Class 2: Structures underlying evaluation

SI 413 - Programming Languages and Implementation

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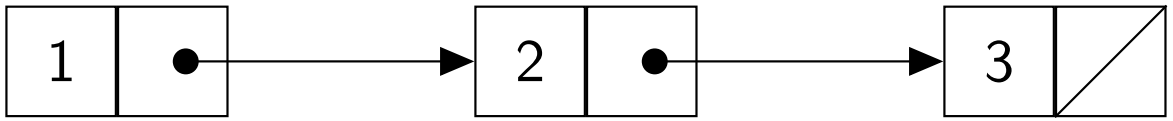
Homework Review

- Is reverse engineering possible?
- Syntax vs. Semantics!
- Stages of interpretation

Lists in Scheme

Remember how a singly-linked list works:



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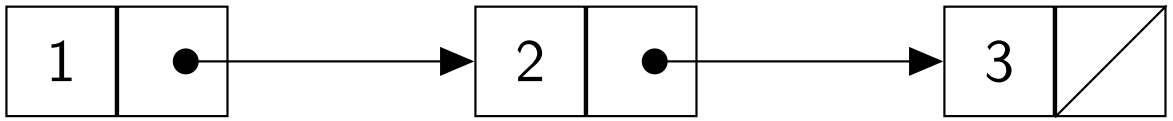

How can we make linked lists in Scheme?

- Use `cons` for every node
- Use `null` for the empty list

The above list is written `(cons 1 (cons 2 (cons 3 null)))`

Using and building lists

- `null` is an empty list.
- For an item `a` and list `L`, `(cons a L)` produces a list starting with `a`, followed by all the elements in `L`.
- `(car L)` produces the first thing in a non-empty list `L`.
- `(cdr L)` produces a list with the first item of `L` removed.
- DrScheme prints the list `(cons 1 (cons 2 (cons 3 null)))` as `(1 2 3)`
- Lists can be nested.

Exercises

Using only `cons`, `null`, `car`, and `cdr`,

1. Write an expression to produce the nested list `(3 (4 5) 6)`.
2. Write a function `(get2nd L)` that returns the second element in the list `L`.
3. **Using recursion**, write a function `split-digits` that takes a number `n` and returns a list with the digits of `n`, in reverse.
   For example, `(split-digits 413)` should produce the list `(3 1 4)`.

Useful list functions

- `(list a b c ...)` builds a list with the elements `a`, `b`, `c`, ...
- `cXXXr`, where `X` is `a` or `d`. A shortcut for long expressions like `(cdr (car (car (cdr L)))) → (cdaadr L)`
- `(cons? L)` — returns true iff `L` is a cons.
- `(null? L)` — returns true iff `L` is an empty list.
- `(append L1 L2)` — returns a list with the elements of `L1`, followed by those of `L2`.
  Can you write this function?

Scheme grammar

Here is a CFG for the Scheme syntax we have seen so far:

CFG for Scheme

exprseq $\rightarrow$ *expr* | *exprseq expr*
expr $\rightarrow$ *atom* | (*exprseq*)
atom $\rightarrow$ *identifier* | *number* | *boolean*

This is incredibly simple!

Scheme is lists!

Everything in Scheme that looks like a list is a list.
Scheme evaluates a list by using a general rule:

- First, turn a list of expressions `(e1 e2 e3 ...)` into a list of atoms `(a1 a2 a3 ...)` by recursively evaluating each `e1`, `e2`, etc.
- Then, apply the procedure `a1` to the arguments `a2`, `a3`, ...

The only exceptions are special forms such as `define` and `cond` that do not evaluate all their arguments.

Scheme evaluation and unevaluation

We can use the built-in function `eval` to evaluate a Scheme expression within Scheme!

- Try `(eval (list + 1 2))`

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We can also ask Scheme not to evaluate an expression by using the (very) special form `quote`.

- Try `(quote (+ 1 2))`

There is a convenient shortcut of `quote`: for example, `'(+ 1 2)`.

Symbols

An unevaluated identifier is called a symbol.
(Note: the predicate `symbol?` is useful here.)

Symbols are useful beyond evaluation and quoting.
We often use them like ENUMs in C++.
Examples: units, months, grades

Symbols are often used to tag data: `(cons 10.3 'feet)`

More exercises

1. Write a function `(my-and a b)` that works similar to the built-in `and` boolean function, but returns a symbol `'true` or `'false` as appropriate.

2. Write a function that takes a list of numbers and adds them up using the + function. (Hint: first build this expression using `cons`, then evaluate it using `eval`.)

3. Repeat #2 using the built-in `apply` function.