Responsive Choice in Mobile Processes

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[1] Joint work with António Ravara

Outline

Goal

- Verifying Calculus Encodings
- Using Choice and Branching to encode Data

$$[\![\,\mathsf{True}\,]\!]_a = !\,a(tf).\overline{t} \qquad [\![\,\mathsf{False}\,]\!]_a = !\,a(tf).\overline{f}$$

$$[\![\,\mathsf{If}\,(e)\ \mathsf{Then}\,(T)\ \mathsf{Else}\,(F)\,]\!] = (\nu\, btf)\,\left([\![e]\!]_b \mid \overline{b}\langle tf\rangle \mid (t.[\![T]\!]+f.[\![F]\!])\right)$$

Contribution

- Activeness and Responsiveness
- Choice Types
- Conditional Dependencies
- Sound Type System

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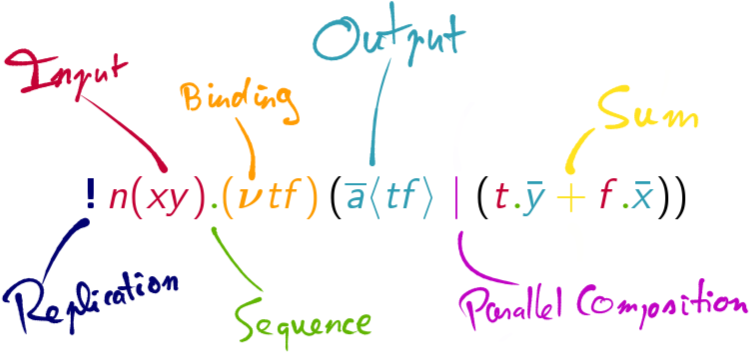
The Synchronous Polyadic π-calculus



$$!\, n(xy).(\nu tf)(\bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x}))$$

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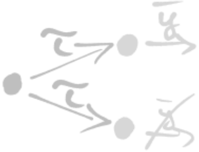
Responsiveness

Definition (A=Activeness)

- $a_{\mathbf{A}}$: I am soon ready to receive at a
- $\bar{a}_{\mathbf{A}}$: I am soon ready to send to a

$$\bar{y}_{\mathbf{A}} \models \bar{t} \mid (t.\bar{y} + f.\bar{x})$$

$$\bar{y}_{\mathbf{A}} \not\models \bar{t} \mid (t.\bar{y} + t.\bar{x})$$



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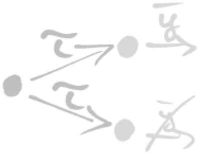

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Responsiveness

Definition (R=Responsiveness)

- $a_{\mathbf{R}}$: If *I* get a message from *you* at a, I'll obey a's protocol
- $\bar{a}_{\mathbf{R}}$: If *you* get a message from *me* at a, I'll obey $\bar{a}$'s protocol

$$r : \mathrm{Bool}, r_{\mathbf{R}} \models \,!\, r(tf).(\nu q)\,(\bar{q} \mid q.\bar{t} \mid q.\bar{f})$$

$$a : \mathrm{Bool}, \bar{a}_{\mathbf{R}} \models (\bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x}))$$

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Multiplicities

Definition (Multiplicity)

p^m: I'll use p *at most* m times.

- p^0: Never
- p^1: Once
- p^ω: Once, replicated
- $p^\bigstar$: Many times

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Choice

Definition (Choice $A \vee B$)

I will either behave like A or like B

$\bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}} \models (\nu q)\,(\bar{q} \mid q.\bar{t} \mid q.\bar{f})$

Definition (Branching $A + B$)

You can make me do A or B (not both)

$(t_{\mathbf{A}} + f_{\mathbf{A}}) \models (t.\bar{y} + f.\bar{x})$

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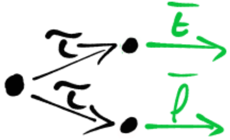

Definition (Branching $A + B$)

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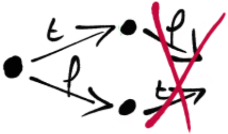
$(t_{\mathbf{A}} + f_{\mathbf{A}}) \models (t.\bar{y} + f.\bar{x})$



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Dependencies

Definition (Dependency $A \lhd B$)

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

$$n_{\mathbf{R}} \lhd (a_{\mathbf{A}} \wedge a_{\mathbf{R}}) \models \, ! \, n(xy).\bar{a}(\nu tf).(t.\bar{y} + f.\bar{x})$$

Types

Definition (Channel Type)

$$(\text{parameters} \quad ; \quad \text{input} \quad ; \quad \text{output})$$

- Bool $\stackrel{\text{def}}{=}$ $(()() \quad ; \quad \bar{1}_{\mathbf{A}} \vee \bar{2}_{\mathbf{A}} \quad ; \quad 1_{\mathbf{A}} + 2_{\mathbf{A}})$
- $!\, a(xy).(\nu q)\,(\bar{q}|q.\bar{x}|q.\bar{y}) \quad | \quad \bar{a}\langle tf\rangle\,|\,(t.P+f.Q)$

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Typing — Composition

$$(\bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}} \vdash \bar{a}\langle tf \rangle$$

$$((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}})) \vdash (t.\bar{y} + f.\bar{x})$$

$$(\bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}})) \vdash \bar{a}\langle tf \rangle \mid (t.\bar{y} + f.\bar{x})$$

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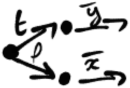

$$(\bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}}) \lhd a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \lhd \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \lhd \bar{f}_{\mathbf{A}})) \vdash \bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x})$$

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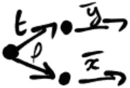


$$(\bar{t}_{\mathbf{A}} \vee \bar{f}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}})) \vdash \bar{a}\langle tf \rangle \mid (t.\bar{y} + f.\bar{x})$$

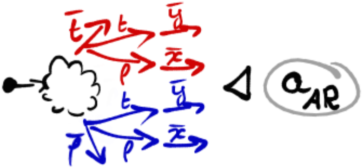
Typing — ∨-Distributivity

∨-Distributivity

"∨ distributes with everything else"

$$(\overline{t}_{\mathbf{A}} \vee \overline{f}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \overline{y}_{\mathbf{A}} \triangleleft \overline{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \overline{x}_{\mathbf{A}} \triangleleft \overline{f}_{\mathbf{A}})) =$$

$$\left(\overline{t}_{\mathbf{A}} \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \overline{y}_{\mathbf{A}} \triangleleft \overline{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \overline{x}_{\mathbf{A}} \triangleleft \overline{f}_{\mathbf{A}}))\right) \quad \vee \quad \left(\overline{f}_{\mathbf{A}} \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \overline{y}_{\mathbf{A}} \triangleleft \overline{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \overline{x}_{\mathbf{A}} \triangleleft \overline{f}_{\mathbf{A}}))\right)$$



Typing — Collapse (1)

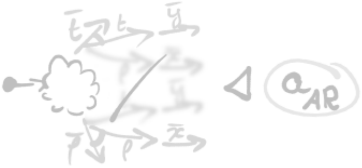
Branching Collapse

$$(\bar{p}_{\mathbf{A}},\ (p_{\mathbf{A}} + \varepsilon)) \hookrightarrow (\bar{p}_{\mathbf{A}} \wedge p_{\mathbf{A}}) \vee (\bar{p}_{\mathbf{A}},\ (p_{\mathbf{A}} + \varepsilon))$$

$$(\bar{t}_{\mathbf{A}} \lhd a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \lhd \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \lhd \bar{f}_{\mathbf{A}}))) \quad \vee$$

$$(\bar{f}_{\mathbf{A}} \lhd a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \lhd \bar{t}_{\mathbf{A}}) + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \lhd \bar{f}_{\mathbf{A}}))) \hookrightarrow$$

$$(\bar{t}_{\mathbf{A}}, t_{\mathbf{A}}, (\bar{y}_{\mathbf{A}} \lhd \bar{t}_{\mathbf{A}})) \lhd a_{\mathbf{AR}} \quad \vee \quad (\bar{f}_{\mathbf{A}}, f_{\mathbf{A}}, (\bar{x}_{\mathbf{A}} \lhd \bar{f}_{\mathbf{A}})) \lhd a_{\mathbf{AR}}$$



Typing — Collapse (1)

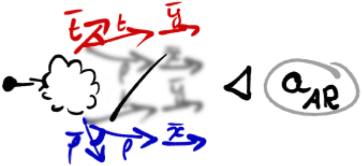
Branching Collapse

$$(\bar{p}_{\mathbf{A}},\ (p_{\mathbf{A}} + \varepsilon)) \hookrightarrow (\bar{p}_{\mathbf{A}} \land p_{\mathbf{A}}) \lor (\bar{p}_{\mathbf{A}},\ (p_{\mathbf{A}} + \varepsilon))$$

$$(\bar{t}_{\mathbf{A}} \triangleleft a_{\mathbf{AR}}, ((t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}}) + \cancel{(f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}})})) \quad \lor$$

$$(\bar{f}_{\mathbf{A}} \triangleleft a_{\mathbf{AR}}, (\cancel{(t_{\mathbf{A}}, \bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}})} + (f_{\mathbf{A}}, \bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}}))) \hookrightarrow$$

$$(\bar{t}_{\mathbf{A}}, t_{\mathbf{A}}, (\bar{y}_{\mathbf{A}} \triangleleft \bar{t}_{\mathbf{A}})) \triangleleft a_{\mathbf{AR}} \quad \lor \quad (\bar{f}_{\mathbf{A}}, f_{\mathbf{A}}, (\bar{x}_{\mathbf{A}} \triangleleft \bar{f}_{\mathbf{A}})) \triangleleft a_{\mathbf{AR}}$$



Typing — Collapse (2)

Dependency Collapse

$$(\alpha \lhd \beta) \wedge (\beta \lhd \gamma) \quad \hookrightarrow \quad (\alpha \lhd \beta \vee \gamma) \wedge (\beta \lhd \gamma)$$

$$((t_{\mathsf{A}} \wedge \bar{t}_{\mathsf{A}}) \lhd a_{\mathsf{AR}}, (\bar{y}_{\mathsf{A}} \lhd \bar{t}_{\mathsf{A}})) \quad \vee \quad ((f_{\mathsf{A}} \wedge \bar{f}_{\mathsf{A}}) \lhd a_{\mathsf{AR}}, (\bar{x}_{\mathsf{A}} \lhd \bar{f}_{\mathsf{A}})) \hookrightarrow$$
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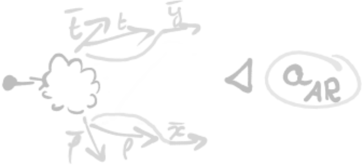

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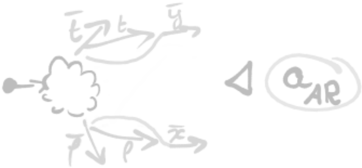

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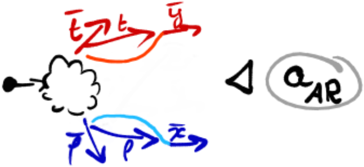

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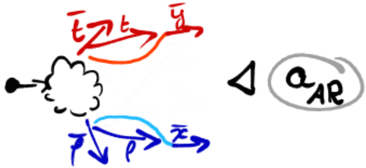

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Typing — Responsiveness

$$n_{\mathbf{R}} \triangleleft \ \ldots \ \vdash \ P = \mathbf{!}\, n(xy).(\boldsymbol{\nu} tf)\,(\bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x}))$$

Responsiveness

$$(\boldsymbol{\nu}\tilde{y})\,\left(n : \sigma \odot n_{\mathbf{R}} \triangleleft \sigma\{^{\tilde{y}}/_{1\ldots n}\} \odot \cdots\right) \ \vdash \ n(\tilde{y})$$

$$(\boldsymbol{\nu} xy)\,\left(n_{\mathbf{R}} \triangleleft (\bar{x}_{\mathbf{A}} \vee \bar{y}_{\mathbf{A}}) \ \wedge \ (\bar{x}_{\mathbf{A}} \vee \bar{y}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}}\right) \ \vdash \ P$$

$$\hookrightarrow n_{\mathbf{R}} \triangleleft a_{\mathbf{AR}} \quad \vdash \quad \mathbf{!}\, n(xy).(\boldsymbol{\nu} tf)\,(\bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x}))$$

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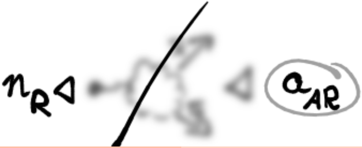
$$(\boldsymbol{\nu}\tilde{y})\left(n : \sigma \odot n_{\mathbf{R}} \triangleleft \sigma\{^{\tilde{y}}/_{1\ldots n}\} \odot \cdots\right) \vdash \ n(\tilde{y})$$

$$(\boldsymbol{\nu} xy)\left(n_{\mathbf{R}} \triangleleft (\bar{x}_{\mathbf{A}} \vee \bar{y}_{\mathbf{A}}) \ \wedge \ (\bar{x}_{\mathbf{A}} \vee \bar{y}_{\mathbf{A}}) \triangleleft a_{\mathbf{AR}}\right) \vdash \ P$$

$$\hookrightarrow n_{\mathbf{R}} \triangleleft a_{\mathbf{AR}} \quad \vdash \quad \mathbf{!}\, n(xy).(\boldsymbol{\nu} tf)\,(\bar{a}\langle tf\rangle \mid (t.\bar{y} + f.\bar{x}))$$



Conclusion

Our contribution:

- A formalism describing liveness properties in the π-calculus
- Choice and Branching types $\Rightarrow$ Data encodings
- Conditional Dependencies $\Rightarrow$ Compositionality

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Thank you!

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More info:

- http://maxime.gamboni.org/