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One-clock synthesis problems

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STACS'26

Reactive syntheses for timed systems

Build a real-time system correct by construction

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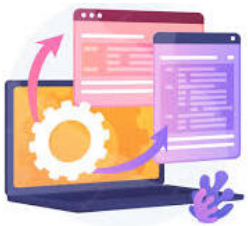

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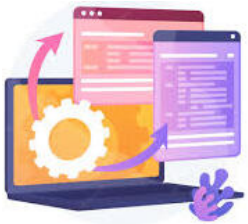

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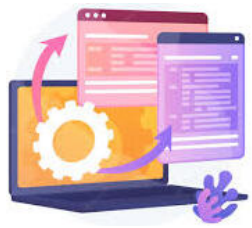


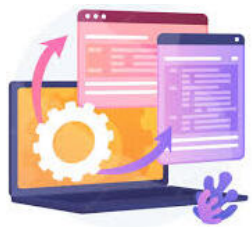
System

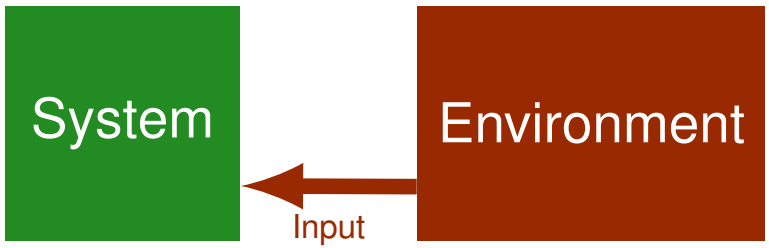
Environment

Reactive syntheses for timed systems

Build a real-time system correct by construction

Input: I^{ω}





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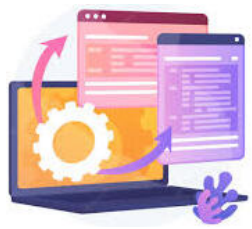
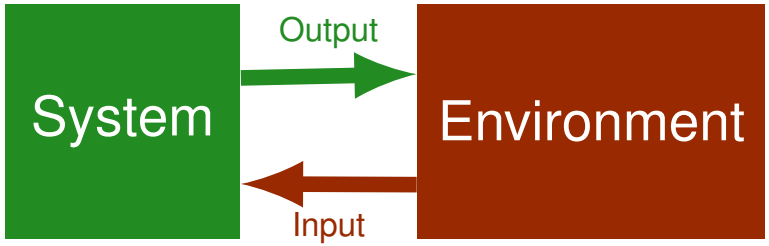
Build a real-time system correct by construction

Output: O^ω Input: I^ω





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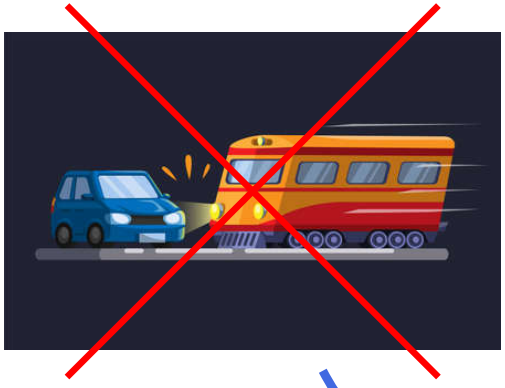

Interactions $\rightsquigarrow i_0 o_0 i_1 o_1 i_2 o_2 \cdots$

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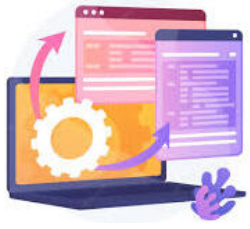

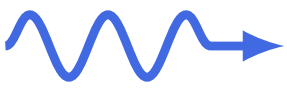

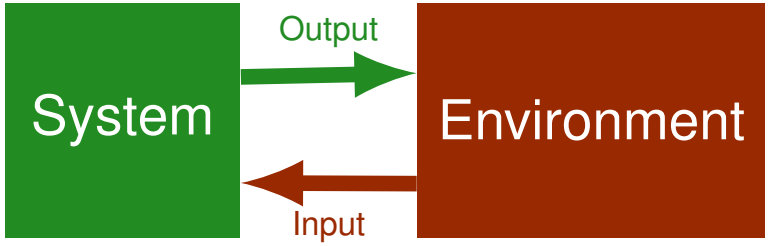

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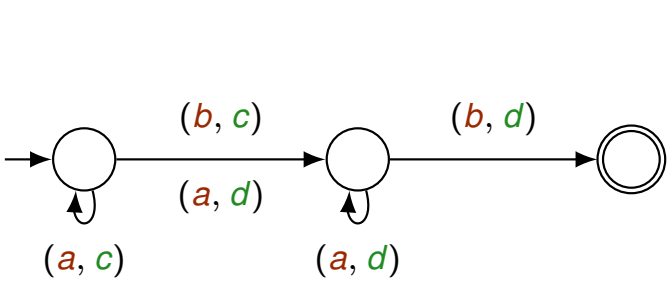

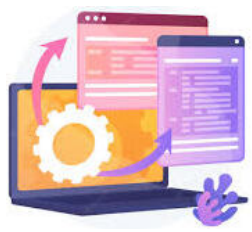

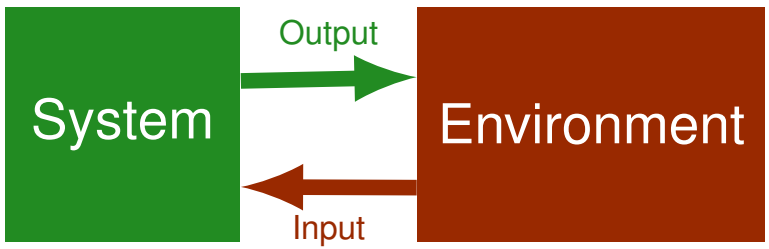

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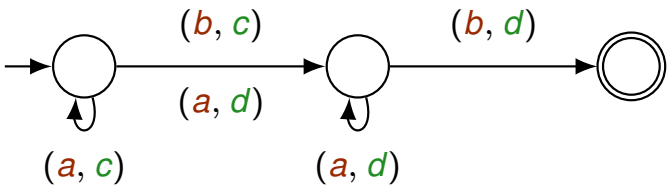

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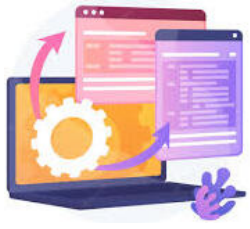
Reactive synthesis



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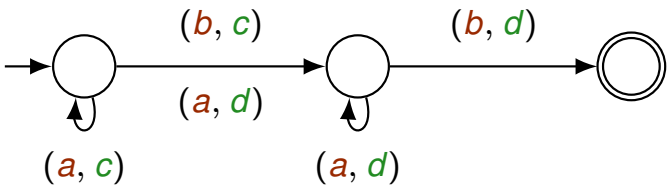

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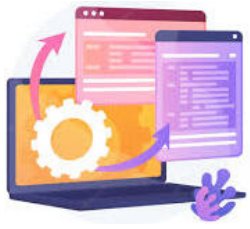
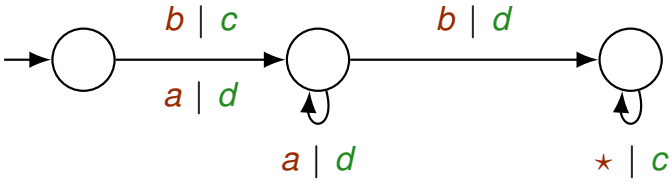


Reactive synthesis

Church synthesis



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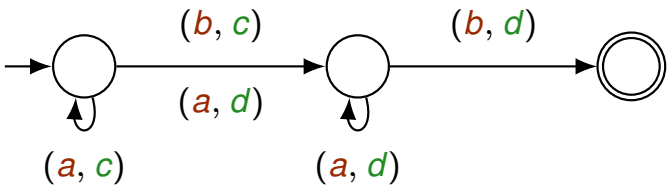

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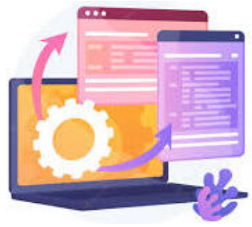

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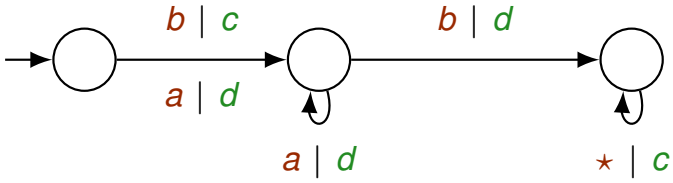

Reactive syntheses problems

EXPTIME-complete for non-deterministic parity automata.

Solving sequential conditions finite-state strategies, J.R. Büchi and L.H. Landweber, 1969, AMS

On the Synthesis of a Reactive Module, A. Pnueli and R. Rosner, 1989, POPL

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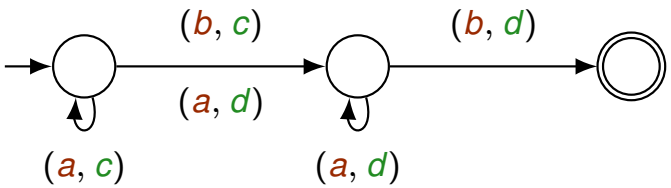

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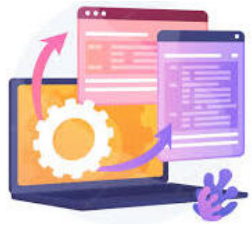

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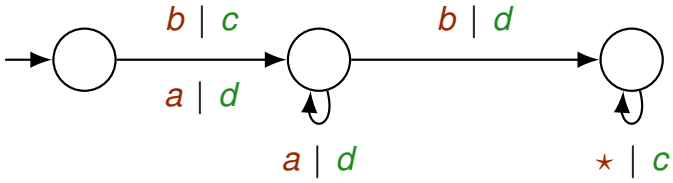

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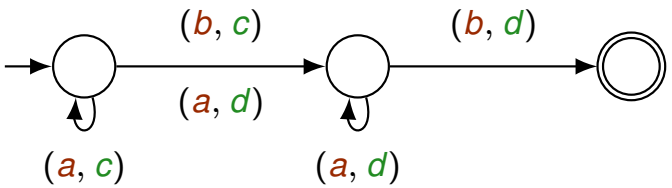

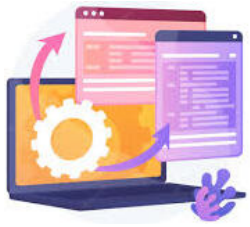

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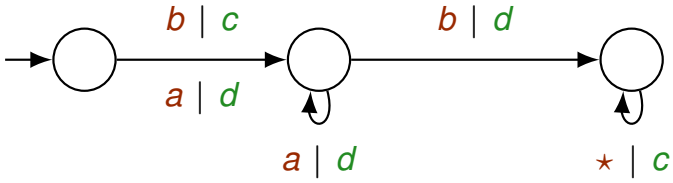

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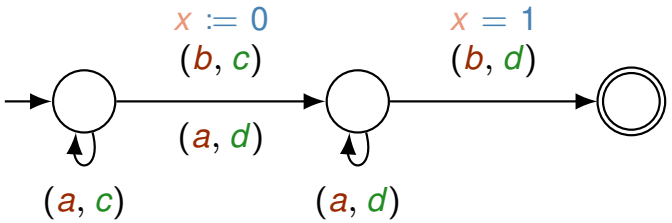

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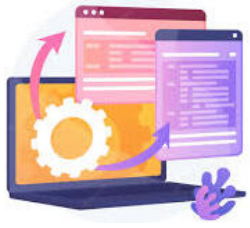

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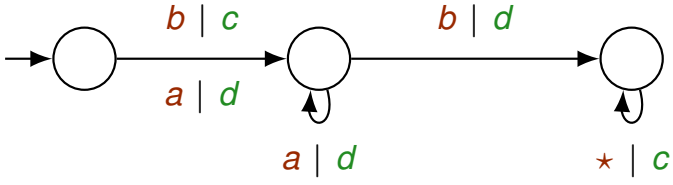

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A theory of timed automata, R. Alur D. Dill, TCS 1994

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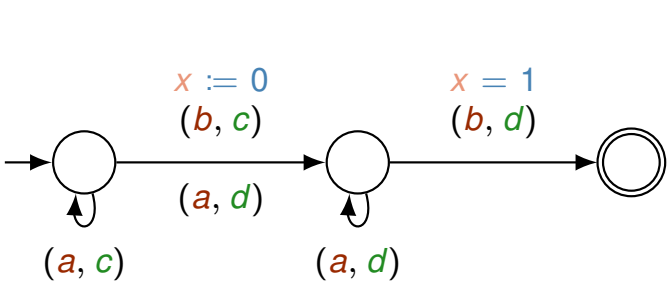

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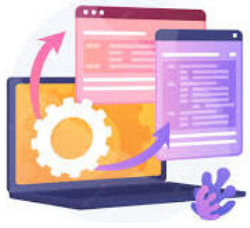

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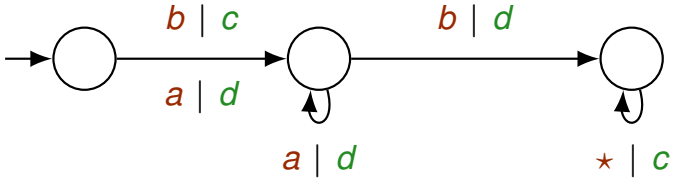

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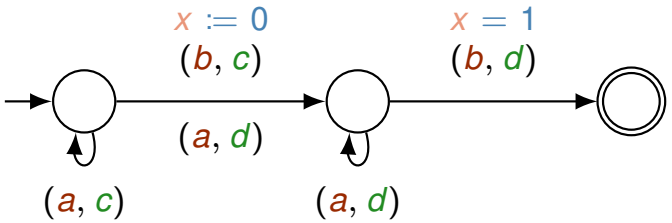

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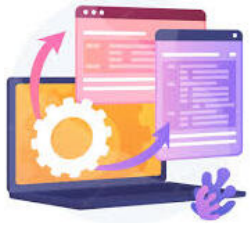

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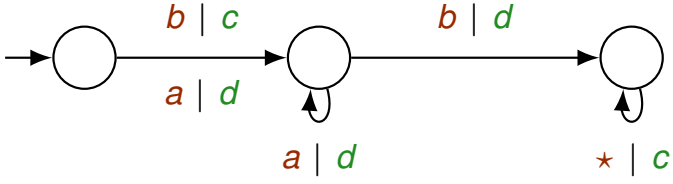

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Reactive synthesis seen as a two-player game

How to play in this game?

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$A \times \mathbb{Q}_{\geqslant 0}$

Reactive synthesis seen as a two-player game

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B

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(a_1, t_1)

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b_2

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$\vdots$

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$\vdots$

b_1

b_2

$\vdots$

Produce $w \in (A \times B \times \mathbb{Q}_{\geqslant 0})^\omega$

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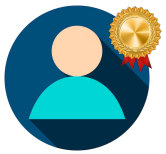
Winning condition: $\mathcal{A}$

a non-deterministic timed automata over $A \times B$



wins $\Leftrightarrow w \in \mathcal{L}(\mathcal{A})$

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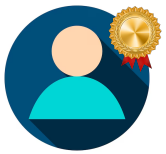

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Deterministic TA defined a timed game on an arena

Reactive synthesis seen as a two-player game

How to play in this game?

$A \times \mathbb{Q}_{\geqslant 0}$

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(a_2, t_2)

$\vdots$

b_1

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$\vdots$

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a non-deterministic timed automata over $A \times B$

wins $\Leftrightarrow w \in \mathcal{L}(\mathcal{A})$

Deterministic TA defined a timed game on an arena

Reactive syntheses on DTA

Problems are decidable over deterministic timed automata.

The element of surprise in timed games, L. de Alfaro, M. Faella, T. Henzinger, R. Majumdar, and M. Stoelinga, CONCUR 2003

Two distinct classes of reactive syntheses

Input : a NTA, the owner of the winning condition, and one player

Reactive synthesis

Church synthesis

Two distinct classes of reactive syntheses

Input : a NTA, the owner of the winning condition, and one player

Reactive synthesis

Output : if the player wins the game

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4 distincts problems

Church synthesis

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- NTA are not complementable

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Output : if the player wins the game with a controller

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What is a controller ?

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Input : a NTA, the owner of the winning condition, and one player

Reactive synthesis

Output : if the player wins the game

4 distincts problems

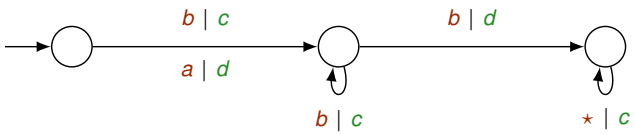
- NTA are not complementable
- Timed language are not Borel (a priori)

$\neq$

Church synthesis

Output : if the player wins the game with a controller

What is a controller ?



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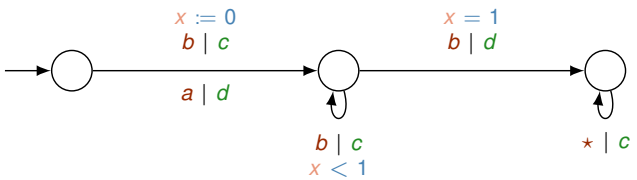

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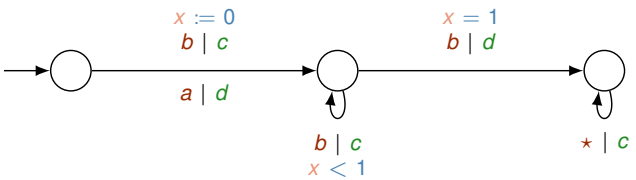

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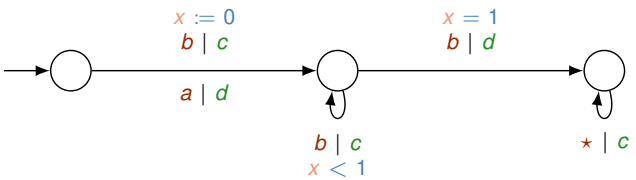

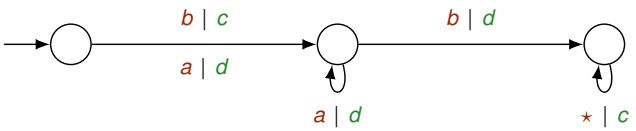

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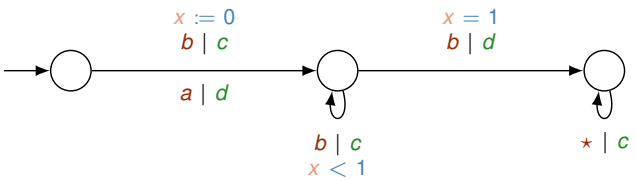

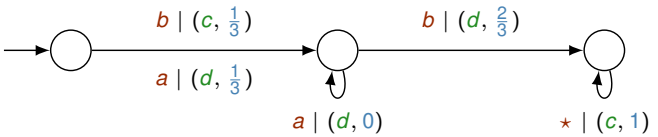

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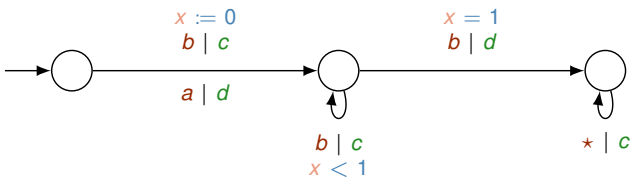

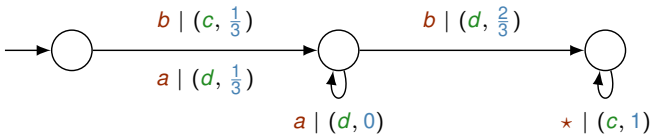

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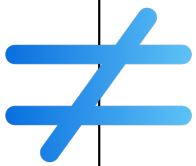

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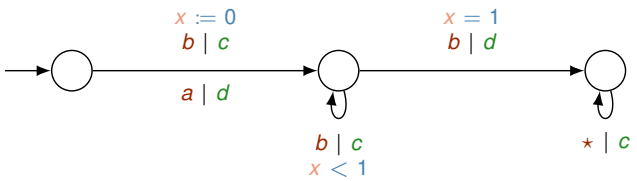

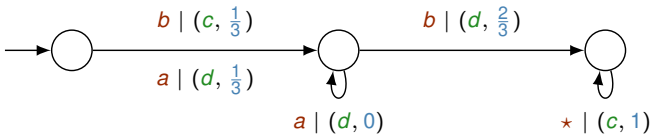

Study the decidability of these 8 problems.

Undecidability of syntheses problems for Büchi NTA_1

			
Reactive synthesis			
Church synthesis			
			

Undecidability of syntheses problems for Büchi NTA_1

			
Reactive synthesis		Universality	
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For NTA_2
Reduction from finitness in lossy counters machines

Timed Games and Deterministic Separability, L. Clemente, S. Lasota, R. Piórkowski, ICALP, 2020

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For NTA_2
Reduction from finitness in lossy counters machines

 Can we adapt this reduction for one-clock setting ?

Timed Games and Deterministic Separability, L. Clemente, S. Lasota, R. Piórkowski, ICALP, 2020

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Finitness in lossy counter machine

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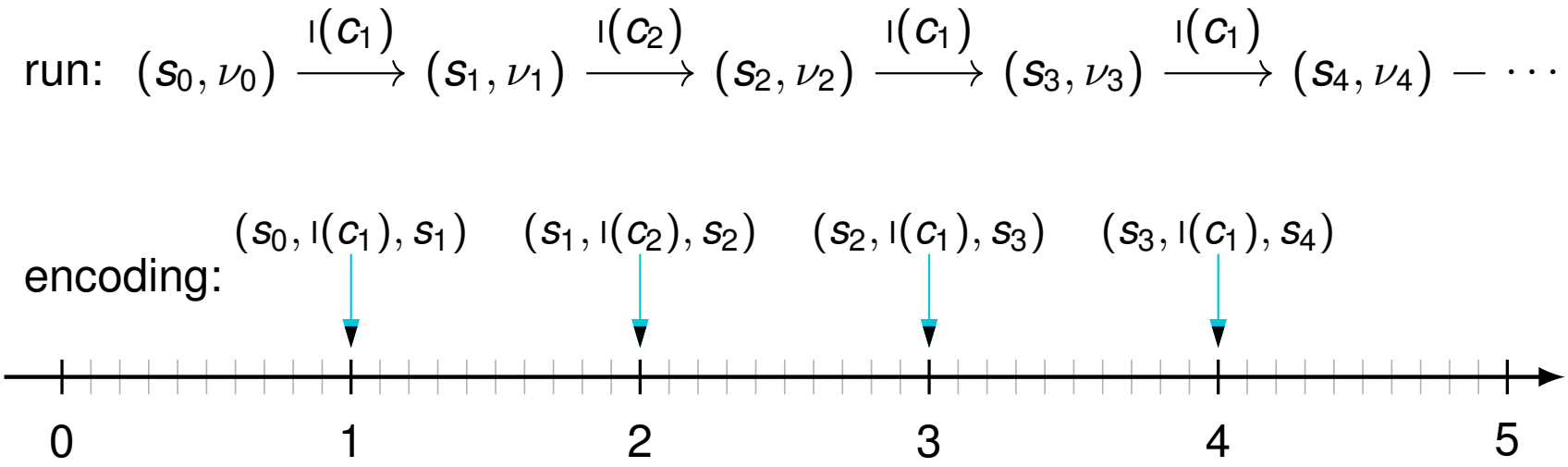

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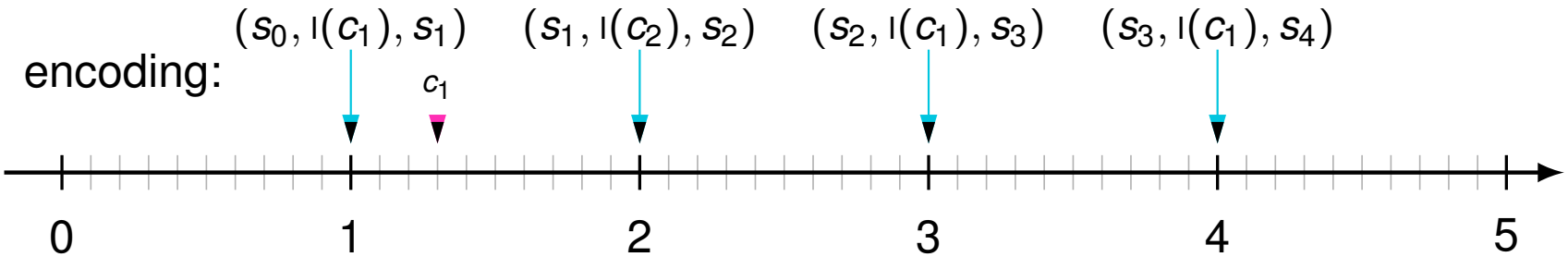

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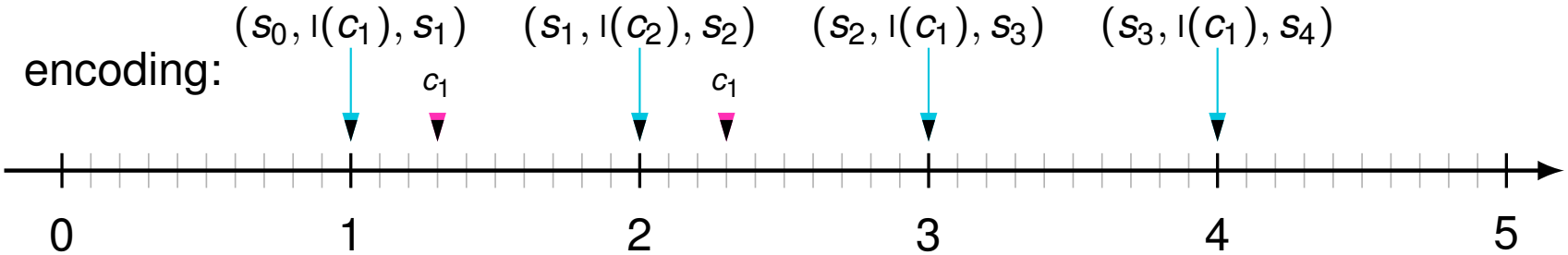

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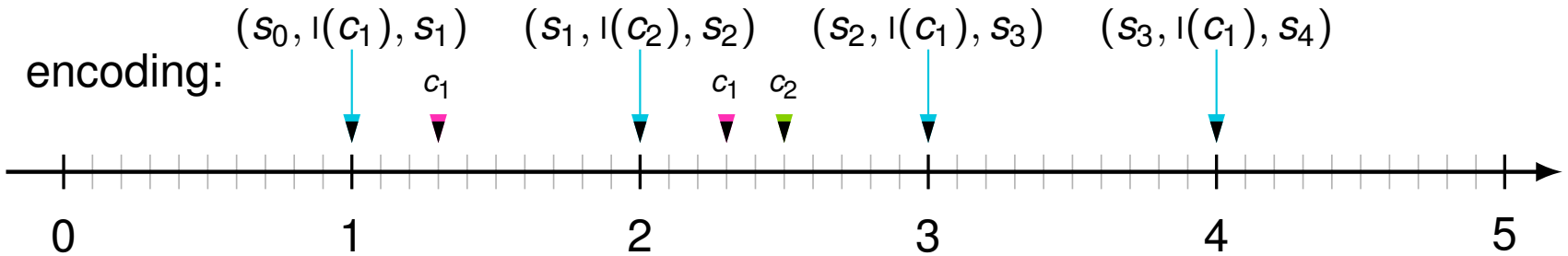

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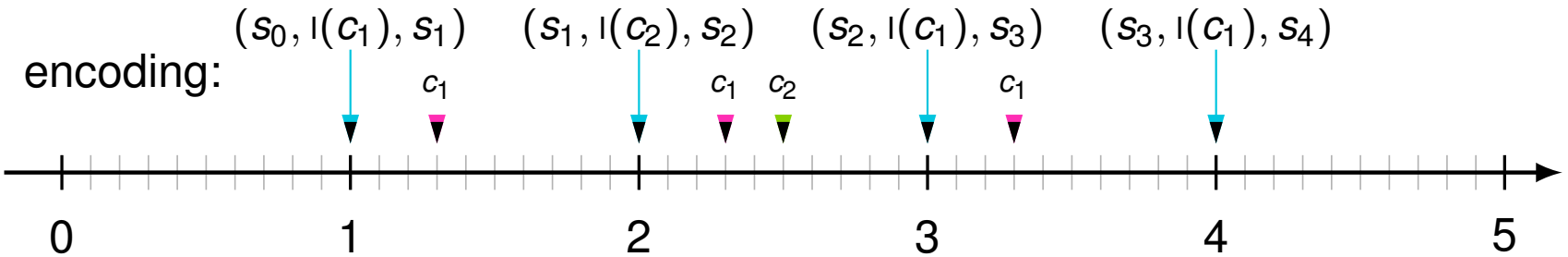

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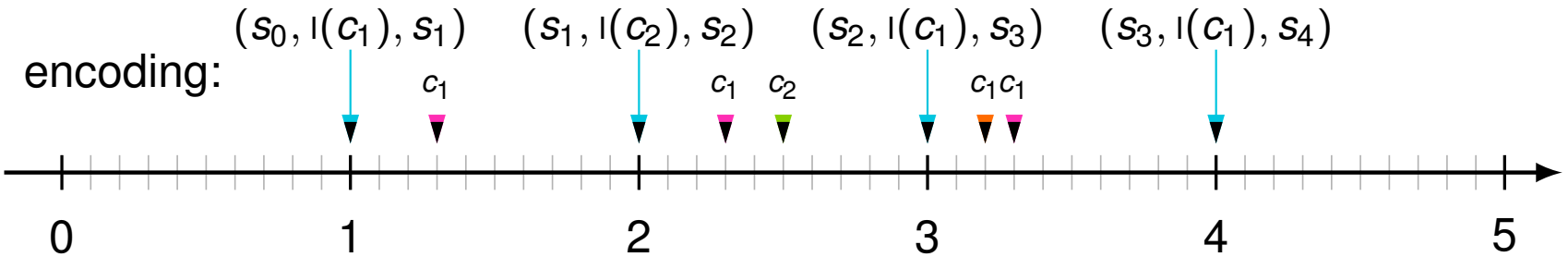

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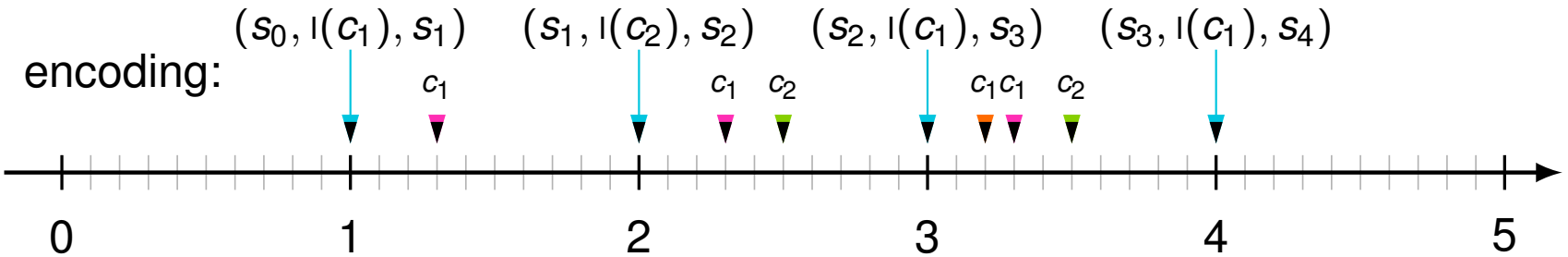

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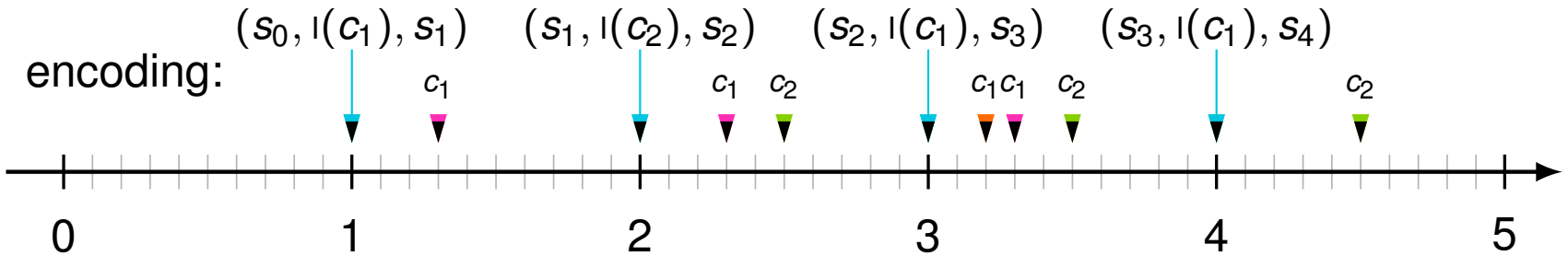

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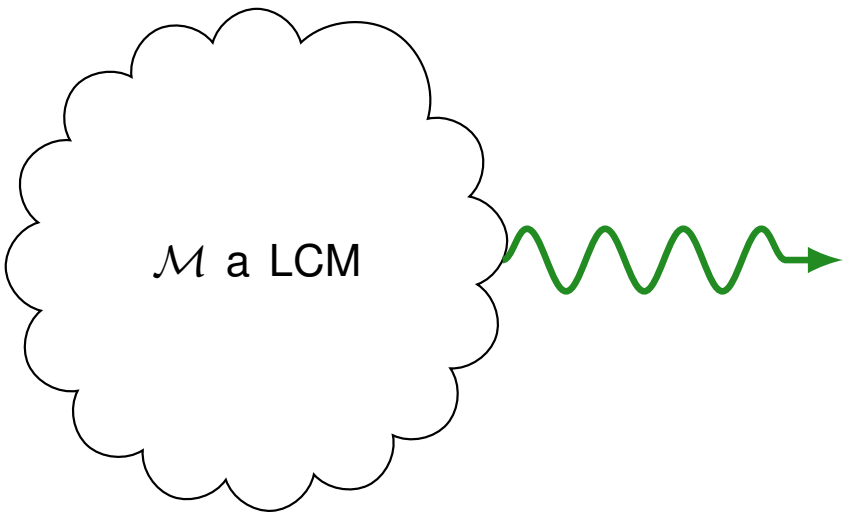

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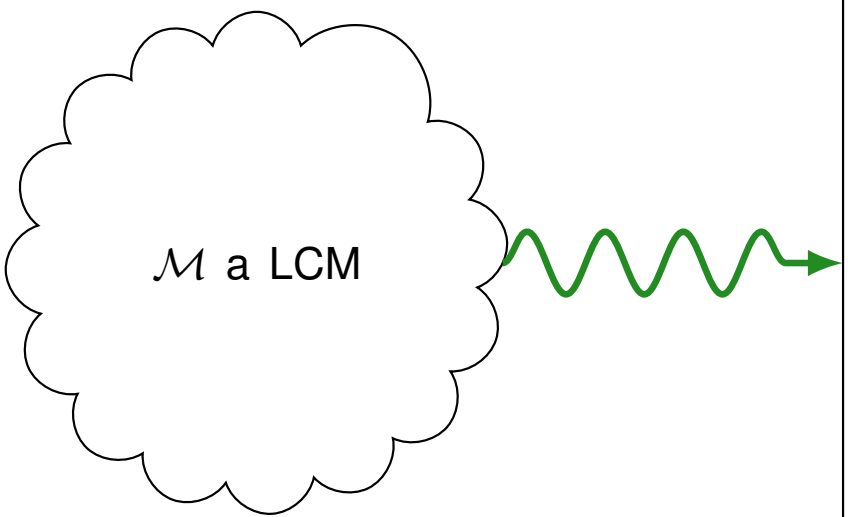

Reactive synthesis game $\mathcal{G}$

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encoding a run or
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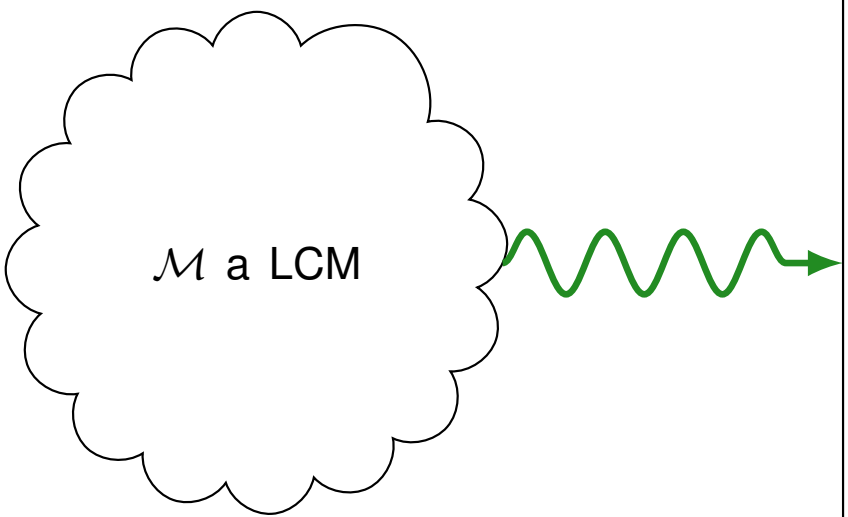

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Why two clocks are needed ?

Removing one clock in the winning condition

  can win by encoding a good run of $\mathcal{M}$

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Büchi in lossy counter machine

Input : $\mathcal{M}$ a lossy counter machine and q_f
Output : if q_f is repeatly reachable.

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 wins with a controller

 needs infinite memory to win

Removing one clock in the winning condition

  can win by encoding a good run of $\mathcal{M}$

Büchi in lossy counter machine

Input : $\mathcal{M}$ a lossy counter machine and q_f
Output : if q_f is repeatly reachable.

 wins with a controller

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 Use a new encoding of runs into timed words

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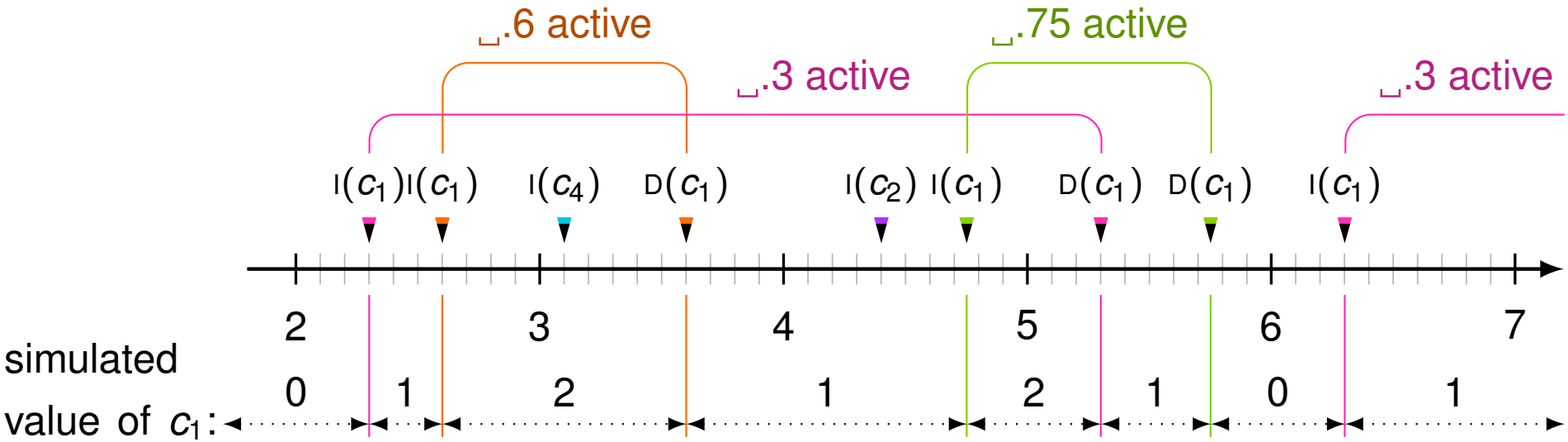

Undecidability of syntheses problems for Büchi NTA_1

			
Reactive synthesis		Universality	
Church synthesis		Universality sampled langages	
		Universality	

For NTA_2
Reduction from finitness in lossy counters machines

Undecidability of syntheses problems for Büchi NTA_1

			
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Synthese of register automata

Challenging questions

Existence of decidable subclass of game ?

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Decidability for resource-bounded synthesis

Timed Games and Deterministic Separability, L. Clemente, S. Lasota, R. Piórkowski, ICALP, 2020

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- change the semantics of timed automata : robustness

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Thank you! Questions ?

Syntheses from universality problem in *NTA*

Universality

Input : $\mathcal{A} \in$ *NTA* over Σ
Output : if $\mathcal{L}(\mathcal{A}) = \mathbb{T}(\Sigma^*)$

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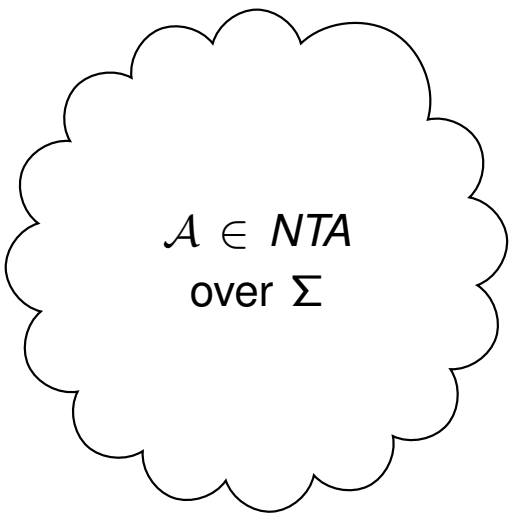

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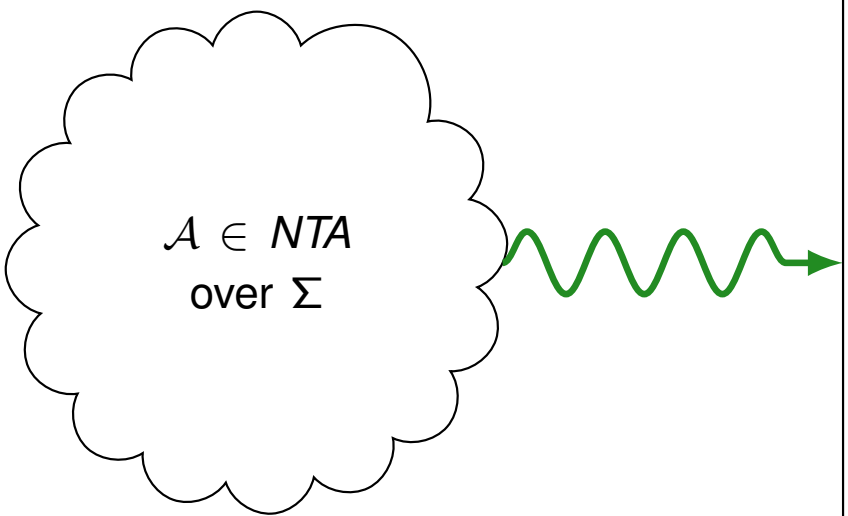

Reactive synthesis game $\mathcal{G}$

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actions → Σ

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How to guarantee a winning controller for

?

Controller for  from universality problems

Universal sampled timed language

Input : $\mathcal{A}$ a *NTA*
Output : if for all $\varepsilon > 0$, $\mathcal{L}_\varepsilon(\mathcal{A})$ is universal.

Controller for  from universality problems

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Sampled universality of timed automata, P.Abdulla, P. Krcal, and W. Yi, FoSSaCS, 2007.

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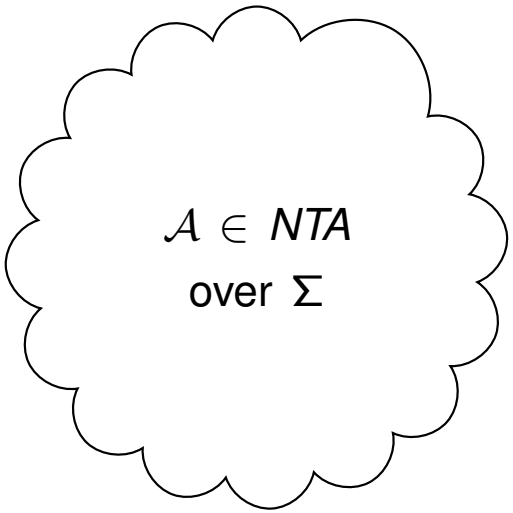

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Tick automata

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On timed automata with discrete time – structural and language theoretical characterization, H. Gruber, M. Holzer, A. Kiehn, and B. König, DLT, 2005.

Interlude : focus on timed automata

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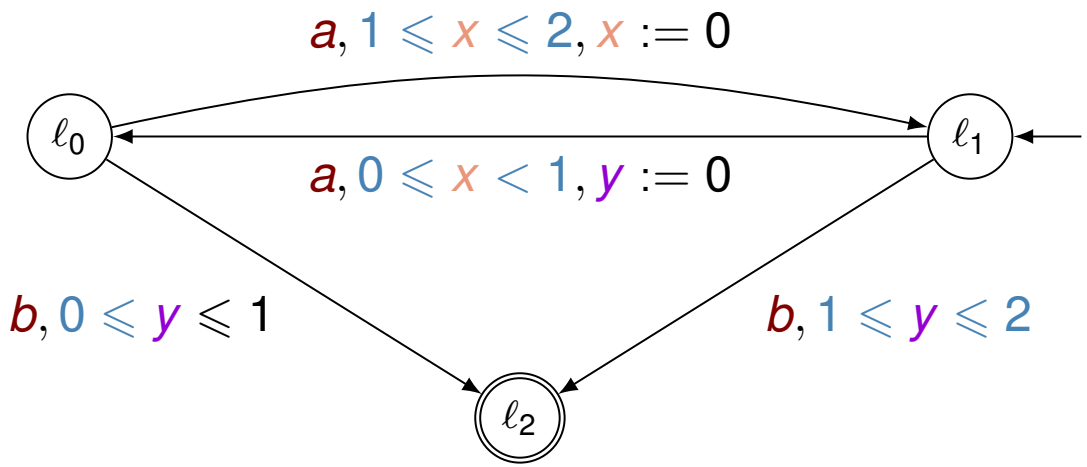

A theory of timed automata, R. Alur D. Dill, TCS 1994

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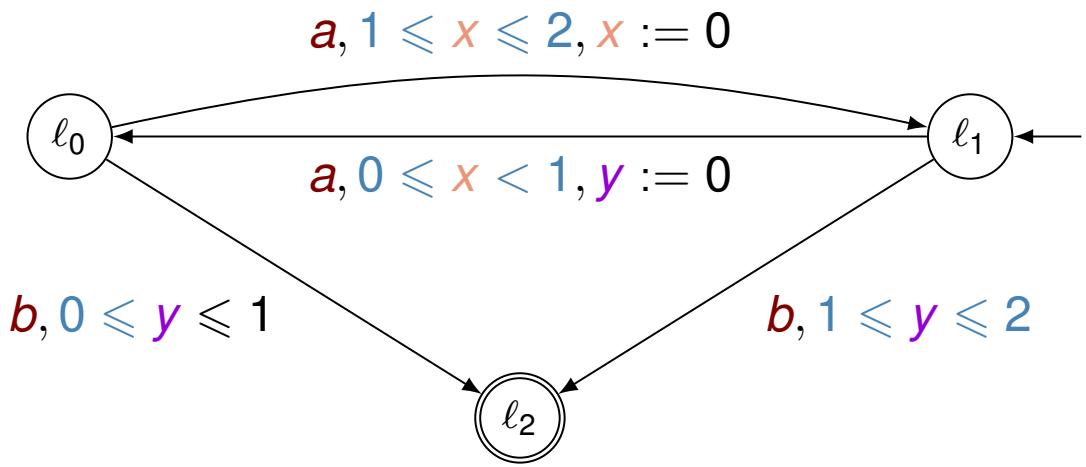

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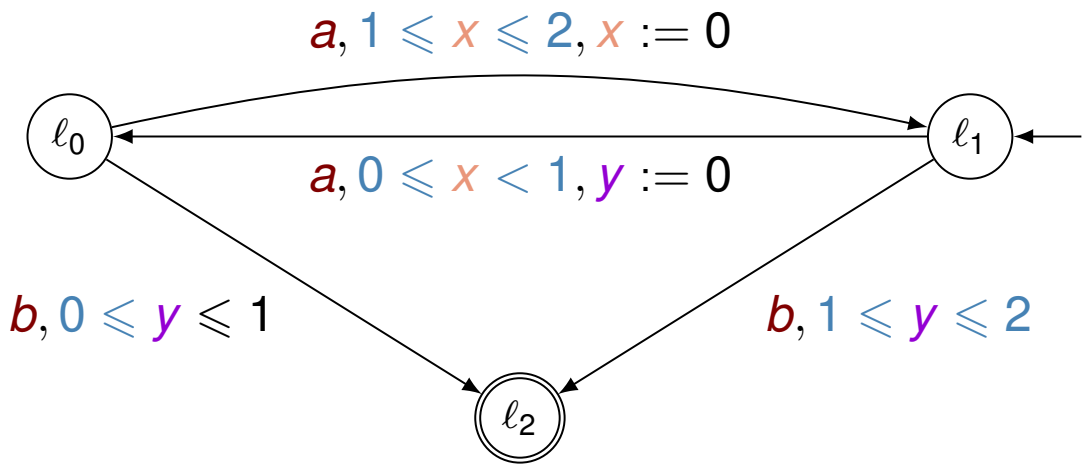

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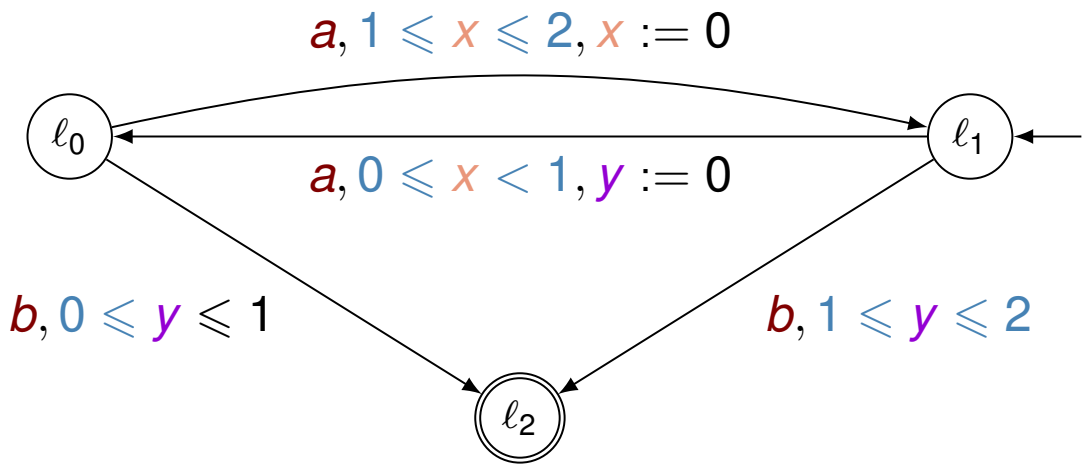

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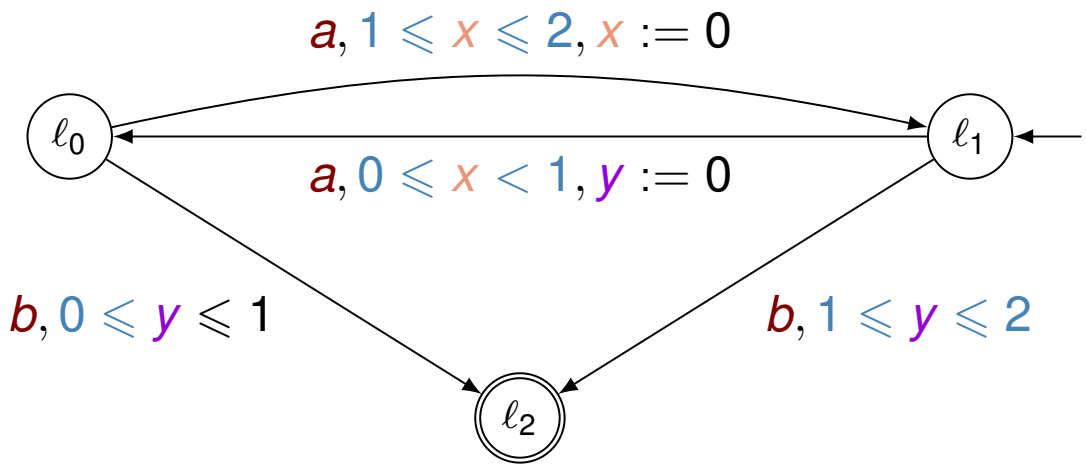

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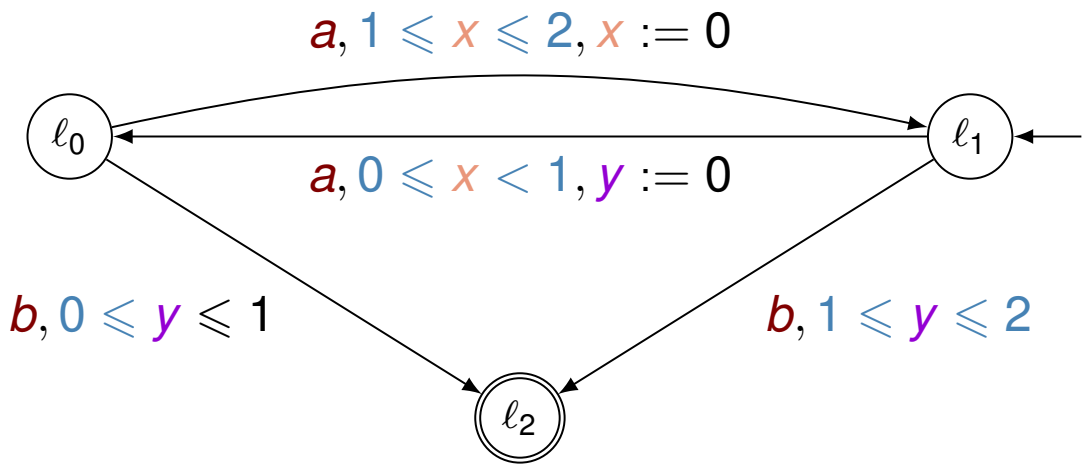

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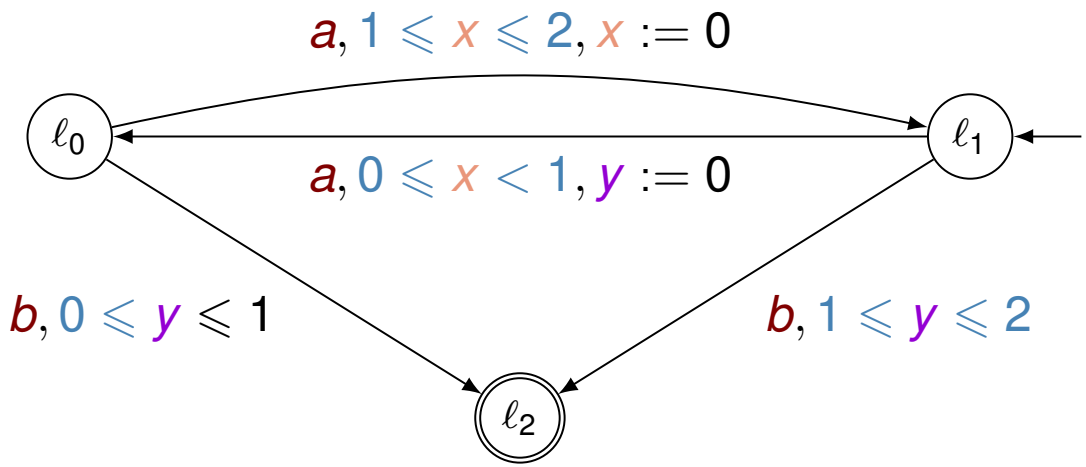

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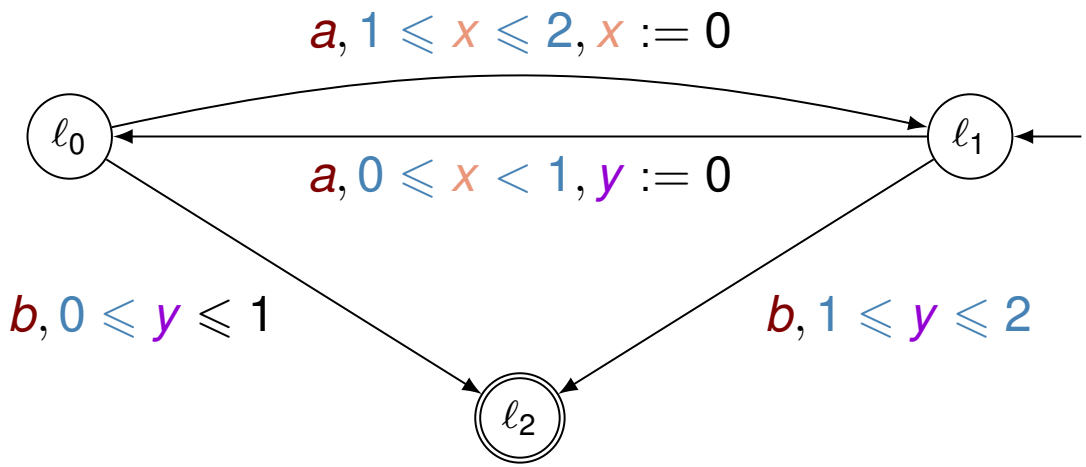

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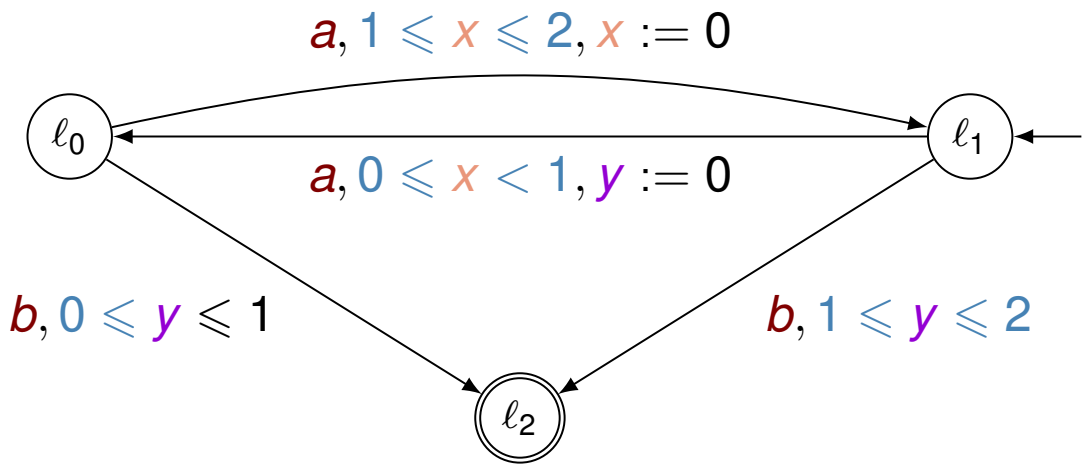

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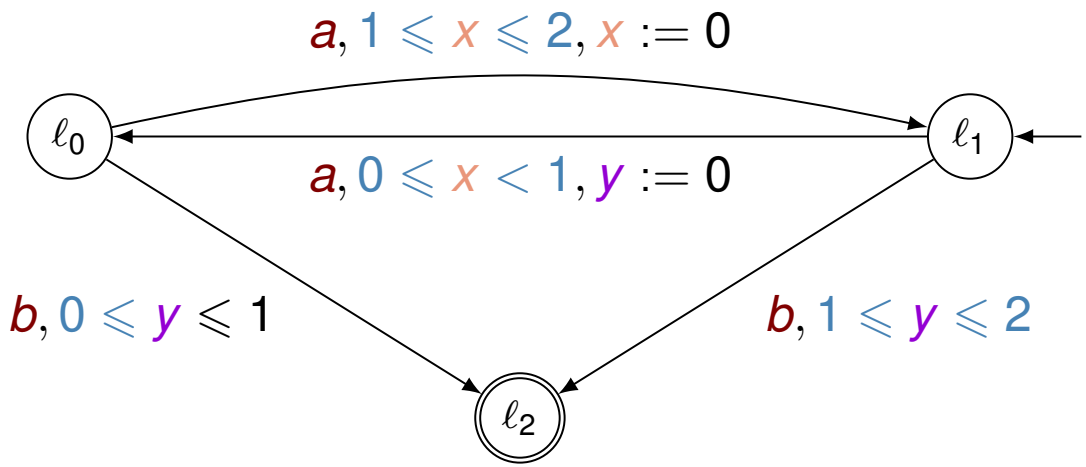

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Wanted properties for timed automata

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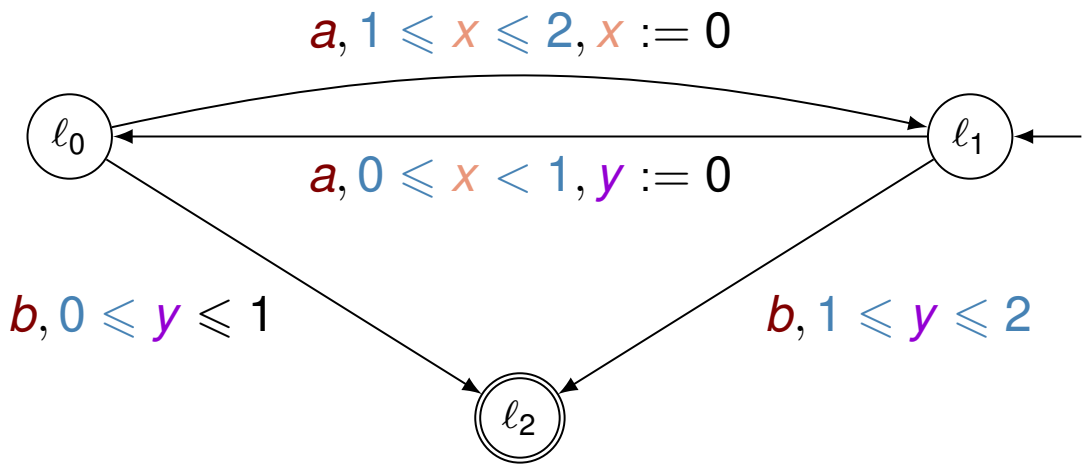

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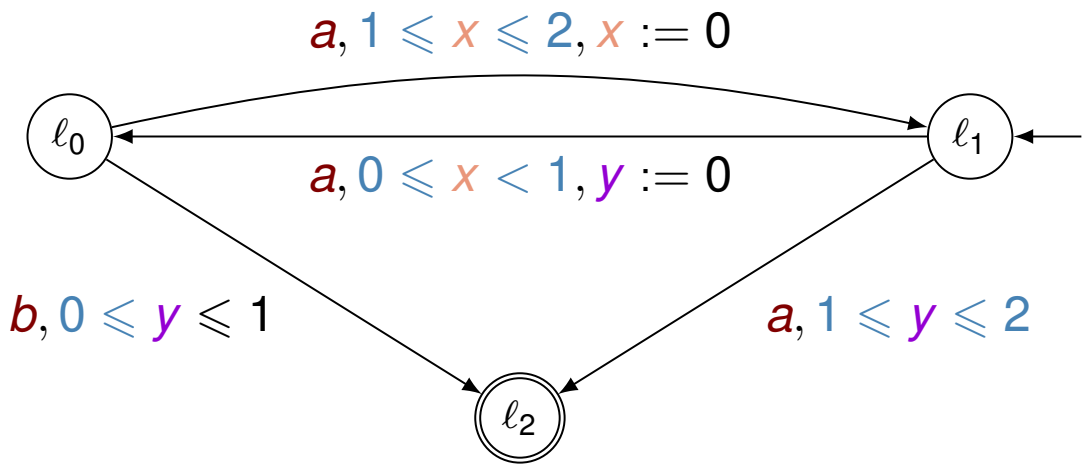

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