

Exercise 1

a) What are all the possible values that can be stored in the variable x after the execution of the following parallel program when assignment is assumed to be an atomic instruction?

$$x := 10; \left((x := x * 2; \quad x := x - 11; \quad x := x + 2) \parallel x := x - 5 \right)$$

b) Does the following parallel program satisfy the given pre and post condition?

$$[x=0] \quad (x++ \parallel x++) \quad [x=2]$$

Exercise 2

Let R be a binary relation on a set A . Let us define the binary relation

$$E \stackrel{\text{def}}{=} \{(x, x) \mid x \in A\}.$$

It is trivially true that $R \cup E$ is a reflexive relation.

- Argue that $R \cup E$ is a reflexive closure of R .

Exercise 3

Let R be a binary relation on a set A . Let us define the binary relation

$$R^{-1} \stackrel{\text{def}}{=} \{(y, x) \mid (x, y) \in R\}.$$

- Argue that $R \cup R^{-1}$ is a symmetric relation.
- Argue that $R \cup R^{-1}$ is a symmetric closure of R .

Exercise 4

Consider a binary relation $\text{succ} \subseteq \mathbb{N} \times \mathbb{N}$ defined by

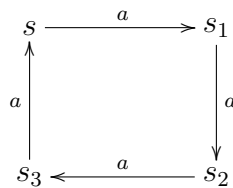
$$\text{succ} = \{(n, n + 1) \mid n \in \mathbb{N}\}.$$

Answer the following questions:

- What relation is the transitive closure of succ ?
- What relation is the reflexive and transitive closure of succ ?
- What relation is the symmetric, reflexive and transitive closure of succ ?

Exercise 5*

Let us consider the following labelled transition system.



- Define the labelled transition system as a triple $(Proc, Act, \{\xrightarrow{a} \mid a \in Act\})$.
- What is the reflexive closure of the binary relation \xrightarrow{a} ? (A drawing is fine.)
- What is the symmetric closure of the binary relation \xrightarrow{a} ? (A drawing is fine.)
- What is the transitive closure of the binary relation \xrightarrow{a} ? (A drawing is fine.)

Exercise 6

Let us consider the following CCS definition of a coffee machine.

$$CM \stackrel{\text{def}}{=} coin.\overline{coffee}.CM$$

- Give a CCS process which describes a coffee machine that may behave like CM but may also steal the money it receives and fail at any time.

Exercise 7

Assume a given labelled transition system $T = (Proc, Act, \{\xrightarrow{a} \mid a \in Act\})$ such that the sets $Proc$ and Act are finite.

- Does it imply that \xrightarrow{a} is also a finite set? Why?
- Draw an example of an LTS with four states and two actions.
- How can your example be described by a sequential fragment of CCS (with Nil, action prefixing, nondeterminism and recursive definitions of names)?
- Show that in general any finite LTS T can be described by using only a sequential fragment of CCS.