Part A: Talking operational semantics

Translating Opsem to Englsih

(a)

x is either a local or global variable

(b)

The expression e evaluates to the value v (without changing any states)

Translating English to Opsem

(a)

If $x \notin \textsc{dom}\xi$, Then $\langle e, \xi, \phi, \rho \rangle \Downarrow \langle v, \xi, \phi, \rho \rangle$

(b)

If $\langle e, \xi, \phi, \rho \rangle \Downarrow \langle v, \xi', \phi, \rho' \rangle$, Then $\xi = \xi'$

(c)

If $\langle e, \xi, \phi, \rho \rangle \Downarrow \langle v, \xi', \phi, \rho' \rangle$, Then $\textsc{Dom}\, \xi = \textsc{Dom}\, \xi'$

Analyzing Inference Rules

While End

There is no difference, as in the book rule, it just breaks up the fact that value evaluates to 0 in two statements; instead of saying that e1 evaluates to some value, and that value is 0, the alternate rule says that e1 evaluates to 0. These things are the same thing, as in the first rule, it only works if e1 evaluates to 0.

Formal Assign

There is a difference, as the alternative rule does not actually set the variable x (as it does not add the mapping of x to v to the ρ' environment). This means that it will only evaluate the expression and the resulting ρ enviornment, instead of actually doing any setting, which is what the set operator is supposed to do.

Consider the following code:

```
(set x 1)
(define foo (x)
    (+ x 1))
(foo (+ 1 1))
```

Notice that to evaluate `(foo (+ 1 1))`, `(+ 1 1)` should be evaluated first. This evaluates to 2. However, notice that in the alternative definition of FormalAssign', the value in the ρ' environment never has x reassigned to the value of 2, so it when evaluating the function, instead of using $x = 2$ as the input, it uses $x = 1$ as it is the value that is in the global environment. Thus, instead of setting the value of n to 2, it doesn't, leading to the function not using the parameters to evaluate, leading to `(foo (+ 1 1))` to return 2. Conversely, in the original rule, the value of ρ' is updated so that $x = 2$, so when the function is being evaluated, it uses $x = 2$ instead of $x = 1$ from the global environment. This means that `(foo (+ 1 1))` to return 3.

Part B: Operational Semantics and Language Design

Extending Impcore to allow references to unbound variables

Awk-like

$$\frac{x \notin \text{dom}\,\rho \quad x \notin \text{dom}\,\xi}{\langle \textsc{Var}(x), \xi, \phi, \rho \rangle \Downarrow \langle 0, \xi\{x \mapsto 0\}, \phi, \rho \rangle} \quad (\textsc{AwkUnboundVariable})$$

Icon-Like

$$\frac{x \notin \text{dom}\,\rho \quad x \notin \text{dom}\,\xi}{\langle \textsc{Var}(x), \xi, \phi, \rho \rangle \Downarrow \langle 0, \xi, \phi, \rho\{x \mapsto 0\} \rangle} \quad (\textsc{IconUnboundVariable})$$

Awk vs Icon

Overall, I prefer the Icon-like semantics for unbound variables. This is because global variables may create bugs in other areas of the code, which can be very hard to find, as the root cause of the bug can be anywhere in the code (as a single unbound variable would be global, and thus, can affect parts of codes in completely different areas). However, if the value is made locally, the impact is limited, and thus, will only

Part C: Derivations and Proofs

(begin (set x 3) x) with $\rho(x) = 99$

$$\dfrac{\dfrac{x \in \textsc{Dom}\ \rho \quad \dfrac{}{\langle \textsc{Literal}(3), \xi, \phi, \rho \rangle \Downarrow \langle 3, \xi, \phi, \rho \rangle}\ (\textsc{Literal})}{\langle \textsc{Set}(x, \textsc{Literal}(3)), \xi, \phi, \rho \rangle \Downarrow \langle 3, \xi, \phi, \rho\{x \mapsto 3\} \rangle}\ (\textsc{FormalAssign}) \quad \dfrac{x \in \textsc{Dom}\ (\rho\{x \mapsto 3\})}{\langle \textsc{Var}(x), \xi, \phi, \rho\{x \mapsto 3\} \rangle \Downarrow \langle 3, \xi, \phi, \rho\{x \mapsto 3\} \rangle}\ (\textsc{FormalVar})}{\langle \textsc{Begin}(\textsc{Set}(x, \textsc{Literal}(3)), \textsc{Var}(x)), \xi, \phi, \rho \rangle \Downarrow \langle 3, \xi, \phi, \rho\{x \mapsto 3\} \rangle}\ (\text{xIs3})$$

Proofs About Derivations

The first statement uses the IfTrue and IfFalse inference rules, while the second case uses the GlobalVar and FormalVar rules. The if statement is true if x evaluates to a non-zero value, and false if x evaluates to a zero value.

There are 4 cases to consider:

1. The variable x is a formal variable and $\rho(x) \neq 0$
2. The variable x is a global variable and $\xi(x) \neq 0$
3. The variable x is a formal variable and $\rho(x) = 0$
4. The variable x is a global variable and $\xi(x) = 0$

However, notice that the second statement only cares if the variable is a global or formal variable, so there are two derivations instead of 4 (as each inference rule works for 2 cases).

Statement 1 (The if statement) Rules:

The variable x is a formal variable and $\rho(x) \neq 0$:

$$\dfrac{\dfrac{x \in \textsc{Dom}\ \rho}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \rho(x), \xi, \phi, \rho\rangle}\ (\textsc{FormalVar}) \quad \rho(x) \neq 0}{\langle \textsc{If}(\textsc{Var}(x), \textsc{Var}(x), \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle \rho(x), \xi, \phi, \rho\rangle}\ (\textsc{IfTrue})$$

The variable x is a global variable and $\xi(x) \neq 0$:

$$\dfrac{\dfrac{x \notin \textsc{Dom}\ \rho\ x \in \textsc{Dom}\ \xi}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \xi(x), \xi, \phi, \rho\rangle}\ (\textsc{GlobalVar}) \quad \xi(x) \neq 0}{\langle \textsc{If}(\textsc{Var}(x), \textsc{Var}(x), \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle \xi(x), \xi, \phi, \rho\rangle}\ (\textsc{IfTrue})$$

The variable x is a formal variable and $\rho(x) = 0$:

$$\dfrac{(\textsc{FormalVar})\ \dfrac{x \in \textsc{Dom}\ \rho}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \rho(x), \xi, \phi, \rho\rangle} \quad \rho(x) = 0 \quad \dfrac{}{\langle \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle 0, \xi, \phi, \rho\rangle}\ (\textsc{Literal})}{\langle \textsc{If}(\textsc{Var}(x), \textsc{Var}(x), \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle 0, \xi, \phi, \rho\rangle}\ (\textsc{IfFalse})$$

The variable x is a global variable and $\xi(x) = 0$:

$$\dfrac{(\textsc{GlobalVar})\ \dfrac{x \notin \textsc{Dom}\ \rho\ x \in \textsc{Dom}\ \xi}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \xi(x), \xi, \phi, \rho\rangle} \quad \xi(x) = 0 \quad \dfrac{}{\langle \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle 0, \xi, \phi, \rho\rangle}\ (\textsc{Literal})}{\langle \textsc{If}(\textsc{Var}(x), \textsc{Var}(x), \textsc{Literal}(0), \xi, \phi, \rho\rangle \Downarrow \langle 0, \xi, \phi, \rho\rangle}\ (\textsc{IfFalse})$$

Statement 2 (The var statement) Rules:

The variable x is a formal variable:

$$\dfrac{x \in \textsc{Dom}\ \rho}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \rho(x), \xi, \phi, \rho\rangle}\ (\textsc{FormalVar})$$

The variable x is a global variable:

$$\dfrac{x \notin \textsc{Dom}\ \rho\ x \in \textsc{Dom}\ \xi}{\langle \textsc{Var}(x), \xi, \phi, \rho\rangle \Downarrow \langle \xi(x), \xi, \phi, \rho\rangle}\ (\textsc{GlobalVar})$$

Consider each case:

1. The variable x is a formal variable and $\rho(x) \neq 0$:

   Statement 1 evaluates to $v_1 = \rho(x)$ and statement 2 also evaluates to $v_2 = \rho(x)$. Thus, $v_1 = v_2$.

2. The variable x is a global variable and $\xi(x) \neq 0$:

   Statement 1 evaluates to $v_1 = \xi(x)$ and statement 2 also evaluates to $v_2 = \xi(x)$. Thus, $v_1 = v_2$.

3. The variable x is a formal variable and $\rho(x) = 0$:

   Statement 1 evaluates to $v_1 = 0$ and statement 2 also evaluates to $v_2 = \rho(x) = 0$. Thus, $v_1 = v_2$.

4. The variable x is a global variable and $\xi(x) = 0$:

   Statement 1 evaluates to $v_1 = 0$ and statement 2 also evaluates to $v_2 = \xi(x) = 0$. Thus, $v_1 = v_2$.

Thus, in all cases, $v_1 = v_2$. Notice that in all cases, both of the statements don't change the environments, and since the evaluations are the same, the functions are equivalent.

Help

Vivan, Jyoti, Kim, Bill from RI, Steven, Etai