Announcements

- Test on Wednesday starting at 8PM. Room assignments on Piazza.
- No lecture on Wednesday.
- No discussion section this week.
- There *are* labs this week (and office hours).

Lecture 28: Interpretating Scheme

A Scheme is essentially an extension of the calculator:

- A component known as the *reader* reads Scheme values (atoms and pairs).
- Since Scheme expressions and programs are a subset of Scheme values, no further parsing is necessary.
- A function `eval` evaluates Scheme expressions.
  - Atoms are its base cases.
  - For function calls, it uses a function `apply`, as for the calculator.

Apply

- The interpreter function `apply(func, args)` has the effect of allowing one to construct and evaluate function calls.
- **Aside:** In Python, we've been writing `func(*args)` to get the effect of `apply(func,args)` in ordinary programs.
- **Aside:** it is made available to Scheme programmers as the built-in function `apply`:

```
(define L '(1 2 3))
   (apply + L) ===> (+ 1 2 3) ===> 6      )
```

- The `apply` function itself has two cases:
  - Either `func` is a primitive, built-in function, in which case, its code is part of the interpreter, or
  - `func` is a user-defined function, in which case its code is stored in it as a Scheme expression, and is evaluated by `eval`.
- So there is a "recursive dance" back and forth between `eval`, and `apply`.

Evaluation for Scheme

- Simple expressions are evaluated as for the calculator.
- A Scheme expression consisting of a number simply evaluates to that number.
- A function call (E_0 E_1 $\cdots$ E_n) is evaluated by recursively evaluating the E_i and then using `apply`.
- But Scheme has a number of other cases to handle.
- **Aside:** As for `apply`, the evaluation function for Scneme is also available to Scheme programmers, in the form of a function `eval`.
- E.g., `(eval (list + 1 2))` and `(eval '(+ 1 2))` produce 3.

Evaluation of Symbols

- In Scheme expressions, most symbols represent identifiers, which we did not encounter in the calculator.
- Obviously, we need more information to evaluate a symbol than just the symbol itself.
- Fortunately, we've already seen exactly what is needed: an *environment*.
- Thus, to evaluate a Scheme expression, we will need both the expression itself and the environment in which to evaluate it.
- As it happens, exactly the same kind of structure as in Python—environment frames linked by parent pointers—is what we need to interpret Scheme.
- This is because Scheme uses nearly the same *scope rules* as Python does.
- Earlier dialects of Lisp, however, used a different kind of scope rule.

Static and Dynamic Scoping

- The *scope rules* of a language are the rules governing what names (identifiers) mean at each point in a program.
- We call the scope rules of Scheme (and Python)—those that are described by environment diagrams as we've been using them—*static* or *lexical* scoping.
- But in original Lisp, scoping was *dynamic*.
- Example (using classic Lisp notation):

```
(defun f (x)    ;; Like (define (f x) ...) in Scheme
      (g))
(defun g ()
      (* x 2))
(setq x 3)      ;; Like set! and also defines x at outer level.
(g)             ;; ===> 6
(f 2)           ;; ===> 4
(g)             ;; ===> 6
```

- That is, the meaning of `x` depends on the most recent and still active definition of `x`, even where the reference to `x` is not nested inside the defining function.

Eval and Scoping

- Dynamic scoping made `eval` easy to define: interpret any variables according to their "current binding."
- But `eval` in pure Scheme behaves like normal functions; it would not have access to the current binding at the place it is called.
- To make it definable (without tricks) in Scheme, one must add a parameter to `eval` to convey the desired environment.
- In the fifth revision of Scheme, one had the choice of indicating an empty environment and the standard, builtin environment.
- Our STk interpreter goes its own way:
  - `(eval E)` evaluates in the global environment.
  - `(eval E (the-environment))` evaluates in the current environment.
  - `(eval E (procedure-environment f))` evaluates in the environment pointed to by function `f`: what we've been calling the *parent pointer* of a function value.

Remaining Cases

- We've dealt with function calls, numbers, and symbols.
- This leaves only the *special forms*.
- All special forms lists indicated by their first symbols:

```
(quote EXPR)     ; Easy: return EXPR unchanged

(lambda (ARGS) EXPR)
(define ID EXPR)
(define (ID ARGS) EXPR)
    ; Same as (define ID (lambda (ARGS) EXPR))

(if EXPR EXPR-IF-TRUE EXPR-IF-FALSE)
(begin EXPR1 ... EXPRn)   ; Evaluate EXPRi, return last
(cond ( (COND-EXPR1 VAL-EXPR1)
        (COND-EXPR2 VAL-EXPR2) ...)
(and EXPR1 EXPR2 ...)
(or EXPR1 EXPR2 ...)
```


Lambda and Functions

- In the interpreter, evaluating the lambda special form returns a value of some type for representing functions.
- Its content is dictated by what `apply` will need:

  `(lambda (ARGS) EXPR)`

  - The list *ARGS*.
  - The body *EXPR*.
  - The parent environment: The environment in which it is evaluated.

Other Special Forms

- Handling the other special forms is pretty straightforward:
- The `if` form is typical: to evaluate

  `(if EXPR EXPR-IF-TRUE EXPR-IF-FALSE)`

  - Evaluate *EXPR*.
  - If returned value is false (`#f`), evaluate *EXPR-IF-FALSE* and return its value.
  - Otherwise, evaluate *EXPR-IF-TRUE* and return its value.