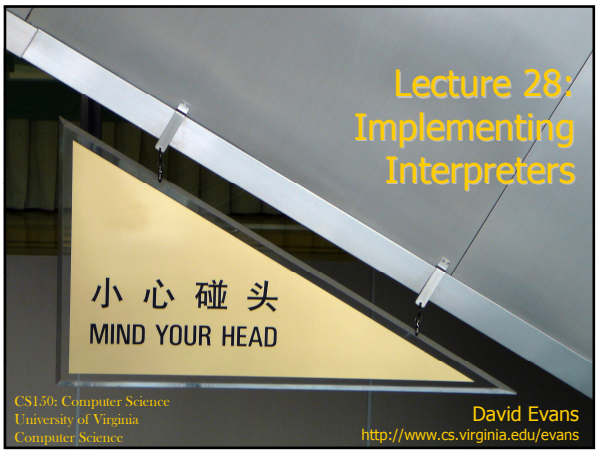


Lecture 28: Implementing Interpreters

CS150: Computer Science
University of Virginia
Computer Science

David Evans
http://www.cs.virginia.edu/evans

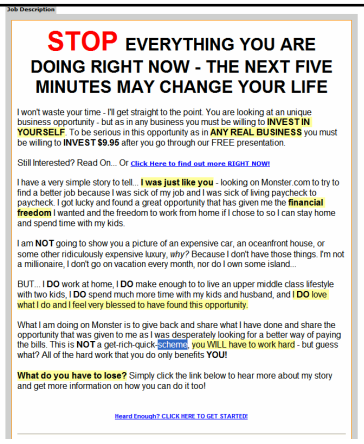
Why learn Python?

Reason 1: Vocational Skill

Job listings at monster.com in Virginia
(27 March 2007, postings in last 3 months):

Python	27	$40-200K
Java	770	$35-200K
SQL	1138	$60-400K
Scheme	55	$100-999K

PS5, PS8 & 9



Job Description

STOP EVERYTHING YOU ARE DOING RIGHT NOW - THE NEXT FIVE MINUTES MAY CHANGE YOUR LIFE

I won't waste your time - I'll get straight to the point. You are looking at an unique business opportunity - but as in any business you must be willing to **INVEST IN YOURSELF**. To be serious in this opportunity as in **ANY REAL BUSINESS** you must be willing to **INVEST $9.95** after you go through our FREE presentation.

Still Interested? Read On... Or Click Here to find out more RIGHT NOW!

I have a very simple story to tell... **I was just like you** - looking on Monster.com to try to find a better job because I was sick of my job and I was sick of living paycheck to paycheck. I got lucky and found a great opportunity that has given me the **financial freedom** I wanted and the freedom to work from home if I chose to so I can stay home and spend time with my kids.

I am **NOT** going to show you a picture of an expensive car, an oceanfront house, or some other ridiculously expensive luxury, *why?* Because I don't have those things. I'm not a millionaire, I don't go on vacation every month, nor do I own some island...

BUT... I **DO** work at home, I **DO** make enough to to live an upper middle class lifestyle with two kids, I **DO** spend much more time with my kids and husband, and I **DO** love what I do and I feel very blessed to have found this opportunity.

What I am doing on Monster is to give back and share what I have done and share the opportunity that was given to me as I was desperately looking for a better way of paying the bills. This is **NOT** a get-rich-quick-Scheme, you WILL have to work hard - but guess what? All of the hard work that you do only benefits **YOU!**

What do you have to lose? Simply click the link below to hear more about my story and get more information on how you can do it too!

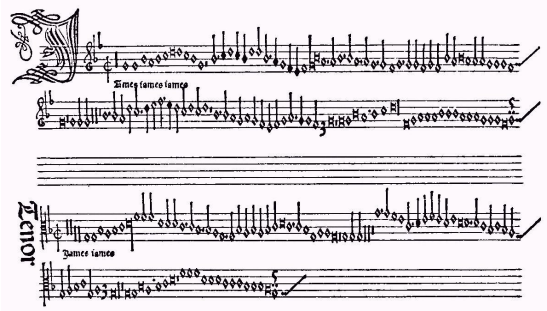
Heard Enough? CLICK HERE TO GET STARTED!

"Scheme" Jobs

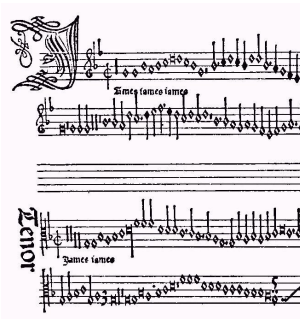
Reason 2: Expanding Minds

Languages change the way we think.

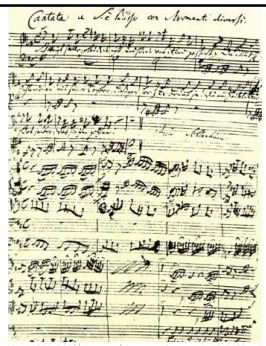
The more languages you know, the more different ways you have of thinking about (and solving) problems.



"Jamais Jamais Jamais" from *Harmonice Musices Odhecaton A*. Printed by Ottaviano Dei Petrucci in 1501 (first music with movable type)



"Jamais Jamais Jamais" from *Harmonice Musices Odhecaton A.* (1501)



J S Bach, "Coffee Cantata", BWV 211 (1732)
www.npj.com/homepage/teritowe/jsbhand.html

Reason 3: Deepening Understanding

By seeing how the same concepts we encountered in Scheme are implemented by a different language, you will understand those concepts better (especially classes/objects, assignment, data abstraction).

Reason 4: Building Confidence

By learning Python (mostly) on your own, the next time you encounter a problem that is best solved using a language you don't know, you will be confident you can learn it (rather than trying to use the wrong tool to solve the problem).

Reason 5: Fun

Programming in Python is fun.

Especially because:
- It is an elegant and simple language
- Most programs mean what you think they mean
- It is dynamic and interactive
- It can be used to build web applications (PS8, PS9)
- It is named after *Monty Python's Flying Circus*
- It was designed by someone named Guido.

Python

- A universal programming language
  - Everything you can compute in Scheme you can compute in Python, and vice versa
- Imperative Language
  - Designed to support a programming where most of the work is done using **assignment statements**: x = e
- Object-Oriented Language
  - Every data thing is an object
  - Built in support for classes, inheritance

Learning New Languages

- **Syntax**: Where the {, ;, $, etc. all go
  - If you can understand a BNF grammar, this is easy
- **Semantics**: What does it mean
  - Learning the evaluation rules
  - Harder, but most programming languages have very similar evaluation rules
- **Style**
  - What are the idioms and customs of experienced programmers in that language?
    - Takes many years to learn
    - Need it to be a "professional" Python programmer, but not to make a useful program

Python If

Instruction ::= **if (***Expression***) :**
Block

Evaluate *Expression*. If it evaluates to true, evaluate the *Block*.

It is similar to (if *Expression* (begin *Statements*))
Differences:
- Indenting and new lines matter!
  - Changing the indentation changes meaning of code
- What "true" means:
  - Scheme: anything that is not **#f**.
  - Python: anything that is not **False**, **None**, **0**, and empty string or container

Computability in Theory and Practice

(Intellectual Computability Discussion on TV Video)

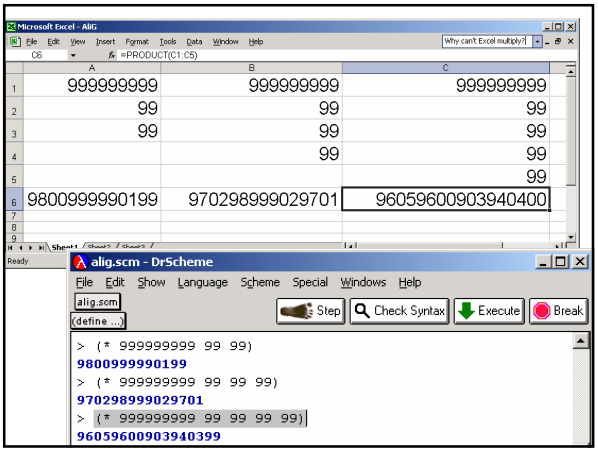
Ali G Problem

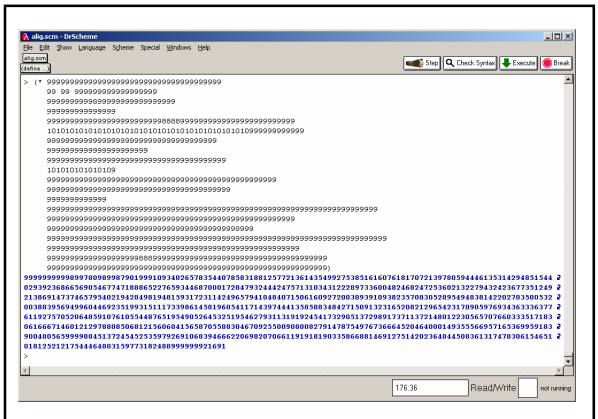
- **Input:** a list of 2 numbers with up to d digits each
- **Output:** the product of the 2 numbers

Is it computable?

Yes – a straightforward algorithm solves it. Using elementary multiplication techniques it is $O(d^2)$

Can *real* computers solve it?





Ali G was Right!

- Theory assumes ideal computers:
  - Unlimited, perfect memory
  - Unlimited (finite) time
- Real computers have:
  - Limited memory, time, power outages, flaky programming languages, etc.
  - There are many computable problems we cannot solve with real computer: the actual inputs ***do*** matter (in practice, but not in theory!)

Implementing Interpreters

Inventing a Language

- Design the grammar
  - What strings are in the language?
  - Use BNF to describe all the strings in the language
- Make up the evaluation rules
  - Describe what everything the grammar can produce means
- Build an evaluator
  - A procedure that evaluates expressions in the language

Is this an exaggeration? (SICP, p. 360)

It is no exaggeration to regard this as the most fundamental idea in programming:

> **The evaluator, which determines the meaning of expressions in the programming language, is just another program.**

To appreciate this point is to change our images of ourselves as programmers. We come to see ourselves as designers of languages, rather than only users of languages designed by others.

Environmental Model of Evaluation

1. To **evaluate** a combination, **evaluate** all the subexpressions and **apply** the value of the first subexpression to the values of the other subexpressions.
2. To **apply** a compound procedure to a set of arguments, evaluate the body of the procedure in a new environment. To construct this environment, make a new frame with an environment pointer that is the environment of the procedure that contains places with the formal parameters bound to the arguments.

Eval and Apply are defined in terms of each other.

Implementing meval

```
def meval(expr, env):
    if isPrimitive(expr):
        return evalPrimitive(expr)
    elif isConditional(expr):
        return evalConditional(expr, env)
    elif isLambda(expr):
        return evalLambda(expr, env)
    elif isDefinition(expr):
        evalDefinition(expr, env)
    elif isName(expr):
        return evalName(expr, env)
    elif isApplication(expr):
        return evalApplication(expr, env)
    else:
        evalError ("Unknown expression type: " + str(expr))
```

Implementing mapply

```
def mapply(proc, operands):
    if (isPrimitiveProcedure(proc)):
        return proc(operands)
    elif isinstance(proc, Procedure):
            params = proc.getParams()
            newenv = Environment(proc.getEnvironment())
            if len(params) != len(operands):
                evalError ("Parameter length mismatch: ...")
            for i in range(0, len(params)):
                newenv.addVariable(params[i], operands[i])
            return meval(proc.getBody(), newenv)
    else:
        evalError("Application of non-procedure: %s" % (proc))
```


Charge

- Friday: Implementing the rest of the interpreter: the evaluation rules, environments, procedures
- Next week: changing the evaluation rules
- Don't wait any longer to start PS7
- The statement, "There will be a surprise quiz someday this week" might still be true