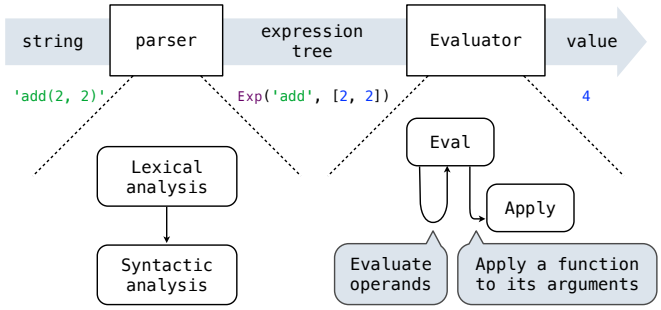
61A Lecture 27

November 2, 2011

Parsing

A Parser takes as input a string that contains an expression and returns an expression tree



Two-Stage Parsing

Lexical analyzer: Analyzes an input string as a sequence of tokens, which are symbols and delimiters

Syntactic analyzer: Analyzes a sequence of tokens as an expression tree, which typically includes call expressions

```
def calc_parse(line):
        """Parse a line of calculator input."""
        tokens = tokenize(line)
        expression_tree = analyze(tokens)
```

Lexical analysis is also called **tokenization**

Parsing with Local State

Lexical analyzer: Creates a list of tokens

Syntactic analyzer: Consumes a list of tokens

```
def calc_parse(line):
        """Parse a line of calculator input."""
        tokens = tokenize(line)
        expression_tree = analyze(tokens)
        if len(tokens) > 0:
            raise SyntaxError('Extra token(s)')
        return expression_tree
```

Lexical analysis is also called **tokenization**

Lexical Analysis (a.k.a., Tokenization)

Lexical analysis identifies symbols and delimiters in a string

Symbol: A sequence of characters with meaning, representing a name (a.k.a., identifier), literal value, or reserved word

Delimiter: A sequence of characters that serves to define the syntactic structure of an expression

```
>>> tokenize('add(2, mul(4, 6))')
['add', '(', '2', ',', 'mul', '(', '4', ',', '6', ')', ')']
```

Symbol: a built-in operator name

Delimiter

Symbol: a literal

Delimiter

(When viewed as a list of Calculator tokens)

Lexical Analysis By Inserting Spaces

Most lexical analyzers will explicitly inspect each character of the input string

For the syntax of Calculator, injecting white space suffices

```
def tokenize(line):
        """Convert a string into a list of tokens."""
        spaced = line.replace('(',' ( ').
        spaced = spaced.replace(')', ' ) ')
        spaced = spaced.replace(',', ' , ')
        return spaced.strip().split()
```

Discard preceding or following white space

Return a list of strings separated by white space

Syntactic Analysis

Syntactic analysis identifies the hierarchical structure of an expression, which may be nested

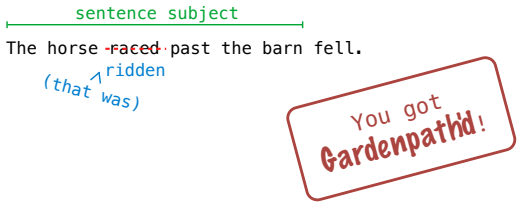
Each call to analyze consumes input tokens for an expression

```
>>> tokens = tokenize('add(2, mul(4, 6))')
>>> tokens
['add','(','2',',','mul','(','4',',','6',')',')']
>>> analyze(tokens)
Exp('add', [2, Exp('mul', [4, 6])])
>>> tokens
[]
```


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?



Recursive Syntactic Analysis

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

```
def analyze(tokens):
    token = analyze_token(tokens.pop(0))
    if type(token) in (int, float):
        return token
    else:
        tokens.pop(0)  # Remove (
        return Exp(token, analyze_operands(tokens))
```

Coerces numeric symbols to numeric values

In Calculator, we inspect 1 token

Numbers are complete expressions

tokens no longer includes first two elements

Mutual Recursion in Analyze

```
['add','(','2',',','3',')']
     ['(','2',',','3',')']
          ['2',',','3',')']
          ['2',',','3',')']
```

Pass 1

```
['2',',','3',')']
['3',')']
[')']
[]
```

Pass 2

```
['3',')']
[')']
[]
```

```
def analyze(tokens):
    token = analyze_token(tokens.pop(0))
    if type(token) in (int, float):
        return token
    else:
        tokens.pop(0)  # Remove (
        return Exp(token, analyze_operands(tokens))

def analyze_operands(tokens):
    operands = []
    while tokens[0] != ')':
        if operands:
            tokens.pop(0)  # Remove ,
        operands.append(analyze(tokens))
    tokens.pop(0)  # Remove )
    return operands
```


Token Coercion

Parsers typically identify the form of each expression, so that eval can dispatch on that form

In Calculator, the form is determined by the expression type

- Primitive expressions are int or float values
- Call expressions are Exp instances

```
def analyze_token(token):
    try:
        return int(token)
    except (TypeError, ValueError):
        try:
            return float(token)
        except (TypeError, ValueError):
            return token
```

What would change if we deleted this?

Error Handling: Analyze

```
known_operators = ['add', 'sub', 'mul', 'div', '+', '-', '*', '/']

def analyze(tokens):
    assert_non_empty(tokens)
    token = analyze_token(tokens.pop(0))
    if type(token) in (int, float):
        return token
    if token in known_operators:
        if len(tokens) == 0 or tokens.pop(0) != '(':
            raise SyntaxError('expected ( after ' + token)
        return Exp(token, analyze_operands(tokens))
    else:
        raise SyntaxError('unexpected ' + token)
```

Error Handling: Analyze Operands

```
def analyze_operands(tokens):
    assert_non_empty(tokens)
    operands = []
    while tokens[0] != ')':
        if operands and tokens.pop(0) != ',':
            raise SyntaxError('expected ,')
        operands.append(analyze(tokens))
        assert_non_empty(tokens)
    tokens.pop(0)  # Remove )
    return elements

def assert_non_empty(tokens):
    """Raise an exception if tokens is empty."""
    if len(tokens) == 0:
        raise SyntaxError('unexpected end of line')
```


Let's Break the Calculator

I delete a statement that raises an exception

You find an input that will crash Calculator