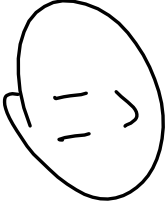


15-15



Final Aug 12 noon-3
in this room

stream s is PRODUCTIVE

if expose s terminates

& if $\text{Cons}(x, xs)$, xs is
productive

$\langle e_1, e_2, \dots \rangle$

stream s is INFINITE

if $\text{expose } s \Rightarrow \text{Cons}(x, xs)$

& xs is infinite

- mutable cells

- read

- write

$$e \Rightarrow e'$$

s is STORE

f

$s + env = state$

$$\{e | s\} \Rightarrow \{e' | s\}$$

$\text{ref } e : + \text{ ref} \quad \text{if } e : +$

$\text{ref } e \stackrel{!}{\Rightarrow} \text{ref } e' \quad \text{if } e \stackrel{!}{\Rightarrow} e'$

$\{ \text{ref } v \mid s \} \stackrel{0}{\Rightarrow} \{ \boxed{\text{id}} \mid [\text{id} \mapsto v] s \}$
id fresh

$!e : \vdash$ if $e : \vdash \text{ref}$

$!e \Rightarrow !e'$ if $e \Rightarrow e'$

$\{! \boxed{e_i} \mid s, i \mapsto v\} \Rightarrow$
 $\{v \mid s, i \mapsto v\}$

$$:= : 'a \text{ ref } * 'a \rightarrow \text{Unit}$$

$$e_1 := e_2 \Rightarrow e_1' := e_2 \\ \text{if } e_1 \Rightarrow e_1'$$

$$v := e_2 \Rightarrow v := e_2' \\ \text{if } e_2 \Rightarrow e_2'$$

$$\{ \boxed{p_i} := v \mid s \} \Rightarrow \{ () \mid [i] \mapsto v \} s \}$$

```

let
  val _ = e1
  val _ = e2
  ...
in
  en
end

```

$(e_1; e_2; \dots; e_n) : \tau$
 if $e_n : \tau$ and otherwise
 e_i is well typed

while e_1 do e_2 : unit

if e_2 well typed

& e_1 : bool

if e_1 then $(e_2 ; \text{while } e_1 \text{ do } e_2)$
else $()$

max
↓
m

calls
↓
n

linear imp: $O(m \times n)$

memo imp: $O(m \log(m) + n \log(m))$

$$\boxed{\lambda p. id} \approx \boxed{id} \quad \text{if } id = id'$$

function same values as before
 & same effects

val x = ref 0

getNext : unit $\rightarrow$ int

getNext () =
(x := !x + 1 ; !x)

getRandom : unit $\rightarrow$ real

print : string $\rightarrow$ unit