Dependency Analysis

as the Basis for a Generic Type System

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Plan

- Behavioural Properties, Existential and Universal
  $p_{\mathbf{A}}$, $p_{\mathbf{I}}$
- Dependency Statements, Behavioural Statements
  $\alpha \lhd \gamma$, $\xi_{\mathrm{O}} = \xi_1 \vee (\xi_2 \wedge \xi_3)$
- Type Systems
  $a_{\mathbf{A}} \vdash_{\mathbf{AR}} t.a|\overline{t}$
- Generic Type System
  $\Gamma \vdash_{\mathcal{K}} P$

Behavioural Properties: Existential vs Universal

Definition (Existential Property)

Available *somewhere*. Good things happen *eventually*.

Activeness (Receptiveness)

Definition (Universal Property)

Available *everywhere*. Bad things *never* happen.

Deadlock-freedom, Isolation, Determinism, “Responsiveness”, “Non-Termination”.

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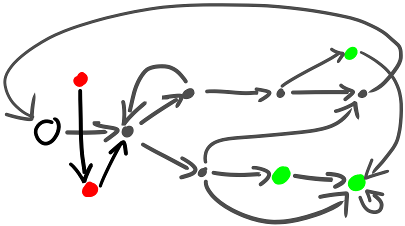

- $\text{good}_k(P)$ implies $\text{good}_k(P \mid Q)$
- $\text{bad}_k(P)$ implies $\text{bad}_k(P \mid Q)$

Dependency Analysis (1)

- *Parallel composition* fundamental to the π-calculus

$$P = P_1 \mid P_2 \mid \ldots \mid P_n$$

- Need to analyse one component at a time

$$\{\Gamma_i \vdash P_i\} \mapsto (\Gamma \vdash P)$$

- Need to make assumptions on the *environment*

$$\Gamma_i = (\Xi_L \blacktriangleleft \Xi_E)$$

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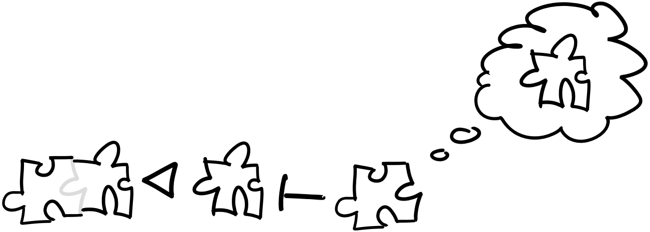
Dependency Statement

Definition (Dependency $A \lhd B$)

If you give me B, I'll give you A.



Behavioural Statements

Definition (Behavioural Statements)

$$\Xi \;::=\; (\gamma \lhd \Xi) \;\mid\; (\Xi \vee \Xi) \;\mid\; (\Xi \wedge \Xi) \;\mid\; \top \;\mid\; \bot$$

$$a_{\mathbf{D}} \lhd (b_{\mathbf{D}} \wedge c_{\mathbf{D}}) \quad \vdash \quad A = \mathbf{!}\, a(tf).\overline{b}(\nu t' f').(t'.\overline{c}\langle tf\rangle + f'.\overline{f})$$

$$b_{\mathbf{D}} \lhd \top \quad \vdash \quad B = \mathbf{!}\, b(tf).\overline{t}$$

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$$a_{\mathbf{D}} \lhd (\top \wedge c_{\mathbf{D}}) \cong a_{\mathbf{D}} \lhd c_{\mathbf{D}} \quad \vdash \quad A \mid B$$

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Activeness and Responsiveness: Semantics

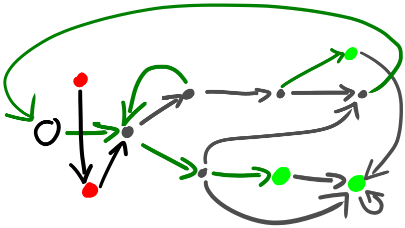
Definition (Immediate Activeness)

$$\text{good}_{\mathbf{A}}(a, (\Gamma; P)) \quad \text{if } P \equiv (\boldsymbol{\nu}\tilde{z})\left(a(\tilde{y}).Q \mid R\right)$$
$$\text{good}_{\mathbf{A}}(\overline{a}, (\Gamma; P)) \quad \text{if } P \equiv (\boldsymbol{\nu}\tilde{z})\left(\overline{a}\langle\tilde{x}\rangle.Q \mid R\right)$$

Definition (Immediate Responsiveness)

$$\text{bad}_{\mathbf{R}}(a, (\Gamma; P)) \quad \text{if } P \xrightarrow{a(tf)} P' \text{ and } \bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}} \not\models P'.$$

Activeness and Responsiveness: Semantics



Type System (Activeness and Responsiveness)

$$\frac{-}{\top \vdash_{\mathbf{AR}} \mathbf{0}}\ (\textsc{Nil}) \qquad \frac{\Gamma_i \vdash_{\mathbf{AR}} P_i}{\Gamma_1 \odot \Gamma_2 \vdash_{\mathbf{AR}} P_1 \mid P_2}\ (\textsc{Par}) \qquad \frac{\Gamma \vdash_{\mathbf{AR}} P}{(\boldsymbol{\nu} x)\,\Gamma \vdash_{\mathbf{AR}} (\boldsymbol{\nu} x)\, P}\ (\textsc{Res})$$

$$\frac{\begin{array}{c}\mathsf{sub}(G_i) = \{p_i\}, \quad (\Xi_{\mathrm{L}i} \blacktriangleleft \Xi_{\mathrm{E}i}) \vdash_{\mathbf{AR}} G_i.P_i, \quad \Xi_{\mathrm{E}} \preceq \bigwedge_i \Xi_{\mathrm{E}i} \\ \left(\Xi_{\mathrm{E}} \text{ has concurrent environment } p_{i'}\right) \Rightarrow \varepsilon = \bot\end{array}}{\left((\sum_i p_i)_{\mathbf{A}} \lhd \varepsilon \wedge \bigvee_i \Xi_{\mathrm{L}i} \blacktriangleleft \Xi_{\mathrm{E}}\right) \vdash_{\mathbf{AR}} \sum_i G_i.P_i}\ (\textsc{Sum})$$

$$\frac{\Gamma \vdash_{\mathbf{AR}} P \quad (\# = 1 \text{ and } m' = \star) \Rightarrow \varepsilon = \bot}{\begin{array}{c}\left(p : \sigma; \blacktriangleleft p^{m} \wedge \bar{p}^{m'}\right) \\ \odot \quad (\boldsymbol{\nu}\tilde{z}) \Big(\Gamma \lhd \bar{p}_{\mathbf{A}} \quad \odot \quad \overline{\sigma}[\tilde{x}] \lhd \bar{p}_{\mathbf{AR}} \\ \odot \quad p_{\mathbf{A}}^{\#} \lhd \varepsilon \quad \wedge \quad p_{\mathbf{R}} \lhd \sigma[\tilde{x}] \quad \Big)^{\#} \vdash_{\mathbf{AR}} (\boldsymbol{\nu}\tilde{z})\, p^{\#}\langle \tilde{x} \rangle.P\end{array}}\ (\textsc{Pre})$$

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Generic Type System

Instantiated with:

- Immediate correctness (semantics)
- Elementary rules (typing)

Generic Type System

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$$\frac{\Gamma \vdash_{\mathcal{K}} P \qquad G = (\boldsymbol{\nu}\tilde{z})\, p^{\#}\langle \tilde{x} \rangle}{\begin{array}{c}\left(p : \sigma;\ \blacktriangleleft p^{m} \wedge \bar{p}^{m'}\right) \odot p^{\#} \\ \odot\ (\boldsymbol{\nu}\tilde{z}) \Big(\Gamma \lhd \mathsf{dep}_{\mathcal{K}}(G) \odot \overline{\sigma}[\tilde{x}] \lhd (\mathsf{dep}_{\mathcal{K}}(G) \wedge \bar{p}_{\mathbf{R}}) \\ \odot\ \mathsf{prop}_{\mathcal{K}}(\sigma, G, m, m')\Big)^{\#} \vdash_{\mathcal{K}} (\boldsymbol{\nu}\tilde{z})\, p^{\#}\langle \tilde{x} \rangle.P\end{array}}\ (\textsc{Pre})$$

Elementary Rules

- Elementary properties of a sum with subjects $\{p_1, p_2, \ldots\}$:

$$\mathsf{sum}_k(\{p_i\}_i, \Xi_{\mathrm{E}})$$

- of a p-guard G with type σ and multiplicities p^m, $\bar{p}^{m'}$:

$$\mathsf{prop}_k(\sigma, G, m, m')$$

- Resources required to consume a guard:

$$\mathsf{dep}_k(G)$$

Activeness

Definition (Activeness)

$\mathsf{good}_{\mathbf{A}}(p, (\Gamma; P))$ if $P \equiv (\boldsymbol{\nu} \tilde{z}) \left(G.Q \mid R\right)$ with $\mathsf{sub}(G) = p$.

- $\mathsf{dep}_{\mathbf{A}}(\mu) = \overline{\mathsf{sub}(\mu)}_{\mathbf{A}}$.
- $\mathsf{prop}_{\mathbf{A}}(G, \sigma, m, m') = \begin{cases} \mathsf{sub}(G)_{\mathbf{A}} & \text{if } \#(G) = \omega \text{ or } m' \neq \star \\ \top & \text{otherwise} \end{cases}$
- $\mathsf{sum}_{\mathbf{A}}(\{p_i\}_i, \Xi) =$
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Determinism

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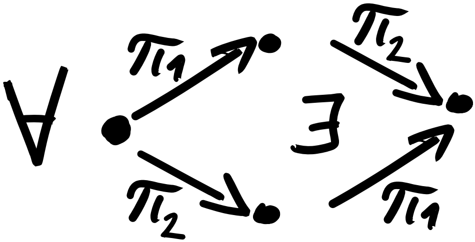
For any pair of transitions $(\Gamma; P) \xrightarrow{\mu_i} (\Gamma_i; P_i)$ s.t. $\pi_1 \neq \pi_2$ are the corresponding steps, $\exists (\Gamma_i; P_i) \xrightarrow{\hat{\mu}_{\bar{\imath}}} (\Gamma'; P')$ s.t. the step corresponding to $\hat{\mu}_i$ is π_i.



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Current and Future Work

- Sound well-formedness criteria.
- Generic Type System Soundness.
- Implementation.
- Extensions (complex channel usages, recursion, subtyping, etc).

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Thank You

http://maxime.gamboni.org

Answers to questions are non-isolated, non-deterministic, non-functional, active, responsive, deadlock-free, and terminate.