**gggtkljhtjbmemtrdnjgkkhjjmgwwwwwwwwwwwwwwwwwmmmmgggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggggmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmmCSSE 304 Assignment #17 (4th interpreter milestone)**

Part b is the first **very** challenging team assignment.

* Same turnin instructions as the previous assignments.
* Some of the test-case points are "regression tests" over language features from the previous assignments. Another chance to get credit for those things, and to make sure that adding new features did not break old ones.

**Code branches:**

**V**

A16

A17a

A17b1

A17b2

A18

**Part a.** Add additional syntax to your interpreted language. Make sure the old stuff still works.

**Summary:** The major new features to be added are:

1. set! for local (bound) variables
2. define (top-level only), including definitions of recursive procedures. You do not need to support the   
   (define (a b c) e) form or any other forms of define that create procedures without using an explicit lambda. You do not need to support local defines (i.e. define inside let, lambda or letrec). Your interpreter must support define inside a top-level begin.
3. any additional primitive procedures that are needed for our test cases. More details below.
4. set! for global (free) variables. As described in class, you only need to have this work for variables that have already been defined. More details below.
5. reset-global-env
6. If top-level-eval or something that it calls creates a global variable or changes the value of a global variable, then the value of that global variable stays in effect through subsequent calls to eval-one-exp, unless reset-global-env is called (or unless evaluation of a later set! expression changes it again).

The purpose of reset-global-env is to handle the case where your interpreter does something wrong and messes up the global environment when evaluating one of your/my test cases. If we call (reset-global-env), we should then be able to continue with the rest of the test cases, without your score being adversely affected by the evaluation of the bad (for you) previous test case. Some of the test cases may call reset-global-env before calling eval-one-exp. **Do not fail to implement it**.

I suggest that you thoroughly test each additional interpreter feature before adding the next one. It is not required, but updating unparse whenever you update parse may help you with debugging.

**Details of some of the above bulleted items:**

1. Write the zero-argument procedure **reset-global-env**, which is a regular Scheme procedure (not something interpreted by your interpreter). The code I have given you below is intended to clarify its function, not to make you rewrite your interpreter. You will need to adapt it to your particular code. You may not already have the make-init-env thunk, but it should be simple to modify your (define init-env ...) code to create it if you want to follow my approach.

**(define reset-global-env**

**(lambda () (set! global-env (make-init-env)))**

Note that, as described in EoPL, set! in our interpreted language is used only to change the values stored in existing bindings, not to create new bindings (*Chez* Scheme and some other implementations also allow the use of set! to create new bindings, but your interpreter is not required to allow this).

1. When you add define to your interpreted language, you are only required to add top-level **define**, a slight variation on <http://scheme.com/tspl4/further.html#./further:h1> . Here is the relevant part of the grammar:

**<form> ::= <definition> | <expression>**

**<definition> ::= <variable definition> | (begin <definition>+ <expression>\*)**

**<variable definition> ::= (define <variable> <expression>)**

Note that Scheme’s define has a very different meaning (and restrictions on where it can be used) when used inside a letrec, let, or lambda; your interpreter **is not required** to implement this in A17. To handle top-level define, you probably will want to modify the top-level-eval procedure so it uses cases to determine whether the form is a define or not; then top-level-eval processes definitions and expressions (the latter by sending them to eval-exp, the former by evaluating the expression part *via* eval-exp, then modifying the global environment). Definitions (and only definitions) change the global environment (set! may change the *value* of something in the global environment, but not the actual binding of the variable, which is a reference). Note that the global environment is "special," in the sense that all other environments are static (no new variables can be added after it is created) , but the global environment is dynamic.

**When you have finished everything up to this point, you should save a copy of your code, to use for Assignment 18 and the final exam; they will not require reference parameters or lexical address. You should probably also make two new “branches” of your code; one that implements pass-by-reference parameters and one that implements lexical address. You are not required to implement both of those in the same interpreter (but you are allowed to do so if you wish.**

**Part b1: reference parameters**

**Reference parameters.** Scheme always passes arguments to procedure applications **by value**. An alternative, calling **by** **reference**, is described in EoPL. What you are to implement is a new syntax that gives the creator of a procedure the ability to specify whether each formal parameter in a lambda expression is a "by-value" parameter or a "by-reference" parameter. If a formal parameter is a single symbol (as usual), it is by-value (i.e. pass to the procedure the value of the argument). If it is   
(ref sym)where sym is a symbol, then it is by-reference (pass to the procedure a reference to the argument). This will require modifying your parser (and most likely modifying some of your datatypes). **Something to think about:** What if the actual argument passed in to a by-reference formal parameter is an expression that is not a variable lookup? You’ll have to think about what to do in this case.

Note that the use of ref here is somewhat like the use of \* in the type of a parameter in C. However, unlike C, the caller of the procedure with a ref parameter does not have to provide the equivalent of C’s & when calling a procedure that was created with a ref parameter. The interpreter has to do the right thing when the procedure call happens.

The following code samples might illuminate the meaning of (ref x):

--> **(let ([a 3]**

**[b 4]**

**[swap (lambda ((ref x) (ref y))** ; both x and y passed by reference

**(let ([temp x])**

**(set! x y)**

**(set! y temp)))])**

**(swap a b)**

**(list a b))**

(4 3)

--> **(let ([a 3]**

**[b 4]**

**[swap (lambda (x y)** ; both x and y passed by value

**(let ([temp x])**

**(set! x y)**

**(set! y temp)))])**

**(swap a b)**

**(list a b))**

(3 4)

--> **(let ([a 3]**

**[b 4]**

**[swap (lambda ((ref x) y)** ; only x passed by reference

**(let ([temp x])**

**(set! x y)**

**(set! y temp)))])**

**(swap a b)**

**(list a b))**

(4 4)

**I do not plan to spend class time on this aspect of the interpreter.** I want your group to read about it and be creative in figuring out how to implement it.

**Part b2 Lexical address**

Modify your parser so it generates lexical-address information for local variable uses and references. Modify apply-env for local environments so that it uses this lexical address info to efficiently go to the location of a local variable without having to actually compare the variable to symbols in the environment. This should make the lookup time for a local variable be Θ (lexical depth), since once we get to the correct local environment, the lookup of the value in the vector will be constant time when we already know the position. The original apply-env implementation is Θ(number of variables in all local envs).

Suggested order of procedure calls: (eval-exp (lexical-address (syntax-expand (parse-exp source-exp))).

**Submission** (two PLC server assignments). There are two A17 assignments on the PLC server. The first assignment has tests for Part 1 (including reference parameters). The second has a smaller number of tests that do not include reference parameters. In order to actually earn the points the server gives you for the second part, you must correctly use lexical address in your interpreter. I will determine this by checking your code by hand.

Piazza Q&A from past terms

(A17 Part a)

A17: Some ideas and code for implementing set! are in the session 26 slides

One of the TAs told me that some students who came to the F-217 lab yesterday were not aware that this code is in the slides.

As a result, set! implementation is something that you should be able to implement and debug in a couple of hours, then move on to the more interesting parts that you have to figure out, such as  define and pass-by-reference parameters.