Dynamic and Local Typing for Mobile Ambients

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Modelling of wide-area distributed and mobile computing:

- interacting components from different locations are unknown or only partially known to each other

$$\Downarrow$$

- each component must carry behavioural information, to be checked at runtime

$$\Gamma \quad \vdash \quad t \quad : \quad T$$

assumptions on the world $\vdash$ component : behavioural properties

A proposal

A typed ambient calculus with:

- behavioural type assumptions local to each ambient
- no global type assumptions on ambient names
- ambient types attached to single ambient constructions, not to ambient names
- runtime types used to check compatibility between components from different localities

Specific features of the calculus:

- no ambient opening
- only local communication
- general process mobility

The typed calculus: mobility primitives

- ambient mobility: in, out

$$\text{(R-in)} \quad n[\,\mathsf{in}\ m\,.\,P \mid Q\,] \mid m[R] \;\longrightarrow\; m[\,n[\,P \mid Q\,] \mid R\,]$$

$$\text{(R-out)} \quad m[\,n[\,\mathsf{out}\ m\,.\,P \mid Q\,] \mid R\,] \;\longrightarrow\; n[\,P \mid Q\,] \mid m[R]$$

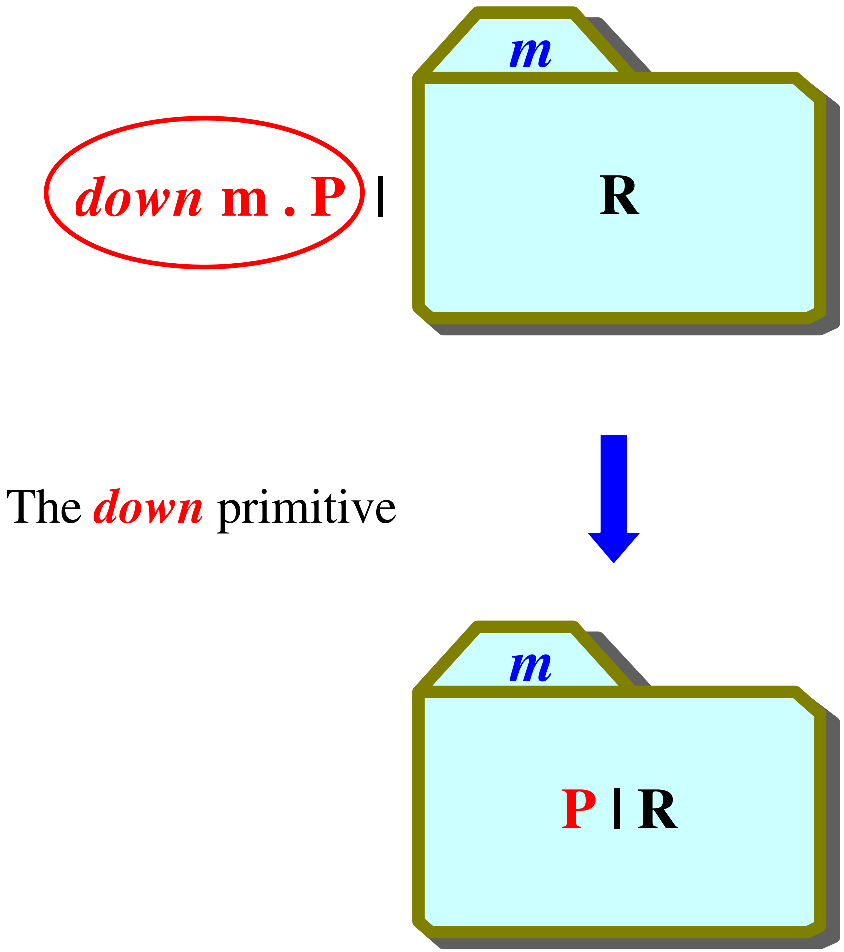
- process mobility: down, up

$$\mathsf{down}\ n\,.\,P \mid n[Q] \;\rightarrow\; n[P \mid Q]$$

$$m[n[\mathsf{up}\ m\,.\,P \mid Q] \mid R] \;\rightarrow\; m[P \mid n[Q] \mid R]$$

Process mobility: **down**

down m moves the continuation process
from its ambient down to an enclosed ambient m



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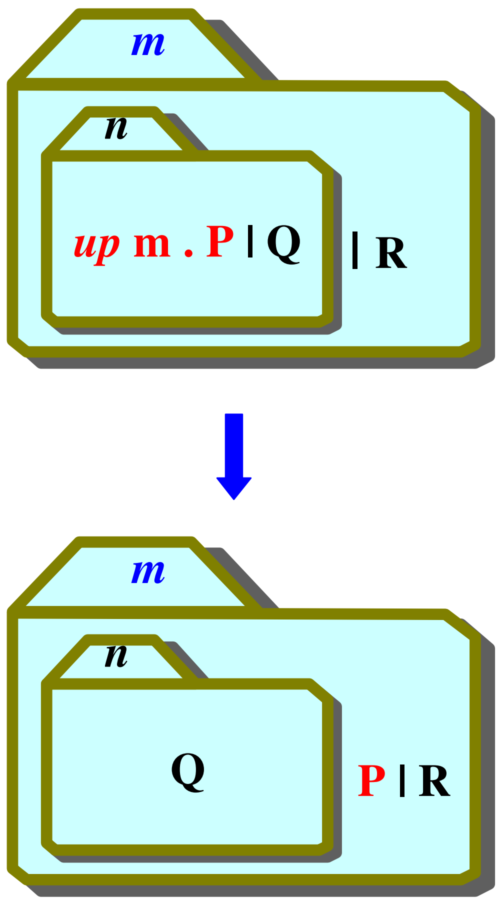

The *up* primitive

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- describe communication and mobility properties

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- are based on ambient groups:
  - a group is a name that labels a set of ambients
  - different ambients with the same name may belong to different groups
  - mobility properties are expressed via groups

Static types: active mobility

- process types $\quad Pro \quad ::= \quad g(G)$
  - g group names
  - $G ::= \mathsf{mc}(\mathscr{C}, \mathscr{E}, T)$ *mobcom* (mobility + communication) types, where:

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- ambient type $\quad$ amb (atomic type)

  no mobcom types for ambient names

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  - process mobility action
    carries the type of its continuation: down/up $\alpha{:}g$ with G

The syntax of types

G	$::=$	$\mathsf{mc}(\mathscr{C}, \mathscr{E}, T)$	*mobcom* type: mobility and communication type
Pro	$::=$	$g(G)$	process type: processes of group g with mobcom type G
Cap	$::=$	$g(G) \rightsquigarrow g'(G')$	capabilities that can be consumed by processes of type $g(G)$ and leave processes of type $g'(G')$ as continuations
W	$::=$		message type
		Cap	capability type
		group	group
		amb	ambient type
T	$::=$		communication type
		shh	no communication
		$\overrightarrow{W}$	communication of messages of type $\overrightarrow{W}$
Σ	$::=$	$\varnothing$	variable environment
		$\Sigma, x : W$	

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Each ambient contains a dynamic characterization of its passive mobility.

Complete form of the ambient construct:

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  - c: multiset of groups of ambients allowed to go in or out of it;
  - e: multiset of permits for processes to go up or down into it:
    - element of e: a pair $\langle g', G'\rangle$, entrance permit for a g'-process with a G'-behaviour; constraint: $G' \leq G$
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  - $\mathsf{add}^{\mathsf{c}}\ g^{\varphi}\ \mathsf{in}\ m{:}g_m$ adds the group g with multiplicity φ to the c component of a local ambient of name m and group g_m
  - $\mathsf{add}^{\mathsf{e}}\ \langle g, G_1\rangle^{\varphi}\ \mathsf{in}\ m{:}g_m$
    adds the group/type pair $\langle g, G_1 \sqcap G_m\rangle$ with multiplicity φ to the e component of a local ambient $m{:}g_m(G_m)[\mathsf{c},\mathsf{e}\|P]$
    - intersection preserves the invariant $\langle g', G'\rangle \in \mathsf{e} \ \Rightarrow\ G' \leq G_m$

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A simplified system

- two cities tur and flo, with their respective stations st_{tur} and st_{flo}
- one train commuting between st_{tur} and st_{flo}.

A public transportation system: stations

A station is an ambient of group g_{st} and of name st_X, with $X = tur, flor$:

$st_X{:}g_{st}(G_{st})[\mathsf{c}_{st},\ \mathsf{e}_{st} \parallel \ldots]$, where:

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     - $G_{\mathsf{arr}}, G_{\mathsf{dep}}$ are accepted behaviours for processes entering the station: the constraints $G_{\mathsf{dep}} \leq G_{\mathsf{st}}$ and $G_{\mathsf{arr}} \leq G_{\mathsf{st}}$ are statically checked.

A public transportation system: the train

A train $\text{TRAIN}_{X,Y}$ commuting between X and Y is a mobile ambient:

$\text{TRAIN} \triangleq$

$tr{:}g_{tr}(G_{tr})[\mathsf{c}_{tr}, \mathsf{e}_{tr} \| \,!\, \mathsf{out}\ st_X{:}g_{st}\,.\,\text{PATH}_{XY}\,.\,\mathsf{in}\ st_Y{:}g_{st}\,.\,\mathsf{out}\ st_Y{:}g_{st}\,.\,\text{PATH}_{YX}\,.\,\mathsf{in}\ st_X{:}g_{st}]$

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    may be entered by at most n processes coming from stations and exhibiting a certified good passenger behaviour G_{psng}
    - $G_{psng} = \mathsf{mc}(\varnothing, \{g_{st}\})$

      a good passenger cannot drive any ambient (no train hijacking), and may only get off the train into a station

A public transportation system: travellers

traveller $\textsf{TRAVELER}_{\mathsf{X,Y}}$ from city X to city Y: is a mobile *process* that goes into X's station where he becomes a passenger bound for Y:

$$\textsf{TRAVELER}_{\mathsf{X,Y}} \triangleq \mathsf{down}\ st_X{:}g_{st}\ \mathsf{with}\ G_{\mathit{dep}}\,.\,\textsf{PSNG}_{\mathsf{Y}}$$

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A public transportation system: initial configuration

The initial configuration is with the train in tur:

$$(\nu\ tur, flo, st_{tur}, st_{flo})\ world : g_w(G_w)[\mathsf{c}_w, \mathsf{e}_w \| \text{REST-OF-THE-WORLD}\ |$$
$$tur : g_{city}(G_{tur})[\mathsf{c}_{tur}, \mathsf{e}_{tur} \| R_t\ |\ \text{TRVLRS}_{tur,flo}\ |\ st_{tur} : g_{st}(G_{st})[\mathsf{c}_{st}, \mathsf{e}_{st} \| \text{TRAIN}]\,]\ |$$
$$flo : g_{city}(G_{flo})\ [\mathsf{c}_{flo}, \mathsf{e}_{flo} \| R_f\ |\ \text{TRVLRS}_{flo,tur}\ |\ st_{flo} : g_{st}(G_{st})[\mathsf{c}_{st}, \mathsf{e}_{st} \| 0\,]\,]\,]$$

where $\text{TRVLRS}_{X,Y}$ is a parallel composition of processes $\text{TRAVELER}_{X,Y}$.
Properties:

- at most n PSNG processes can be within the train at the same time, by the initial definitions of e_{tr} and $\text{TRAVELER}_{X,Y}$;
- no traveller can get into the train when this is outside a station: any such action is dynamically blocked by e_{tr};
- ...

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Let FLORENTINE be a process whose behaviour is accepted in flor. Then:

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- on the other hand, the process BADPSNG:
  - statically can be put inside a station, since G_{st} allows processes to go to trains: $g_{tr} \in \mathscr{E}(G_{\mathit{st}})$
  - dynamically is prevented from boarding the train, since no permit $\langle g_{st}, G_{\mathit{bad}}\rangle$ is available in the train's e-component.

The global permit-granting hierarchy

Static global assumption of a partial order $\mathcal{O}$ over group names: the action

$$\mathsf{add}^{\bullet}\ \delta^{\varphi}\ \mathsf{in}\ m{:}g \text{ (with } \bullet = \mathsf{c},\mathsf{e}\text{)}$$

is statically allowed in a g'-process only if $g \leq_{\mathcal{O}} g'$.

$$\frac{\langle\!\langle g, g' \rangle\!\rangle \in \mathcal{O} \quad \mathcal{O};\Sigma \vdash \alpha : \mathsf{amb} \quad \mathcal{O};\Sigma \vdash \gamma : \mathsf{group}}{\mathcal{O};\Sigma \vdash \mathsf{add}^{\mathsf{c}}\ \gamma^{\varphi}\ \mathsf{in}\ \alpha{:}g : g'(G) \rightsquigarrow g'(G)} \quad (\textsc{Add-c})$$

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2. (typed) reduction semantics
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Results:

- subject reduction
- soundness of bisimilarity w.r.t. the barbed congruence

Conclusions

A typed ambient/process calculus with:

- interplay between static and dynamic type-checking, and between *active* and *passive* rights, for handling the security requirements of global computing applications:
  - static type-checking controls (communication and) *active* mobility rights;
  - dynamic type-checking controls *passive* rights;
- packing of a type within a mobile process and its check at destination as a (very) abstract modelling of the proof-carrying code approach;
- purely local static type checking, except for the global $\mathcal{O}$ hierarchy.

Some unsatisfactory aspects (future work?):

- authorization to add permits is too coarse-grain (either no adding, or adding with any multiplicity)
- absence of group restriction, useful for protection from external untrusted agents;
- lack of expressive synchronizing mechanisms (only communication), making awkward to control unwanted nondeterminism;
- ...