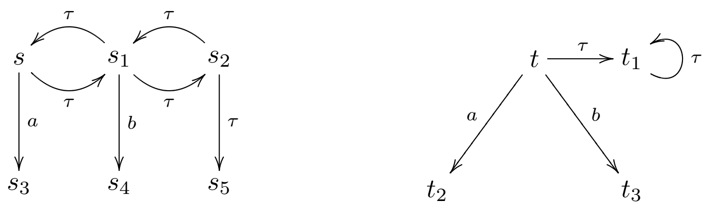
# Tutorial 4

## Exercise 1

Assume an arbitrary CCS defining equation $K \stackrel{\mathrm{def}}{=} P$ where $K$ is a process constant and $P$ is a CCS expression. Prove that $K \sim P$. (Hint: by using SOS rules for CCS, examine the possible transitions from $K$ and $P$.)

## Exercise 2*

Consider the following labelled transition system.




Show that $s \approx t$ by finding a weak bisimulation $R$ containing the pair $(s, t)$.

## Exercise 3*

Decide whether the following claims are true or false. Support your claims either by using bisimulation games or directly the definition of strong/weak bisimilarity.

- $a.\tau.Nil \stackrel{?}{\sim} \tau.a.Nil$
- $\tau.a.A + b.B \stackrel{?}{\sim} \tau.(a.A + b.B)$
- $\tau.Nil + (a.Nil \,|\, \overline{a}.Nil) \smallsetminus \{a, b\} \stackrel{?}{\sim} \tau.Nil$
- $a.(\tau.Nil + b.B) \stackrel{?}{\sim} a.Nil + a.b.B$

The same processes but weak bisimilarity instead of the strong one.

- $a.\tau.Nil \stackrel{?}{\approx} \tau.a.Nil$
- $\tau.a.A + b.B \stackrel{?}{\approx} \tau.(a.A + b.B)$
- $\tau.Nil + (a.Nil \,|\, \overline{a}.Nil) \smallsetminus \{a, b\} \stackrel{?}{\approx} \tau.Nil$
- $a.(\tau.Nil + b.B) \stackrel{?}{\approx} a.Nil + a.b.B$

Hint: draw first the LTS generated by the CCS processes.
Home exercise: try to verify your claims by using the tool CWB.

## Exercise 4

Prove that for any CCS process $P$ the following law (called idempotency) holds.

- $P + P \sim P$

By using Proposition 2 from *A Note on Game Characterization of Strong and Weak Bisimilarity* conclude that also $P + P \approx P$.

## Exercise 5

In the weak bisimulation game the attacker is allowed to use $\stackrel{a}{\longrightarrow}$ moves for the attacks and the defender can use $\stackrel{a}{\Longrightarrow}$ in response. Argue that if we modify the game rules so that the attacker can also use the long moves $\stackrel{a}{\Longrightarrow}$ then this does not provide any additional power for the attacker. Conclude that both versions of the game provide the same answer about bisimilarity/nonbisimilarity of two processes.

## Exercise 6 (optional)

Define two CCS process constants $A$ and $B$ such that

- $A$ has infinitely many reachable states,
- $B$ has only finitely many reachable states, and
- $A \sim B$.

**Challenging continuation of the exercise:**
Can you think of a CCS process $C$ with infinitely many reachable states such that there is no CCS process with only finitely many reachable states strongly bisimilar to it? How would you support your claim?

## Exercise 7 (optional, easy but recommended)

Consider the tiny communication protocol from Lecture 4.

- Draw the labelled transition system generated by the processes $Spec$ and $Impl$.
- Prove (by hand) that $Spec \approx Impl$. Hint: define a weak bisimulation relation containing $(Spec, Impl)$.

**If you give me your group solution of this exercise in a written form, I will correct it for you.**