Lecture 2
Functional Programming & Scheme

T. METIN SEZGIN

Announcements

1. Reading SICP 1.1 (pages 1-31) next lecture
2. Etutor – at the end
3. Etutor assignment due next Friday
4. Labs (PSes) start this week

Lecture Nuggets

nugget

/ˈnʌgɪt/

noun

a small lump of gold or other precious metal found ready-formed in the earth.

- a small chunk or lump of another substance.
  "nuggets of meat"

  Benzer: lump | chunk | small piece | hunk | mass | clump | wad

- a valuable idea or fact.
  "nuggets of information"

Lecture Nuggets

- You only know one way of programming/thinking
  - You are imperative programmers
  - Functional programming an entirely new concept
- We can specify programs entirely through functions
- 3 major elements of language
  - Primitives
  - Means Combination
  - Abstraction
- Read-Eval-Print loop
- Functions are first class citizens

Nugget

You only know one way of programming/thinking

Main programming paradigms

Paradigm	Description	Main traits	Related paradigm(s)	Examples
Imperative	Programs as statements that *directly* change computed state (datafields)	Direct assignments, common data structures, global variables		C, C++, Java, Kotlin, PHP, Python, Ruby
Procedural	Derived from structured programming, based on the concept of modular programming or the *procedure call*	Local variables, sequence, selection, iteration, and modularization	Structured, imperative	C, C++, Lisp, PHP, Python
Functional	Treats computation as the evaluation of mathematical functions avoiding state and mutable data	Lambda calculus, compositionality, formula, recursion, referential transparency, no side effects	Declarative	C++,[1] C#,[2][*circular reference*] Clojure, CoffeeScript,[3] Elixir, Erlang, F#, Haskell, Java (since version 8), Kotlin, Lisp, Python, R,[4] Ruby, Scala, SequenceL, Standard ML, JavaScript, Elm
Object-oriented	Treats datafields as *objects* manipulated through predefined methods only	Objects, methods, message passing, information hiding, data abstraction, encapsulation, polymorphism, inheritance, serialization-marshalling	Procedural	Common Lisp, C++, C#, Eiffel, Java, Kotlin, PHP, Python, Ruby, Scala, JavaScript[8][9]
Declarative	Defines program logic, but not detailed control flow	Fourth-generation languages, spreadsheets, report program generators		SQL, regular expressions, Prolog, OWL, SPARQL, Datalog, XSLT

Source: Wikipedia

Nugget

We can specify programs entirely through functions

Write a function for factorial

- Fact(x) = x * fact(x-1) (if x>1)
- Fact(x) = 1 (if x==1)
- Y=x^2

Advantages of functional programming

- Intuitive
- Functions are first-class citizens
  - Create
  - Bind to variables
  - Pass to functions
  - Return
- Allows declarative and composable style
  - Emphasis on modularity
  - Purely functional programming is easy to reason about
  - No side effects
  - Formally verifiable, fewer bugs
  - Finding increasing use in modern development patterns/languages

Advantages of functional programming

- Functions are first-class citizens
  - Create
  - Bind to variables
  - Pass to functions
  - Return
- Allows declarative and composable style
  - Emphasis on modularity
  - Purely functional programming is easy to reason about
  - No side effects
  - Formally verifiable, fewer bugs
  - Finding increasing use in modern development patterns/languages

1. Understand functional way of thinking
2. Understand how interpreters work
3. Think like an interpreter
4. Build an interpreter using scheme

Nugget

Three major elements of a language

Kinds of Language Constructs

- Primitives
- Means of combination
- Means of abstraction

```
def create_adder(x):
    global tic
    tic = x

    def adder():
        global tic
        tic = tic + 1
        return tic

    return adder


fun_a = create_adder(0)
fun_b = create_adder(0)

print(fun_a(), fun_b(), fun_a(), fun_b())
```

Language elements – primitives

- Self-evaluating primitives – value of expression is just object itself
  - Numbers: 29, -35, 1.34, 1.2e5
  - Strings: “this is a string” “ this is another string with %&^ and 34”
  - Booleans: #t, #f

Language elements – primitives

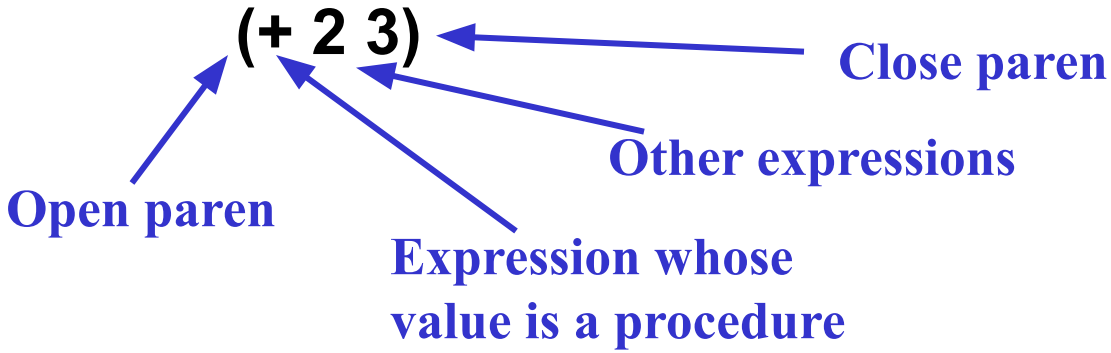
- Built-in procedures to manipulate primitive objects
  - Numbers: +, -, *, /, >, <, >=, <=, =
  - Strings: string-length, string=?
  - Booleans: boolean/and, boolean/or, not

Language elements – primitives

- Names for built-in procedures
  - +, *, -, /, =, …
  - What is the value of such an expression?
  - + □ [#procedure …]
  - Evaluate by looking up value associated with name in a special table

Language elements – combinations

- How do we create expressions using these procedures?



- Evaluate by getting values of sub-expressions, then applying operator to values of arguments

Language elements - combinations

- Can use nested combinations – just apply rules recursively

  (+ (* 2 3) 4) □10

  (* (+ 3 4) (- 8 2)) □42

Language elements -- abstractions

- In order to abstract an expression, need way to give it a name

(define score 23)

- This is a special form
  - Does not evaluate second expression
  - Rather, it pairs name with value of the third expression
- Return value is unspecified

Language elements -- abstractions

- To get the value of a name, just look up pairing in environment

  score □ 23

  – Note that we already did this for +, *, …

  (define total (+ 12 13))

  (* 100 (/ score total)) □ 92

- This creates a loop in our system, can create a complex thing, name it, treat it as primitive

Scheme Basics

- Rules for evaluation

1. If **self-evaluating,** return value.
2. If a **name,** return value associated with name in environment.
3. If a **special form,** do something special.
4. If a **combination,** then

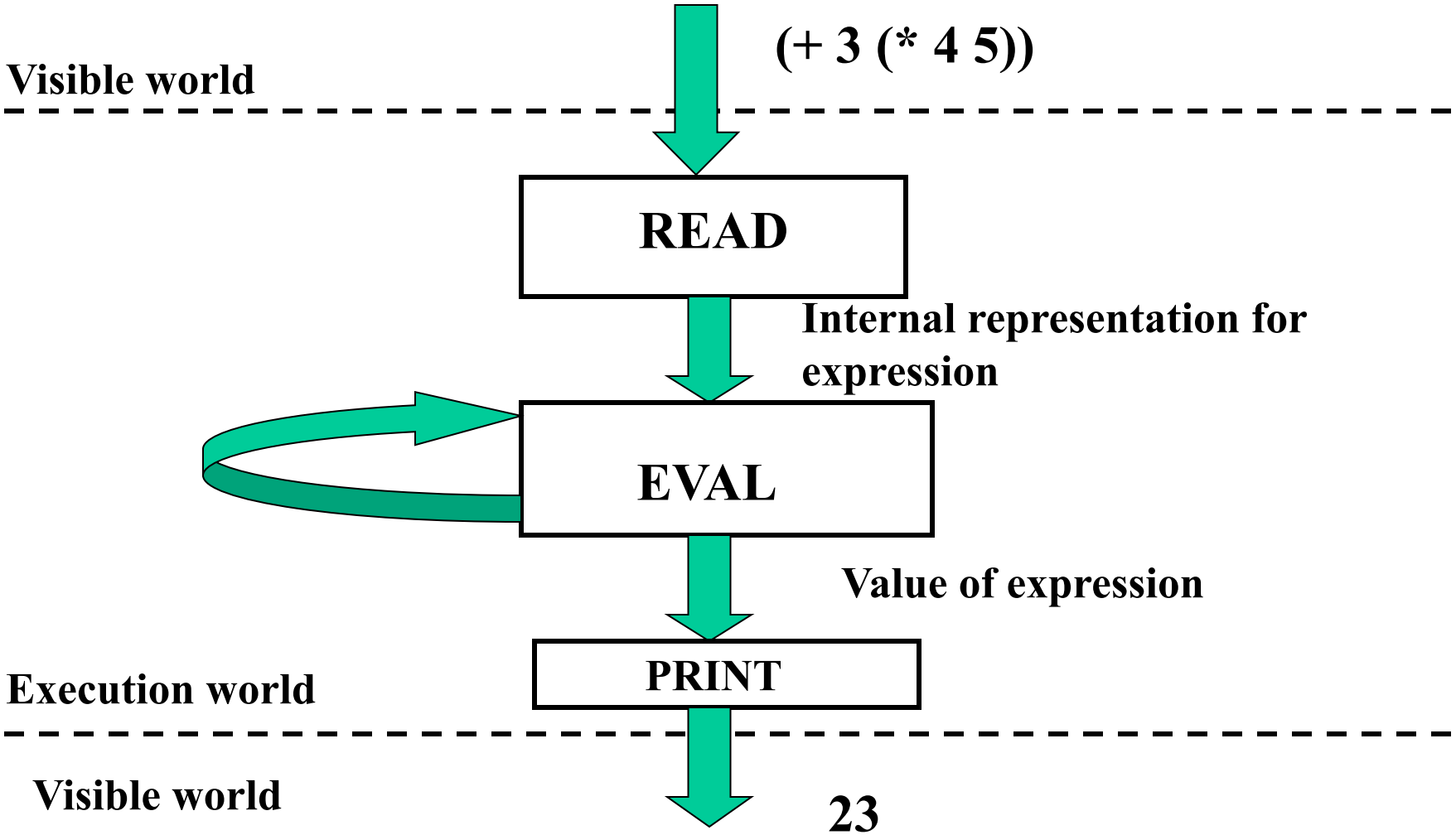
   a. *Evaluate* all of the subexpressions of combination (in any order)

   b. *apply* the operator to the values of the operands (arguments) and return result

Nugget

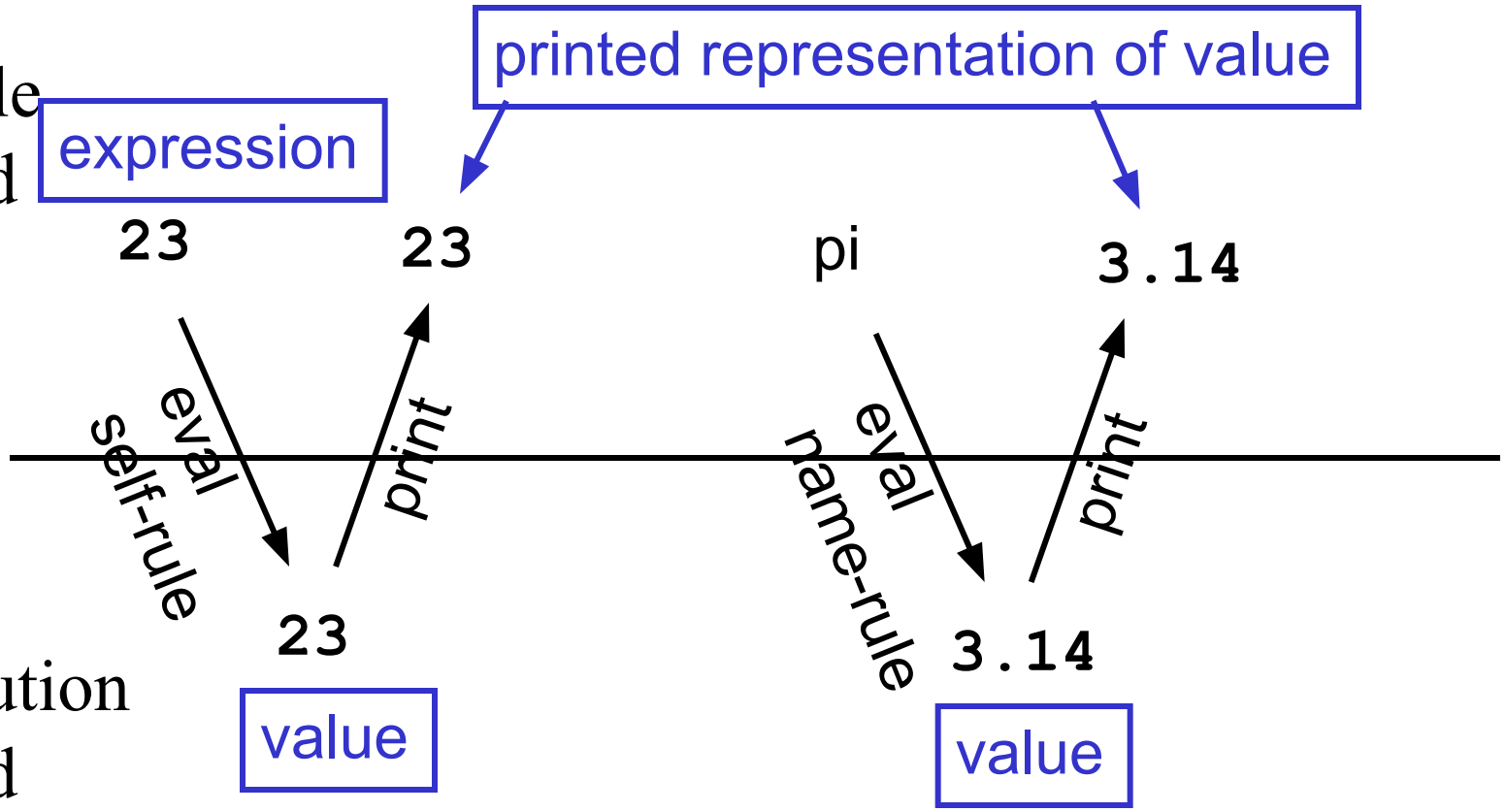
The concept of Read-Eval-Print

Read-Eval-Print



A new idea: two worlds

- visible world
- execution world

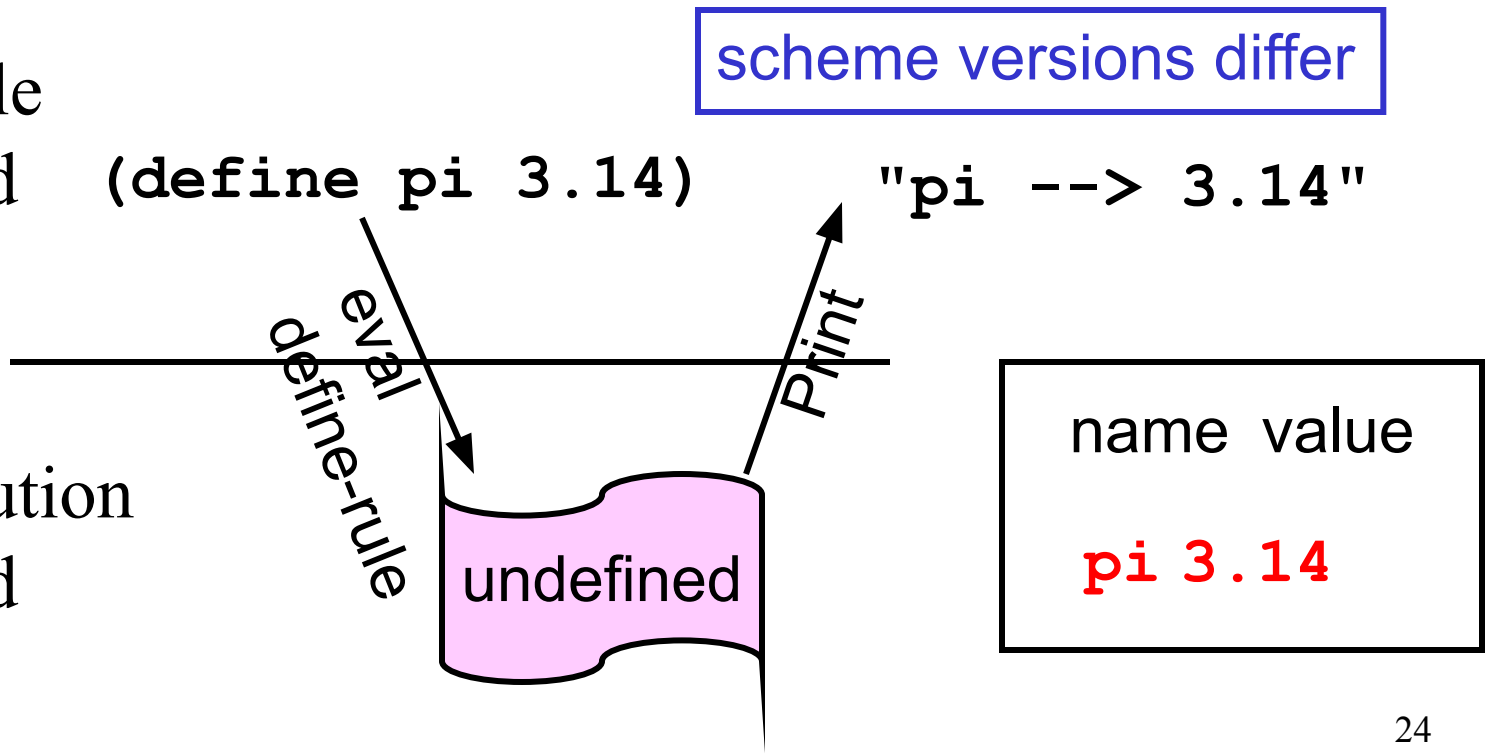


name-rule: look up value of name in current environment

Define special form

- define-rule:
  - evaluate 2nd operand only
  - name in 1st operand position is bound to that value
  - overall value of the define expression is undefined

- visible world
- execution world



Mathematical operators are just names

```
(+ 3 5)          □ 8

(define fred +)  □ undef

(fred 4 6)       □ 10
```

- How to explain this?

- Explanation
  - + is just a name
  - + is bound to a value which is a procedure
  - line 2 binds the name **`fred`** to that same value

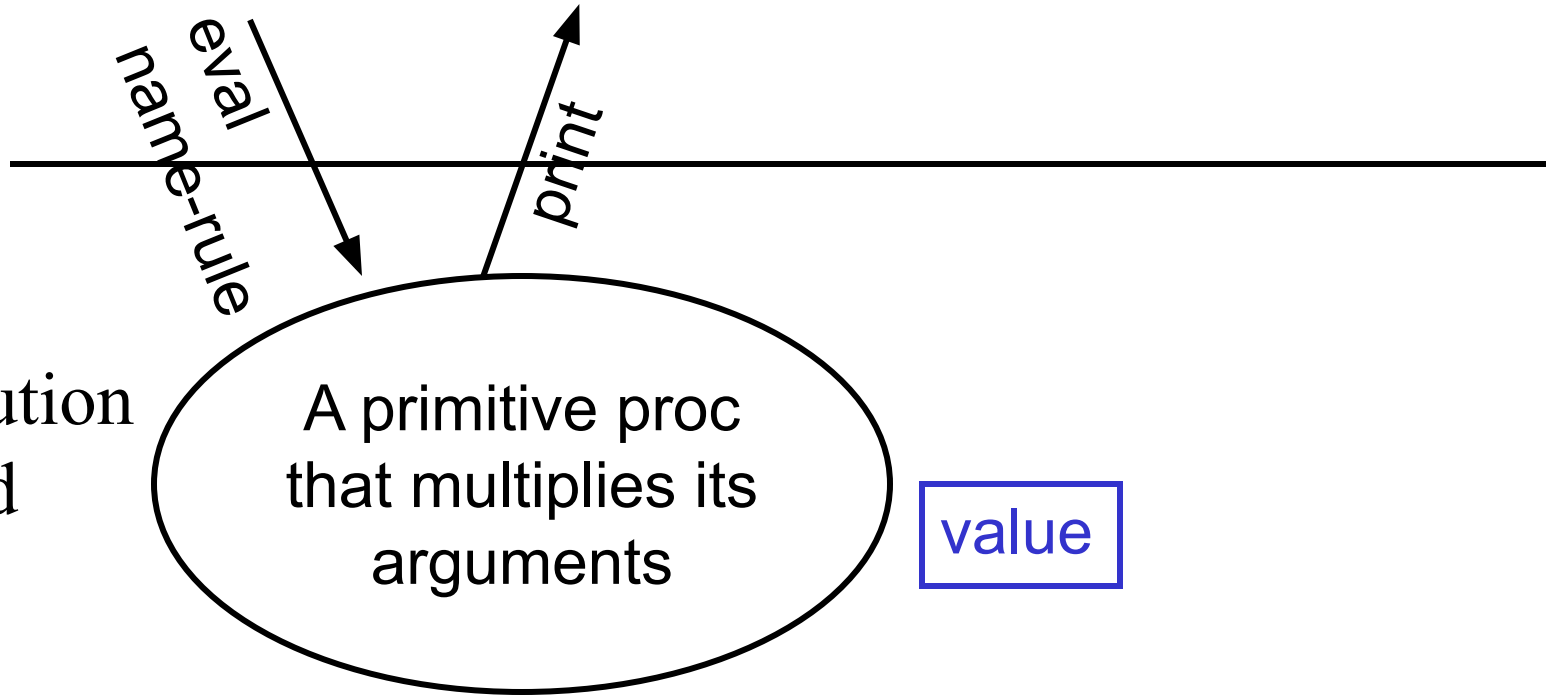
Primitive procedures are just values

- visible world

expression

printed representation of value

```
* #[compiled-procedure 8 #x583363]
```



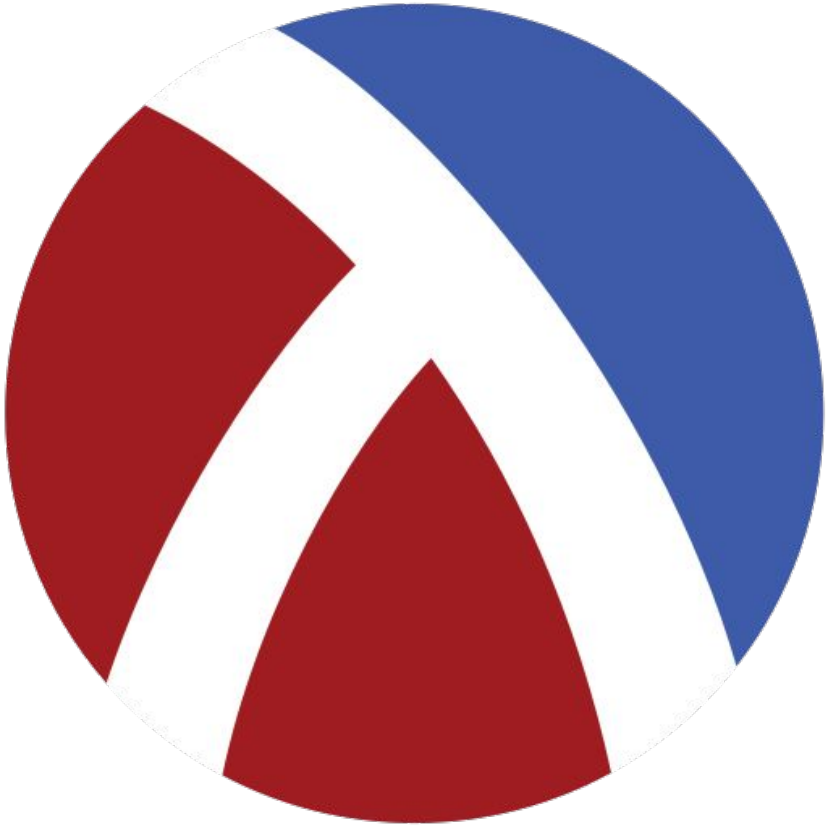
- execution world

value

Nugget

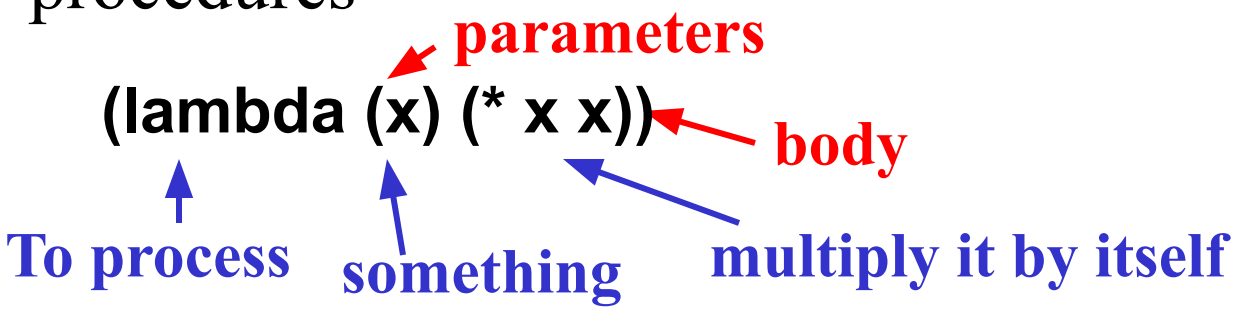
Functions are first class citizens

Hold your breath



Language elements -- abstractions

- Need to capture ways of doing things – use procedures



- Special form – creates a procedure and returns it as value

Language elements -- abstractions

- Use this anywhere you would use a procedure

  ((lambda (x) (* x x)) 5)

Scheme Basics

- Rules for evaluation

1. If **self-evaluating,** return value.
2. If a **name,** return value associated with name in environment.
3. If a **special form,** do something special.
4. If a **combination,** then
   a. *Evaluate* all of the subexpressions of combination (in any order)
   b. *apply* the operator to the values of the operands (arguments) and return result

- Rules for application

1. If procedure is **primitive procedure,** just do it.
2. If procedure is a **compound procedure,** then:
   evaluate the body of the procedure with each formal parameter replaced by the corresponding actual argument value.

Language elements -- abstractions

- Use this anywhere you would use a procedure

  ((lambda (x) (* x x)) 5)

  (* 5 5)

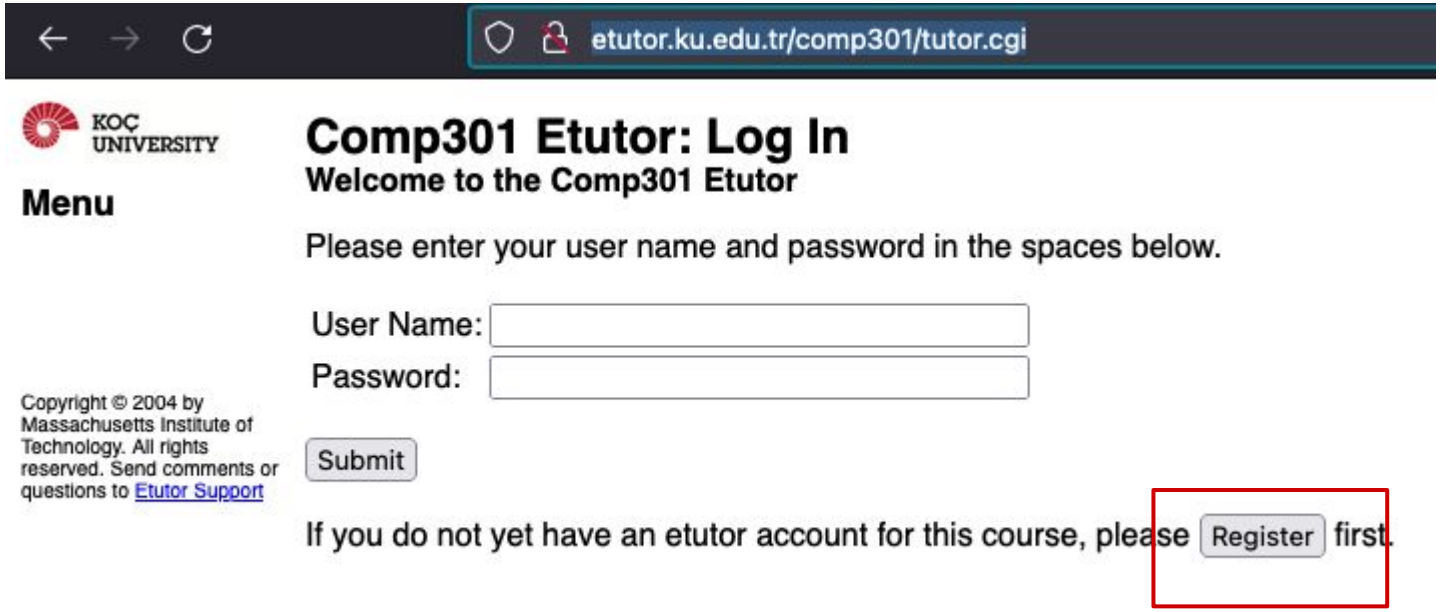
  25

- Can give it a name

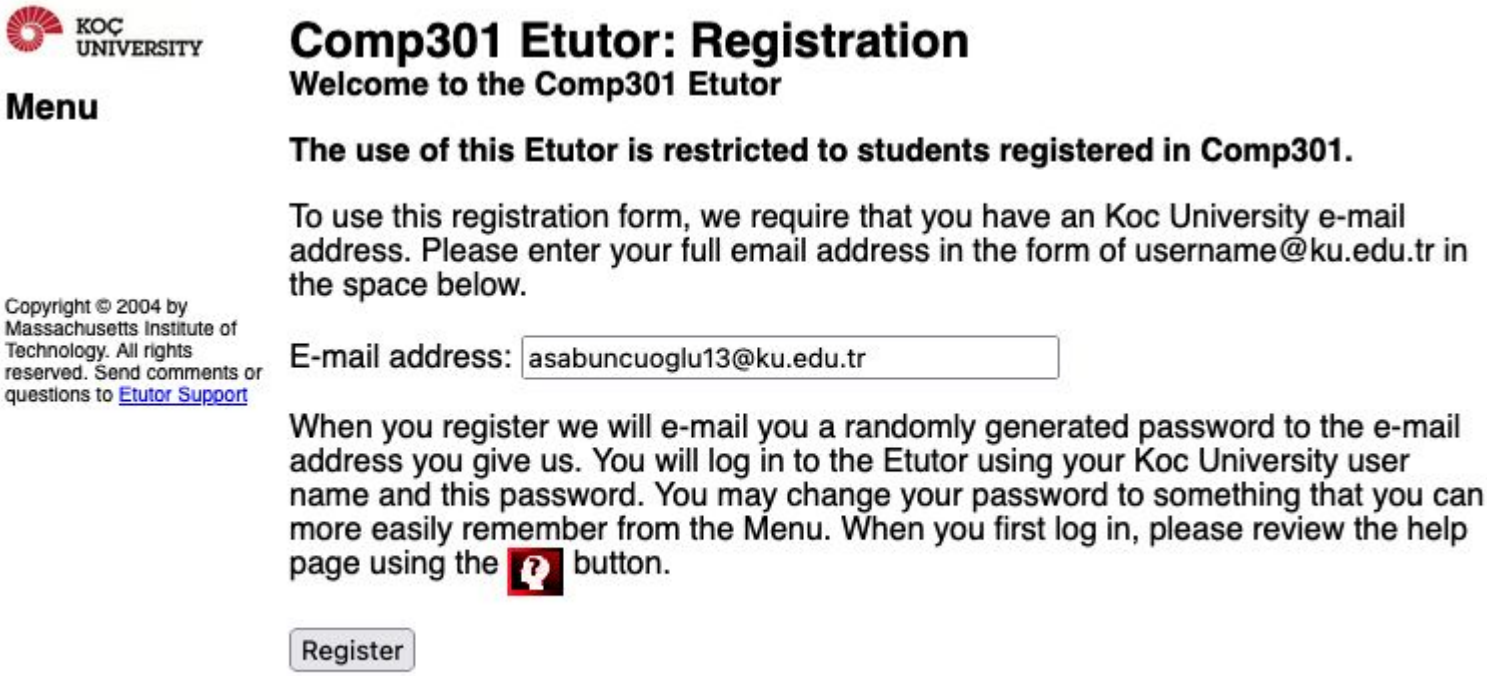
  (define square (lambda (x) (* x x)))
  (square 5) 25

Introducing Etutor

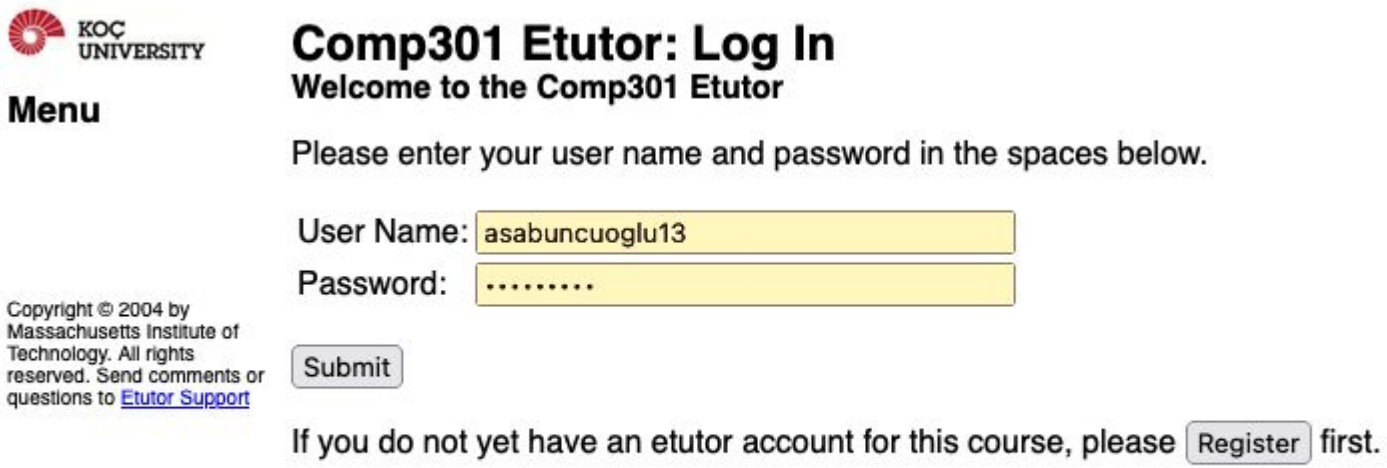
1.OPEN http://etutor.ku.edu.tr/comp301/tutor.cgi



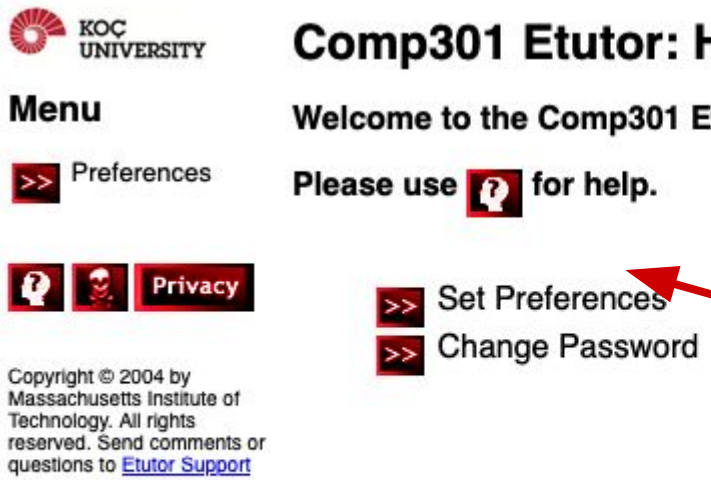
2. REGISTER WITH YOUR KU E-MAIL



3. A PASSWORD WILL BE SENT TO YOUR E-MAIL. USE YOUR KUNET ID AND PASSWORD TO LOGIN



4. CHOOSE A PROBLEM SET TO START YOUR ASSIGNMENT



It will appear here, but not yet. When we assign the project, you will see here.

Lecture Nuggets

- You only know one way of programming/thinking
  - You are imperative programmers
  - Functional programming an entirely new concept
- We can specify programs entirely through functions
- 3 major elements of language
  - Primitives
  - Means Combination
  - Abstraction
- Functions are first class citizens