κ-VM : model

The κ-calculus : Syntax

$$
\begin{array}{llll}
P & ::= & \mathsf{0} \mid V \mid P[P] \mid (P \mid P) \mid (P\ P) \mid (\nu\ r)\ P & \text{Process} \\
 & \mid & ([u\ =\ u]\ P\ ,\ P) \mid \langle D \rangle \mid \mathsf{pass}\, V & \\
V & ::= & r \mid \lambda\, x.P & \text{Value} \\
D & ::= & J = P \mid D; D & \text{Definition} \\
J & ::= & r \mid J \mid J & \text{Join-pattern} \\
u & ::= & x \mid r & \text{Name}
\end{array}
$$

Free names

$$\mathsf{fn}(0) = \emptyset \qquad \mathsf{fn}(u) = \{u\}$$

$$\mathsf{fn}(\lambda\, x.P) = \mathsf{fn}(P) \setminus \{x\} \qquad \mathsf{fn}(P[Q]) = \mathsf{fn}(P) \cup \mathsf{fn}(Q)$$

$$\mathsf{fn}((P \mid Q)) = \mathsf{fn}(P) \cup \mathsf{fn}(Q) \qquad \mathsf{fn}(P\ Q)) = \mathsf{fn}(P) \cup \mathsf{fn}(Q)$$

$$\mathsf{fn}((\nu\ r)\ P) = \mathsf{fn}(P) \setminus \{r\} \qquad \mathsf{fn}(([u\ =\ v]\ P\ ,\ Q)) = \{u, v\} \cup \mathsf{fn}((P \mid Q))$$

$$\mathsf{fn}(\langle D \rangle) = \mathsf{fn}(D) \qquad \mathsf{fn}(D; D') = \mathsf{fn}(D) \cup \mathsf{fn}(D')$$

$$\mathsf{fn}(J = P) = \mathsf{fn}(J) \cup \mathsf{fn}(P) \qquad \mathsf{fn}(r_1 \mid \ldots \mid r_q) = \{r_1, \ldots, r_q\}$$

$$\mathsf{fn}(\mathsf{pass}\, V) = \mathsf{fn}(V)$$

Defined names

$$\mathsf{df}(\mathsf{0}) = \emptyset \qquad \mathsf{df}(u) = \emptyset$$

$$\mathsf{df}(\lambda\, x.P) = \mathsf{df}(P) \qquad \mathsf{df}(P[Q]) = \mathsf{df}(P) \cup \mathsf{df}(Q)$$

$$\mathsf{df}((P \mid Q)) = \mathsf{df}(P) \cup \mathsf{df}(Q) \qquad \mathsf{df}((P\ Q)) = \mathsf{df}(P) \cup \mathsf{df}(Q)$$

$$\mathsf{df}((\nu\ r)\ P) = \mathsf{df}(P) \setminus \{r\} \qquad \mathsf{df}([u\ =\ v]\ P\ ,\ Q)) = \mathsf{df}((P \mid Q))$$

$$\mathsf{df}(\langle D \rangle) = \mathsf{df}(D) \qquad \mathsf{df}(D; D') = \mathsf{df}(D) \cup \mathsf{df}(D')$$

$$\mathsf{df}(J = P) = \mathsf{df}(J) \cup \mathsf{df}(P) \qquad \mathsf{df}(r_1 \mid \ldots \mid r_q) = \{r_1, \ldots, r_q\}$$

$$\mathsf{df}(\mathsf{pass}\, V) = \mathsf{df}(V)$$

Evaluation Contexts

$$\mathbf{E} \quad ::= \quad \cdot \mid (\mathbf{E}\, V) \mid (P\ \mathbf{E}) \mid (\mathbf{E} \mid P) \mid (\nu\ r)\ \mathbf{E} \mid \mathbf{E}[P] \mid P[\mathbf{E}]$$

Structural equivalence

$$
\begin{array}{rcllr}
\mathsf{0} \mid P & \equiv & P & & \text{(par.nil)} \\
P \mid Q & \equiv & Q \mid P & & \text{(par.com)} \\
P \mid (Q \mid R) & \equiv & (P \mid Q) \mid R & & \text{(par.ass)} \\
\langle D_1 ; D_2 \rangle & \equiv & \langle D_2 ; D_1 \rangle & & \text{(decl.com)} \\
\langle D_1 ; (D_2 ; D_3) \rangle & \equiv & \langle (D_1 ; D_2) ; D_3 \rangle & & \text{(decl.ass)} \\
((\nu\ r)\ P\ Q) & \equiv & (\nu\ r)\ (P\ Q) & r \notin \mathsf{fn}(Q) & \text{(new.appl)} \\
(\nu\ r)\ P \mid Q & \equiv & (\nu\ r)\ (P \mid Q) & r \notin \mathsf{fn}(Q) & \text{(new.par)} \\
((\nu\ r)\ P)[Q] & \equiv & (\nu\ r)\ P[Q] & r \notin \mathsf{fn}(Q) & \text{(new.dom.control)} \\
P[(\nu\ r)\ Q] & \equiv & (\nu\ r)\ P[Q] & r \notin \mathsf{fn}(P) & \text{(new.dom.content)} \\
P =_\alpha Q & \Longrightarrow & P \equiv Q & & \text{(alpha)} \\
P \equiv Q & \Longrightarrow & \mathbf{E}\{P\} \equiv \mathbf{E}\{Q\} & & \text{(context.eq)}
\end{array}
$$

Reduction

$$\frac{}{([u\ =\ u]\ P\ ,\ Q) \longrightarrow P} \qquad \text{(if.then)}$$

$$\frac{}{([u\ =\ v]\ P\ ,\ Q) \longrightarrow Q} \quad u \neq v \qquad \text{(if.else)}$$

$$\frac{}{(\lambda\ x.P\ V) \longrightarrow P\{V/x\}} \qquad \text{(beta)}$$

$$\frac{\langle D \rangle = \langle D_0^*\ ;\ r_1 \mid \ldots \mid r_q = P \rangle}{\langle D \rangle \mid r_1 \widetilde{V_1} \mid \ldots \mid r_q \widetilde{V_q} \longrightarrow \langle D \rangle \mid P \widetilde{V_1} \ldots \widetilde{V_q}} \qquad \text{(com)}$$

$$\frac{}{(P \mid \mathsf{pass}\, V)[Q] \longrightarrow V(\lambda \cdot P)(\lambda \cdot Q)} \qquad \text{(passiv)}$$

$$\frac{P \longrightarrow Q}{\mathbf{E}\{P\} \longrightarrow \mathbf{E}\{Q\}} \quad \text{(context)} \qquad \frac{P \equiv P' \quad P' \longrightarrow Q' \quad Q' \equiv Q}{P \longrightarrow Q} \quad \text{(struct)}$$

$$\frac{}{(r\widetilde{V} \mid P[Q]) \longrightarrow (r\widetilde{V} \mid P)[Q]} \quad \begin{array}{l} r \in \mathsf{df}(P) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(in)}$$

$$\frac{}{(r\widetilde{V} \mid P)[Q] \longrightarrow P[(r\widetilde{V} \mid Q)]} \quad \begin{array}{l} r \in \mathsf{df}(Q) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(intrude)}$$

$$\frac{}{(r\widetilde{V} \mid P[Q]) \longrightarrow ((\mathbf{i}\ \lambda \cdot r\widetilde{V}) \mid P)[Q]} \quad \begin{array}{l} r \in \mathsf{df}(Q) \\ \mathbf{i} \in \mathsf{df}(P) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(filter.in)}$$

$$\frac{}{(r\widetilde{V} \mid P)[Q] \longrightarrow (r\widetilde{V} \mid P[Q])} \quad \begin{array}{l} r \notin \mathsf{df}(P[Q]) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(out)}$$

$$\frac{}{P[(r\widetilde{V} \mid Q)] \longrightarrow (r\widetilde{V} \mid P)[Q]} \quad \begin{array}{l} r \in \mathsf{df}(P) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(extrude)}$$

$$\frac{}{P[(r\widetilde{V} \mid Q)] \longrightarrow ((\mathbf{o}\ \lambda \cdot r\widetilde{V}) \mid P)[Q]} \quad \begin{array}{l} r \notin \mathsf{df}(P[Q]) \\ \mathbf{o} \in \mathsf{df}(P) \\ r \notin \{\mathbf{i}, \mathbf{o}\} \end{array} \qquad \text{(filter.out)}$$