61A Lecture 26

Friday, April 3
Announcements

• Guerrilla Section 5 this weekend on Scheme & functional programming
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  - Sunday 4/5 12:00pm – 2:30pm in 271 Soda
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Python 3

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    return x * x
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def square(x):
    return x * x

from dis import dis
dis(square)
```

**Python 3 Byte Code**

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Metalinguistic Abstraction

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To create a new programming language, you either need a:

- **Specification:** A document describe the precise syntax and semantics of the language
- **Canonical Implementation:** An interpreter or compiler for the language
Parsing
Parsing

A Parser takes text and returns an expression
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Parsing

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\[
'( + 1 )
\]

\[
'( - 23 )
\]

\[
'( * 4 5.6 )
\]
A Parser takes text and returns an expression

A diagram shows the process:

- **Text**
  - '(+ 1'
  - ' (- 23)'
  - ' (* 4 5.6))'

- **Lexical analysis**
- **Tokens**
- **Syntactic analysis**
- **Expression**
A Parser takes text and returns an expression

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'(+ 1'
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Lexical analysis

Tokens

Syntactic analysis

Expression
A Parser takes text and returns an expression

```
(+ 1
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```

- **Lexical analysis**
  - Text: `'(+ 1'
  - Tokens: `'(, '+', 1`

- **Syntactic analysis**
  - Tokens: `'(, '+', 1`
  - Expression: `'(+ 1`

- **Expression**
  - Expression: `'(+ 1`
Parsing

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Text

Lexical analysis

Tokens

Syntactic analysis

Expression

'(+ 1'

'(', '+', 1

'(- 23)'

'(', '-', 23, ')'

'(* 4 5.6))'

'(', '*', 4, 5.6, ')', ')

'(',
A Parser takes text and returns an expression

"(+ 1"  "(- 23)"  "(* 4 5.6))"
**Parsing**

A Parser takes text and returns an expression

- **Lexical analysis**
  - Text: `'(+ 1' '(- 23)' '(* 4 5.6))'`
  - Tokens: `'(', '+', 1 ('
    '(', '-', 23, ')'
    '(', '*', 4, 5.6, ')', ')')`'

- **Syntactic analysis**

- **Expression**

  • Iterative process
A Parser takes text and returns an expression

- **Lexical analysis**
  - Tokens
  - Syntactic analysis

- Iterative process
- Checks for malformed tokens

Text: `'(+ 1' '(- 23)' '(* 4 5.6))'`

Expression: `( + 1 '(- 23)' '(* 4 5.6))'
Parsing

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Lexical analysis

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• Iterative process
• Checks for malformed tokens
• Determines types of tokens
Parsing

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Text

Lexical analysis

Tokens

Syntactic analysis

Expression

• Iterative process
• Checks for malformed tokens
• Determines types of tokens
• Processes one line at a time

'(+ 1'
'(− 23)
'(* 4 5.6)'

'( '+', 1
'(−', '−', 23, ')
'(∗', '∗', 4, 5.6, ')', ')'
Parsing

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Text

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  - '(+ 1')
  - '(- 23)
  - '(* 4 5.6)'

- **Tokens**
  - '(' ' ' '+ ' 1
  - '(' ' ' '-' 23 ' ' ')
  - '(' ' ' '*' 4 5.6 ' ' ')
  - ')

- **Syntactic analysis**
  - Pair('+', Pair(1, ...))

- **Expression**
  - printed as
  - (+ 1 (- 23) (* 4 5.6))

- **Iterative process**
- Checks for malformed tokens
- Determines types of tokens
- Processes one line at a time

- **Tree-recursive process**
A Parser takes text and returns an expression.

**Lexical analysis**
- Iterative process
- Checks for malformed tokens
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- Processes one line at a time

**Syntactic analysis**
- Tree-recursive process
- Balances parentheses

Text: `('+ 1' '(- 23)' '(* 4 5.6)')`

Tokens: `('+', '+', 1 '(', '+', 23, ')') '(', '+', 4, 5.6, ')', '}'`

Expression: `Pair('+', Pair(1, ...))`

Printed as: `(+ 1 (- 23) (* 4 5.6))`
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- Iterative process
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- Tree-recursive process
- Balances parentheses
- Returns tree structure

Text: `(+ 1 (- 23) (* 4 5.6))`

Tokens: 
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ridden
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\[ \text{ridden} \]

\( \text{(that was)} \)
Recursive Syntactic Analysis

A predictive recursive descent parser inspects only k tokens to decide how to proceed, for some fixed k.

Can English be parsed via predictive recursive descent?

```
sentence subject

The horse-ridden past the barn fell.

(that was)
```
Reading Scheme Lists

A Scheme list is written as elements in parentheses:
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(Demo)
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**Base case:** symbols and numbers

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(Demo)
Calculator

(Demo)
The Pair Class

The Pair class represents Scheme pairs and lists. A list is a pair whose second element is either a list or nil.
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```python
class Pair:
    """A Pair has two instance attributes: first and second.
    For a Pair to be a well-formed list, second is either a well-formed list or nil.
    Some methods only apply to well-formed lists."""

    def __init__(self, first, second):
        self.first = first
        self.second = second
```
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>>> len(s)
3
```
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    '''
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>>> s = Pair(1, Pair(2, Pair(3, nil)))
>>> print(s)
(1 2 3)
>>> len(s)
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The Pair class represents Scheme pairs and lists. A list is a pair whose second element is either a list or nil.

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Traceback (most recent call last):
  ...TypeError: length attempted on improper list
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(Demo)
Calculator Syntax
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Expression | Expression Tree | Representation as Pairs
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(* 3 (+ 4 5) (* 6 7 8)) | ![Expression Tree Image] | ![Representation as Pairs Image]
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The value of a calculator expression is defined recursively.

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Expression Tree
Calculator Semantics

The value of a calculator expression is defined recursively.

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\[
(* 3 \\
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Expression Tree

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<td>(* 3</td>
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<td>(+ 4 5)</td>
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<tr>
<td>(* 6 7 8)</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
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<td>6</td>
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\[
(*) 3 \\
+ (4 5) \\
(* 6 7 8))
\]

expression tree:

```
           *
          /
         /
        3  + 9
       /
      4  5
    /
   6  7
```

Expression Tree

```
  3  + 9
   /
  4  5
```

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![Expression and Expression Tree Diagram]
Evaluation
The Eval Function
The Eval Function

The eval function computes the value of an expression, which is always a number.
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```python
def calc_eval(exp):
    if type(exp) in (int, float):
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    else:
        raise TypeError
```

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**Language Semantics**

- A number evaluates... to itself
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A number evaluates...
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- **A number evaluates...**
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- **A call expression evaluates...**
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  - combined by an operator
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Recursive call returns a number for each operand

```
'+', '-'
'*', '/'
```

'+' and '-' are addition and subtraction operators.

'*' and '/' are multiplication and division operators.
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A Scheme list of numbers

A number evaluates...
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Applying Built-in Operators
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The apply function applies some operation to a (Scheme) list of argument values.
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Applying Built-in Operators

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**Implementation**

```python
def calc_apply(operator, args):
    if operator == '+':
        return reduce(add, args, 0)
    elif operator == '-':
        ...
    elif operator == '*':
        ...
    elif operator == '/':
        ...
    else:
        raise TypeError
```

**Language Semantics**
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<td>...</td>
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</tr>
<tr>
<td>elif operator == '*':</td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
</tr>
<tr>
<td>elif operator == '/':</td>
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(Demo)
Interactive Interpreters
Read-Eval-Print Loop
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The user interface for many programming languages is an interactive interpreter.
Read-Eval-Print Loop

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1. Print a prompt
Read-Eval-Print Loop

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(Demo)
Raising Exceptions
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Exceptions are raised within lexical analysis, syntactic analysis, eval, and apply.
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- **Lexical analysis**: The token `2.3.4` raises `ValueError("invalid numeral")`
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• **Apply:** No arguments to – raises `TypeError("– requires at least 1 argument")`
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