On the expressivity of the Mobile Ambients and the π-calculus

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Divergence seems to be the intrinsic distance between MA and π.

The syntax of Mobile Ambients

We consider the pure Mobile Ambients, with recursion.

$$P ::= \mathbf{0} \mid X \mid M.P \mid (\nu n)P \mid P|P' \mid \mu X.P \mid n[P]$$
$$M ::= in\ n \mid out\ n \mid open\ n$$

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$$\mu X.P \equiv P[\mu X.P/X], \text{up to } \alpha\text{-conversion}$$

The operational semantics of Mobile Ambients

$$n[in\ m.P|Q]|m[R] \rightarrow m[n[P|Q]|R] \qquad In$$

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\end{array}
$$

The operational semantics of Mobile Ambients

$n[in\ m.P \mid Q] \mid m[R] \rightarrow m[n[P \mid Q] \mid R]$	*In*
$m[n[out\ m.P \mid Q] \mid R] \rightarrow n[P \mid Q] \mid m[R]$	*Out*
$open\ n.P \mid n[Q] \rightarrow P \mid Q$	*Open*

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$open\ n.P \mid n[Q] \rightarrow P \mid Q$	*Open*
$P \rightarrow Q \Rightarrow (\nu\ n)P \rightarrow (\nu\ n)Q$	*Res*

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$n[in\ m.P \vert Q] \vert m[R] \rightarrow m[n[P \vert Q] \vert R]$	*In*
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$P \rightarrow Q \Rightarrow n[P] \rightarrow n[Q]$	*Amb*

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$P \rightarrow Q \Rightarrow P \mid R \rightarrow Q \mid R$	*Par*
$P' \equiv P, P \rightarrow Q, Q \equiv Q' \Rightarrow P' \rightarrow Q'$	$\equiv$

The syntax of π-calculus

A polyadic version, with process identifiers:

$$Q \quad ::= \quad \mathbf{0} \;\mid\; \pi.Q \;\mid\; (\nu a)Q \;\mid\; Q|Q' \;\mid\; Q + Q' \;\mid$$
$$[x = a]Q \;\mid\; [x \neq a]Q \;\mid\; Ide(\tilde{x}) = Q, where\ fn(Q) = \tilde{x}$$

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$$\frac{P \xrightarrow{\overline{a}\tilde{b}} P', \{\tilde{b}\} \cap fn(P) = \emptyset}{(\nu\ \tilde{b})P \xrightarrow{\overline{a}\langle\tilde{b}\rangle} P'}\ (bound\ out)$$

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$$\frac{P \xrightarrow{\overline{a}\langle\tilde{b}\rangle} P', Q \xrightarrow{a(\tilde{x})} Q'}{P|Q \xrightarrow{(\overline{a}\langle\tilde{b}\rangle, a(x))} (\nu\ \tilde{b})(P'|Q'[\tilde{b}/\tilde{x}])}\ (bound\ com)$$

Main mechanisms: who I am, where I am

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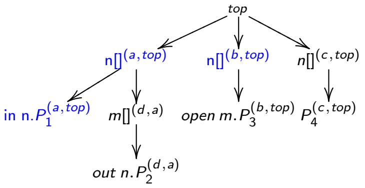
- **top** identifies the topmost ambient

The basic dynamics

$A = n[\text{in } n.P_1 \,|\, m[out\ n.P_2]] \mid n[open\ m.P_3] \mid n[P_4]$

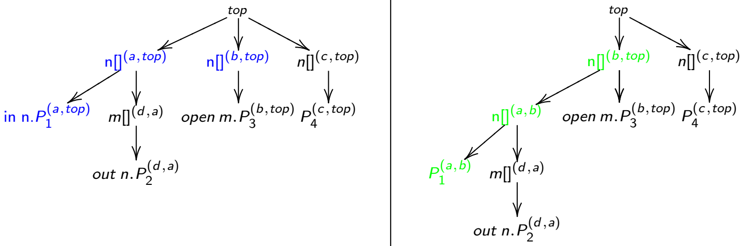


(1)

The basic dynamics

$A = n[\mathsf{in}\ \mathsf{n}.P_1 \,|\, m[out\ n.P_2]] \mid \mathsf{n}[open\ m.P_3] \mid n[P_4]$

$B = n[n[P_1 \,|\, m[out\ n.P_2]] \mid open\ m.P_3] \mid n[P_4]$



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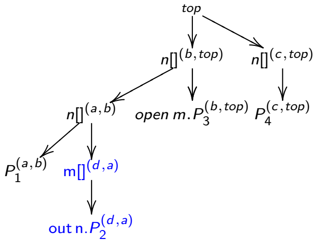

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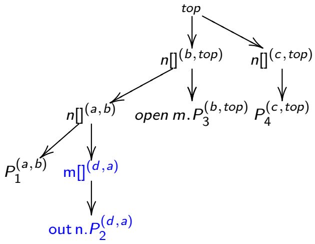

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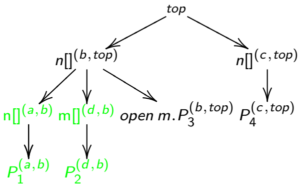
$$C = n[n[P_1]|m[P_2]|open\; m.P_3] \mid n[P_4]$$



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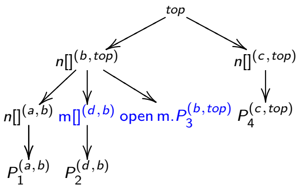

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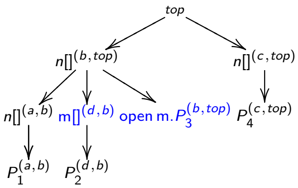

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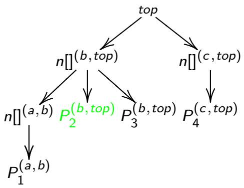
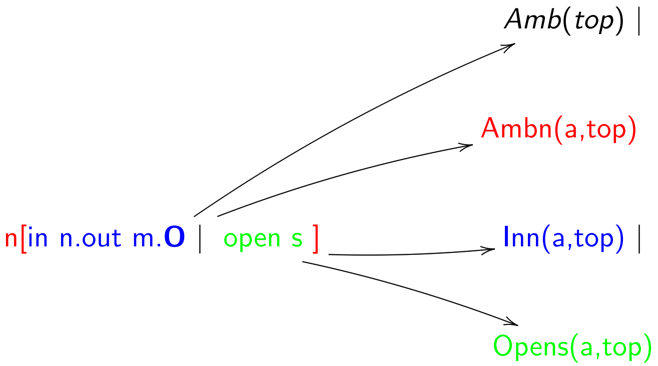
$D = n[n[P_1]|P_2|P_3] \mid n[P_4]$



(4)

The basic idea



Main encoding function

$$\mathcal{T} : \mathcal{P}_{MA} \times \mathcal{N} \rightarrow \mathcal{P}_{\pi}$$

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where:

- $\tilde{m} = fn(\mathcal{T}_a(P, \mathrm{top}, \mathrm{top}))$,
- $\mathcal{T}_a : \mathcal{P}_{MA} \times \mathcal{N} \times \mathcal{N} \to \mathcal{P}_\pi$

An example

$$P = open\ n.\mathbf{0} | n[out\ n.\mathbf{0}] | m[open\ n.\mathbf{0}]$$

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$$\begin{array}{rcl} \mathcal{T}(P, top) \equiv Q & = & (\nu\ top, a, b, \dots) \\ & & Amb(top) | Openn(top, top) \\ & | & Ambn(a, top) | Outn(a, top) \\ & | & Ambm(b, top) \mid Openn(b, top) \end{array}$$

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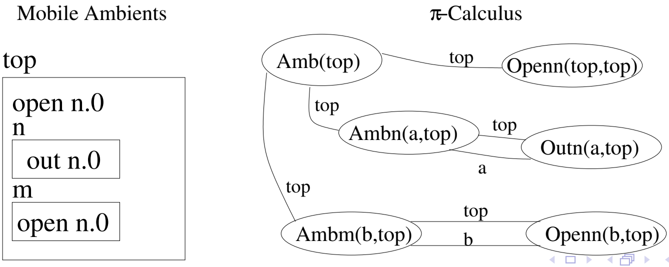

Encoding processes at work

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Mimicking a capability:

$$\begin{array}{rcl} \mathcal{T}(P, top) \stackrel{\tilde{\theta}}{\rightarrow}{}^{*} Q' & \equiv & Amb(top) \\ & | & \text{Opened(a,top,top)} | Outn(a, top) \\ & | & Ambm(m', top) | Openn(m', top) \end{array}$$

Acting as a link

The code:

$$
\begin{array}{rcl}
Opened(a, a', f') & = & a(x).\overline{x}\langle a', f'\rangle.Opened(a, a', f') \\
& & + \\
& & a(x, x').\overline{x}\langle a', f'\rangle.Opened(a, a', f')
\end{array}
$$

Running *encoding processes*

$$\mathcal{T}(P, top) = Q \xrightarrow{\theta} Q' \equiv (\nu top, a, \ldots)Amb(top)|\text{Opened(a,top,top)}|Outn(a, top)|Ambm(m', top)|Openn(m', top)$$

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- Process Opened(a,top,top) has substituted the dissolved Ambn(a,top).
- The old coordinates will be updated as soon as Outn(a,top) will try to mimic the 'out n' capability.

Opened(a,top,top) only acts as a link between the old channel name **a** of the dissolved ambient, and the unique channel name **top** associated to the ambient which has taken its place.

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$$\mathcal{T}(P', top) = Q'' \equiv \quad (\nu\ top, b, \ldots)\ Amb(top) \mid Outn(top, top) \mid Ambm(b, top)|Openn(b, top)$$

Encoding processes at work

Now we have that:

$$Q' \equiv Amb(top)|$$
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$$\begin{aligned} \mathcal{T}(P', top) = Q'' \quad \equiv & \quad (\nu \; top, b) \; Amb(top) \\ | & \quad Outn(top, top) \\ | & \quad Ambm(b, top)|Openn(b, top) \end{aligned}$$

Q' differs from Q'' as it contains the subprocess $Opened(a, top, top)$ and different coordinates for $Outn(a, top)$.

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- The set of the derivatives of the encoding processes
  - $A\pi_{op} = \{Q' \,|\, Q \rightarrow^* Q',\, Q \in A\pi\ A\pi,\ Q' \equiv \Pi_{i=1}^{N}(\nu\tilde{m}_i)Ide_i(\tilde{m}_i)\}$

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  - i.e. those processes that differs from $A\pi$ because may contain *Opened*() subprocesses.

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If $R \in A_{\pi_{op}}$ (i.e. contains Opened() processes) and it exists a process $Q \in A_{\pi}$ (doesn't) and still may mimic the same set of capabilities

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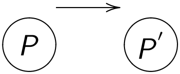
The notions of traces

A capability execution in MA: $P \;\rightarrow\; P'$
A capability mimicking in π-calculus:

$$\mathcal{T}(P, top) \xrightarrow{\theta_1} \ldots \xrightarrow{\theta_n} Q'$$

- Q' records the effects of a capability simulation, $\xi = \theta_1 \ldots \theta_n$ is a *simulating trace*
- if $Q' \equiv \mathcal{T}(P, top)$ then we have an *aborting trace*

The simulation of a capability



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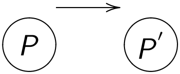

Simulating trace: ξ

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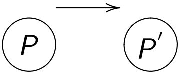
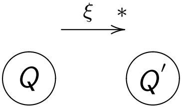
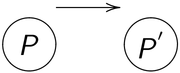
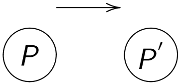


Simulating trace:ξ

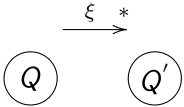


The simulation of a capability

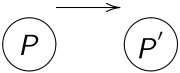




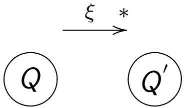
Simulating trace: ξ

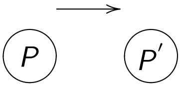


The simulation of a capability



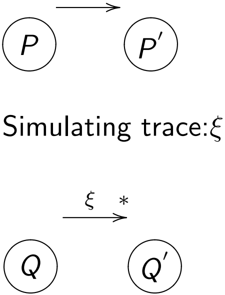
Simulating trace:ξ

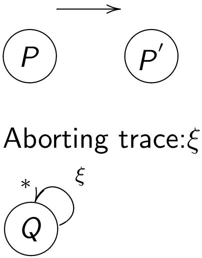




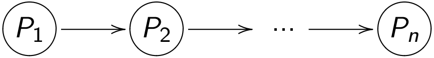
Aborting trace:ξ

The simulation of a capability





Ordered execution of traces



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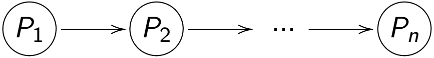
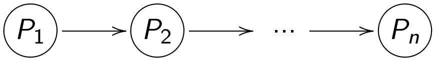


Assuming to execute orderly a trace per time.

Ordered execution of traces



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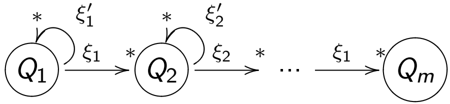

Weak soundness

Let P be a MA process,
if $\mathcal{T}(P, top) = Q \stackrel{\tilde{\theta}_a}{\longrightarrow}^* Q'$, then $\exists\ P'$, Q'' such that $Q' \stackrel{\tilde{\theta}_b}{\longrightarrow}^* Q''$, $Q'' \simeq \mathcal{T}(P', top)$ with $P \longrightarrow^* P'$.

Completeness

Let P be a MA process, if $P \longrightarrow^{*} P'$ then there exists a process Q' such that $\mathcal{T}(P, top) \stackrel{\tilde{\theta}}{\longrightarrow}{}^{*} Q'$ and $\mathcal{T}(P', top) \simeq Q'$.

Who I am - Where I am

A clear separation of the two information.

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$D = n[n[P_1]|P_2|P_3] \mid n[P_4]$

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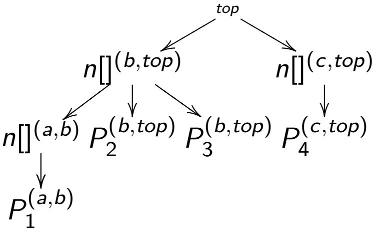

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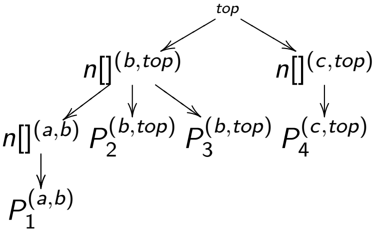
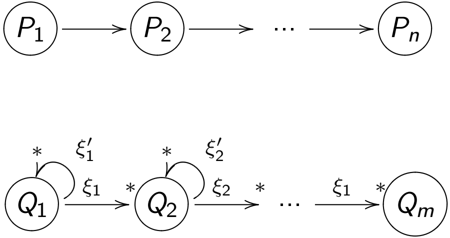


The ambient construct delimits a computing environment, and also holds a precise position within a hierarchical structure, hence each ambient has a unique ‘address’.

The two transition systems

A clear relation between the two transition systems.



Behavioral characterization and LTL for MA

- A more elegant characterization between the two languages in terms of a behavioral equivalence, for example the testing equivalence.
- The understanding of the two roles of the ambients (Who-I-am,Where-I-am) could help in defining a simple LTL for MA.

Merci de votre attention