Lessons from 6.001

6.037 - Structure and Interpretation of Computer Programs

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Lecture 8

Contexualizing 6.001

- We said at the start that this wasn't a class in Scheme
- You're probably never again going to code in Scheme
- Instead, this is a class in Computation
- How do the concepts from 6.001 apply elsewhere?

Syllabus and key ideas

- Procedural and data abstraction
- Conventional interfaces & programming paradigms
  - Type systems
  - Streams
  - Object-oriented programming
- Metalinguistic abstraction
  - Creating new languages
  - Evaluators

Static scoping is now standard

- Scheme stole static scoping (aka lexical scoping) from **ALGOL**
- Most languages now are statically scoped, if only by block
- Environment model still describes how bindings work!

Higher-order functions

- Many modern languages support first-class functions:
- Javascript, Perl, Python, Ruby, MATLAB, Mathematica, C++11, C#, Clojure
- Many even call anonymous functions lambdas

Closures

- Static scoping + first-class functions = closures
- Great for data hiding
- ... access mediation
- ... iterators
- ... continuation passing style for flow control
- ... laziness or other delayed evaluation

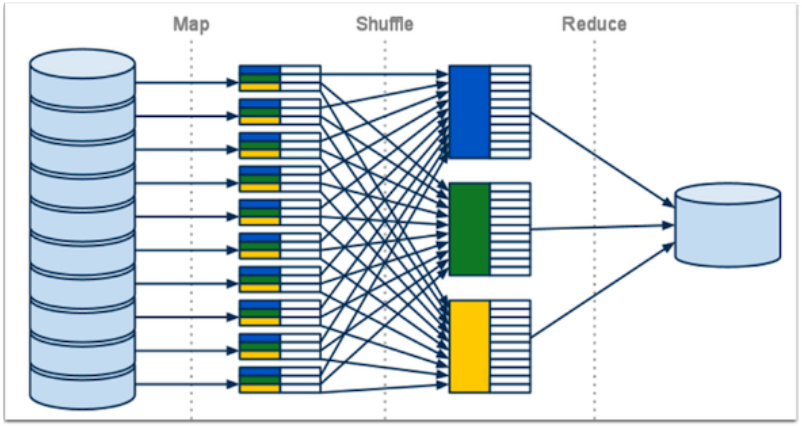
List operations with anonymous functions

- Other languages have `filter`, `map`, `reduce`...
- Map... Reduce?

MapReduce

- Massively parallel architecture for handling Big Data™
- Purely *functional* code is easy to parallelize – no read/write contention
- Idea based on every call to `func` in `(map func lst)` being able to be called in parallel
- ... then also fed into `fold-right` in parallel

MapReduce



Congratulations, you already know how to write for Hadoop/MapReduce clusters

You know how to write evaluators

- What good is writing an evaluator?
- Allows you to move the level of abstraction
- Writing code in Python but need to generate HTML forms?
- Requires programmer have HTML knowledge
- ..or write a Domain-Specific Language (DSL) to generate it for you

External DSLs

- Read and parse a string (syntax)
- Apply arbitrary rules for meaning (semantics)
- We know how to do the latter; there are tools for the former

Internal DSLs

- Can also just write clever function names
- Let your language do the parsing
- Constrains you to the syntax rules of your language
- “For when you want to write code in one language, and get your errors in another!”

Data as code, and vice versa

- Scheme is useful because code and data are just a quote away
- Genetic Programming “evolves” programs by mutating syntax – doable because syntax is simple
- Lisp/Scheme key in early Artificial Intelligence in 1980s
- Useful in deduction languages – which led to `PROLOG`

Data as code now

- Computers use a language where data is code all of the time
- Assembly language is just bytes
- Data it works on is just bytes

Some random bytes

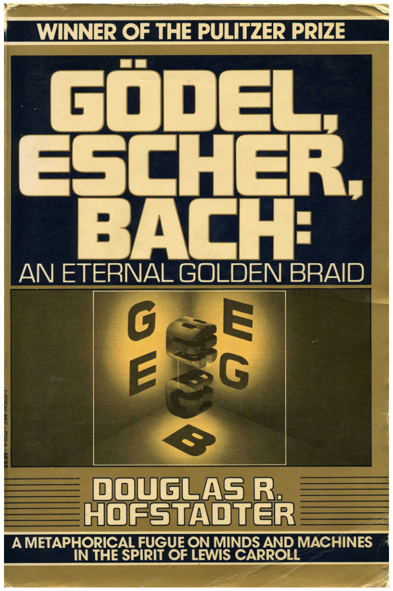
```
BF FF FF FF FF 41 80
3C 08 00 75 F9 C3 90
```

```
BF FFFFFFFF      Store -1 in variable C
41               Add 1 to C
80 3C 08 00      Compare memory at (A + C) to 0
75 F9            If that is not 0, go back 6 bytes
C3               Return
90               Do nothing
```


When data should not be code

- The most common security vulnerabilities are when computers are convinced that data is actually code
- a.k.a “Buffer overflows”
- Equivalent to making Scheme run an arbitrary function from inside `m-eval`
- “Jumping out of the system”

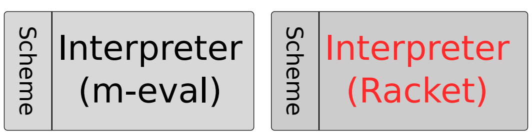
Aside: Gödel, Escher, Bach



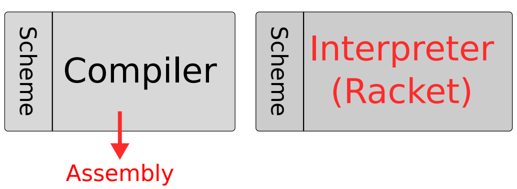
Evaluators as translators

- Change our evaluator to work in two phases; one parses the expression and returns a *Scheme* lambda
- The second phase just applies that lambda with a starting environment
- The first phase is a translator from one language to another
- No reason the language we translate to has to be scheme...
- ...how about assembly?

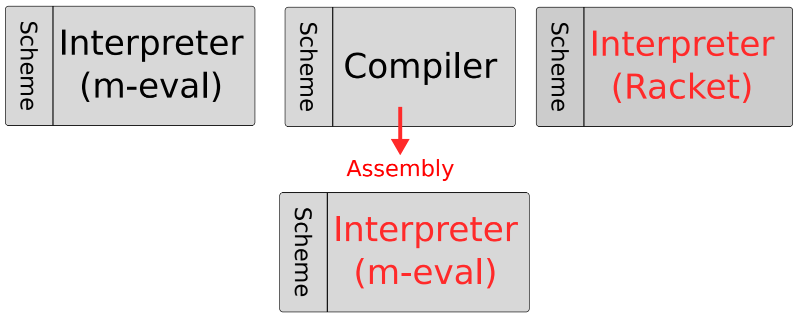
Lowering the abstraction barrier



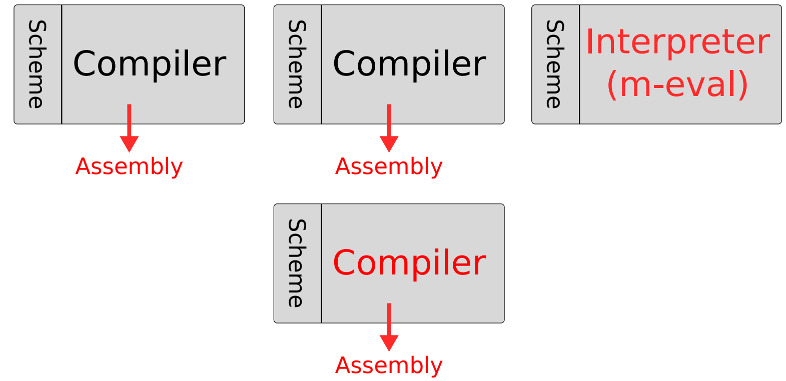
Lowering the abstraction barrier



Lowering the abstraction barrier



Lowering the abstraction barrier



Transforming from any language to an language

- Now have interpreter in assembly, for Scheme
- How *simple* a language can we build on?
- Are there functions which can be computed in Java but not Scheme?
- **Church-Turing** thesis: Turing Machines!

Church-Turing thesis

- If a function can be computed by an algorithm, then it must also be computable by a Turing Machine
- And vice-versa
- Thus Java, Scheme, Python, etc, are all equivalent in the functions they can compute

Language equivalence

- So if all languages are fundamentally equivalent
- . . . so what do we like about Scheme?
- Lexical scoping, procedures as first-class objects, garbage collection, `eval` and `apply`, asynchronous event handling. . .
- We have just such a language: Javascript

Javascript

- Brendan Eich was hired by Netscape in 1995 with the promise of "doing Scheme for the browser"
- But Java was also being implemented for the browser
- So if there was a second language, it should "look like Java"
- So syntax closer to Java, but semantics stolen from Scheme
- . . . JavaScript!

Code comparison

Scheme:

```
(define (make-counter incrementer)
  (let ((counter 0))
    (lambda ()
      (let ((current-val counter))
        (set! counter (incrementer counter))
        current-val))))
```

Javascript:

```
function make-counter(incrementer) {
  var counter = 0;
  return function () {
    var current_val = counter;
    counter = incrementer(counter);
    return current_val;
  };
}
```


And now...

And now for some magic!