

Aula 2: Labelled Transition Systems (cont.) and Calculus of Communicating Systems

Interaction & Concurrency Course Unit: Reactive Systems Module

April 12, 2023

Recommended reading

Chapter 2 and 3 of Aceto et al. 2007 and Chapter 2 of Groote and Mousavi 2014.

Concepts introduced and discussed:

- game characterization of bisimilarity,
- universal winning strategy of the defender or of the attacker,
- strong bisimilarity and universal winning strategy of the defender,
- process algebras,
- input or output actions,
- processes interacting via synchronized communication,
- Milner's Calculus of Communicating Systems (CCS),
- basic constructions: *Nil*, action prefixing, choice operator, parallel composition operator, restricted actions, relabelling function, definitions (recursive definitions are allowed),
- complementary actions and communication in parallel composition,
- internal actions (τ),
- semantics of CCS expressions defined as LTS via structural operation semantics (SOS) rules.

Game (Método Atacante / Defensor)

1º O atacante escolhe transição $s \Rightarrow s'$

2º Defensor responde com $t \Rightarrow t'$

Se um dos jogadores não se conseguir mover, o outro jogador ganha.

Se o jogo for infinito, o defensor ganha.

Estratégia vencedora universal → independentemente de como o outro jogador está a seleccionar os movimentos, o outro jogador pode sempre ganhar o jogo.

Os estados s_1 e t_1 de um LTS são **fortemente bissimilares** sse o defensor tem uma **estratégia vencedora universal** no jogo de bissimulação forte a partir da configuração (s_1, t_1)

C.C., ou seja, se o atacante tem uma **estratégia vencedora universal** então s_1, t_1 **não** são **fortemente** bissimilares.

Ação τ



Figure 2.11: The internal action τ is not visible

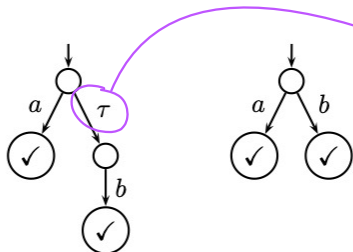


Figure 2.12: The internal action τ is indirectly visible

→ Estes sistemas não podem ser distinguidos, uma vez que τ após a não pode ser observado.

→ não pode ser removido sem alterar o comportamento

Neste caso conseguimos observar a presença de uma ação interna, embora a ação por si só não possa ser vista

se a ação interna aconteceu então podemos ter mais ações *

Some relevant definitions and examples (from Aceto et al. 2007):

- Definition 3.5 (Strong bisimulation game);
- Examples 3.5, 3.6 and 3.7.
- Definition 2.3 (formal syntax CCS)
- Table 2.2 (SOS rules for CCS)

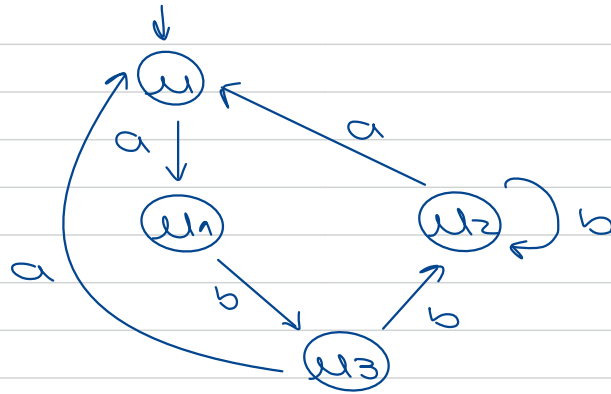
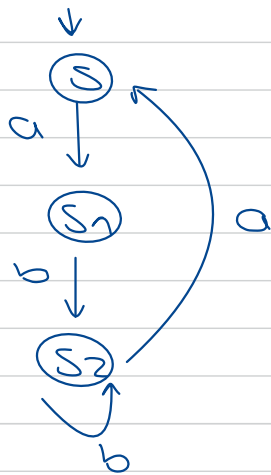
Exercises suggested (from Aceto et al. 2007):

- Exercise 3.5; pg 48
- ~~Exercise 3.7;~~
- Exercise 3.37; pg 78
- ~~Exercises 2.1, 2.2 and 2.3;~~ ver ex máquina café
- Exercise 2.6. Aulas T pg 21

References

- Aceto, Luca et al. (2007). *Reactive Systems - Modelling, Specification and Verification*. Cambridge University Press.
- Groote, Jan and Mohammad Mousavi (2014). *Modelling and Analysis of Communicating Systems*. The MIT Press.

Game (Atacante / Defensor)



$(S, U) \in R$

A $S \xrightarrow{a} S1$

D $U \xrightarrow{a} U1$

$(S1, U1) \in R$

A $S1 \xrightarrow{b} S2$

D $U1 \xrightarrow{b} U3$

$(S2, U3) \in R$

A $S2 \xrightarrow{b} S2$
 $S2 \xrightarrow{a} S$
 $U3 \xrightarrow{b} U2$
 $U3 \xrightarrow{a} U$

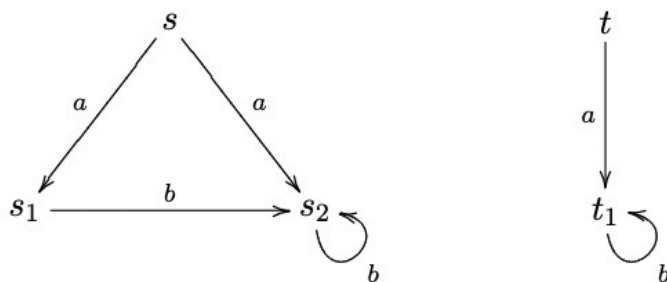
D $U3 \xrightarrow{b} U2$
 $U3 \xrightarrow{a} U$
 $S2 \xrightarrow{b} S2$
 $S2 \xrightarrow{a} S$

$(S2, U2) \in R$

A $S2 \xrightarrow{b} S2$
 $S2 \xrightarrow{a} S$
 $U2 \xrightarrow{b} U2$
 $U2 \xrightarrow{a} U$

D $U2 \xrightarrow{b} U2$
 $U2 \xrightarrow{a} U$
 $S2 \xrightarrow{b} S2$
 $S2 \xrightarrow{a} S$

Estatégia vencedora do defensor



(s, t)

A	$s \xrightarrow{a} s_1$	D	$t \xrightarrow{a} t_1$	(s_1, t_1)
	$s \xrightarrow{a} s_2$		$t \xrightarrow{a} t_1$	(s_2, t_1)
	$t \xrightarrow{b} t_1$		$s \xrightarrow{b} s_1$	(s_1, t_1)

(s_1, t_1)

A	$s_1 \xrightarrow{b} s_2$	D	$t_1 \xrightarrow{b} t_1$	(s_2, t_1)
	$t_1 \xrightarrow{b} t_1$		$s_1 \xrightarrow{b} s_2$	(s_2, t_1)

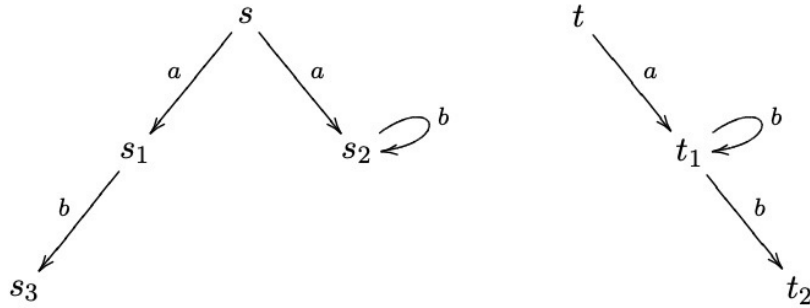
(s_2, t_1)

A	$s_2 \xrightarrow{b} s_2$	D	$t_1 \xrightarrow{b} t_1$	(s_2, t_1)
	$t_1 \xrightarrow{b} t_1$		$s_2 \xrightarrow{b} s_2$	

Como o defensor tem uma estratégia vencedora universal podemos concluir que $s \sim t$

forçadamente
bissimilares

$s \not\sim t$ (Estratégia do Atacante)



(s, t)

A	$s \xrightarrow{a} s_1$	⊙	$t \xrightarrow{a} t_1$	(s_1, t_1) ✓
	$s \xrightarrow{a} s_2$		$t \xrightarrow{a} t_1$	(s_2, t_1) ✓
	$t \xrightarrow{a} t_1$		$s \xrightarrow{a} s_1$	(s_1, t_1) ✓

(s_1, t_1)

A	$s_1 \xrightarrow{b} s_3$	⊙	$t_1 \xrightarrow{b} t_1$	(s_3, t_1)
	$t_1 \xrightarrow{b} t_1$		$s_1 \xrightarrow{b} s_3$	(s_3, t_1)
	$t_1 \xrightarrow{b} t_2$		$s_1 \xrightarrow{b} s_3$	(s_3, t_2)

(s_2, t_1)

A	$s_2 \xrightarrow{b} s_2$	⊙	$t_1 \xrightarrow{b} t_1$	
	$t_1 \xrightarrow{b} t_1$		$s_2 \xrightarrow{b} s_2$	
	$t_1 \xrightarrow{b} t_2$		$s_2 \xrightarrow{b} s_2$	

(s_3, t_1)

A	$t_1 \xrightarrow{b} t_1$	⊙	$s_3 \not\rightarrow$	
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We will define attacker's universal winning strategy from (s, t) and hence show that $s \not\sim t$.

In the first round the attacker plays on the left-hand side the move $s \xrightarrow{a} s_1$ and the defender can only answer by $t \xrightarrow{a} t_1$. The current configuration becomes (s_1, t_1) . In the second round the attacker plays on the right-hand side according to the transition $t_1 \xrightarrow{b} t_1$ and the defender can only answer by $s_1 \xrightarrow{b} s_3$. The current configuration becomes (s_3, t_1) . Now the attacker wins by playing again the transition $t_1 \xrightarrow{b} t_1$ (or $t_1 \xrightarrow{b} t_2$) and the defender loses because $s_3 \not\rightarrow$.