Automated Planning Tools for Intelligent Decision Making

AALBORG UNIVERSITET

Planning

Planning

From Wikipedia, the free encyclopedia

"Forethought" redirects here. For the defunct software company, see Forethought, Inc.

Planning (also called **forethought**) is the process of thinking about and organizing the activities required to achieve a desired goal. It involves the creation and maintenance of a plan, such as psychological aspects that require conceptual skills. There are even a couple of tests to measure someone's capability of planning well. As such, planning is a fundamental property of intelligent behavior.

Also, planning has a specific process and is necessary for multiple occupations (particularly in fields such as management, business, etc.). In each field there are different types of plans that help companies achieve efficiency and effectiveness. An important, albeit often ignored aspect of planning, is the relationship it holds to forecasting. Forecasting can be described as predicting what the future will look like, whereas planning predicts what the future should look like for multiple scenarios. Planning combines forecasting with preparation of scenarios and how to react to them. Planning is one of the most important project management and time management techniques. Planning is preparing a sequence of action steps to achieve some specific goal. If a person does it effectively, they can reduce much the necessary time and effort of achieving the goal. A plan is like a map. When following a plan, a person can see how much they have progressed towards their project goal and how far they are from their destination.

nning Tools, ...

Scheduling

In computing, **scheduling** is the method by which work specified by some means is assigned to resources that complete the work. The work may be virtual computation elements such as threads, processes or data flows, which are in turn scheduled onto hardware resources such as processors, network links or expansion cards.

A scheduler is what carries out the scheduling activity. Schedulers are often implemented so they keep all computer resources busy (as in load balancing), allow multiple users to share system resources effectively, or to achieve a target quality of service. Scheduling is fundamental to computation itself, and an intrinsic part of the execution model of a computer system; the concept of scheduling makes it possible to have computer multitasking with a single central processing unit (CPU).

A scheduler may aim at one of many goals, for example, maximizing *throughput* (the total amount of work completed per time unit), minimizing *response time* (time from work becoming enabled until the first point it begins execution on resources), or minimizing *latency* (the time between work becoming enabled and its subsequent completion),[1] maximizing *fairness* (equal CPU time to each process, or more generally appropriate times according to the priority and workload of each process). In practice, these goals often conflict (e.g. throughput versus latency), thus a scheduler will implement a suitable compromise. Preference is given to any one of the concerns mentioned above, depending upon the user's needs and objectives.

In real-time environments, such as embedded systems for automatic control in industry (for example robotics), the scheduler also must ensure that processes can meet deadlines; this is crucial for keeping the system stable. Scheduled tasks can also be distributed to remote devices across a network and managed through an administrative back end.

Topics / People

I. Planning via Model Checking

Kim Larsen, Peter Gjøl Jensen


II. Planning via Operations Research

Peter Nielsen, Mohamed El Yafrani, Inkyung Sung



III. Planning via AI

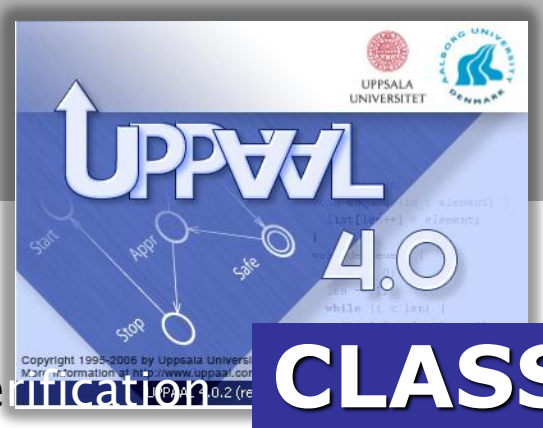
Alvaro Torralba

Planning
via
Model Checking

AALBORG UNIVERSITET

“Plan”

- Timed Automata
  - Model Checking
  - Time-optimal Planning
  - Zones
- Priced Timed Automata
  - Cost-optimal Planning
  - Priced Zones A*
- Timed Games
  - Dynamic Planning
  - Strategies, Zones
- Stochastic Timed Automata
  - Performance Analysis
  - Statistical Model Checking
- Stochastic Priced Timed Games
  - Expected Cost Optimal Adaptive Planning
  - Strategies
  - Reinforcement Learning
- Applications



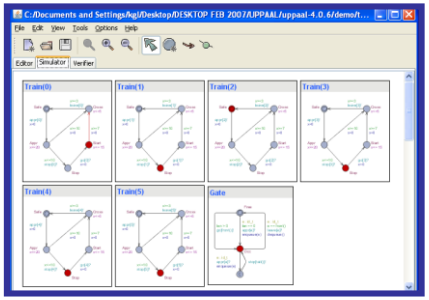
Verification	CLASSIC	1995
Optimization	CORA	2001
Synthesis	TIGA	2005
Component	ECDAR	2010
Testing	TRON	2004
Performance Analysis	SMC	2011
	STRATEGO	2014

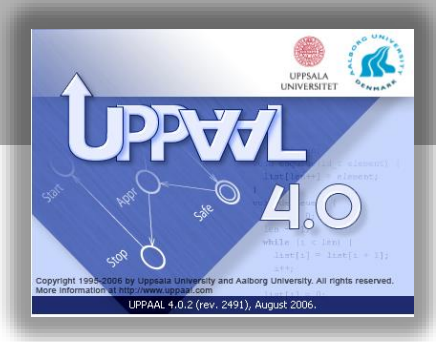
Timed Automata

Model Checking

AALBORG UNIVERSITET

QUANTITATIVE Model Checking





Time

Cost

Probability

System Description

No!

Debugging Information

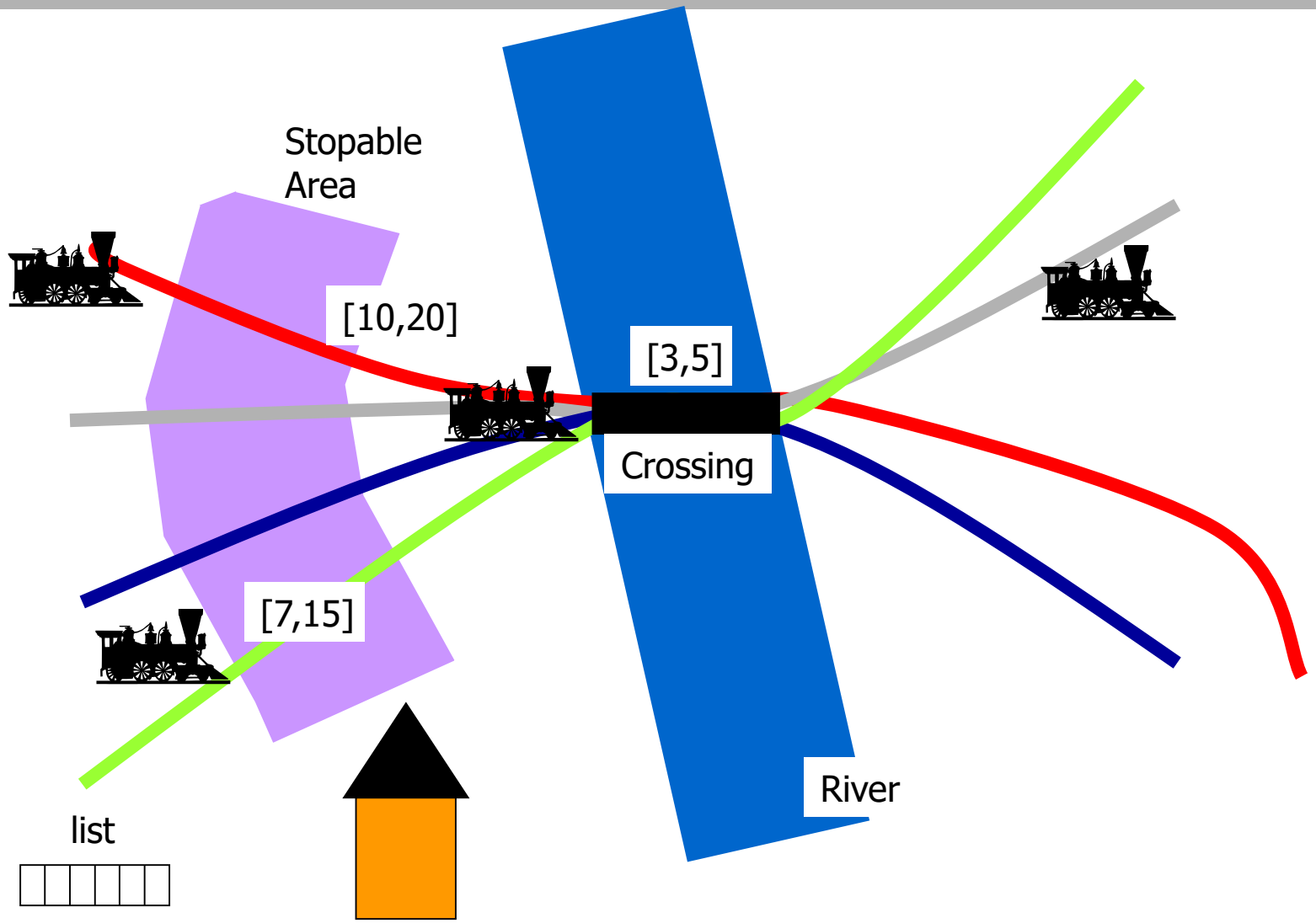
Requirement

A[](req => A<> grant)

Yes

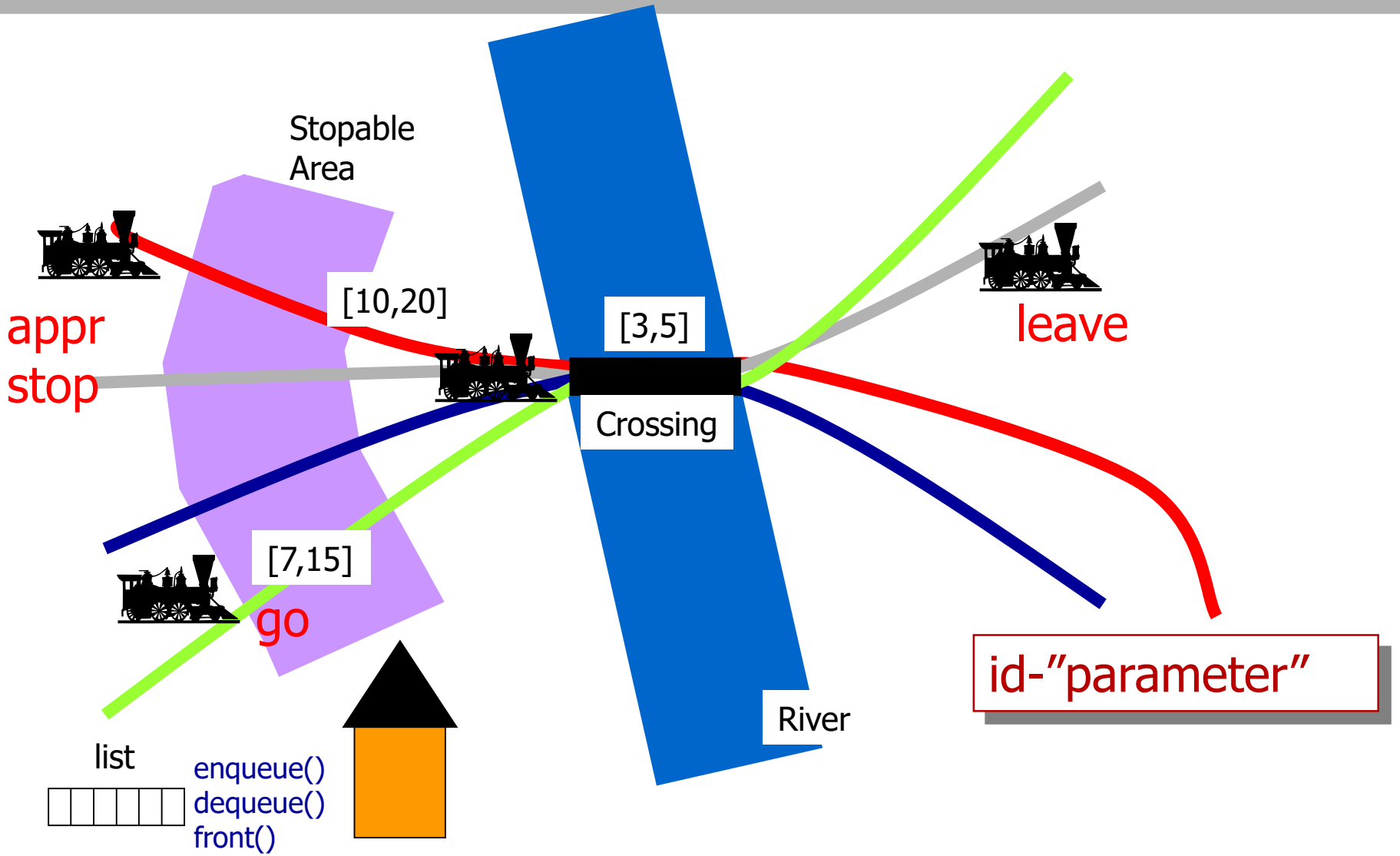
Prototypes
Executable Code
Test sequences

Train Crossing



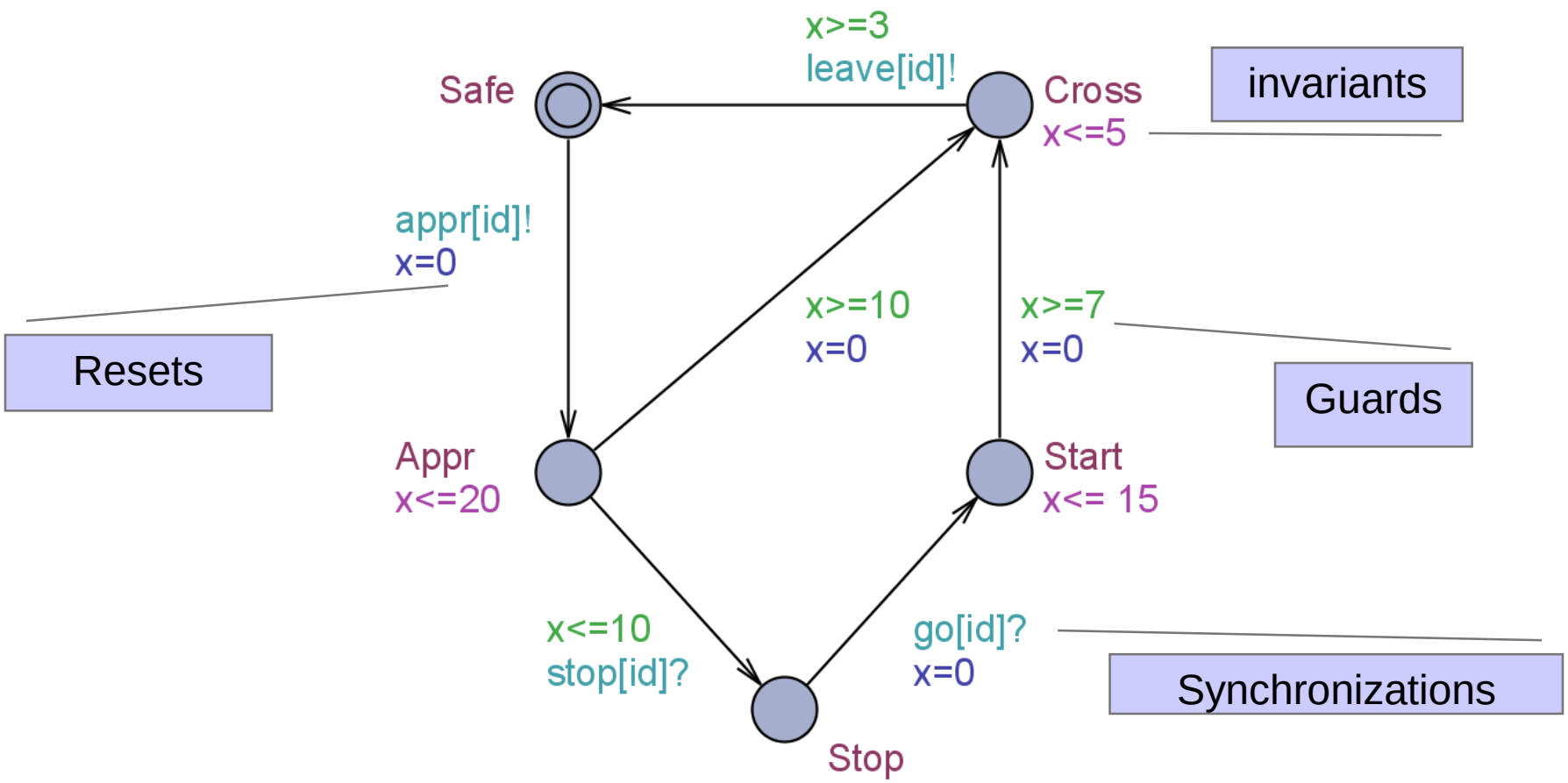
Train Crossing

Communication via channels!



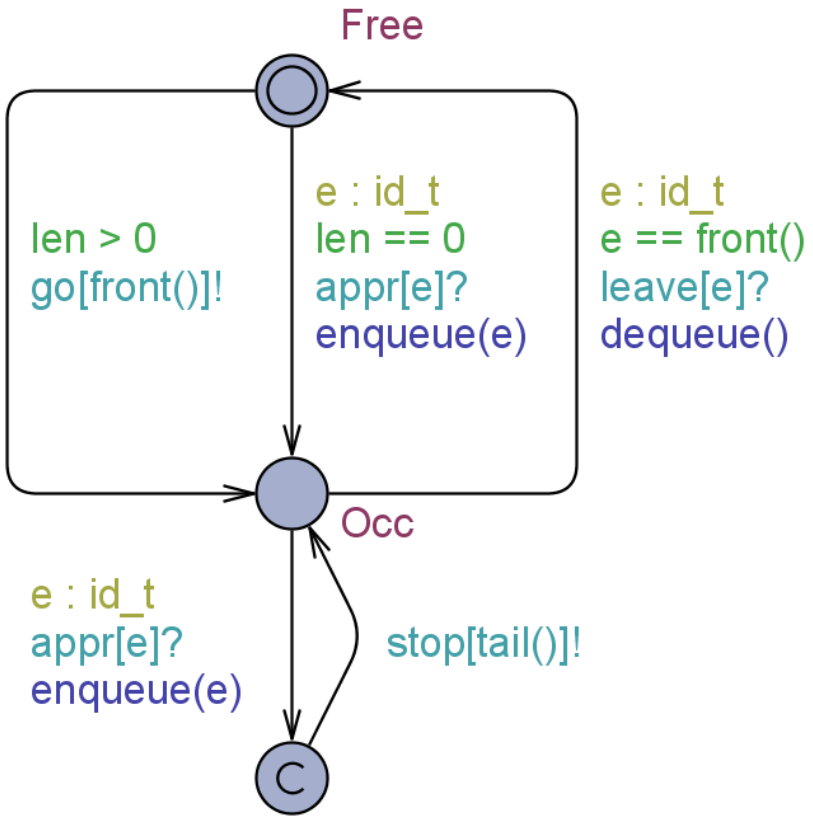
Timed Automata [Train]

= Finite State Control
+ Real Valued Clocks



Timed Automata [Gate]

= Finite State Control
+ Real Valued Clocks
+ Discrete Variables

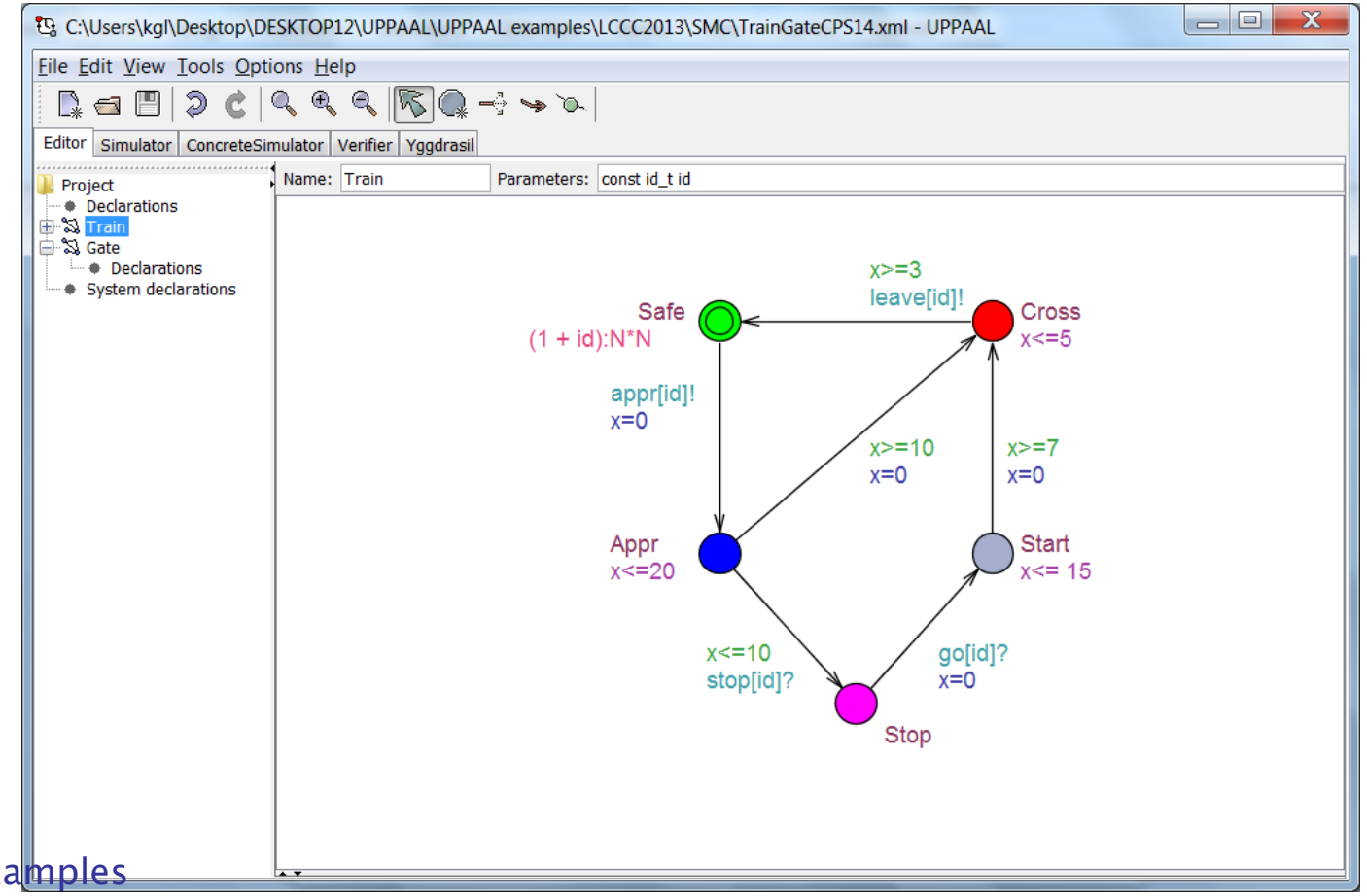



```
id_t list[N+1];
int[0,N] len;

// Put an element at the end of the queue
void enqueue(id_t element)
{
        list[len++] = element;
}

// Remove the front element of the queue
void dequeue()
{
        int i = 0;
        len -= 1;
        while (i < len)
        {
                list[i] = list[i + 1];
                i++;
        }
        list[i] = 0;
}
```

UPPAAL DEMO



UPPAAL Examples
SSFT15/UPPAAL SMC/

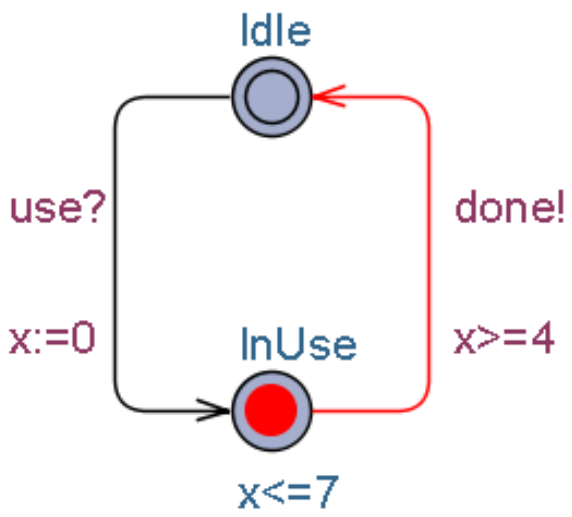
Timed Automata

Time-Optimal Scheduling

AALBORG UNIVERSITET

Resources & Tasks

Resource

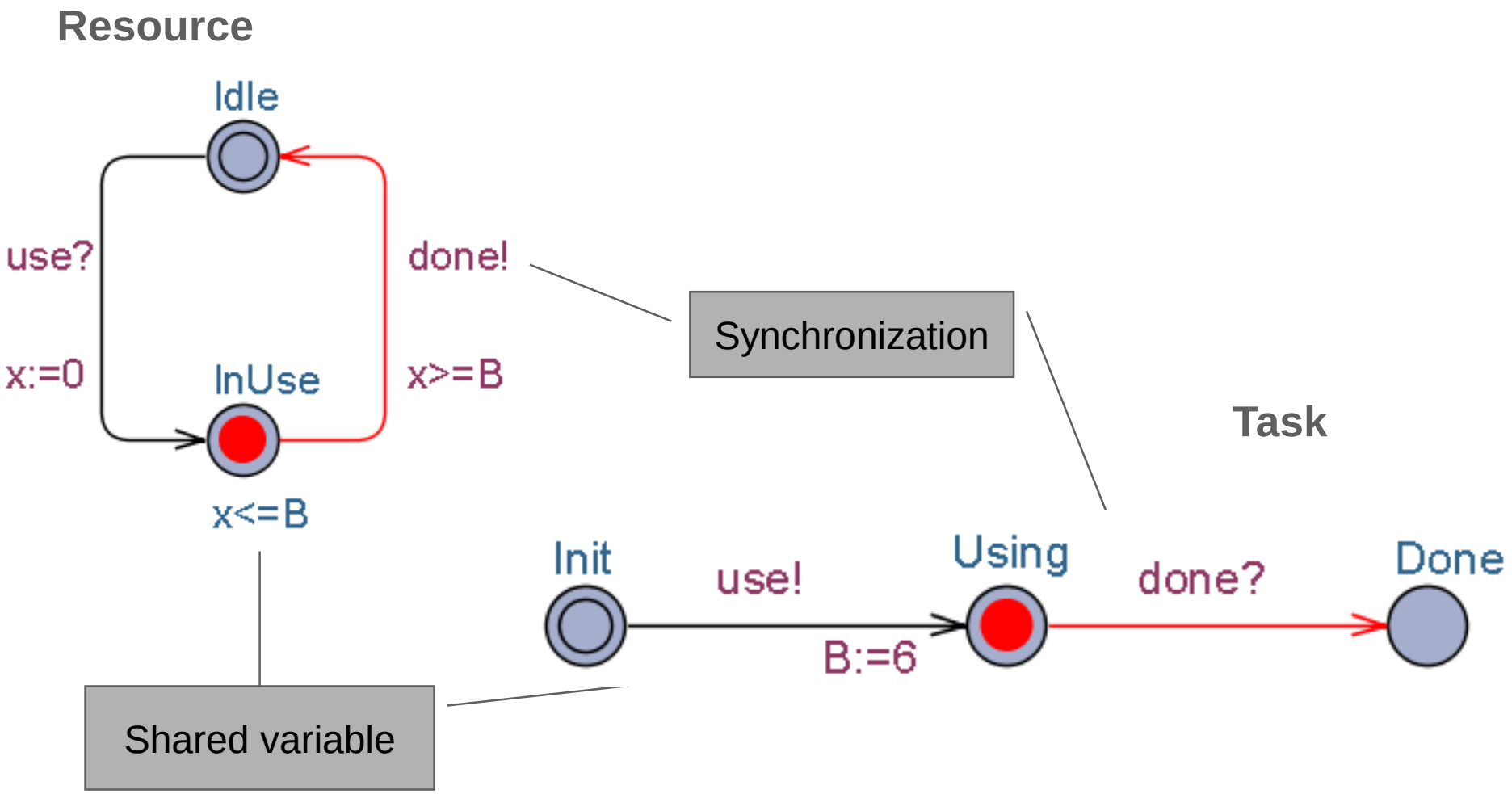


Semantics:

(Idle , x=0)

→ (Idle , x=2.5)	d(2.5)
→ (InUse , x=0)	use?
→ (InUse , x=5)	d(5)
→ (Idle , x=5)	done!
→ (Idle , x=8)	d(3)
→ (InUse , x=0)	use?

Resources & Tasks



Resources & Tasks

Semantics:

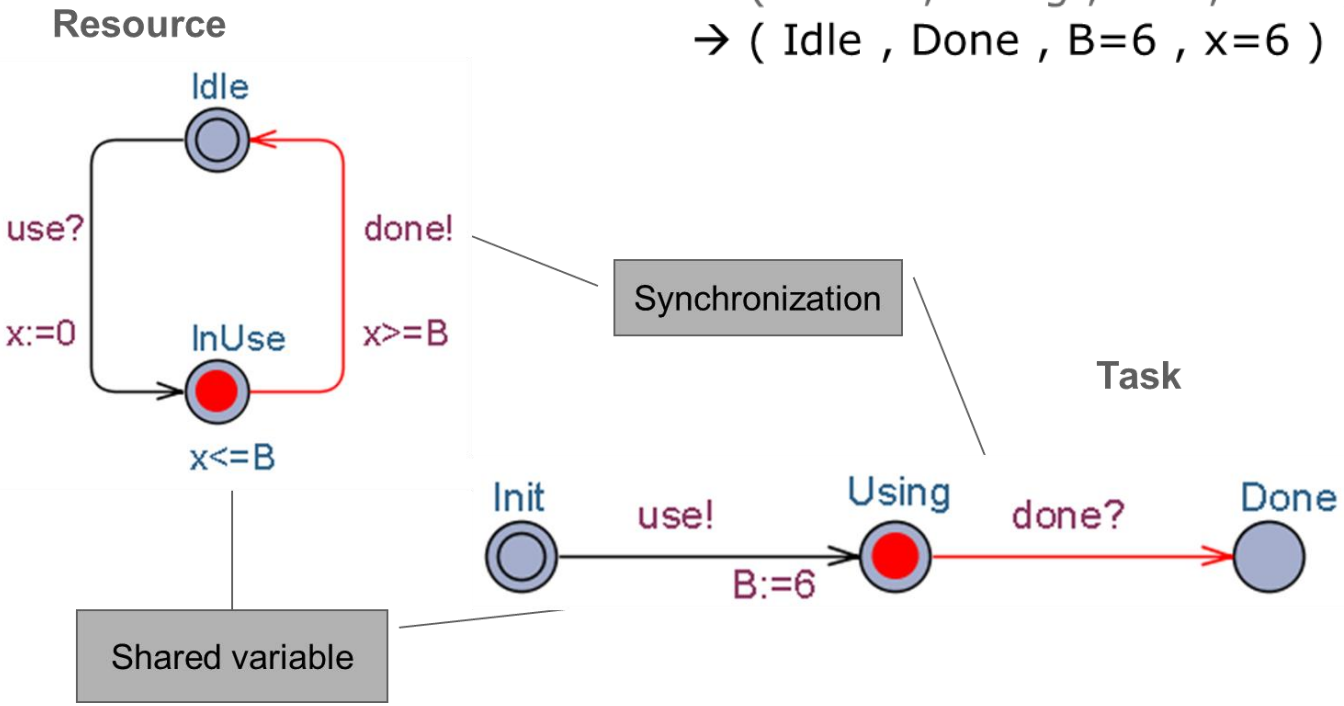
(Idle , Init , B=0, x=0)

→ (Idle , Init , B=0 , x=3.1415) d(3)

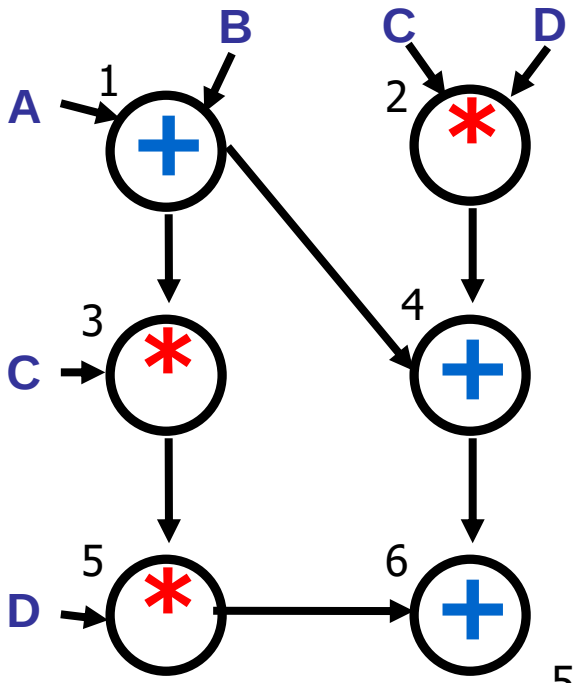
→ (InUse , Using , B=6, x=0) use

→ (InUse , Using , B=6, x=6) d(6)

→ (Idle , Done , B=6 , x=6) done



Task Graph Scheduling – Example



Compute :

$$\frac{(D * (C * (A + B)) + ((A + B) + (C * D))}{4}$$

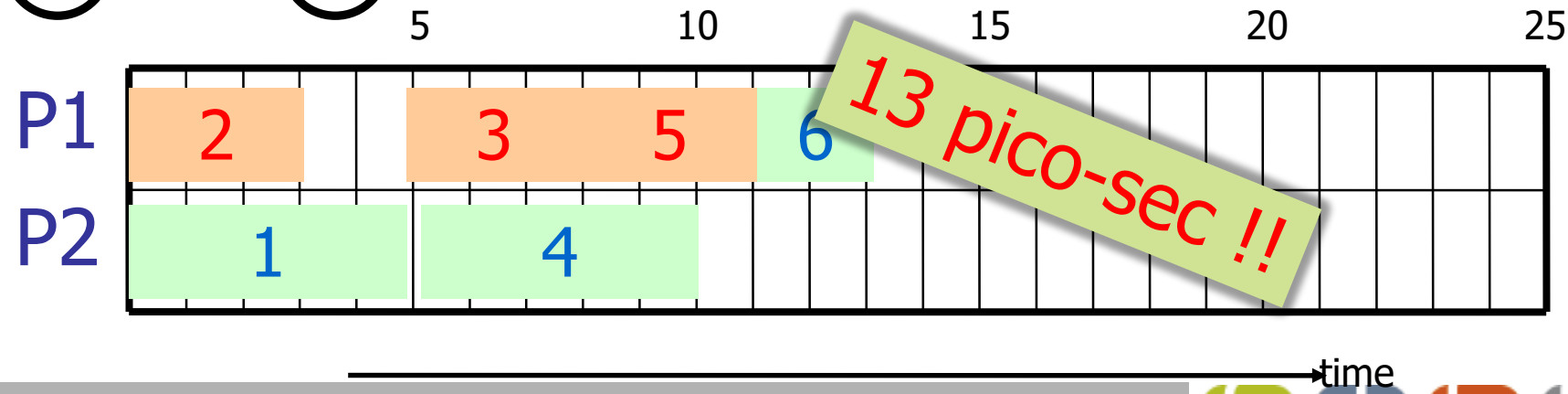
using 2 processors

P1 (fast)

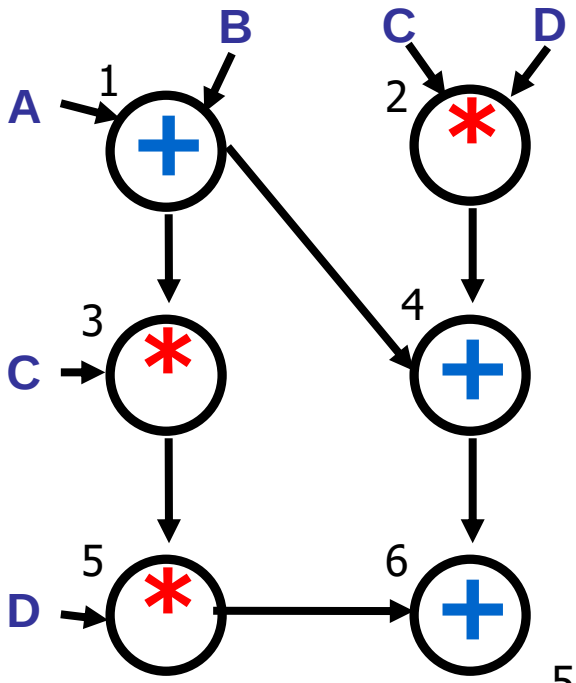
+	2ps
*	3ps

P2 (slow)

+	5ps
*	7ps



Task Graph Scheduling – Example



Compute :
(D * (C * (A + B)) + ((A + B) + (C * D))

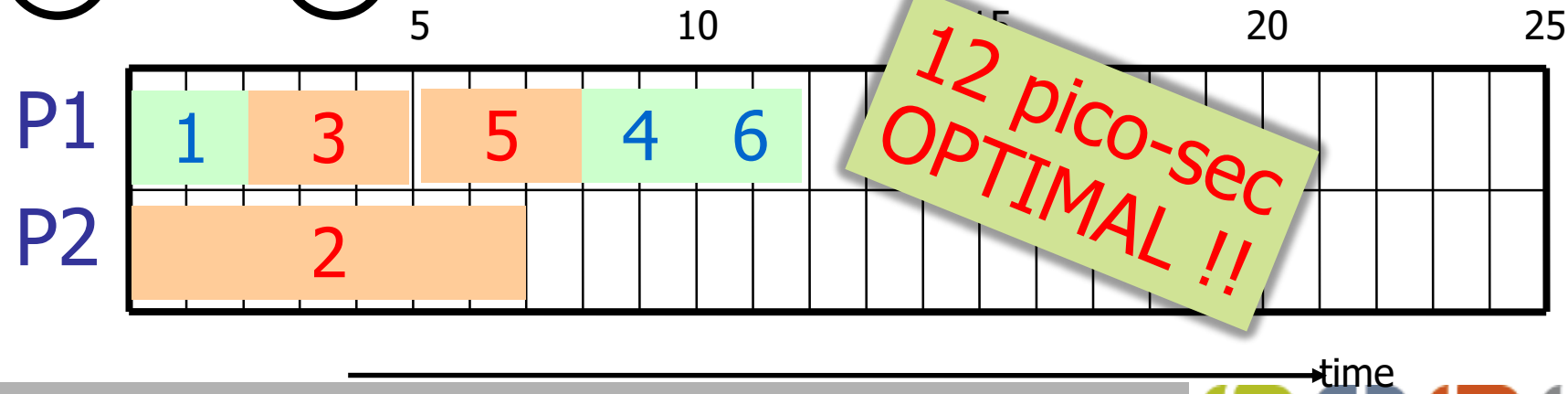
using 2 processors

P1 (fast)

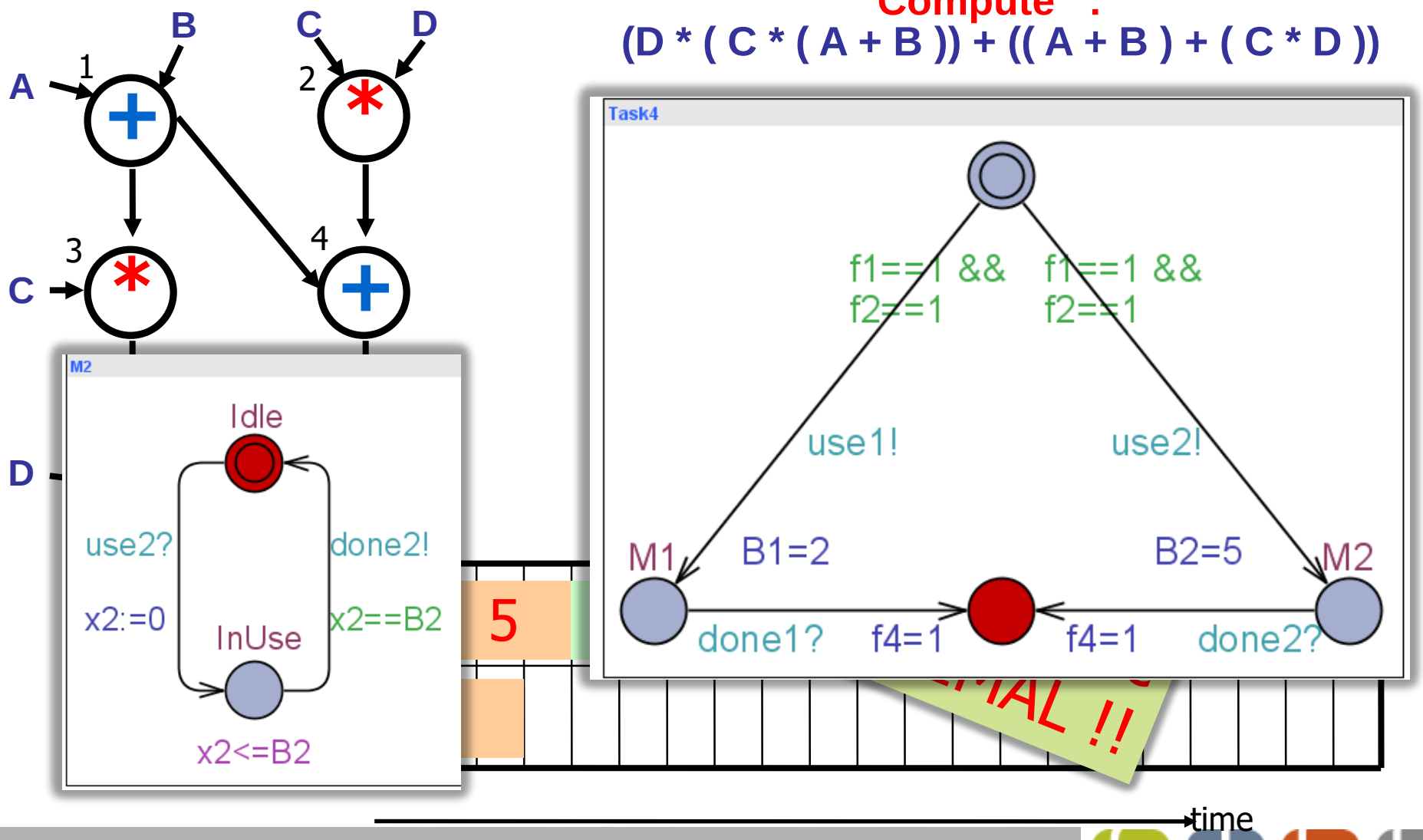
+	2ps
*	3ps

P2 (slow)

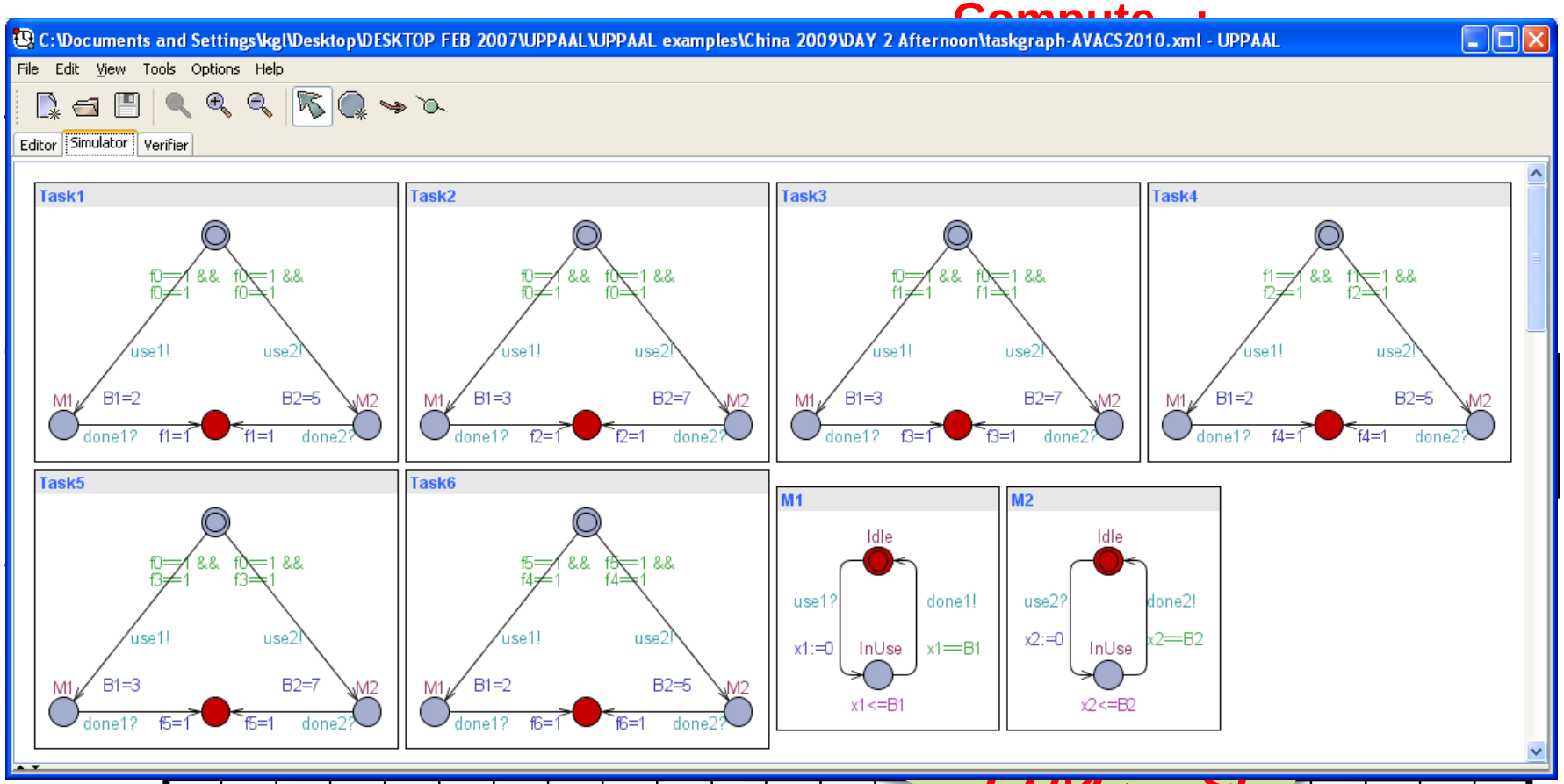
+	5ps
*	7ps



Task Graph Scheduling – Example



Task Graph Scheduling – Example



P2

E<> (Task1.End and … and Task6.End)

time

Experimental Results

name	#tasks	#chains	# machines	optimal	TA
001	437	125	4	1178	1182
000	452	43	20	537	537
018	730	175	10	700	704
074	1007	66	12	891	894
021	1145	88	20	605	612
228	1187	293	8	1570	1574
071	1193	124	20	629	634
271	1348	127	12	1163	1164
237	1566	152	12	1340	1342
231	1664	101	16	t.o.	1137
235	1782	218	16	t.o.	1150
233	1980	207	19	1118	1121
294	2014	141	17	1257	1261
295	2168	965	18	1318	1322
292	2333	318	3	8009	8009
298	2399	303	10	2471	2473

AMETIST
advanced methods for timed systems

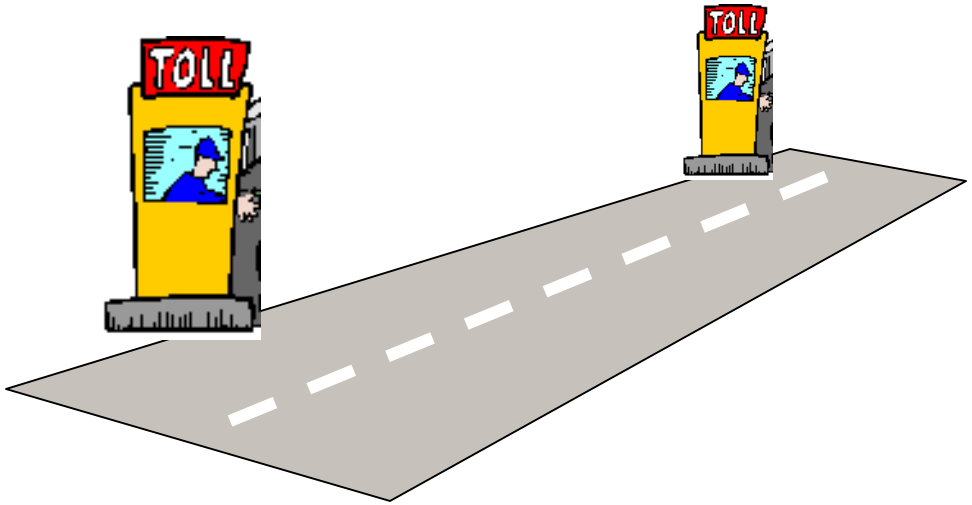
Symbolic A*
Branch-&-Bound
60 sec

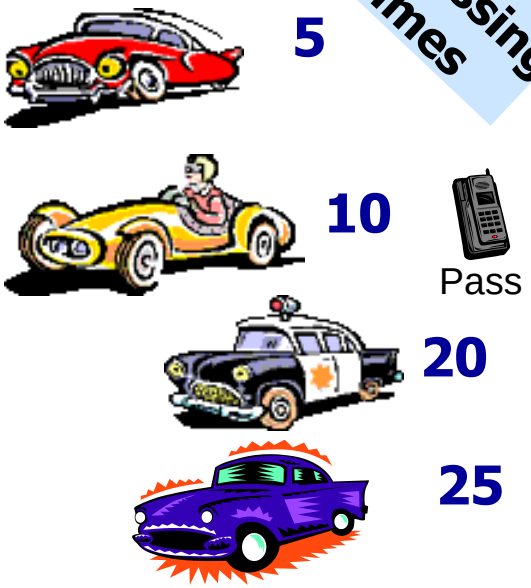
Abdeddaïm, Kerbaa, Maler

Real Time Scheduling

- Only 1 "Pass"
- Cheat is possible
  (drive close to car with "Pass")

UNSAFE

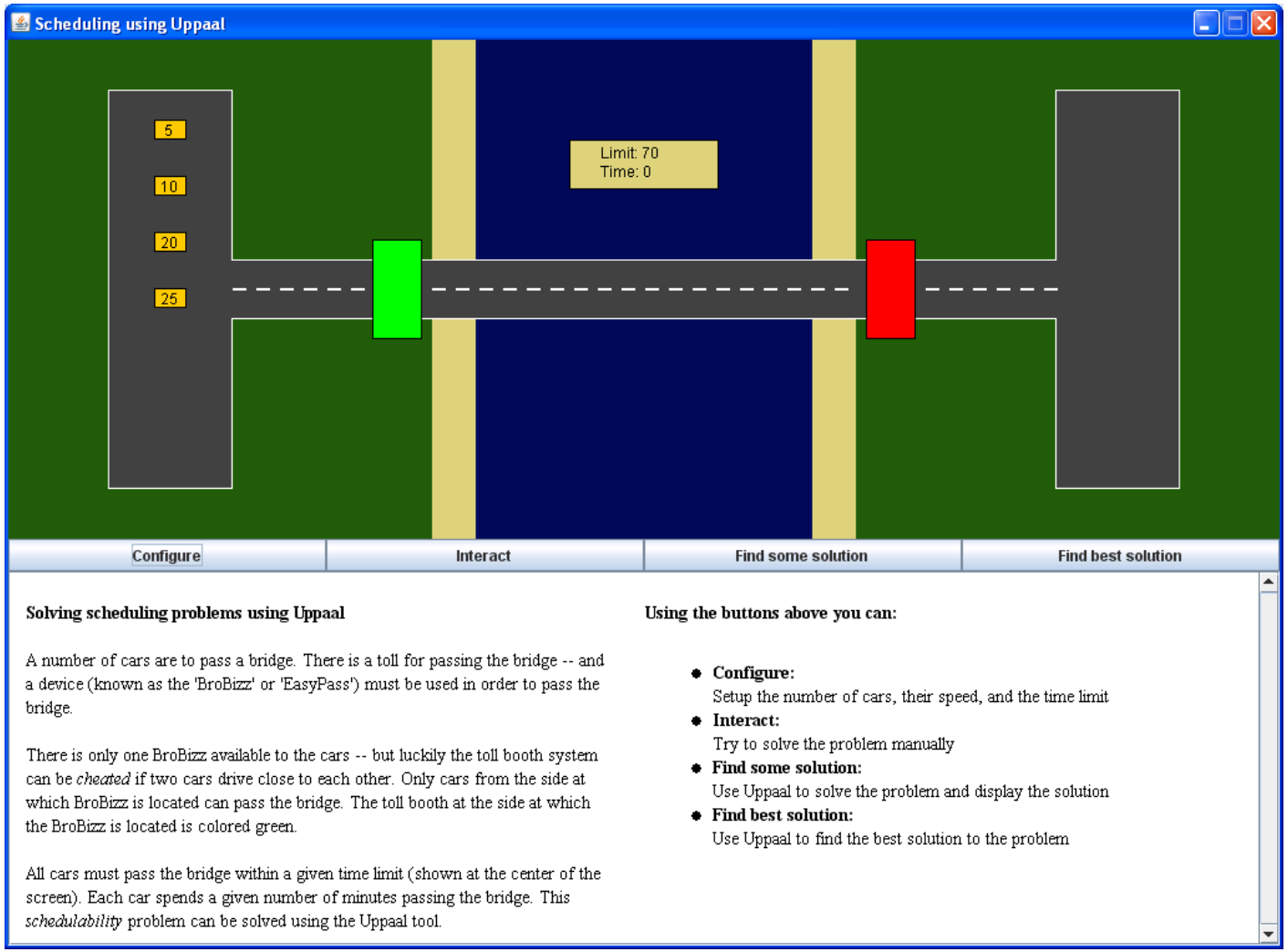




SAFE

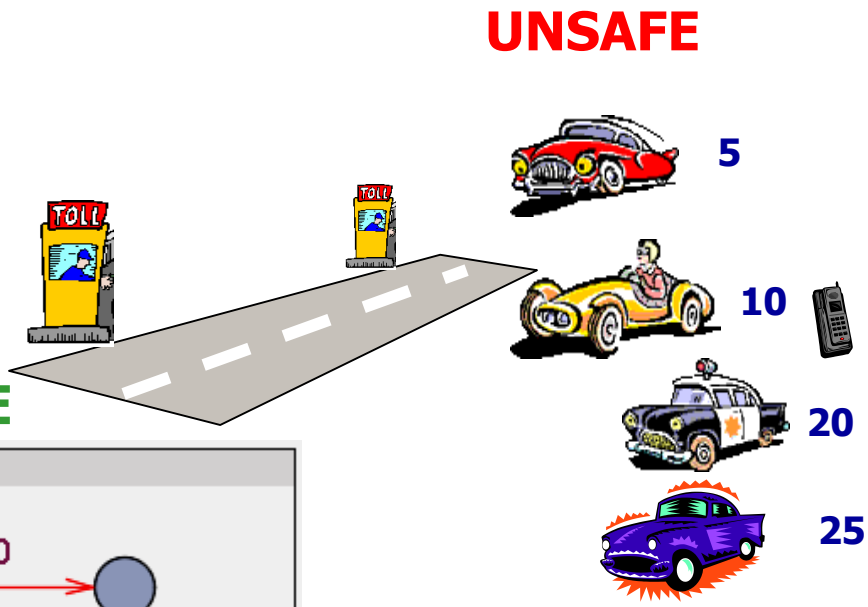
CAN THEY MAKE IT TO SAFE WITHIN 70 MINUTES ???

Let us play!

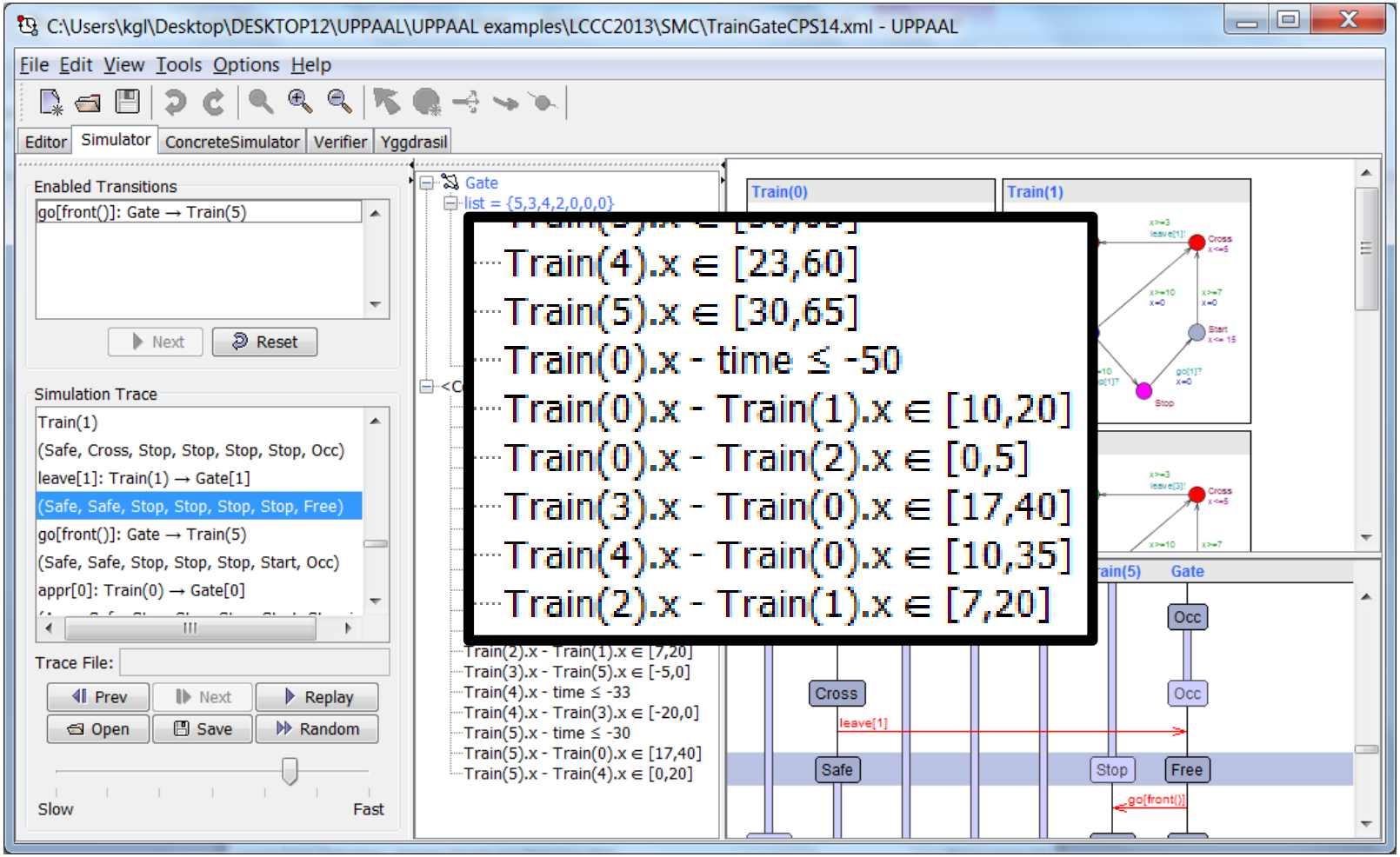

Scheduling using Uppaal
5
10
20
25
Limit: 70
Time: 0
Configure
Interact
Find some solution
Find best solution
Solving scheduling problems using Uppaal
A number of cars are to pass a bridge. There is a toll for passing the bridge -- and a device (known as the 'BroBizz' or 'EasyPass') must be used in order to pass the bridge.
There is only one BroBizz available to the cars -- but luckily the toll booth system can be cheated if two cars drive close to each other. Only cars from the side at which BroBizz is located can pass the bridge. The toll booth at the side at which the BroBizz is located is colored green.
All cars must pass the bridge within a given time limit (shown at the center of the screen). Each car spends a given number of minutes passing the bridge. This schedulability problem can be solved using the Uppaal tool.
Using the buttons above you can:
Configure:
Setup the number of cars, their speed, and the time limit
Interact:
Try to solve the problem manually
Find some solution:
Use Uppaal to solve the problem and display the solution
Find best solution:
Use Uppaal to find the best solution to the problem

Real Time Scheduling

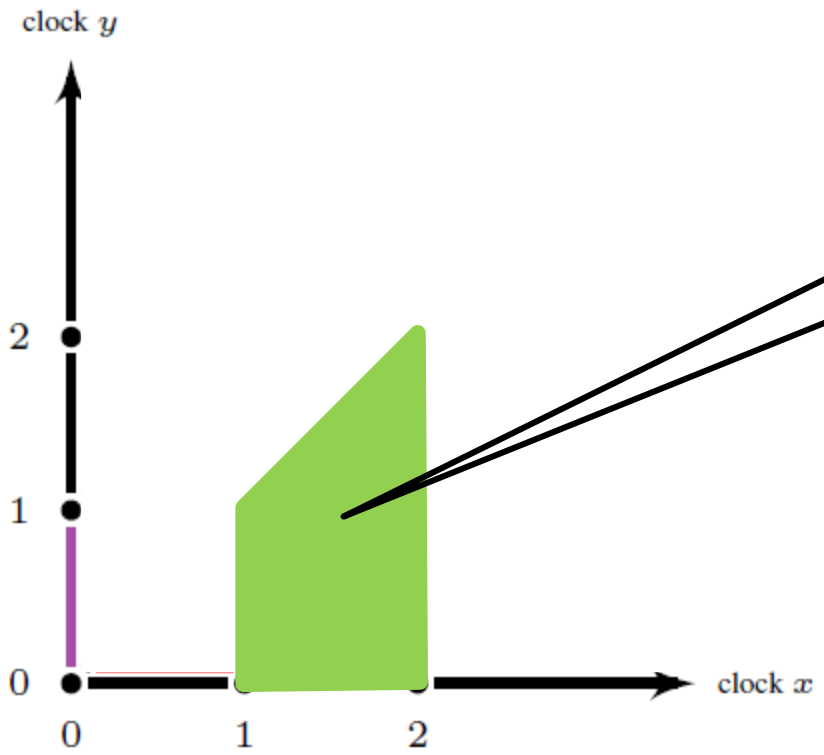
Solve Scheduling Problem using UPPAAL



The ”secret” of UPPAAL



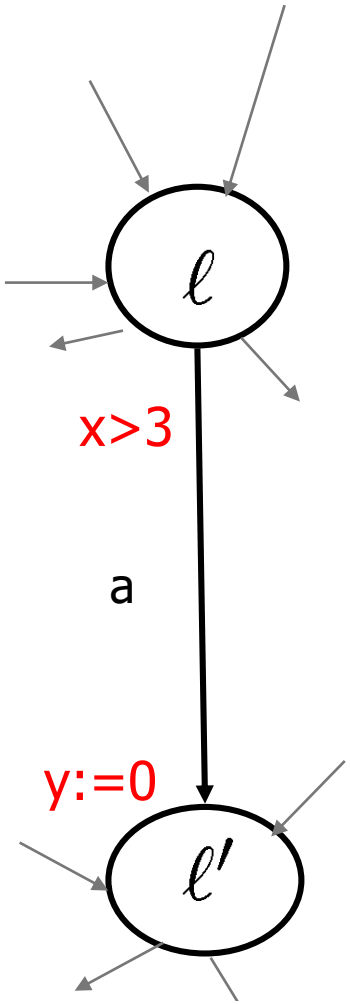
Zones – From Finite to Efficiency

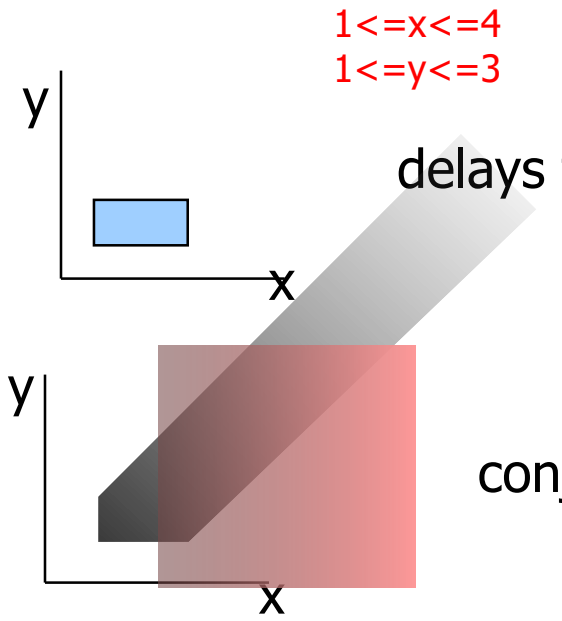


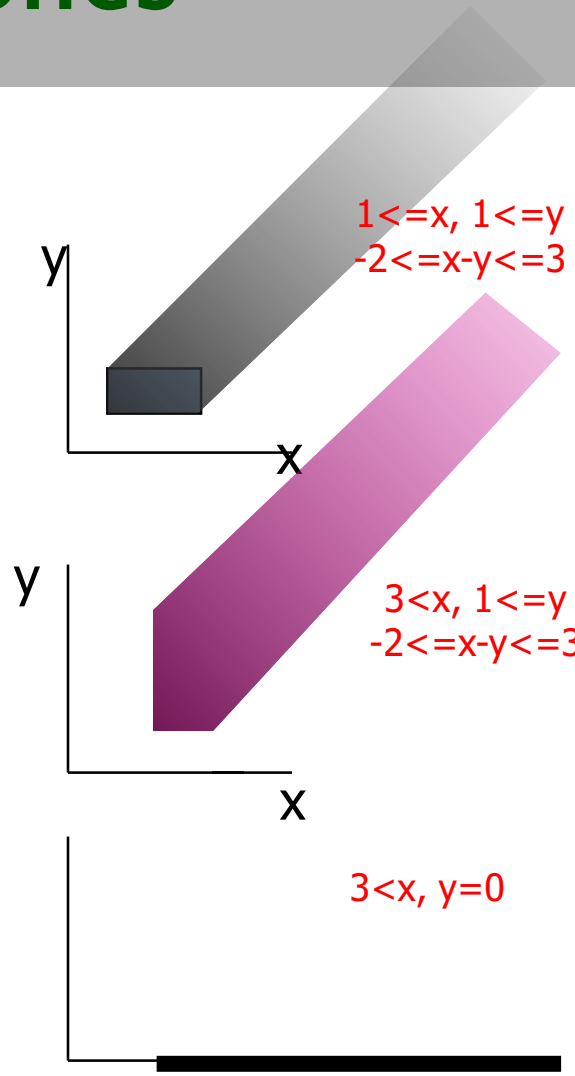
A zone Z:

$1 \leq x \leq 2 \ \wedge$
$0 \leq y \leq 2 \ \wedge$
$x - y \geq 0$

Symbolic Transitions / Zones



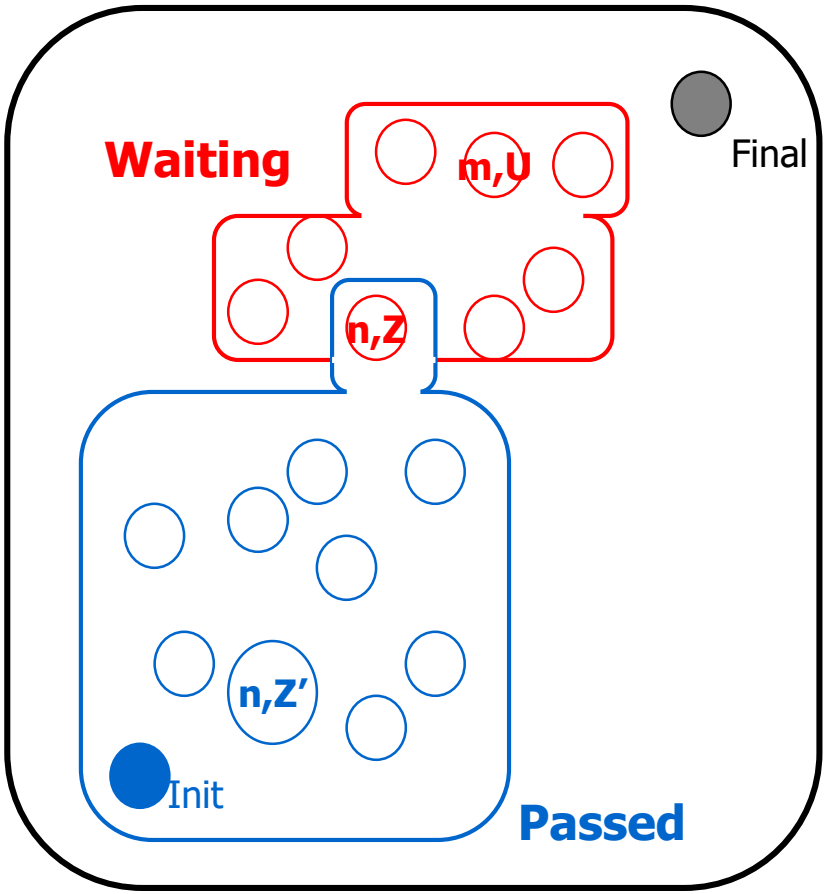




$$(\ell, 1 \leq x \leq 4, 1 \leq y \leq 3) \Rightarrow_a (\ell', 3 < x, y = 0)$$

Forward Rechability

Init -> Final ?



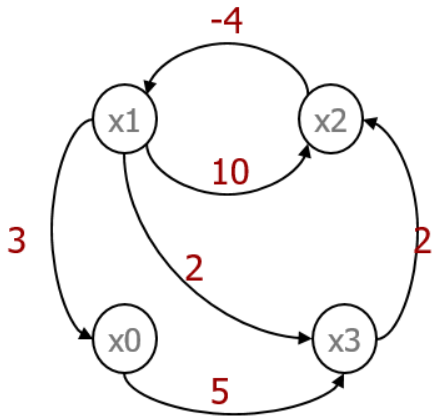
INITIAL **Passed** := Ø;
Waiting := {(n0,Z0)}

REPEAT
- pick (n,Z) in **Waiting**
- **if** for some Z' ⊇ Z
  (n,Z') in **Passed** **then** **STOP**
- **else** /explore/ add
  { (m,U) : (n,Z) => (m,U) }
  to **Waiting**;
  Add (n,Z) to **Passed**

UNTIL **Waiting** = Ø
or
Final is in **Waiting**

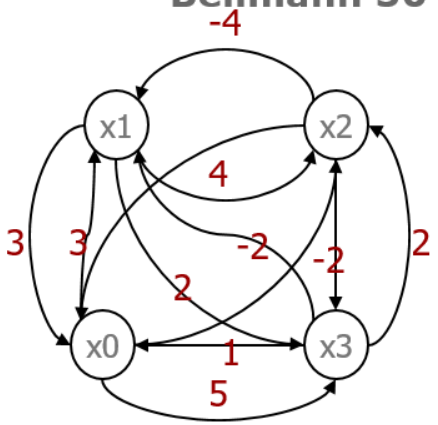
Canonical Zone Representation

x1-x2<=4
x2-x1<=10
x3-x1<=2
x2-x3<=2
x0-x1<=3
x3-x0<=5

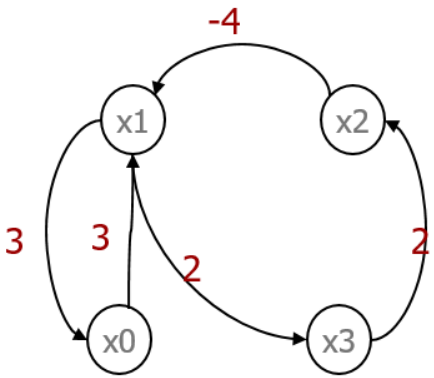


Shortest Path Closure O(n^3)

DBMs
Bellmann 56



Shortest Path Reduction O(n^3)



Space worst O(n^2)
practice O(n)

Minimal Constraint Form
RTSS'97

Datastructures for Zones

- DBM package
- Mi
  Fo
- Cl
  Di