0.1 Transition Rules

[VAR-DECL]
$$\frac{\langle D_V, env_V[x \mapsto l][\text{next} \mapsto \text{new } l], sto[l \mapsto v]\rangle \rightarrow_{DV} (env'_V, sto')}{\langle \textbf{var } x <-- a; D_V, env_V, sto\rangle \rightarrow_{DV} (env'_V, sto')}$$

where $env_V, sto \vdash a \rightarrow_a v$
and $l = env_V$ next

[EMPTY-VAR-DECL] $\langle \varepsilon, env_V, sto\rangle \rightarrow_{DV} (env_V, sto)$

[FUNC-DECL]
$$\frac{env_V \vdash \langle D_P, env_P[p \mapsto (S, env_V, env_P)]\rangle \rightarrow_{DP} env'_P}{env_V \vdash \langle \textbf{proc } p \textbf{ is } S; D_P, env_P\rangle \rightarrow_{DP} env'_P}$$

[FUNC-PARA-DECL]
$$\frac{env_V \vdash \langle D_P, env_P[p \mapsto (S, x, env_V, env_P)]\rangle \rightarrow_{DP} env'_P}{env_V \vdash \langle \textbf{proc } p(\textbf{var } x) \textbf{ is } S; D_P, env_P\rangle \rightarrow_{DP} env'_P}$$

[EMPTY-FUNC-DECL] $env_V \vdash \langle \varepsilon, env_P\rangle \rightarrow_{DP} env_P$

Table 0.1: Declarations

[VAR-ASS] $env_C, \vdash \langle x <-- e,\ sto\rangle \rightarrow sto[l \mapsto v]$

where $env_C,\ sto \vdash e \rightarrow_e v$
and $env_V\ x = l$

[ARR-ASS] $env_C \vdash \langle r[a] <-- e,\ sto\rangle \rightarrow sto[l \mapsto v_2]$

where $env_C,\ sto \vdash a \rightarrow_a v_1$
and $env_C,\ sto \vdash e \rightarrow_e v_2$
and $env_A\ r[v_1] = l$

Table 0.2: Assignments

[IF-TRUE]
$$\frac{env_C \vdash \langle C,\ sto\rangle \rightarrow sto'}{env_C\ \langle \textbf{if}(b) \text{ begin } C \text{ end},\ sto\rangle \rightarrow sto'}$$

if $env_C,\ sto \vdash b \rightarrow_b$ true

[IF-FALSE] $env_C \vdash \langle \textbf{if}(b) \text{ begin } C \text{ end},\ sto\rangle \rightarrow sto$

if $env_C,\ sto \vdash b \rightarrow_b$ false

[IF-ELSE-TRUE]
$$\frac{env_C \vdash \langle C_1,\ sto\rangle \rightarrow sto'}{env_C \vdash \langle \textbf{if}(b) \text{ begin } C_1 \text{ end}, \textbf{ else} \text{ begin } C_2 \text{ end},\ sto\rangle \rightarrow sto'}$$

if $env_C,\ sto \vdash b \rightarrow_b$ true

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[IF-ELSE-FALSE] $$\frac{env_C \vdash \langle C_2,\ sto\rangle \rightarrow sto'}{env_C \vdash \langle \textbf{if}(b) \text{ begin } C_1 \text{ end},\ \textbf{else} \text{ begin } C_2 \text{ end},\ sto\rangle \rightarrow sto'}$$

if $env_C,\ sto \vdash b \rightarrow_b$ false

[WHL-TRUE] $$\frac{env_C \vdash \langle C,\ sto\rangle \rightarrow sto'' \ env_C \vdash \langle \textbf{while}(b) \text{ begin } C \text{ end},\ sto''\rangle \rightarrow sto'}{env_C \vdash \langle \textbf{while}(b) \text{ begin } C \text{ end},\ sto\rangle \rightarrow sto'}$$

if $env_C,\ sto \vdash b \rightarrow_b$ true

[WHL-FALSE] $$env_C \vdash \langle \textbf{while}(b) \text{ begin } C \text{ end},\ sto\rangle \rightarrow sto$$

if $env_C,\ sto \vdash b \rightarrow_b$ false

[FROM-TRUE] $$\frac{}{env_V, env_P \vdash \langle \textbf{from } x < - - n_1 \textbf{ to } n_2 \textbf{ step } n_3 \textbf{ begin } C \textbf{ end}, sto\rangle} \rightarrow sto'$$

[FROM-FALSE]

[CALL-BY-VAL] $$\frac{env'_V[x \mapsto l][\text{next} \mapsto \text{new } l, env'_P \vdash \langle S, sto[l \mapsto v]\rangle \rightarrow sto'}{env_V, env_P \vdash \langle \textbf{call } p(a), sto\rangle \rightarrow sto'}$$

where $env_P p = (S, x, env'_V, env'_P)$,
and $env_V, sto \vdash a \rightarrow_a v$
and $l = env_V$

[CALL-BY-REF] $$\frac{env'_V[x \mapsto l][\text{next} \mapsto l'], env'_P \vdash \langle S, sto\rangle \rightarrow sto'}{env_V, env_P \vdash \langle \textbf{call } p(y), sto\rangle \rightarrow sto'}$$

where $env_P p = (S, x, env'_V, env'_P)$,
and $l = env_V y$
and $l' = env_V$ next

Table 0.3: Commands

[EQL-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \ \ env_V,\ sto \vdash a_2 \rightarrow_e v_2}{env_V,\ sto \vdash a_1 = a_2 \rightarrow_b \text{true}}$$

if $v_1 = v_2$

[EQL-FALSE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \ \ env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 = a_2 \rightarrow_b \text{false}}$$

if $v_1 \neq v_2$

[NEQ-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \ \ env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 ! = a_2 \rightarrow_b \text{true}}$$

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if $v_1 \neq v_2$

[NEQ-FALSE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 != a_2 \rightarrow_b \text{false}}$$

if $v_1 = v_2$

[GRT-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 > a_2 \rightarrow_b \text{true}}$$

if $v_1 > v_2$

[GRT-FALSE] $$\frac{env_E,\ sto \vdash e_1 \rightarrow_e v_1 \quad env_E,\ sto \vdash e_2 \rightarrow_e v_2}{env_E,\ sto \vdash e_1 > e_2 \rightarrow_b \text{false}}$$

if $v_1 \leq v_2$

[GEQ-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 >= a_2 \rightarrow_b \text{true}}$$

if $v_1 \geq v_2$

[GEQ-FALSE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 >= a_2 \rightarrow_b \text{false}}$$

if $v_1 < v_2$

[LES-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 < a_2 \rightarrow_b \text{true}}$$

if $v_1 < v_2$

[LES-FALSE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 < a_2 \rightarrow_b \text{false}}$$

if $v_1 \geq v_2$

[LEQ-TRUE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 <= a_2 \rightarrow_b \text{true}}$$

if $v_1 \leq v_2$

[GEQ-FALSE] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 <= a_2 \rightarrow_b \text{false}}$$

if $v_1 > v_2$

[NOT-TRUE] $$\frac{env_V,\ sto \vdash b \rightarrow_b \text{true}}{env_V,\ sto \vdash !(b) \rightarrow_b \text{false}}$$

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[NOT-FALSE]	$\dfrac{env_V,\ sto \vdash b \rightarrow_b \text{false}}{env_V,\ sto \vdash !(b) \rightarrow_b \text{true}}$
[AND-TRUE]	$\dfrac{env_V,\ sto \vdash b_1 \rightarrow_b \text{true}\ env_V, sto \vdash b_2 \rightarrow_b \text{true}}{env_V,\ sto \vdash b_1 \text{ AND } b_2 \rightarrow_b \text{true}}$
[AND-FALSE]	$\dfrac{env_V,\ sto \vdash b_i \rightarrow_b \text{false}}{env_V,\ sto \vdash b_1 \text{ AND } b_2 \rightarrow_b \text{false}}$ $(i \in \{1, 2\})$
[OR-TRUE]	$\dfrac{env_E,\ sto \vdash b_1 \vee b_2 \rightarrow_b \text{true}}{env_E,\ sto \vdash b_1 \text{ OR } b_2 \rightarrow_b \text{true}}$
[OR-FALSE]	$\dfrac{env_E,\ sto \vdash b_1 \wedge b_2 \rightarrow_b \text{false}}{env_E,\ sto \vdash b_1 \text{ OR } b_2 \rightarrow_b \text{false}}$
[PAR]	$\dfrac{env_E,\ sto \vdash b_1 \rightarrow_b v}{env_E,\ sto \vdash (b_1) \rightarrow_b v}$

Table 0.4: Boolean expressions

[ADD] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 + a_2 \rightarrow_a v}$$

where $v = v_1 + v_2$

[SUB] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 - a_2 \rightarrow_a v}$$

where $v = v_1 - v_2$

[MUL] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash a_1 * a_2 \rightarrow_a v}$$

where $v = v_1 * v_2$

[DIV] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1 \quad env_V,\ sto \vdash a_2 \rightarrow_a v_2}{env_V,\ sto \vdash \frac{a_1}{a_2} \rightarrow_a v}$$

where $v = \frac{v_1}{v_2}$

[PAR] $$\frac{env_V,\ sto \vdash a_1 \rightarrow_a v_1}{env_V,\ sto \vdash (a_1) \rightarrow_a v_1}$$

[NUM] $env_V,\ sto \vdash n \rightarrow_a v$

if $\mathcal{N}[n] = v$
where $\mathcal{N}$ **:** $\mathbf{Num} \rightarrow \mathbb{R}$

[VAR] $env_V,\ sto \vdash x \rightarrow_a v$

if $env_V\ x = l$
and $sto\ l = v$

[ARR] $env_A,\ sto \vdash r[a_1] \rightarrow_a v_2$

if $env_A\, r[v_1] = l$ and $sto\, l = v_2$
where $a_1 \rightarrow_a v_1$

Table 0.5: Aritmethic expressions