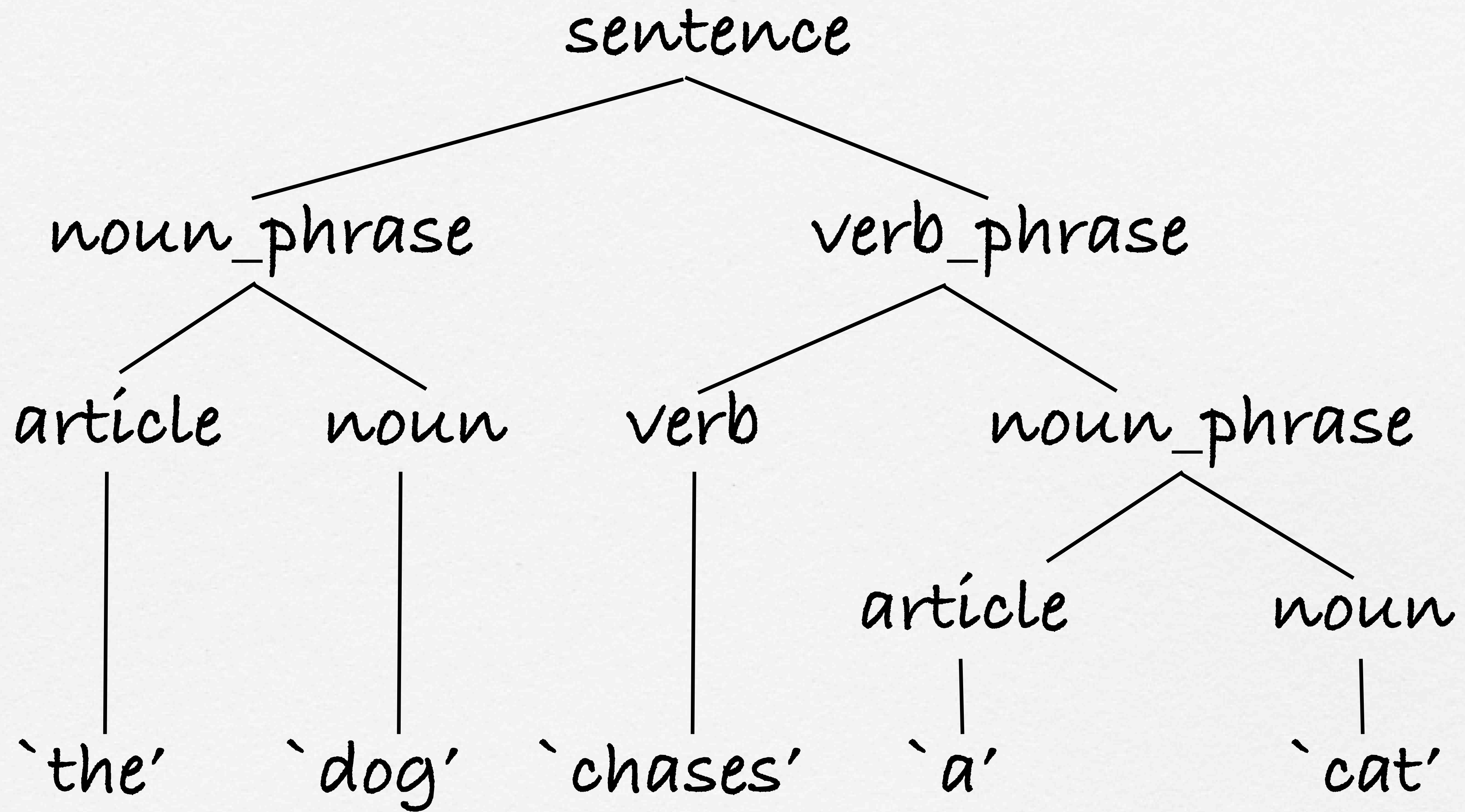
Presented by Clifford Heath,
Data Constellation.

Parsing = syntax recognition

- Regular Expressions
  - Can't handle recursive definitions
- Regex + ad-hoc code
- Context-free grammars
  - CFG generates all legal sentences

Context-free grammar

- sentence ->noun_phrase verb_phrase '.'
- noun_phrase -> article noun
- verb_phrase -> verb | verb noun_phrase
- article -> 'a' | 'the'
- noun -> 'dog' | 'cat'
- verb -> 'bites' | 'sleeps' | 'chases'


sentence
noun_phrase
verb_phrase
article
noun
verb
noun_phrase
article
noun
`the'
`dog'
`chases'
`a'
`cat'

Parsing techniques

- Left-Left (Top down) parsing - LL
  - implemented by recursive descent
- Left-Right (bottom up) parsing - LR
  - needs a parser generator
- Left and Left-Right parsing - LALR
  - e.g. yacc
- All these rely on limited lookahead, e.g. LALR(2)
- Parsing Expression Grammar (PEG) - new technique!

but where is the ambiguity?

- if expr stmt
- if expr stmt else stmt
- if exp stmt if e2 stmt else stmt...?
- Parsing techniques differ in their handling
- CFGs encode no rule priorities
  - Requires unlimited backtracking
  - O(n^m) time

PEG (packrat) parsing

- 'if' expr stmt 'else' stmt / 'if' expr stmt
- / encodes alternatives with <u>preference</u>
- PEG parsers are <u>greedy</u>
  - take first alternative if possible
  - Backtrack if not
- Results are <u>memoized</u>
  - O(n) space, O(n) time

Greed is good...?

- Care is needed:
  - word* ‘end’
  - <u>word</u> eats up too much input
  - then ‘end’ fails
- (!’end’ word)* ‘end’
  - Much better!
- Must avoid left-recursion!

Basic Treetop constructs

- Terminals:
  - string literals, e.g. “foo”, ‘bar’
  - character classes, e.g. [a-z]
  - anything: . (match any single char)
- non-terminals, defined by ‘rule’
- alternatives, separated by /
- sequence, separated by space (maybe with parentheses)
- zero-or-more (*), one-or more (+), optional (?)
- lookahead: negative (!), positive (&)

Arithmetic Example

```
rule expr
   term ( add_op term )*
end
rule term
   factor ( mul_op term )?
end
rule factor
   variable / number / `(` expr `)`
end
rule variable
   [a-zA-Z_] [a-zA-Z0-9]*
end
rule number
   [1-9] [0-9]* / `0`
end
rule add_op `+` / `-` end
rule mul_op `*` / `/` / `%` end
```

Note right-recursion!
Makes it right-associative.

This example doesn't account for white space!

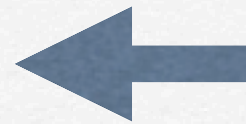
Lex Rex?

- Packrat parsers typically don't LEX
- Every character must be accounted for, including white space...

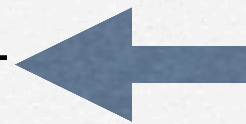
```
rule white
    [ \r\t\n]
end
rule expr
    white* expr ( add_op term )*
end
... etc.
```

Comments etc

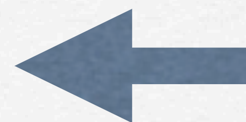
```
rule comment_c_style
   '/*' (!'*/' . )* '*/'
end
rule white
   [ \t\n\r]+
end
rule S
   ( white / comment_c_style )+
end
rule s
   S?
end
```



Illustrates negative Look-ahead



Mandatory space



Optional Space

Modules, grammars

```
module MyLang
    grammar Arithmetic
        rule ...
        end
    end
end
```

Module is optional!

```
$ tt arith.treetop
$ cat arith.rb
module MyLang
  module Arithmetic
    ...
  end
  ...
  class ArithmeticParser < Treetop::Runtime::CompiledParser
    include Arithmetic
    ...
  end
end
```

Syntax Tree

```
$ ruby -e '
require "treetop"
require "arith"
p MyLang::ArithmeticParser.new.parse("x+2")
'
SyntaxNode+Expr1 offset=0, "x+2" (term):
  SyntaxNode+Term1 offset=0, "x" (factor):
    SyntaxNode+Factor1 offset=0, "x" (s):
      SyntaxNode+Variable0 offset=0, "x":
        SyntaxNode offset=0, "x"
    SyntaxNode offset=1, ""
  SyntaxNode offset=1, "+2":
    SyntaxNode+Expr0 offset=1, "+2" (s,add_op,expr):
      SyntaxNode offset=1, "+"
      SyntaxNode+Expr1 offset=2, "2" (term):
        SyntaxNode+Term1 offset=2, "2" (factor):
          SyntaxNode+Factor1 offset=2, "2" (s):
             SyntaxNode+Number0 offset=2, "2":
              SyntaxNode offset=2, "2"
$
```

Nodes for white-space have been stripped out!

Actions

- Add methods to SyntaxNodes:

```
rule number
  ([1-9] [0-9]* / `0`)
    { def value
        text_value.to_i
      end
    }
end
```

Note the parentheses.
Action blocks bind
tighter than /

Every SyntaxNode
has text_value method

Actions II

```
rule expr
   s term seq:( s add_op s term )* s
       { def value
              seq.elements.inject(term.value) { | a, t |
                     t.add_op.operate(a, t.term.value)
                  }
          end
       }
end

rule add_op
   '+'        { def operate(a, b); a+b end }
   / '-'      { def operate(a, b); a-b end }
end
```

Note the seq: label

Every SyntaxNode has elements method

Custom SyntaxNodes

```
rule variable
  [a-zA-Z]+ <VarNode>
end
```

Instantiates subclass VarNode instead of SyntaxNode

- As you'd expect, the VarNode class can be re-opened elsewhere in your code.

Demonstration

Resources

- sudo gem install treetop
- http://treetop.rubyforge.org
- http://rubyconf2007.confreaks.com/d1t1p5_treetop.html
- http://pdos.csail.mit.edu/~baford/packrat/popl04/peg-popl04.pdf

Questions