

Side Effects

- Mutate variable
- I/O
- Randomization
- Sys calls *

Fb: functions have input and output
Side-effect: any behavior that affects a program outside of typical data flow

any state other than the program itself which affects evaluation

Fb?
 $n \in \mathbb{Z}$
Random $\Rightarrow n$
⋮
Random + 1 $\Rightarrow 5$

⋮
Random + 1 $\Rightarrow -700$

Advantages of Side-Effects

- Communicate between different places without a lot of mess

Disadvantages of Side-Effects

- Understanding is harder: expressions can affect each other

Mutation in FbS S-Store.

$e ::= \dots \mid \text{Ref } e \mid !e \mid e := e$

$v ::= \dots \mid c$

$c ::=$ infinite set of cell names

$S ::= \{c \mapsto v, \dots\}$

with c unique

$Fb, FbR, FbV, FbP, \dots : e \Rightarrow v$

$FbS : \langle S, e \rangle \Rightarrow \langle S, v \rangle$

Ref $\frac{\langle S, e \rangle \Rightarrow \langle S', v \rangle \quad c \notin S' \quad S' \{c \mapsto v\} = S''}{\langle S, \text{Ref } e \rangle \Rightarrow \langle S'', c \rangle}$ Ref(Ref 0)

(!e) $\frac{\langle S, e \rangle \Rightarrow \langle S', c \rangle \quad (c \mapsto v) \in S'}{\langle S, !e \rangle \Rightarrow \langle S', v \rangle}$

(:=) $\frac{\langle S, e_1 \rangle \Rightarrow \langle S', c \rangle \quad c \in S' \quad \langle S', e_2 \rangle \Rightarrow \langle S'', v \rangle \quad S'' \{c \mapsto v\} = S'''}{\langle S, e_1 := e_2 \rangle \Rightarrow \langle S''', v \rangle}$

$\langle S, \underbrace{1 + (!(\text{Ref } 2))}_{\text{green bracket}} \rangle \Rightarrow \langle S', 3 \rangle$

$e \Rightarrow v$

$\langle S, e \rangle \Rightarrow \langle S, v \rangle$

Plus Rule $\frac{\langle S, e_1 \rangle \Rightarrow \langle S', v_1 \rangle \quad \langle S', e_2 \rangle \Rightarrow \langle S'', v_2 \rangle \quad v \text{ is the sum of } v_1 \text{ and } v_2}{\langle S, e_1 + e_2 \rangle \Rightarrow \langle S'', v \rangle}$

$e_{Fb} \Rightarrow_{Fb} v_{Fb}$

$e_{FbR} \Rightarrow_{FbR} v_{FbR}$

Value Rule $\frac{}{\langle S, v \rangle \Rightarrow \langle S, v \rangle}$

Let $x = \text{Ref } 0 \text{ In}$

$(x := 4) + (!x) \Rightarrow 8$

FbS sequence

$$e ::= \dots | e; e$$

$$\text{Sequence} \frac{\langle S, e_1 \rangle \Rightarrow \langle S', v_1 \rangle \quad \langle S', e_2 \rangle \Rightarrow \langle S'', v_2 \rangle}{\langle S, e_1; e_2 \rangle \Rightarrow \langle S'', v_2 \rangle}$$