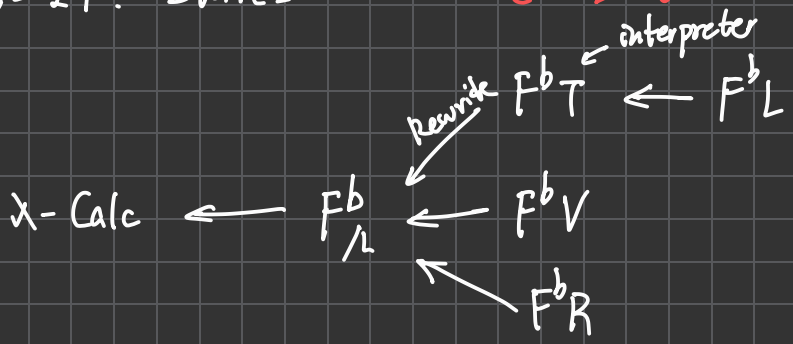
Lecture 14. States

$e \Rightarrow v$



$e \equiv$ Let $x = e_1$ In e_2 $\in F^b$

$\equiv$

$e' \equiv (\text{Fun } x \to e_2)\ e_1$ $\in F^b$

$(\lambda x.\ e_2)\ e_1$ $\in \lambda$-calc

C $\rightarrow$ C with OOP

$\searrow$ C++

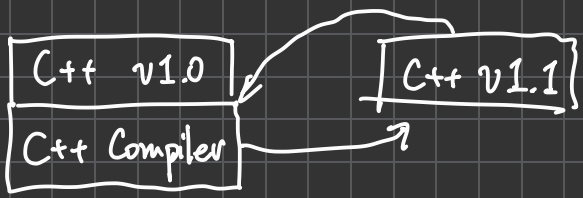
1979 - 1982 CFront : C++ $\to$ C

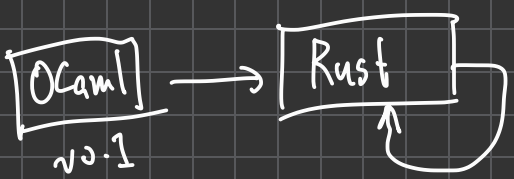
C++ $\xrightarrow{\text{CFront}}$ C $\xrightarrow{\text{cc}}$ Asm $\xrightarrow{\text{Asm}}$ Byte Code BC

1982 - 1991 CFront 1.0 2.X . 3.X

1991 - .. C++ Compilers g++ clang++

Bootstrapping





State

F^b $\quad e \Rightarrow v$ ← Pure

F^b with state → F^b_S $\quad \langle e, \sigma \rangle \Rightarrow \langle v, \sigma' \rangle$ ← Impure

F^b_S $\quad e ::= (\cdots F^b \text{Syntax} \cdots)$

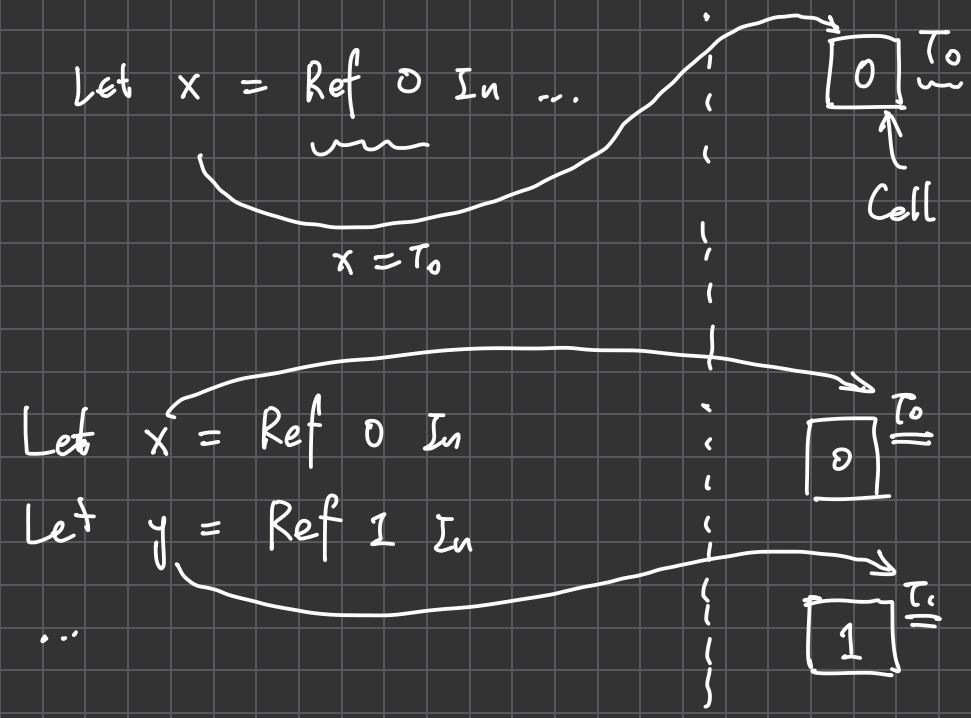
$\quad\quad | \quad \text{Ref } e$ ← Constructor Reference Cell

$\quad\quad | \quad !\, e$ ← Dereference

$\quad\quad | \quad e_1 := e_2$

(Cell name) $c ::=$ (impl dep) e.g. indices, ptrs, string

$v ::= (\cdots F^b \text{ Values} \cdots) \mid c$



c is a new cell name

$$[\text{Ref}]\ \frac{\langle e, \sigma_{before} \rangle \Rightarrow \langle v, \sigma' \rangle \qquad c \notin Dom(\sigma')}{\langle \text{Ref } e, \sigma_{before} \rangle \Rightarrow \langle c, \sigma'[c \mapsto v] \rangle}$$

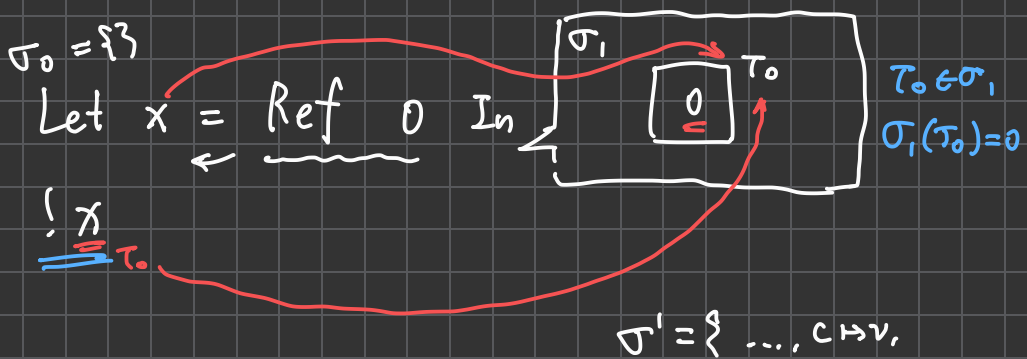
$$\sigma ::= \{ c_0 \mapsto v_0, c_1 \mapsto v_1, \ldots \}$$

Implementation: Py : Dict JS : Dict

cell names : indices

C/C++ : Ptr malloc $\Leftrightarrow$ Ref

cell names : pointer



$$[\text{Deref}]\ \frac{\langle e, \sigma_{before}\rangle \Rightarrow \langle c, \sigma'\rangle \quad c \in DOM(\sigma') \quad v = \sigma'(c)}{\langle\, !e\ , \sigma_{before}\rangle \Rightarrow \langle\ v\ , \sigma'\rangle}$$

Mutability $\quad e_1^{\leftarrow} := e_2^{\downarrow}$

Pure Lang + Mutability $\Rightarrow$ Impure Lang

↓

State

$$F^b\ [\text{Add}]\ \frac{e_1 \Rightarrow v_1 \quad e_2 \Rightarrow v_2 \quad v_1, v_2 \in \mathbb{Z}}{e_1 + e_2 \Rightarrow (v_1 + v_2)}$$

$$F^b_S\ \frac{\langle e_1, \sigma_1\rangle \Rightarrow \langle v_1, \sigma_2\rangle \quad \langle e_2, \sigma_2\rangle \Rightarrow \langle v_2, \sigma_3\rangle \quad v_1, v_2 \in \mathbb{Z}}{\langle e_1 + e_2, \sigma_1\rangle \Rightarrow \langle v_1 + v_2, \sigma_3\rangle}$$

$$a + b \cong b + a$$

C++/ $(x{+}{+}) + ((y{+}{+}) + (x{+}{+}))$

Substitution

$$e[v/x]$$

$$e \Rightarrow v \quad \cong \quad v + v$$

Fb $(\text{Fun } x \to x + x)\ e \quad \cong \quad e + e$

$\sigma_0 = \{x \mapsto 0\}$

FbS $(\text{Fun } x \to x + x)\ (x := !x + 1;\ !x)$

$1 + 1 \Rightarrow 2$

$1 + 2 \Rightarrow 3$

σ is of the form $\{c_1 \mapsto v_1, \ldots c_n \mapsto v_n\}$

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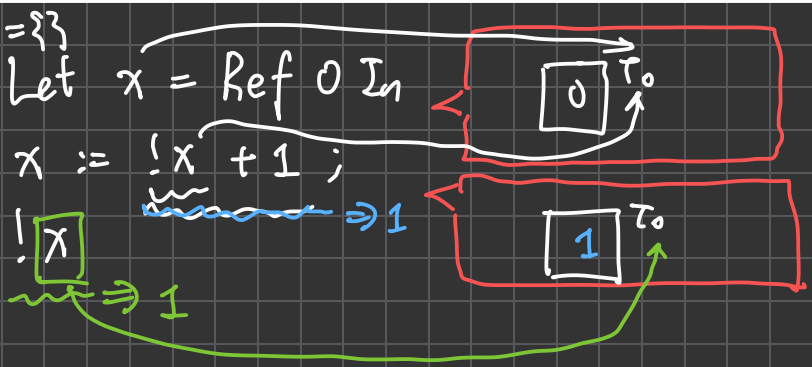
1. $\sigma_0 = \{\}$

Let x = Ref 0 In

x := !x + 1 ;

!x ⇒ 1



$e_1 ; e_2 \equiv (\text{Fun } \underline{x} \to e_2)\ e_1$ where $x \notin FV(e_2)$

↑ nefa var

$\equiv (\text{Fun } \_ \to e_2)\ e_1$

Fbs

Let temp = Ref !x In

(Fun z → y := temp) (x := !y)

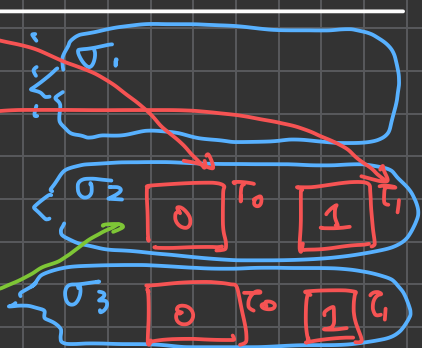
3.

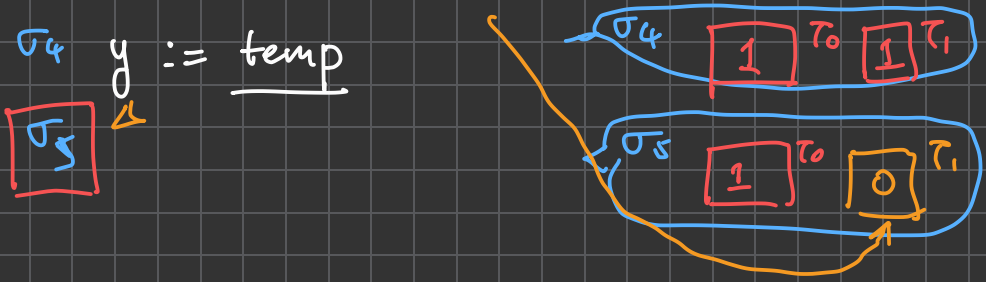
σ_0 Let x = Ref 0 In

σ_1 Let y = Ref 1 In

σ_2 Let temp = !x In

σ_3 x := !y ; ⇒ 1





$$\frac{}{\langle e_1 := e_2 \;, \sigma_1 \rangle \Rightarrow \langle v, \sigma_3[c \mapsto v] \rangle}$$