

1 Definicje

$$f[a := b](x) = \begin{cases} b & \text{gd}y \ x = a \\ f(x) & \text{w p.p.} \end{cases} \quad [a := b](x) = \begin{cases} b & \text{gd}y \ x = a \\ \perp & \text{w p.p.} \end{cases}$$

$$\oplus ::= + \mid - \mid * \mid / \mid \% \quad c \in \mathbb{Z} \quad I = \{\mathbf{a} \dots \mathbf{z}\}^* \quad i \in I$$

2 Bolek

$$\Gamma : I \rightarrow \mathbb{Z}$$

$$e ::= e_1 \oplus e_2 \mid i \mid c \mid e_1 \textbf{ where } i = e_2$$

$$\frac{}{\overline{\Gamma \vdash c \rightarrow c}} \quad \frac{}{\overline{\Gamma \vdash i \rightarrow \Gamma(i)}} \quad \frac{\Gamma \vdash e_1 \rightarrow c_1 \quad \Gamma \vdash e_2 \rightarrow c_2}{\overline{\Gamma \vdash e_1 \oplus e_2 \rightarrow c_1 \oplus c_2}} \quad \frac{\Gamma \vdash e_2 \rightarrow c_2 \quad \Gamma[i := c_2] \vdash e_1 \rightarrow c_1}{\overline{\Gamma \vdash e_2 \textbf{ where } i = e_2 \rightarrow c_1}}$$

3 Żółw

$$L = \{ \text{"}i\text{"} \mid i \in I \} \quad l \in L$$

$$e ::= e_1 \oplus e_2 \mid i \mid c \mid l \mid \textbf{new} \mid \textbf{null} \mid e_1.i \mid \textbf{isnull}(e_1) \mid e_0(e_1, \dots, e_n)$$

$$s ::= \textbf{print } e \mid \textbf{var } i = e \mid e_1 = e_2 \mid \{s_1; \dots; s_n\} \mid \textbf{skip} \mid \\ \textbf{if } (e) s_1 \textbf{ else } s_2 \mid \textbf{while } (e) s_1 \mid \textbf{fun } i_0(i_1, \dots, i_n) s_1$$

$$V = \mathbb{Z} \cup L \cup O \cup \{\textbf{null}\} \quad O = \{ \textbf{obj}(q) \mid q \in \mathbb{N} \} \quad C = \{ \textbf{cell}(q) \mid q \in \mathbb{N} \}$$

$$v \in V \quad \Gamma : I \rightarrow C \cup (\Gamma \times s) \quad \eta : C \rightarrow V \quad \Theta : O \times I \rightarrow V$$

3.1 Wyrażenia

$$\overline{(\Gamma, \eta, \Theta) \vdash c \rightarrow (c, \eta, \Theta)} \quad \overline{(\Gamma, \eta, \Theta) \vdash l \rightarrow (l, \eta, \Theta)} \quad \overline{(\Gamma, \eta, \Theta) \vdash \textbf{null} \rightarrow (\textbf{null}, \eta, \Theta)}$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (\textbf{null}, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash \textbf{isnull}(e_1) \rightarrow (1, \eta', \Theta')} \quad \frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash \textbf{isnull}(e_1) \rightarrow (0, \eta', \Theta')} \text{ where } v \neq \textbf{null}$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v_1, \eta', \Theta') \quad (\Gamma, \eta', \Theta') \vdash e_2 \rightarrow (v_2, \eta'', \Theta'')}{(\Gamma, \eta, \Theta) \vdash e_1 \oplus e_2 \rightarrow (v_1 \oplus v_2, \eta'', \Theta'')}$$

$$\frac{}{(\Gamma, \eta, \Theta) \vdash i \rightarrow (\eta(\Gamma(i)), \eta, \Theta)} \quad \frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v_1, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash e_1.i \rightarrow (\Theta'(v_1, i), \eta', \Theta')}$$

$$\frac{}{(\Gamma, \eta, \Theta) \vdash \mathbf{new} \rightarrow (\mathbf{obj}(q), \eta, \Theta[(\mathbf{obj}(q), \cdot) := \mathbf{null}])} \quad \text{where } \Theta(\mathbf{obj}(q), \cdot) = \perp$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_0 \rightarrow ((\Gamma', \lambda(i_1, \dots, i_n) s), \eta_0, \Theta_0) \quad \{(\Gamma, \eta_{k-1}, \Theta_{k-1}) \vdash e_k \rightarrow (v_k, \eta_k, \Theta_k)\}_{k=1}^n \quad \text{where } \forall i. \eta_n(\mathbf{cell}(q_i)) = \perp}{(\Gamma'[\mathbf{value} := \mathbf{cell}(q_0)][i_k := \mathbf{cell}(q_k)]_{k=1}^n, \eta_n[\mathbf{cell}(q_k) := v_k]_{k=1}^n, \Theta_n) \vdash s \Rightarrow (\Gamma'', \eta'', \Theta'')} \quad (\Gamma, \eta, \Theta) \vdash e_0(e_1, \dots, e_n) \rightarrow (\eta''(\mathbf{cell}(q_0)), \eta'', \Theta'')$$

3.2 Instrukcje

$$\frac{}{(\Gamma, \eta, \Theta) \vdash \mathbf{skip} \Rightarrow (\Gamma, \eta, \Theta)} \quad \frac{\{(\Gamma_{k-1}, \eta_{k-1}, \Theta_{k-1}) \vdash s_k \Rightarrow (\Gamma_k, \eta_k, \Theta_k)\}_{k=1}^n}{(\Gamma_0, \eta_0, \Theta_0) \vdash \{s_1; \dots; s_n\} \Rightarrow (\Gamma, \eta_n, \Theta_n)}$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (0, \eta', \Theta') \quad (\Gamma, \eta', \Theta') \vdash s_2 \Rightarrow (\Gamma'', \eta'', \Theta'')}{(\Gamma, \eta, \Theta) \vdash \mathbf{if}(e_1) s_1 \mathbf{else} s_2 \Rightarrow (\Gamma, \eta'', \Theta'')}$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v, \eta', \Theta') \quad (\Gamma, \eta', \Theta') \vdash s_1 \Rightarrow (\Gamma'', \eta'', \Theta'')}{(\Gamma, \eta, \Theta) \vdash \mathbf{if}(e_1) s_1 \mathbf{else} s_2 \Rightarrow (\Gamma, \eta'', \Theta'')} \quad \text{where } v \neq 0$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (0, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash \mathbf{while}(e_1) s \Rightarrow (\Gamma, \eta', \Theta')}$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v, \eta', \Theta') \quad (\Gamma, \eta', \Theta') \vdash s \Rightarrow (\Gamma'', \eta'', \Theta'') \quad (\Gamma, \eta'', \Theta'') \vdash \mathbf{while}(e_1) s \Rightarrow (\Gamma''', \eta''', \Theta''')}{(\Gamma, \eta, \Theta) \vdash \mathbf{while}(e_1) s \Rightarrow (\Gamma, \eta''', \Theta''')} \quad \text{where } v \neq 0$$

$$\frac{}{(\Gamma, \eta, \Theta) \vdash \mathbf{fun} i_0(i_1, \dots, i_n) s \Rightarrow (\Gamma', \eta, \Theta)} \quad \text{where } \Gamma' = \Gamma[i_0 := (\Gamma', \lambda(i_1, \dots, i_n) s)]$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e \rightarrow (v, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash \mathbf{var} i = e \Rightarrow (\Gamma[i := \mathbf{cell}(q)], \eta'[\mathbf{cell}(q) := v], \Theta')} \quad \text{where } \eta'(\mathbf{cell}(q)) = \perp$$

$$\frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v_1, \eta', \Theta')}{(\Gamma, \eta, \Theta) \vdash i = e_1 \Rightarrow (\Gamma, \eta'[i := v_1], \Theta')} \quad \frac{(\Gamma, \eta, \Theta) \vdash e_1 \rightarrow (v_1, \eta', \Theta') \quad (\Gamma, \eta', \Theta') \vdash e_2 \rightarrow (v_2, \eta'', \Theta'')}{(\Gamma, \eta, \Theta) \vdash e_1.i = e_2 \Rightarrow (\Gamma, \eta'', \Theta''[(v_1, i) := v_2])}$$