

Big-step operational semantics of BFAE

$$\begin{aligned}
e ::= & \mid n \\
& \mid e + e \\
& \mid e - e \\
& \mid x \\
& \mid \lambda x. e \\
& \mid e \ e \\
& \mid \text{ref } e \\
& \mid e := e \\
& \mid !e \\
& \mid e; e \\
& \mid (e)
\end{aligned}$$

 n

$$\sigma, M \vdash n \Rightarrow n, M$$

 $e + e$

$$\frac{\sigma, M \vdash e_1 \Rightarrow v_1, M_1 \quad \sigma, M_1 \vdash e_2 \Rightarrow v_2, M_2}{\sigma, M \vdash e_1 + e_2 \Rightarrow v_1 + v_2, M_2}$$

 $e - e$

$$\frac{\sigma, M \vdash e_1 \Rightarrow v_1, M_1 \quad \sigma, M_1 \vdash e_2 \Rightarrow v_2, M_2}{\sigma, M \vdash e_1 - e_2 \Rightarrow v_1 - v_2, M_2}$$

 x

$$\frac{x \in \text{Domain}(\sigma)}{\sigma, M \vdash x \Rightarrow \sigma(x), M}$$

 $\lambda x. e$

$$\sigma, M \vdash \lambda x. e \Rightarrow \langle \lambda x. e, \sigma \rangle, M$$

 $e \ e$

$$\frac{\sigma, M \vdash e_1 \Rightarrow \langle \lambda x. e, \sigma' \rangle, M_1 \quad \sigma, M_1 \vdash e_2 \Rightarrow v_2, M_2 \quad \sigma'[x \mapsto v_2], M_2 \vdash e \Rightarrow v, M_3}{\sigma, M \vdash e_1 \ e_2 \Rightarrow v, M_3}$$

 $\text{ref } e$

$$\frac{\sigma, M \vdash e \Rightarrow v, M_1 \quad M_1, v \vdash M_1[|M_1| + 1] \mapsto v \Rightarrow M_2}{\sigma, M \vdash \text{ref } e \Rightarrow \langle |M_1| + 1 \rangle, M_2}$$

 $e := e$

$$\frac{\sigma, M \vdash e_1 \Rightarrow \langle a \rangle, M_1 \quad \sigma, M_1 \vdash e_2 \Rightarrow v, M_2 \quad M_2, a, v \vdash M_2[a \mapsto v] \Rightarrow M_3}{\sigma, M \vdash e_1 := e_2 \Rightarrow v, M_3}$$

 $!e$

$$\frac{\sigma, M \vdash e \Rightarrow \langle a \rangle, M_1 \quad \sigma, M_1 \vdash M_1(a) \Rightarrow v, M_1}{\sigma, M \vdash !e \Rightarrow v, M_1}$$

 $e; e$

$$\frac{\sigma, M \vdash e_1 \Rightarrow v_1, M_1 \quad \sigma, M_1 \vdash e_2 \Rightarrow v_2, M_2}{\sigma, M \vdash e_1; e_2 \Rightarrow v_2, M_2}$$

 (e)

$$\frac{\sigma, M \vdash e \Rightarrow v, M_1}{\sigma, M \vdash (e) \Rightarrow v, M_1}$$