Semantics and Verification 2008

Lecture 2

- informal introduction to CCS
- syntax of CCS
- semantics of CCS

CCS Basics (Sequential Fragment)

- Nil (or 0) process (the only atomic process)
- action prefixing (a.P)
- names and recursive definitions $(\stackrel{\text{def}}{=})$
- nondeterministic choice (+)

This is Enough to Describe Sequential Processes

Any finite LTS can be (up to isomorphism) described by using the operations above.

Sequential Fragment Parallelism and Renaming

CCS Basics (Parallelism and Renaming)

- parallel composition (|) (synchronous communication between two components = handshake synchronization)
- restriction $(P \smallsetminus L)$
- relabelling (*P*[*f*])

Introduction to CCS Notation Syntax of CCS CCS Process Expressions Semantics of CCS CCS Defining Equations

Definition of CCS (channels, actions, process names)

Let

- A be a set of channel names (e.g. *tea*, *coffee* are channel names)
- L = A ∪ A be a set of labels where
 A = {ā | a ∈ A} (A are called names and A are called co-names)
 by convention ā = a
- Act = L ∪ {τ} is the set of actions where

 τ is the internal or silent action
 (e.g. τ, tea, coffee are actions)
- \mathcal{K} is a set of process names (constants) (e.g. CM).

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Definition of CCS (expressions)

$$P := K$$

$$\alpha.P$$

$$\sum_{i \in I} P_i$$

$$P_1 | P_2$$

$$P \smallsetminus L$$

$$P[f]$$

process constants ($K \in K$) prefixing ($\alpha \in Act$) summation (I is an arbitrary index set) parallel composition restriction ($L \subseteq A$) relabelling ($f : Act \rightarrow Act$) such that • $f(\tau) = \tau$ • $f(\overline{a}) = \overline{f(a)}$

The set of all terms generated by the abstract syntax is called CCS process expressions (and denoted by \mathcal{P}).

Notation

$$P_1 + P_2 = \sum_{i \in \{1,2\}} P_i$$

 $Nil = 0 = \sum_{i \in \emptyset} P_i$

Notation CCS Process Expressions CCS Defining Equations

Precedence

Precedence

- restriction and relabelling (tightest binding)
- 2 action prefixing
- oparallel composition

summation

Example: $R + a.P|b.Q \setminus L$ means $R + ((a.P)|(b.(Q \setminus L)))$.

Introduction to CCS Notation Syntax of CCS CCS Process Expressions Semantics of CCS CCS Defining Equations

Definition of CCS (defining equations)

CCS program

A collection of defining equations of the form

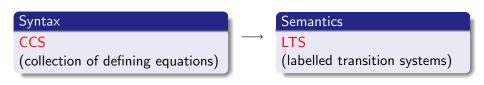
$$K\stackrel{\mathrm{def}}{=} P$$

where $K \in \mathcal{K}$ is a process constant and $P \in \mathcal{P}$ is a CCS process expression.

- Only one defining equation per process constant.
- Recursion is allowed: e.g. $A \stackrel{\text{def}}{=} \overline{a}.A \mid A$.

Motivation SOS Rules for CCS Examples

Semantics of CCS



HOW?

Motivation SOS Rules for CCS Examples

Structural Operational Semantics for CCS

Structural Operational Semantics (SOS) – G. Plotkin 1981

Small-step operational semantics where the behaviour of a system is inferred using syntax driven rules.

Given a collection of CCS defining equations, we define the following LTS (*Proc*, Act, $\{\stackrel{a}{\longrightarrow} | a \in Act\}$):

- $Proc = \mathcal{P}$ (the set of all CCS process expressions)
- $Act = \mathcal{L} \cup \{\tau\}$ (the set of all CCS actions including τ)
- transition relation is given by SOS rules of the form:

Introduction to CCS Motivation Syntax of CCS Sos Rules for CCS Semantics of CCS Examples

SOS rules for CCS ($\alpha \in Act$, $a \in \mathcal{L}$)

ACT
$$\alpha . P \xrightarrow{\alpha} P$$
 SUM_j $\frac{P_j \xrightarrow{\alpha} P'_j}{\sum_{i \in I} P_i \xrightarrow{\alpha} P'_j} j \in I$

| COM1 | $\underline{P \xrightarrow{\alpha} P'}$ | COM2 | $\underline{\qquad Q \xrightarrow{\alpha} Q'}$ |
|------|---|-------|--|
| | $P Q \xrightarrow{lpha} P' Q$ | 00012 | $\overline{P Q \stackrel{\alpha}{\longrightarrow} P Q'}$ |

COM3
$$\xrightarrow{P \xrightarrow{a} P' \quad Q \xrightarrow{\overline{a}} Q'}{P|Q \xrightarrow{\tau} P'|Q'}$$

$$\operatorname{RES} \quad \frac{P \xrightarrow{\alpha} P'}{P \smallsetminus L \xrightarrow{\alpha} P' \smallsetminus L} \quad \alpha, \overline{\alpha} \notin L \qquad \qquad \operatorname{REL} \quad \frac{P \xrightarrow{\alpha} P'}{P[f] \xrightarrow{f(\alpha)} P'[f]}$$

 $\begin{array}{ccc} \text{CON} & \frac{P \stackrel{\alpha}{\longrightarrow} P'}{K \stackrel{\alpha}{\longrightarrow} P'} & K \stackrel{\text{def}}{=} P \\ \\ \text{Lecture 2} & \text{Semantics and Verification 2008} \end{array}$

Motivation SOS Rules for CCS Examples

Deriving Transitions in CCS

Let $A \stackrel{\text{def}}{=} a.A$. Then

 $((A | \overline{a}.Nil) | b.Nil)[c/a] \xrightarrow{c} ((A | \overline{a}.Nil) | b.Nil)[c/a].$

$$\operatorname{REL} \frac{\operatorname{COM1} \frac{A\operatorname{CT}}{A \xrightarrow{a} A} A \stackrel{\text{def}}{=} a.A}{(A \mid \overline{a}.Nil \xrightarrow{a} A) A} A \stackrel{\text{def}}{=} a.A}{(A \mid \overline{a}.Nil \xrightarrow{a} A \mid \overline{a}.Nil)}$$



