Modeling real-time systems

--- **UPPAAL modeling language**

Timed Automata in UPPAAL

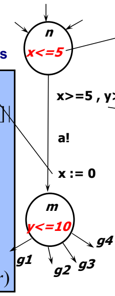
Clock Assignments

$x := n$

Variable Assignments

$i := Expr$

$Expr ::= i \mid i[Expr] \mid$
$n \mid -Expr \mid$
$Expr + Expr \mid$
$Expr - Expr \mid$
$Expr * Expr \mid$
$Expr / Expr \mid$
$(g_d \, ? \, Expr : Expr)$



Location Invariants

$inv ::= x < n \mid x <= n \mid inv, inv$

clock natural number "and"

$g ::= g_c \mid g_d \mid g, g$

$g_c ::= x \otimes n \mid x \otimes y + n$ — **Clock guards**

$g_d ::= Expr \ op \ Expr$ — **Data guards**

$\otimes \in \{<, <=, ==, >=, >\}$

$op \in \{<, <=, ==, >=, >, !=\}$

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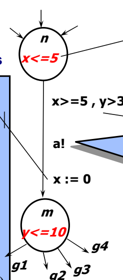


Location Invariants

$inv ::= x < n \mid x <= n \mid inv, inv$

clock natural number "and"

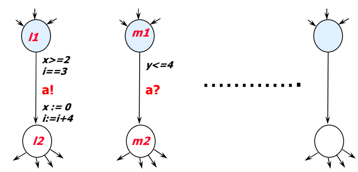
guards

guards

Actions:

- "a" name of action
- a! or a?
- one or zero per edge

Networks of Timed Automata



Two-way synchronization on **complementary** actions.

Closed Systems!

Declarations in UPPAAL

- The syntax used for declarations in UPPAAL is similar to the syntax used in the C programming language.
- **Clocks**:
  - **Syntax:**

```
clock x1, …, xn ;
```

  - **Example:**
  - `clock x, y;` **Declares two clocks: x and y.**

Declarations in UPPAAL (cont.)

- **Data variables**
  - **Syntax:**

`int n1, … ;`	**Integer with "default" domain.**
`int[l,u] n1, … ;`	**Integer with domain from "l" to "u".**
`int n1[m], … ;`	**Integer array w. elements n1[0] to n1[m-1].**

  - **Example;**
  - `int a, b;`
  - `int[0,1] a, b[5];`

Declarations in UPPAAL (cont.)

- Actions (or channels):
  - **Syntax:**

```
chan a, … ;
urgent chan b, … ;
```

Ordinary channels.
Urgent actions (described later)

  - **Example:**
  - `chan a, b[2];`
  - `urgent chan c;`

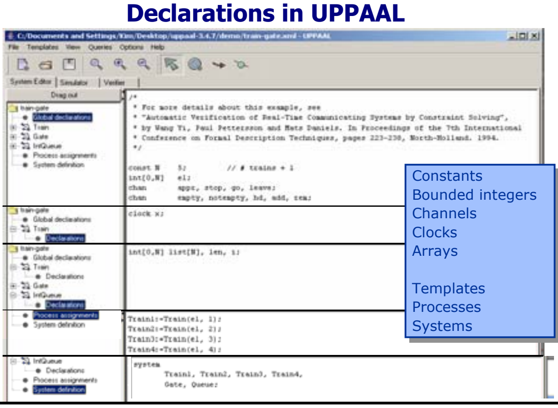
Declarations UPPAAL (const.)

- Constants
  - **Syntax:**

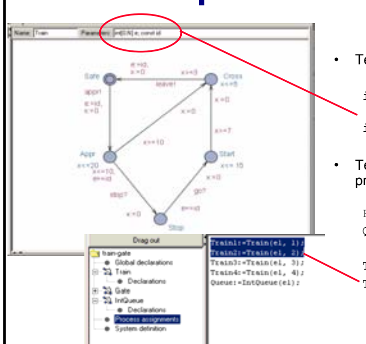
```
const int c1 = n1;
```

  - **Example:**
  - `const int[0,1] YES = 1;`
  - `const bool NO = false;`

Declarations in UPPAAL



Templates in UPPAAL



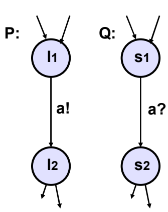
- Templates may be parameterised:

```
int v; const min; const max
int[0,N] e; const id
```

- Templates are instantiated to form processes:

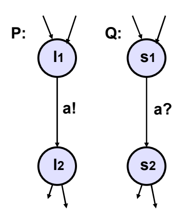
```
P:= A(i,1,5);
Q:= A(j,0,4);

Train1:=Train(el, 1);
Train2:=Train(el, 2);
```


Urgent Channels: Example 1



- Suppose the two edges in automata P and Q should be taken as soon as possible.
- I.e. as soon as both automata are ready (simultaneously in locations l_1 and s_1).
- How to model with invariants if either one may reach l_1 or s_1 first?

Urgent Channels: Example 1



- Suppose the two edges in automata P and Q should be taken as soon as possible
- I.e. as soon as both automata are ready (simultaneously in locations l_1 and s_1).
- How to model with invariants if either one may reach l_1 or s_1 first?
- **Solution**: declare action "a" as urgent.

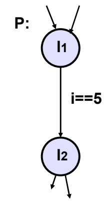
Urgent Channels

```
urgent chan hurry;
```

Informal Semantics:
- There will be no delay if transition with urgent action can be taken.

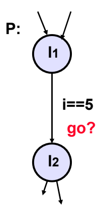
Restrictions:
- No clock guard allowed on transitions with urgent actions.
- Invariants and data-variable guards are allowed.

Urgent Channel: Example 2

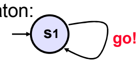


- Assume i is a data variable.
- We want P to take the transition from l1 to l2 as soon as i==5.

Urgent Channel: Example 2



- Assume i is a data variable.
- We want P to take the transition from l1 to l2 as soon as i==5.
- **Solution**: P can be forced to take transition if we add another automaton:



where "go" is an urgent channel, and we add "go?" to transition l1→l2 in automaton P.

Broadcast Synchronisation

```
broadcast chan a, b, c[2];
```

- If a is a broadcast channel:
  - `a!` = Emmision of broadcast
  - `a?` = Reception of broadcast
- A set of edges in different processes can synchronize if one is emitting and the others are receiving on the same b.c. channel.
- A process can always emit.
- Receivers *must* synchronize if they can.
- No blocking.

Urgent Location

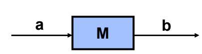
Click "Urgent" in State Editor.

Informal Semantics:
- No delay in urgent location.

Note: the use of urgent locations **reduces** the number of clocks in a model, and thus the complexity of the analysis.

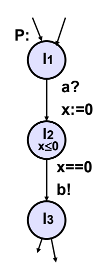
Urgent Location: Example

- Assume that we model a simple media M:



that receives packages on channel a and immediately sends them on channel b.

- P models the media using clock x.



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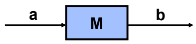
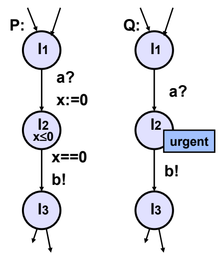


  that receives packages on channel a and immediately sends them on channel b.
- P models the media using clock x.
- Q models the media using **urgent location**.
- P and Q have the same behavior.



Committed Location

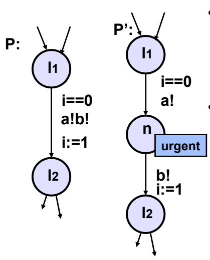
Click "Committed" i State Editor.

Informal Semantics:

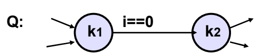
- No delay in committed location.
- Next transition must involve automata in committed location.

Note: the use of committed locations **reduces** the number of interleaving in state space exploration (and also the number of clocks in a model), and thus allows for more space and time efficient analysis.

Committed Location: Example 1



- **Assume:** we want to model a process (P) simultaneously sending message a and b to two receiving processes (when i==0).
- P' sends "a" two times at the same time instant, but in location "n" other automata, e.g. Q may interfear



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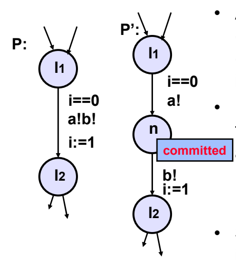

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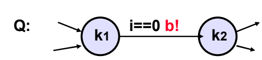

- **Solution:** mark location n "committed" in automata P' (instead of "urgent").

Committed Location: Example 2

- **Assume:** we want to pass the value of integer "k" from automaton P to variable "j" in Q.
- The value of k can is passed using a global integer variable "t".
- Location "n" is committed to ensure that no other automat can assign "t" before the assignment "j:=t".