Multi-threaded Processes
4 Multi-threaded Processes

4.1 Structural Semantics of Channel-Based Communication

Structural Semantics of Channel-Based Communication
Processes and channels

• Abstract syntax (blackboard):
  – Syntactic categories;
  – Language constructs.

• Variable-independence of processes (blackboard).
Informally about the approach

• Behaviour levels (blackboard):
  – Local behaviour;
  – Communication capabilities;
  – Global behaviour.

• Communication models (blackboard):
  – Synchronous communication;
  – Asynchronous communication.
4.1 Structural Semantics of Channel-Based Communication

Local level

- Semantics of local behaviour (blackboard).
  - Configurations and terminal configurations;
  - Transitions;
  - Axioms and rules (Table 8.1).
Synchronous communication model

- **Rendezvous** — communication unit in the synchronous model, involving exactly two processes (blackboard).

- Semantics of rendezvous (blackboard):
  - Configurations and terminal configurations;
  - Transitions;
  - Axioms and rules (Table 8.2).

- Problem 8.3 (blackboard).
4 Multi-threaded Processes

4.1 Structural Semantics of Channel-Based Communication

Global level

• Semantics of global behaviour (blackboard):
  – Configurations, start configurations, terminal configurations;
  – Transitions;
  – Axioms and rules (Table 8.3).
Exercises

• Find two as different as possible structural semantics derivation sequences of the program \( \text{par}(S_1, S_2) \) where

\[
S_1 = x := 1 ; (k ? y ; z := x + y) \\
S_2 = (a := 2 ; k ! (a + 3)) ; \\
\text{if } \neg(b = 0) \text{ then } k ! b \text{ else skip}
\]

in the initial state with all values of variables being 0, assuming synchronous communication model (blackboard).

• Problem 8.4: find two derivation sequences that end in different stuck configurations (oneself).
Asynchronous communication model

• Media (blackboard):
  – Channel environments;
  – Operations on media.

• Semantics of communication (blackboard):
  – Configurations and terminal configurations;
  – Transitions;
  – Axioms and rules (analogous to Table 8.4).
Global level

- Semantics of global behaviour (blackboard):
  - Configurations, start configurations, terminal configurations;
  - Transitions;
  - Axioms and rules (Table 8.5).
Exercises

• Find two structural semantics derivation sequences of the program

\[
\text{par}(S_1, \ S_2) \text{ where}
\]

\[
S_1 = x := 1 \ ; \ (k \ ? \ y \ ; \ z := x + y)
\]

\[
S_2 = (a := 2 \ ; \ k ! (a + 3)) \ ;
\]

\[
\text{if } \neg (b = 0) \ \text{then} \ k ! b \ \text{else} \ \text{skip}
\]

in the initial state with all values of variables being 0, assuming asynchronous communication model with queue-like media, one of which has no analogue in the synchronous model (blackboard).

• Problem 8.5: find two derivation sequences, the first of which ends normally and the second mimics the first with a different type of media (oneself).
4 Multi-threaded Processes

4.2 Bisimulation equivalence

Bisimulation equivalence
Bisimulation and bisimilarity

- Definition 8.8 in both textual and diagrammatic form (blackboard):
- Examples (blackboard):
  - Empty relation;
  - Configurations with only infinite derivation sequences.
- Prove the theorem: Bisimilarity is a bisimulation itself (blackboard).
Bisimilarity as equivalence

• Problem 8.9 (blackboard):
  – Proof that the claim reduces to three properties of bisimulations listed in the textbook;
  – Diagrammatic proof of the three properties.
Application

• Semantic equivalence as a bisimulation (blackboard).
4.3 The Pi-Calculus
Definition

- Abstract syntax (blackboard):
  - Syntactic categories;
  - Formation rules.

- Informal semantics (blackboard).
Free and bound names

- Definition 8.10 (blackboard).
- Definition 8.11 (blackboard).
Exercises

• A moment’s thought 8.12 (blackboard).
• Find the free and bound names of $\pi$-term

\[ x(y).(yz.0/b(w).0)/\nu b.\overline{xb}.0 \]

(oneself).

• A moment’s thought 8.13 (blackboard):
  – Name that is both free and bound has different meanings, so does name that occurs bound by several binders;
  – Needed a more precise concept of free and bound occurrences!
Structural equivalence

• Problem 8.14 (oneself).

• Structural equivalence of $\pi$-terms (blackboard):
  – $\alpha$-congruence;
  – Axioms and rules (Table 8.6).
Exercises

• Find the result of renaming the free name $b$ to $c$ in the $\pi$-term

$$\bar{b}a.\overline{ab}.0/!(a(b).0)/\nu c.b(x).\overline{xc}.0$$

(blackboard).

• Rename the bound name $b$ in the $\pi$-term

$$x(y).(\overline{yz}.0/b(w).0)/\nu b.\overline{xb}.0$$

so that it would be possible to extend the scope of $\nu$ to the whole term (oneself).
Reduction semantics

• Transforming of the terms (blackboard):
  – Transitions;
  – Rewrite axioms and rules (Table 8.7).
Exercises

• Reduce the $\pi$-term (8.1) as long as possible (blackboard).

• Reduce the $\pi$-term (8.2) as long as possible (oneself).

• Reduce the $\pi$-term

$$\overline{ba} \overline{ab}.0/(a(b).0)/\nu c.b(x).\overline{x}c.0$$

as long as possible (oneself).
Labelled reduction semantics

• Syntax of labels (blackboard).

• Free and bound names in labels (blackboard).

• Transforming of the terms (blackboard):
  – Transitions;
  – Rewrite axioms and rules (Table 8.7).
Exercises

• Find and verify a $\tau$-labelled reduction step from the $\pi$-term

$$a(x).P/\nu u.\overline{a}u.Q$$

assuming that $u \notin \text{fv}(P)$ (blackboard).

• Reduce the $\pi$-term (8.2) as long as possible with $\tau$-reductions and show the proof tree of every step (oneself).

• Reduce the $\pi$-term (8.1) as long as possible with $\tau$-reductions and show the proof tree of every step (home).