

1 Introduction

2 Syntax

$v ::= ()$	$f ::= \lambda x.e$	$e ::= v$
$n \in \mathbb{N}$	$v \ v$	let $x = v$ in e
$b \in \mathbb{B}$	$\text{ref } v$	let $x = f$ in e
x	$!v$	if v then e_1 else e_2
	$v := v$	

3 Transforming to NCL

4 An Abstract Machine

Let $\kappa' = \langle \text{frame } \Gamma, y, e', \kappa \rangle$.

4.1 computation

- $\langle \Gamma, \sigma, (\lambda x.e), y, e', \kappa \rangle \mapsto \langle \sigma, \gamma(\Gamma, \sigma, \lambda x.e), \kappa' \rangle$
- $\langle \Gamma, \sigma, (v_1 \ v_2), y, e', \kappa \rangle \mapsto \langle \Gamma'', \sigma', e'', \kappa' \rangle$
 - $\langle \text{cl } \Gamma', x', e'' \rangle = \gamma(\Gamma, \sigma, x)$
 - $l \notin \text{dom}(\sigma)$
 - $\Gamma'' = \Gamma'[x' := l]$
 - $\sigma' = \sigma[l := \gamma(\Gamma, \sigma, v)]$
- $\langle \Gamma, \sigma, (\text{ref } v), y, e', \kappa \rangle \mapsto \langle \sigma', \langle \text{ref } l \rangle, \kappa' \rangle$
 - $l \notin \text{dom}(\sigma)$
 - $\sigma' = \sigma[l := \gamma(\Gamma, \sigma, v)]$
- $\langle \Gamma, \sigma, (!v), y, e', \kappa \rangle \mapsto \langle \sigma, \sigma(l), \kappa' \rangle$
 - $\langle \text{ref } l \rangle = \gamma(\Gamma, \sigma, v_1)$ and $l \in \text{dom}(\sigma)$
- $\langle \Gamma, \sigma, (v_1 := v_2), y, e', \kappa \rangle \mapsto \langle \sigma', \langle \text{unit} \rangle, \kappa' \rangle$
 - $\langle \text{ref } l \rangle = \gamma(\Gamma, \sigma, v_1)$ and $l \in \text{dom}(\sigma)$
 - $\sigma' = \sigma[l := \gamma(\Gamma, \sigma, v_2)]$

4.2 expressions

- $\langle \Gamma, \sigma, v, \kappa \rangle \mapsto \langle \sigma, \gamma(\Gamma, \sigma, v), \kappa \rangle$
- $\langle \Gamma, \sigma, (\text{let } y = v \text{ in } e'), \kappa \rangle \mapsto \langle \sigma, \gamma(\Gamma, \sigma, v), \kappa' \rangle$
- $\langle \Gamma, \sigma, (\text{let } x = f \text{ in } e), \kappa \rangle \mapsto \langle \Gamma, \sigma, f, x, e, \kappa \rangle$
- $\langle \Gamma, \sigma, (\text{if } v \text{ then } e_1 \text{ else } e_2), \kappa \rangle \mapsto \langle \Gamma, \sigma, e, \kappa \rangle$
 - $e = \begin{cases} e_1, & \text{if } \gamma(\Gamma, \sigma, v) = \langle \text{bool true} \rangle \\ e_2, & \text{if } \gamma(\Gamma, \sigma, v) = \langle \text{bool false} \rangle \end{cases}$

4.3 values

- $\langle \sigma, v, \langle \text{frame } \Gamma, x, e, \kappa \rangle \rangle \mapsto \langle \Gamma', \sigma', e, \kappa \rangle$
 - $l \notin \text{dom}(\sigma)$
 - $\Gamma' = \Gamma[x := l]$
 - $\sigma' = \sigma[l := v]$

The function $\gamma(\Gamma, \sigma, v)$ is defined by

- $\gamma(\Gamma, \sigma, ()) = \langle \text{unit} \rangle$
- $\gamma(\Gamma, \sigma, n) = \langle \text{int } n \rangle$
- $\gamma(\Gamma, \sigma, b) = \langle \text{bool } b \rangle$
- $\gamma(\Gamma, \sigma, x) = \sigma(\Gamma(x))$
- $\gamma(\Gamma, \sigma, \lambda x.e) = \langle \text{cl } \Gamma, x, e \rangle$