expression)*]

assign ::= '=' | ':=' | '+=' | '-=' | '*=' | '/=' | '%=' | '|=' | '&=' | '^=' | '<<=' | '>>='

unary ::= '+' | '-' | '!' | 'not'

binary ::= '<' | '<=' | '==' | '!=' | '>=' | '>' | '+' | '-' | '*' | '/' | '%' | '&' | '|' | '^' | '<<' | '>>' | '&&' | '||' | '<?' | '>?' | 'or' | 'and' | 'imply'

type – *predefined or created type of data*

Verification in UPPAAL

Verification of reachability, liveness and safety

- Reachability:

  E<> D.s – the state s of the automaton D may be reached,
  A<> D.s – the state s of the automaton D will be reached.

- Liveness: D.s --> D.z==3

  – if the state s of the automaton D is reached, it will result in reaching its local variable z == 3,

  in CTL: $AG(D.s \Rightarrow AF\ D.z{=}{=}3)$.

- Safety:

  E[] D.s – the automaton D may be still in the state s,
  A[] D.s – the automaton D is still in the state s.

Verification in UPPAAL

What is possible?

- to use temporal operators F (as “<>”) and G (as “[ ]”),
- to check, whether a given state is/will be active and whether a given variable has/will have a declared value, e.g.:
  - A[] aut.s imply aut.z >= x
    – certainly always *aut.s* implies aut.z >= x,
  - E<> aut.s and aut.z >= x
    – possibly finally *aut.s* and *aut.z* >= *x* at once,
  - A[] aut.s1 + aut.s2 + aut.s3 <= 1
    – certainly always at most one of the states *aut.s1*, *aut.*s1 and *aut.s3* is active.

Verification in UPPAAL

What is possible?

- to check, whether the system of automata is blocked (the *deadlock* expression), i.e. it is not possible to change any state, e.g.:
  - E<>deadlock
    – the deadlock may finally be possible,
  - A[] not deadlock
    – the deadlock is never possible,
- to use quantifiers, e.g. for automata:
  - “for all”, e.g.: E<> forall (i:range) aut(i).s
  - “exists”, e.g.: E<> exists (i:range) aut(i).s

Verification in UPPAAL

What is not possible?

- to use other temporal operators than G and F,
- to nest temporal operators,
- to use more than one temporal operator in one formula,
- to use the operator --> together with a temporal operator,
- to use the operator --> together with the *deadlock* expression.

The end

Literature:

- G. Behrmann et al. “A tutorial on UPPAAL”, 2004, at: www.uppaal.com
- A. David et al. “UPPAAL 4.0: Small tutorial”, 2009, at: www.uppaal.com
- “UPPAAL Language Reference”, http://www.uppaal.com/index.php?sida=217&rubrik=101