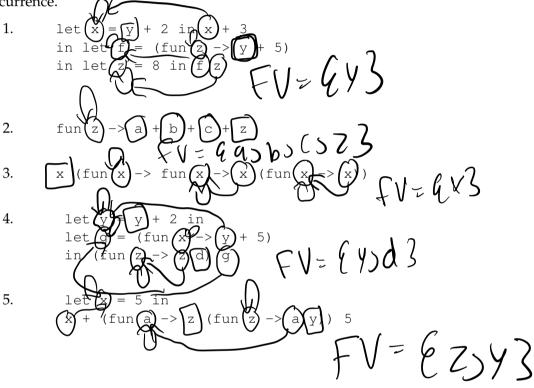
CS51 Spring 2024

Code Review 9: Semantics

1 Practice Problems (1)

Problem 1.1 (Free Variables). **Instructions**: Write a box around the free variables in the following expressions. For the bound variables, draw an arrow indicating its corresponding binding occurrence.



Problem 1.2 (Substitution). Write out the result of the following substitutions.

1.
$$((x + 1) + (y + 2)) [x -> 3]$$

2. (let
$$x = x + 1$$
 in $x + 2$) [x -> 3]

3. (let
$$x = y + 2$$

in let
$$z = 5$$

in
$$z + x + j$$
 a) $[x -> 5][j -> (fun $x -> x * x)][a -> 4]$$

1

4. (let
$$y = y + 2$$
 in let $q = (\text{fun } x \rightarrow y + 5)$



in
$$(\text{fun } z \rightarrow z d) q))[v \rightarrow 8][d \rightarrow 4]$$

5. (let
$$x = 5$$
 in $x + (fun a -> z (fun z -> a y)) 5) [a -> 2] [z -> fun x -> x]$

Problem 1.3 (Substitution Semantics). Use the Substitution Semantic Evaluation Rules to derive the result of the following expression.

Problem 1.4 (Environment Semantics).

- 1. Define an expression that evaluates to different values under lexical and dynamic semantic systems
- 2. Write out two derivations for the result of the expression: one using lexical semantics and the other using dynamic semantics. Omit Soln
- 3. Derive the evaluation for the result of the following expression

let
$$f = (fun \times - \times \times 2)$$
 in
let $x = ref \ 42$ in
 $(x := !x - 10; \ !x) + f \ !x ;;$

$$Omit Solut(0)$$

Problem 1.5 (Extending Semantics Models). Extend the substitution semantics and environment semantics (under mutable storage) models to support the additional language constructs:

- 1. Tuple Pairs. In addition, define semantic rules for the functions fst and snd.
- 2. Conditional Expressions. Define semantic rules for operators | | and &&. In addition, define a semantic rule for the if e1 then e2 else e3 construct
- 3. Lists. Define semantic rules for the hd and t1 functions, and the :: constructor.

Problem 1.2

3.

(let
$$x = y + 2m$$
)

 $let z = 5m$
 $z + x + 5q$
 $z + x + 2m$
 $let z = 5m$
 $z + x + (fun x - 7x + x) = [al - 2d]$
 $= [let x = y + 2m]$
 $= [let x = y + 2m]$

4 (lety=4+2 in letg = funx74+5 m

$$= \frac{(\text{fun} 777d)g}{(\text{fun} 777d)g}(\text{fun} 777d)g$$

2nd Sub. Z+> fun x-7xix

X+ (fun a-> (fun x->xix) (fun z->ay)

X+ (fun a-> (fun x->xix) (fun z->ay)

X+ (fun a-> (fun x->xix) (fun z->ay)

Problem 1.4

let x=5 m

let f = fun y -> x+7 m

let x=3 m

f x jj

Problem 1.5 1) E 3 S H (P3 Q)() ESFPUVASI ESSFPUVASI U (VEVA)SII

Essiph (Visva), S' Vos' Similarly for and 2) ESSHPLLQ11, Ess-Plltruess' Ess'-Qlltruess' trues 5" ESSH Pll QU Ess - All truess' Ess' - Glifuless' Falses 511 Add 2 more cases for Il (P=false and P=true) and (P=false and Q= false) in a similar fashion.

11. Do the same thing writing out rules for cases accordingly.

if P the Qele EU

Est-Pll truess' Est-Pll truess' Uvoss'

Add another case when P= falle and evaluate Rinstead.

note... 15 right associative metavar to represent EJSHP: QU ESSI-PUVIS [V1) V2)....) Vn), S! ES = hd L () JESSHL WEUS....JUDS! UVDS!

Define rule similarly for tail

replacing viin las + line with