61A Lecture 26

Monday, November 3

Announcements

- Homework 7 due Wednesday 11/5 @ 11:59pm
  - Homework party Monday 11/3 6pm–8pm in 145 Dwinelle
- Project 1 composition revisions due Wednesday 11/5 @ 11:59pm
  - Copy hog.py to an instructional server and run: **submit proj1revision**
- Quiz 2 released Wednesday 11/5 & due Thursday 11/6 @ 11:59pm
  - Open note, open interpreter, closed classmates, closed Internet
- Midterm survey due Monday 11/10 @ 11:59pm (Thanks!)

Programming Languages

Programming Languages

A computer typically executes programs written in many different programming languages.

Machine languages: statements are interpreted by the hardware itself.

- A fixed set of instructions invoke operations implemented by the circuitry of the central processing unit (CPU).
- Operations refer to specific hardware memory addresses; no abstraction mechanisms.

High-level languages: statements & expressions are interpreted by another program or compiled (translated) into another language.

- Provide means of abstraction such as naming, function definition, and objects.
- Abstract away system details to be independent of hardware and operating system.

Python 3

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

```
from dis import dis
dis(square)
```

Python 3 Byte Code

```
LOAD_FAST                0 (x)
LOAD_FAST                0 (x)
BINARY_MULTIPLY
RETURN_VALUE
```


Metalinguistic Abstraction

A powerful form of abstraction is to define a new language that is tailored to a particular type of application or problem domain.

Type of application: Erlang was designed for concurrent programs. It has built-in elements for expressing concurrent communication. It is used, for example, to implement chat servers with many simultaneous connections.

Problem domain: The MediaWiki mark-up language was designed for generating static web pages. It has built-in elements for text formatting and cross-page linking. It is used, for example, to create Wikipedia pages.

A programming language has:

- **Syntax**: The legal statements and expressions in the language.
- **Semantics**: The execution/evaluation rule for those statements and expressions.

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.

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.

```
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
```

```
>>> s = Pair(1, Pair(2, Pair(3, nil)))
>>> print(s)
(1 2 3)
>>> len(s)
3
>>> print(Pair(1, 2))
(1 . 2)
>>> print(Pair(1, Pair(2, 3)))
(1 2 . 3)
>>> len(Pair(1, Pair(2, 3)))
Traceback (most recent call last):
  ...
TypeError: length attempted on improper list
```

Scheme expressions are represented as Scheme lists! Source code is data

Calculator Syntax

The Calculator language has primitive expressions and call expressions. (That's it!)

A primitive expression is a number: 2, -4, 5.6

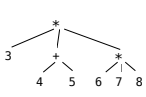
A call expression is a combination that begins with an operator (+, -, *, /) followed by 0 or more expressions: (+ 1 2 3), (/ 3 (+ 4 5))

Expressions are represented as Scheme lists (Pair instances) that encode tree structures.

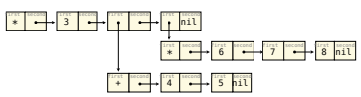
Expression

```
(* 3
   (+ 4 5)
   (* 6 7 8))
```

Expression Tree



Representation as Pairs



Calculator Semantics

The value of a calculator expression is defined recursively.

Primitive: A number evaluates to itself.

Call: A call expression evaluates to its argument values combined by an operator.

+: Sum of the arguments

*: Product of the arguments

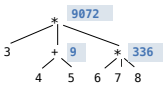
−: If one argument, negate it. If more than one, subtract the rest from the first.

/: If one argument, invert it. If more than one, divide the rest from the first.

Expression

```
(* 3
   (+ 4 5)
   (* 6 7 8))
```

Expression Tree



Evaluation

The Eval Function

The eval function computes the value of an expression, which is always a number.

It is a generic function that dispatches on the type of the expression (primitive or call).

Implementation

```
def calc_eval(exp):
    if type(exp) in (int, float):
        return exp
    elif isinstance(exp, Pair):
        arguments = exp.second.map(calc_eval)
        return calc_apply(exp.first, arguments)
    else:
        raise TypeError
```

Recursive call returns a number for each operand

'+', '−', '*', '/'

A Scheme list of numbers

Language Semantics

A number evaluates...

to itself

A call expression evaluates...

to its argument values combined by an operator

Applying Built-in Operators

The apply function applies some operation to a (Scheme) list of argument values.

In calculator, all operations are named by built-in operators: +, −, *, /

Implementation

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

Language Semantics

+:

Sum of the arguments

−:

...

...

(Demo)

Interactive Interpreters

Read-Eval-Print Loop

The user interface for many programming languages is an interactive interpreter.

1. Print a prompt
2. Read text input from the user
3. Parse the text input into an expressio
4. Evaluate the expression
5. If any errors occur, report those errors, otherwise
6. Print the value of the expression and repeat

(Demo)

Raising Exceptions

Exceptions are raised within lexical analysis, syntactic analysis, eval, and apply.

Example exceptions

- **Lexical analysis:** The token 2.3.4 raises ValueError("invalid numeral")
- **Syntactic analysis:** An extra) raises SyntaxError("unexpected token")
- **Eval:** An empty combination raises TypeError("() is not a number or call expression")
- **Apply:** No arguments to − raises TypeError("− requires at least 1 argument")

(Demo)

Handling Exceptions

An interactive interpreter prints information about each error.

A well-designed interactive interpreter should not halt completely on an error, so that the user has an opportunity to try again in the current environment.

(Demo)