

Linguagem L1 com listas e exceções

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Sintaxe abstrata

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$$\begin{aligned} e &\in \text{Expr} \\ e &::= n \\ &\quad | b \\ &\quad | e_1 \text{ op } e_2 \\ &\quad | \text{not } e_1 \\ &\quad | \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \\ &\quad | x \\ &\quad | e_1 e_2 \\ &\quad | \text{fn } x:T \Rightarrow e \\ &\quad | \text{fn } x \Rightarrow e \\ &\quad | \text{let } x:T = e_1 \text{ in } e_2 \\ &\quad | \text{let } x = e_1 \text{ in } e_2 \\ &\quad | \text{let rec } f:T_1 \rightarrow T_2 = (\text{fn } y:T_1 \Rightarrow e_1) \text{ in } e_2 \\ &\quad | \text{let rec } f = (\text{fn } y \Rightarrow e_1) \text{ in } e_2 \\ &\quad | \text{nil} \\ &\quad | e_1 :: e_2 \\ &\quad | \text{isempty } e \\ &\quad | \text{hd } e \\ &\quad | \text{tl } e \\ &\quad | \text{raise} \\ &\quad | \text{try } e_1 \text{ with } e_2 \end{aligned}$$
  

$$\begin{aligned} T &\in \text{Types} \\ T &::= X \mid \text{int} \mid \text{bool} \mid T_1 \rightarrow T_2 \mid T \text{ list} \end{aligned}$$

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onde

$$\begin{aligned} n &\in \text{conjunto de numerais inteiros} \\ b &\in \{\text{true}, \text{false}\} \\ x &\in \text{Ident} \\ \text{op} &\in \{+, -, *, \text{div}, ==, \text{and}, \text{or}\} \end{aligned}$$

Semântica operacional *big-step*

$v \in \text{Values}$

$v ::= n \mid b \mid l \mid \langle x, e, \text{env} \rangle \mid \langle f, x, e, \text{env} \rangle$

$l ::= \text{nil} \mid v :: l$

$\text{env} \in \text{Env}$

$\text{env} ::= [] \mid \{x \mapsto v\} + \text{env}$

$$\text{env} \vdash n \Downarrow n \quad (\text{BS-NUM})$$

$$\text{env} \vdash b \Downarrow b \quad (\text{BS-BOOL})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow n_2 \quad n = n_1 + n_2}{\text{env} \vdash e_1 + e_2 \Downarrow n} \quad (\text{BS-OP+})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 + e_2 \Downarrow \text{raise}} \quad (\text{BS-OP+RS1})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 + e_2 \Downarrow \text{raise}} \quad (\text{BS-OP+RS2})$$

$$\frac{\text{env} \vdash e_2 \Downarrow 0}{\text{env} \vdash e_1 \text{ div } e_2 \Downarrow \text{raise}} \quad (\text{BS-OPDIVZERO})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow n_2 \quad n_2 \neq 0 \quad n = n_1 \div n_2}{\text{env} \vdash e_1 \text{ div } e_2 \Downarrow n} \quad (\text{BS-OPDIV})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 \text{ div } e_2 \Downarrow \text{raise}} \quad (\text{BS-OPDIVRS1})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 \text{ div } e_2 \Downarrow \text{raise}} \quad (\text{BS-OPDIVRS2})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow n_2 \quad n_1 = n_2}{\text{env} \vdash e_1 == e_2 \Downarrow \text{true}} \quad (\text{BS-OP==TR})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow n_2 \quad n_1 \neq n_2}{\text{env} \vdash e_1 == e_2 \Downarrow \text{false}} \quad (\text{BS-OP==FLS})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 == e_2 \Downarrow \text{raise}} \quad (\text{BS-OP==RS1})$$

$$\frac{\text{env} \vdash e_1 \Downarrow n_1 \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 == e_2 \Downarrow \text{raise}} \quad (\text{BS-OP==RS2})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{false} \quad \text{env} \vdash e_2 \Downarrow b_2}{\text{env} \vdash e_1 \text{ and } e_2 \Downarrow \text{false}} \quad (\text{BS-OPANDFLS})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{true} \quad \text{env} \vdash e_2 \Downarrow b_2}{\text{env} \vdash e_1 \text{ and } e_2 \Downarrow b_2} \quad (\text{BS-OPANDTR})$$

$$\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 \text{ and } e_2 \Downarrow \text{raise}} \quad (\text{BS-OPANDRS1})$$

$$\frac{\text{env} \vdash e_1 \Downarrow b_1 \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 \text{ and } e_2 \Downarrow \text{raise}} \quad (\text{BS-OPANDRS2})$$

$$\frac{\text{env} \vdash e \Downarrow \text{true}}{\text{env} \vdash \text{not } e \Downarrow \text{false}} \quad (\text{BS-OPNOTTR})$$

$$\frac{\text{env} \vdash e \Downarrow \text{false}}{\text{env} \vdash \text{not } e \Downarrow \text{true}} \quad (\text{BS-OPNOTFLS})$$

$$\frac{\text{env} \vdash e \Downarrow \text{raise}}{\text{env} \vdash \text{not } e \Downarrow \text{raise}} \quad (\text{BS-OPNOTRS})$$

$$\frac{\text{env}(x) = v}{\text{env} \vdash x \Downarrow v} \quad (\text{BS-ID})$$

$$\begin{array}{c}
\frac{\text{env} \vdash e_1 \Downarrow \text{true} \quad \text{env} \vdash e_2 \Downarrow v}{\text{env} \vdash \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Downarrow v} \text{ (BS-IFTR)} \qquad \frac{\text{env} \vdash e_1 \Downarrow \text{false} \quad \text{env} \vdash e_3 \Downarrow v}{\text{env} \vdash \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Downarrow v} \text{ (BS-IFFLS)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Downarrow \text{raise}} \text{ (BS-IFRS1)} \qquad \frac{\text{env} \vdash e_1 \Downarrow \text{true} \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Downarrow \text{raise}} \text{ (BS-IFRS2)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{false} \quad \text{env} \vdash e_3 \Downarrow \text{raise}}{\text{env} \vdash \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \Downarrow \text{raise}} \text{ (BS-IFRS3)} \qquad \text{env} \vdash (\text{fn } x \Rightarrow e) \Downarrow \langle x, e, \text{env} \rangle \quad \text{ (BS-FN)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow v' \quad \{x \mapsto v'\} + \text{env} \vdash e_2 \Downarrow v}{\text{env} \vdash \text{let } x = e_1 \text{ in } e_2 \Downarrow v} \text{ (BS-LET)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash \text{let } x = e_1 \text{ in } e_2 \Downarrow \text{raise}} \text{ (BS-LETRS1)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow v' \quad \{x \mapsto v'\} + \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash \text{let } x = e_1 \text{ in } e_2 \Downarrow \text{raise}} \text{ (BS-LETRS2)} \\
\\
\frac{\{f \mapsto \langle f, x, e_1, \text{env} \rangle\} + \text{env} \vdash e_2 \Downarrow v}{\text{env} \vdash \text{let rec } f = (\text{fn } x \Rightarrow e_1) \text{ in } e_2 \Downarrow v} \text{ (BS-LETREC)} \\
\\
\frac{\{f \mapsto \langle f, x, e_1, \text{env} \rangle\} + \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash \text{let rec } f = (\text{fn } x \Rightarrow e_1) \text{ in } e_2 \Downarrow \text{raise}} \text{ (BS-LETRECRS)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow v' \quad \{x \mapsto v'\} + \text{env}' \vdash e \Downarrow v}{\text{env} \vdash e_1 \ e_2 \Downarrow v} \text{ (BS-APP)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRS1)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRS2)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow v' \quad \{x \mapsto v'\} + \text{env}' \vdash e \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRS3)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle f, x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow v' \quad \{x \mapsto v'\} + \{f \mapsto \langle f, x, e, \text{env}' \rangle\} + \text{env}' \vdash e \Downarrow v}{\text{env} \vdash e_1 \ e_2 \Downarrow v} \text{ (BS-APPREC)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRECRS1)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle f, x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRECRS2)} \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \langle f, x, e, \text{env}' \rangle \quad \text{env} \vdash e_2 \Downarrow v' \quad \{x \mapsto v'\} + \{f \mapsto \langle f, x, e, \text{env}' \rangle\} + \text{env}' \vdash e \Downarrow \text{raise}}{\text{env} \vdash e_1 \ e_2 \Downarrow \text{raise}} \text{ (BS-APPRECRS3)}
\end{array}$$

$$\begin{array}{c}
\text{env} \vdash \text{nil} \Downarrow \text{nil} \quad (\text{BS-NIL}) \qquad \frac{\text{env} \vdash e_1 \Downarrow v \quad \text{env} \vdash e_2 \Downarrow l}{\text{env} \vdash e_1 :: e_2 \Downarrow v :: l} \quad (\text{BS-CONS}) \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise}}{\text{env} \vdash e_1 :: e_2 \Downarrow \text{raise}} \quad (\text{BS-CONSR1}) \qquad \frac{\text{env} \vdash e_1 \Downarrow v \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash e_1 :: e_2 \Downarrow \text{raise}} \quad (\text{BS-CONSR2}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{nil}}{\text{env} \vdash \text{isempty } e \Downarrow \text{true}} \quad (\text{BS-ISEMPTYNIL}) \qquad \frac{\text{env} \vdash e \Downarrow v :: l}{\text{env} \vdash \text{isempty } e \Downarrow \text{false}} \quad (\text{BS-ISEMPTYCONS}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{raise}}{\text{env} \vdash \text{isempty } e \Downarrow \text{raise}} \quad (\text{BS-ISEMPTYRS}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{nil}}{\text{env} \vdash \text{hd } e \Downarrow \text{raise}} \quad (\text{BS-HDNIL}) \qquad \frac{\text{env} \vdash e \Downarrow v :: l}{\text{env} \vdash \text{hd } e \Downarrow v} \quad (\text{BS-HDCONS}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{raise}}{\text{env} \vdash \text{hd } e \Downarrow \text{raise}} \quad (\text{BS-HDRS}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{nil}}{\text{env} \vdash \text{tl } e \Downarrow \text{raise}} \quad (\text{BS-TLNIL}) \qquad \frac{\text{env} \vdash e \Downarrow v :: l}{\text{env} \vdash \text{tl } e \Downarrow l} \quad (\text{BS-TLCONS}) \\
\\
\frac{\text{env} \vdash e \Downarrow \text{raise}}{\text{env} \vdash \text{tl } e \Downarrow \text{raise}} \quad (\text{BS-TLRS}) \\
\\
\text{env} \vdash \text{raise} \Downarrow \text{raise} \quad (\text{BS-RAISE}) \qquad \frac{\text{env} \vdash e_1 \Downarrow v}{\text{env} \vdash \text{try } e_1 \text{ with } e_2 \Downarrow v} \quad (\text{BS-TRY}) \\
\\
\frac{\text{env} \vdash e_1 \Downarrow \text{raise} \quad \text{env} \vdash e_2 \Downarrow v}{\text{env} \vdash \text{try } e_1 \text{ with } e_2 \Downarrow v} \quad (\text{BS-TRYRS1}) \qquad \frac{\text{env} \vdash e_1 \Downarrow \text{raise} \quad \text{env} \vdash e_2 \Downarrow \text{raise}}{\text{env} \vdash \text{try } e_1 \text{ with } e_2 \Downarrow \text{raise}} \quad (\text{BS-TRYRS1})
\end{array}$$