Inference of Global Progress Properties for Dynamically Interleaved Multiparty Sessions

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The problem

$$a(y).b(z).y?(x).z!\langle x\rangle$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

- two distinct sessions
- each session is well typed
- the system gets stuck

The problem

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad y : ?\mathtt{int} \qquad z : !\mathtt{int}$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \qquad y : !\mathtt{int} \qquad z : ?\mathtt{int}$$

- two distinct sessions
- each session is well typed
- the system gets stuck

The "interaction" type system

If $\vdash P$, then P never gets stuck

- ☺ Bettini, Coppo, D'Antoni, De Luca, Dezani-Ciancaglini, Yoshida, **Global Progress in Dynamically Interleaved Multiparty Sessions**, CONCUR 2008
- ☹ **not syntax-directed**

Outline

1. Progress
2. Key ideas of the type system
3. Two examples
4. Remarks

Progress 1/2

$$\begin{array}{rl} \text{If} & P \to^* \mathcal{E}\,[\ s?(x).P'\ ] \\ \text{Then} & \quad\ \to^* \mathcal{E}'[\ s?(x).P' \mid s : m \cdot h\ ] \end{array}$$

$$\begin{array}{rl} \text{If} & P \to^* \mathcal{E}\,[\ s : m \cdot h\ ] \\ \text{Then} & \quad\ \to^* \mathcal{E}'[\ s : m \cdot h \mid s?(x).P'\ ] \end{array}$$

A process without progress

$$a(y).b(z).y?(x).z!\langle x\rangle \mid \overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

A process without progress

$$a(y).b(z).y?(x).z!\langle x\rangle \mid \overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

$$\downarrow_*$$

$$(\nu s)(\nu s')(s?(x).s'!\langle x\rangle \mid s'?(x).s!\langle c\rangle \mid s : \varnothing \mid s' : \varnothing)$$

A process without progress

$$a(y).b(z).y?(x).z!\langle x\rangle \mid \overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

$$\downarrow_*$$

$$(\nu s)(\nu s')(s?(x).s'!\langle x\rangle \mid s'?(x).s!\langle c\rangle \mid s : \varnothing \mid s' : \varnothing)$$

Progress 2/2

A **good** process that looks like a **bad** one

$$P \rightarrow^* \mathcal{E}[\ s?(x).P' \mid \overline{b}(y).s!\langle 3\rangle.Q'\ ]$$

A **bad** process that looks like a **good** one

$$c(y).(\text{a process that gets stuck})$$

Progress 2/2

A **good** process that looks like a **bad** one

$$P \to^* \mathcal{E}[\ s?(x).P' \mid \overline{b}(y).s!\langle 3 \rangle.Q'\ ]$$

A **bad** process that looks like a **good** one

$$c(y).(\text{a process that gets stuck})$$

Idea

- define progress modulo **catalyzers**
- catalyzer = missing participant that never gets stuck

Consequence

- session initiation can be considered non-blocking

Interaction type system: basic ideas

1. associate processes with dependencies $a \prec b$

   "an action of service a blocks an action of service b"

2. a process is well typed if it yields no circular dependencies

Computing service dependencies

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad a \prec b$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \qquad b \prec a$$

Service names as messages

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad a \prec b$$

$$\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

$$c(t).t!\langle a\rangle$$

Service names as messages

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad\qquad a \prec b$$

$$t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

$$t!\langle a\rangle$$

Service names as messages

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad a \prec b$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \qquad b \prec a$$

Service names as messages

$$a(y).b(z).y?(x).z!\langle x\rangle \qquad a \prec b$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle$$

Idea

- identify a class of safe services even if mutually dependent
- restrict messages to services in this class

Nested services

Definition

a is a nested service if $\lambda \prec a$ implies that λ is a nested service

		Nested?
$\overline{a}(y).\overline{a}(z).z?(x).y?(x')$	$a \prec a$	✔
$\overline{a}(y).\overline{b}(z).z?(x).y?(x')$ $\mid \overline{b}(z).\overline{a}(y).y?(x).z?(x')$	$b \prec a$ $a \prec b$	✔
$\overline{a}(y).\overline{b}(z).y?(x).z?(x')$	$y \prec b$	✘

Private services

$$a(y).(\nu b)(b(z).z?(x).y!\langle x\rangle)$$

- no catalyzer can help starting the session on b

Private services

$$a(y).(\nu b)(b(z).z?(x).y!\langle x\rangle)$$

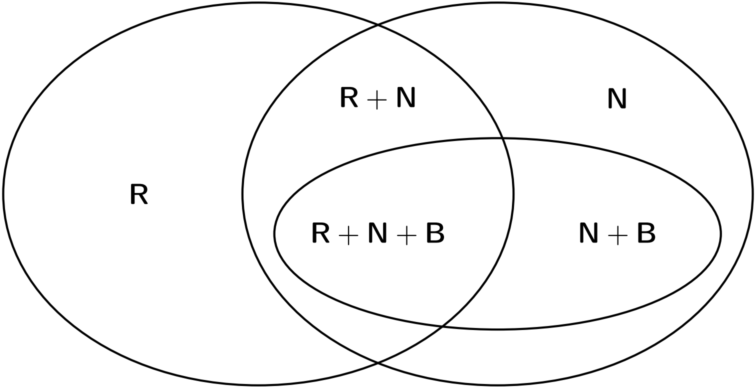
- no catalyzer can help starting the session on b

Definition

a is boundable if it is never followed by free channels

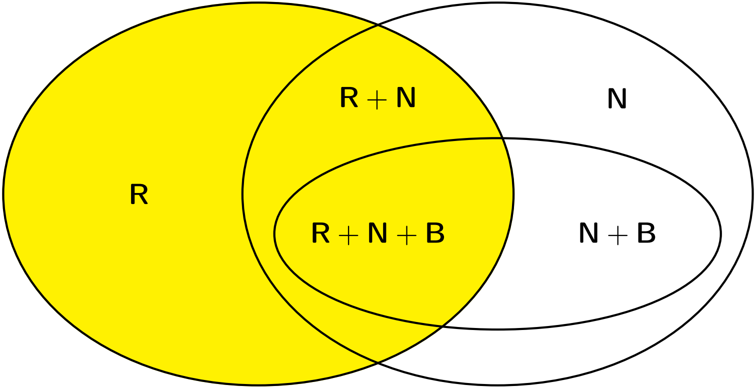
- b is nested but not boundable

Service classification



- each service can have up to three features ...
- ... which the interaction type system guesses

Service classification



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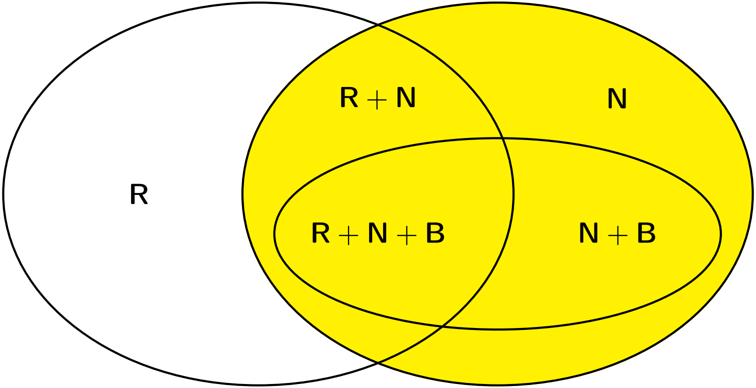
Service classification



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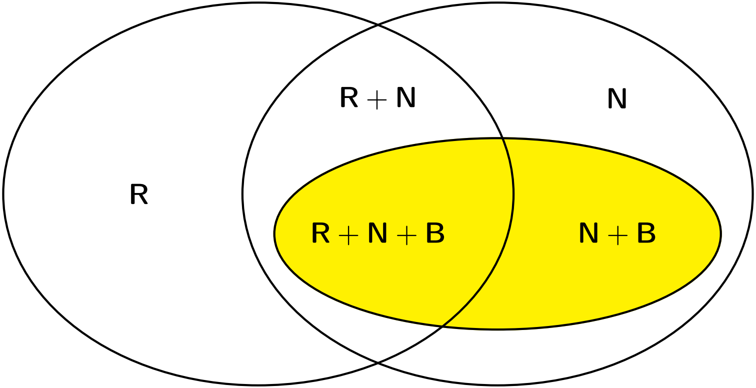
Service classification



- each service can have up to three features ...
- ... which the interaction type system guesses

Algorithm judgments

$$P \Mapsto \mathsf{D}; \mathsf{R}; \mathsf{N}; \mathsf{B}$$

If...

$$\begin{aligned} \mathsf{D}^\infty &\subseteq \mathsf{N} \setminus \mathsf{R} \\ \mathsf{D} \downarrow \mathsf{N} &\subseteq \mathsf{N} \\ \mathsf{fs}(P) &\subseteq \mathsf{R} \cup \mathsf{N} \end{aligned}$$

Example 1

$$\overline{}$$

$$a(y).b(z).y?(x).z!\langle x\rangle \mapsto$$

Example 1

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \Mapsto}{z!\langle x\rangle \Mapsto}}{y?(x).z!\langle x\rangle \Mapsto}}{b(z).y?(x).z!\langle x\rangle \Mapsto}}{a(y).b(z).y?(x).z!\langle x\rangle \Mapsto}$$

Example 1

all services have all features

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{z!\langle x\rangle \mapsto}}{y?(x).z!\langle x\rangle \mapsto}}{b(z).y?(x).z!\langle x\rangle \mapsto}}{a(y).b(z).y?(x).z!\langle x\rangle \mapsto}$$

Example 1

$$\cfrac{\cfrac{\cfrac{\cfrac{0 \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{z!\langle x\rangle \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{y?(x).z!\langle x\rangle \mapsto}}{b(z).y?(x).z!\langle x\rangle \mapsto}}{a(y).b(z).y?(x).z!\langle x\rangle \mapsto}$$

Example 1

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{z!\langle x \rangle \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{y?(x).z!\langle x \rangle \mapsto \{y \prec z\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{b(z).y?(x).z!\langle x \rangle \mapsto}}{a(y).b(z).y?(x).z!\langle x \rangle \mapsto}$$

Example 1

$$
\begin{array}{c}
0 \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S} \\
\hline
z!\langle x \rangle \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S} \\
\hline
y?(x).z!\langle x \rangle \mapsto \{y \prec z\}; \mathcal{S}; \mathcal{S}; \mathcal{S} \\
\hline
b(z).y?(x).z!\langle x \rangle \mapsto \{y \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\} \\
\hline
a(y).b(z).y?(x).z!\langle x \rangle \mapsto
\end{array}
$$

$\mathrm{B} \subseteq \mathrm{N}$

$\mathrm{D} \downarrow \mathrm{N} \subseteq \mathrm{N}$

Example 1

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{z!\langle x\rangle \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{y?(x).z!\langle x\rangle \Mapsto \{y \prec z\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{b(z).y?(x).z!\langle x\rangle \Mapsto \{y \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}}{a(y).b(z).y?(x).z!\langle x\rangle \Mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}$$

Example 1 (cont.)

$$\frac{}{\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle}$$

$$\frac{}{a(y)\cdots \mid \overline{a}(y)\cdots \Mapsto}$$

Example 1 (cont.)

$$\cfrac{\cfrac{\cfrac{\cfrac{0 \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{y!\langle x\rangle \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{z?(x).y!\langle x\rangle \Mapsto \{z \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}$$

$$\overline{\quad a(y)\cdots \mid \overline{a}(y)\cdots \Mapsto \quad}$$

Example 1 (cont.)

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{y!\langle x\rangle \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{z?(x).y!\langle x\rangle \Mapsto \{z \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}$$

$$\dfrac{a(y)\cdots \Mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}{a(y)\cdots \mid \overline{a}(y)\cdots \Mapsto}$$

Example 1 (cont.)

$$\frac{\frac{\frac{\frac{0 \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{y!\langle x\rangle \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{z?(x).y!\langle x\rangle \Mapsto \{z \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}$$

$$\frac{a(y)\cdots \Mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\} \quad \overline{a}(y)\cdots \Mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}{a(y)\cdots \mid \overline{a}(y)\cdots \Mapsto}$$

Example 1 (cont.)

$$0 \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$y!\langle x\rangle \Mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$z?(x).y!\langle x\rangle \Mapsto \{z \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$\frac{a(y)\cdots \Mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\} \qquad \cdots \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}{a(y)\cdots \mid \overline{a}(y)\cdots \Mapsto \{a \prec b, b \prec a\}; \mathcal{S} \setminus \{a, b\}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}$$

$D^{\infty} \subseteq N \setminus R$

Example 1 (cont.)

$$\dfrac{\dfrac{\dfrac{\dfrac{0 \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}{y!\langle x\rangle \mapsto \emptyset; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{z?(x).y!\langle x\rangle \mapsto \{z \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{b}(z).z?(x).y!\langle x\rangle \mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}}{\overline{a}(y).\overline{b}(z).z?(x).y!\langle x\rangle \mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}$$

$$\dfrac{a(y)\cdots \mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\} \quad \overline{a}(y)\cdots \mapsto \{b \prec a\}; \mathcal{S}; \mathcal{S}; \mathcal{S}}{a(y)\cdots \mid \overline{a}(y)\cdots \mapsto \{a \prec b, b \prec a\}; \mathcal{S} \setminus \{a, b\}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}$$

Example 2

$$\frac{}{\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto}$$

$$\frac{a(y)\cdots \Mapsto \{a \prec b\};\mathcal{S};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\} \quad \overline{c}(t)\cdots \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Mapsto \{a \prec b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\}}$$

Example 2

$$\dfrac{\dfrac{\dfrac{\dfrac{\vdots}{\overline{b}(z).z?(x).y!\langle x\rangle \Rrightarrow \{b \prec y\};\mathcal{S};\mathcal{S};\mathcal{S}}}{\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Rrightarrow}}{t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Rrightarrow}}{\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Rrightarrow}$$

$$\dfrac{a(y)\cdots \Rrightarrow \{a \prec b\};\mathcal{S};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\} \quad \overline{c}(t)\cdots \Rrightarrow \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Rrightarrow \{a \prec b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\}}$$

Example 2

$$\vdots$$

$$\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\}; \mathcal{S}; \mathcal{S}; \mathcal{S}$$

$$\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset; \mathcal{S} \setminus \{b\}; \mathcal{S}; \mathcal{S}$$

$$t?(x).\overline{x}(y).\overline{b}(\ldots$$

$$\overline{c}(t).t?(x).\overline{x}(y)\ldots \Mapsto$$

x **must** be nested, so b too

dependencies discharged

$$\frac{a(y)\cdots \Mapsto \{a \prec b\}; \mathcal{S}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\} \quad \overline{c}(t)\cdots \Mapsto \emptyset; \mathcal{S} \setminus \{b\}; \mathcal{S}; \mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Mapsto \{a \prec b\}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}; \mathcal{S} \setminus \{b\}}$$

Example 2

$$\dfrac{\dfrac{\dfrac{\dfrac{\vdots}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\};\mathcal{S};\mathcal{S};\mathcal{S}}}{\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}$$

$$\dfrac{a(y)\cdots \Mapsto \{a \prec b\};\mathcal{S};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\} \quad \overline{c}(t)\cdots \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Mapsto \{a \prec b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\}}$$

Example 2

$$\dfrac{\dfrac{\dfrac{\dfrac{\vdots}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\};\mathcal{S};\mathcal{S};\mathcal{S}}}{\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}$$

$$\frac{a(y)\cdots \Mapsto \{a \prec b\};\mathcal{S};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\} \quad \overline{c}(t)\cdots \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Mapsto \{a \prec b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\}}$$

Example 2

$$\frac{\frac{\frac{\frac{\vdots}{\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \{b \prec y\};\mathcal{S};\mathcal{S};\mathcal{S}}}{\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}}{\overline{c}(t).t?(x).\overline{x}(y).\overline{b}(z).z?(x).y!\langle x\rangle \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}$$

$$\frac{a(y)\cdots \Mapsto \{a \prec b\};\mathcal{S};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\} \quad \overline{c}(t)\cdots \Mapsto \emptyset;\mathcal{S}\setminus\{b\};\mathcal{S};\mathcal{S}}{a(y)\cdots \mid \overline{c}(t)\cdots \Mapsto \{a \prec b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\};\mathcal{S}\setminus\{b\}}$$

Result

Theorem

If $P \Mapsto \mathsf{D}; \mathsf{R}; \mathsf{N}; \mathsf{B}$, then P has progress

Proof.

The algorithm is sound and complete wrt the inference type system (cf. CONCUR 2008) □

Result

Theorem

If $P \Mapsto \mathsf{D}; \mathsf{R}; \mathsf{N}; \mathsf{B}$, *then* P *has progress*

Proof.

The algorithm is sound and complete wrt the inference type system (cf. CONCUR 2008) (for finite processes only) □

Soon to come

Inference for recursive processes

Wrap up

- static analysis for (multiparty) session interleaving

- progress $\neq$ absence of deadlock
  - diverging systems do not necessarily have progress
  - catalyzers may help reduction

- efficient inference algorithm

Future work

- many simple program patterns are **ill typed**
  - ☛ more flexible type discipline is required
- π-calculus $\neq$ **programming language**
  - ☛ richer/more compositional types are needed
- type systems for liveness properties are **complex**
  - ☛ traditional concepts/techniques (fairness, subtyping, coinductive reasoning, . . .) must be revisited

A simple ill-typed process with progress

$$\begin{array}{ll} \texttt{def}\ X(y,z) = y!\langle 3\rangle.z?(x).X(y,z)\ \texttt{in} & b \prec a \\ \texttt{def}\ Y(y,z) = y?(x).z!\langle x\rangle.Y(y,z)\ \texttt{in} & a \prec b \\ a(y).b(z).X(y,z) \mid \overline{a}(y).\overline{b}(z).Y(y,z) & \end{array}$$