Architecture modeling in Calculus of Communicating Systems (CCS) Structure and Interactions

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Outline

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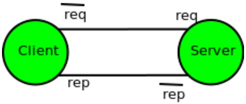
1. About the CCS Approach
2. The calculus
3. Semantics
4. Readings

Components and Connections between them

- Components are seen as Agents in CCS
- No separate abstraction is provided for connections
- If connections need to have behavior of their own, they are modeled as agents.
- A send of an agent and a corresponding receive act together as an indivisible (Atomic) action.. there is no delay or separation between them.



Abilities of CCS

- Agent are expressed through agent expressions
- Agents have input and output ports
- Agents perform input and output actions on ports
- Agent Expressions can be sequences of these actions
- Agent Expressions make use of non-determinism
- Agents can be composed together to form bigger systems and so on
- Before composing a system with another, some ports can be hidden
- Before composing a system with another, some ports can be renamed

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Agent expressions: actions, sequences and connections

$$\begin{aligned} Client &= \overline{req}.rep.Client \\ Server &= req.\overline{rep}.Server \\ System &= Client|Server \end{aligned}$$

- A non-terminating system of client and server
- rep, req are **input actions** on input ports
- $\overline{rep}$, $\overline{req}$ are **output actions** on output ports
- *dot* operator called **prefix combinator** makes a sequences of actions
- $|$ operator called **composition combinator** makes a composition of two agents, connecting the corresponding input and output ports

Agent expressions: Non-determinism

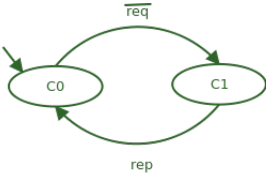
$$\begin{aligned} Client_1 &= \overline{req_1}.rep_1.Client_1 \\ Client_2 &= \overline{req_2}.rep_2.Client_2 \\ Server &= (req_1.\overline{rep_1} + req_2.\overline{rep_2}).Server \\ System &= Client_1 | Client_2 | Server \end{aligned}$$

- A non-terminating system of 2 clients and a server
- The server may pick up any of its inputs
- + is the **summation combinator** which represents a non-deterministic choice between two agent sub-expressions. Once a choice is made, the expression must be completely executed.

Outline

The state machine (transition diagram) of the client

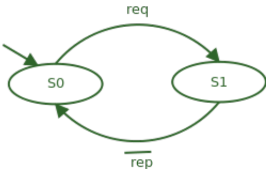
$$Client = \overline{req}.rep.Client$$



$$\overline{req} \rightarrow rep \rightarrow \overline{req} \rightarrow rep \rightarrow \ldots$$

The state machine of the server

$$Server = req.\overline{rep}.Server$$

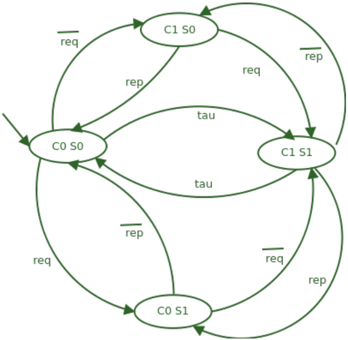


$$req \rightarrow \overline{rep} \rightarrow req \rightarrow \overline{rep} \rightarrow \ldots$$

The state machine of the composition

$Client = \overline{req}.rep.Client \qquad Server = req.\overline{rep}.Server$

$System = Client|Server$



- Client and Server may proceed independently or communicate via corresponding actions

Transitions including τ actions

$$A = p.A' \qquad A' = \overline{q}.A \qquad B = q.B' \qquad B' = r.B$$

$$System = (A|B)$$

- We know that $A \xrightarrow{p} A'$, $B \xrightarrow{q} B'$, $A' \xrightarrow{\overline{q}} A$, and $B' \xrightarrow{r} B$,
- So $A|B \xrightarrow{p} A'|B$. Similarly, $A|B \xrightarrow{q} A|B'$
- Also $A'|B \xrightarrow{\overline{q}} A|B$. Similarly, $A'|B \xrightarrow{q} A'|B'$
- We also have a τ action, due to which, $A'|B \xrightarrow{\tau} A|B'$
- Similarly, work out other possible transitions?

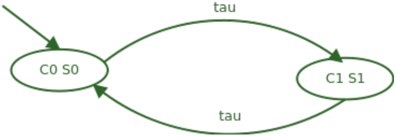
τ actions

- τ action represents a handshake
- It's a perfect (completed) action
- It is not visible like the other actions that are visible
- Visible actions can be used in a subsequent composition with another agent
- τ action is also called *unobservable action*
- Whenever a pair of complementary actions $(a, \overline{a})$ is possible in a composite agent, a τ action is possible

The Restriction Operator '\'

$Client = \overline{req}.rep.Client \qquad Server = req.\overline{rep}.Server$

$System = (Client|Server)\backslash\{req, rep\}$



- Independent actions $req, \overline{req}, rep, \overline{rep}$ are restricted (prohibited), only the τ actions occur inside the composition.
- The restricted ports are also not available for further composition with other agents
- Both input and output ports corresponding to names in restriction set are restricted

Exercise

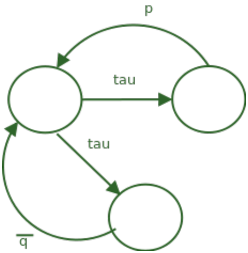
$$UI = input.\overline{rpc\_request}.rpc\_reply.\overline{print\_result}.0$$

$$BL = rpc\_request.\overline{log\_request}.\overline{rpc\_reply}.0$$

$$System = (UI|BL)\backslash\{rpc\_request, rpc\_reply\}$$

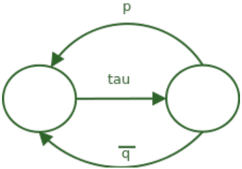
Build the transition diagram (state machine) for agent 'System'?

Exercise



Build CCS agent expressions which result in the above State transition diagram. ?

Exercise



Build CCS agent expressions which result in the above State transition diagram. ?

Exercises

Build CCS expressions representing the following architectural patterns: (1) OR split (2) OR join (2) AND split (3) AND join (4) MVC (5) 3-tiered architecture (6) Semaphore Synchronization

Exercise: Semaphore Synchronization- fill in the blanks?

$$Sem = \text{..............}??$$

$$Client\_1 = \overline{p}.start\_print.end\_print.\overline{v}.Client\_1$$

$$Client\_2 = \text{............}??$$

$$System = (Client\_1 | Client\_2 | Sem) \backslash \{\text{............}??\}$$

Value passing CCS

$$
\begin{aligned}
Client_1 &= \overline{req(1)}.rep_1.Client_1 \\
Client_2 &= \overline{req(2)}.rep_2.Client_2 \\
Server &= req(v).if(v = 1)\ \overline{rep_1}.Server\ else\ \overline{rep_2}.Server \\
System &= Client_1 | Client_2 | Server
\end{aligned}
$$

- we can eliminate some ports

Relabeling of Agents

$$
\begin{aligned}
Client_1 &= \overline{req_1}.rep_1.Client_1 \\
Client_2 &= Client_1[req_2/req_1, rep_2/rep_1] \\
Server &= req_1.\overline{rep_1}.Server + req_2.\overline{rep_2}.Server \\
System &= Client_1|Client_2|Server
\end{aligned}
$$

- we can reuse agent expressions

Agent that diverts the odds from the evens

$$Diverter = req(v).if\ (v\%2)\overline{req_1}.Diverter\ else\ \overline{req_2}.Diverter$$

Abstracting the Diverter by removing value passing

$$
\begin{aligned}
Diverter &= req(v).Diverter' \\
Diverter' &= \overline{req_1}.Diverter + \overline{req_2}.Diverter
\end{aligned}
$$

- In the architectural abstraction, we bring in all possibilities and remove computation (as much as possible).
- Abstract out conditional interactions as possibilities through non-determinism

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- Robin Milner, Communication and Concurrency, Prentice Hall, 1989.
- David Walker, Introduction to Calculus of Communicating Systems, Technical Report, University of Edinburgh, 1987.