Learn Parsing Theory with pyparsing

Goal of parsing:

Arrange input data in a memory layout which is suitable for further computation and processing.

World's most famous parser: Web browser

☞ Parses HTML and determines appropriate bit colors on screen.

Lexing and Parsing

- ☞ Lexing: Assigning meaning to words
- ☞ Parsing: Assigning meaning to sentences

Lexing and Parsing

- ☞ A lexer cannot tell you that 'Run Spot see' is not a valid sentence; a parser is required
- ☞ A lexer can tell you that 'Run', 'Spot', and 'see' are all valid English words

Lexemes

Lexemes are the basic 'words' of your text, before they are ascribed a meaning or placed in a category.

Lexemes

The lexemes of the C statement

```
double x = 3.14;
```

are `double`, `x` , `=`, `3.14`, and `;`.

Tokenization

Once we ascribe a category to the lexeme, it becomes a token.

So

```
('double', 'primitive type'),
('x', 'identifier'),
('=', 'assignment'),
('3.14', 'float literal'),
(';', 'end of statement')
```

constitute a tokenization of the C statement.

Backus-Naur Form

We wish to clarify our thoughts about parsing our grammar by first writing a description of the problem.

We use Backus-Naur form to achieve this.

Backus-Naur Form

A way of describing a grammar.

Backus-Naur Form

```
<C statement> ::= <type> + <identifier> + <assignment> + <value> + <end of statement>
<type> ::= 'float'|'double'|'long double'
<identifier> ::= Alphanumeric
<assignment> ::= '='
<value> ::= <identifier>|<number>
<end of statement> ::= ';'
```

The components of "C statement" must occur in order.

pyparsing

Let's see if we can get the python pyparsing module to parse our C statement:

```
$ pip3 install pyparsing
```

Example 1: Parse a C assignment statement

```
from pyparsing import Word, Literal, alphas, alphanums, nums, oneOf
type = oneOf(["float", "double", "long double"])
identifier=Word(alphas, alphanums+'_')
assignment=Literal("=")
number=Word(nums+".")
eos=Literal(";")
cstatement=type + identifier + assignment \
... + (number|identifier) + eos
cstatement.parseString('double x = 7;')
# (['double', 'x', '=', '7', ';'], {})
cstatement.parseString('double y = x;')
# (['double', 'y', '=', 'x', ';'], {})
```

Aside: When should I use Pyparsing?

Pyparsing is a single-file, MIT licensed parser with no dependencies; I am aware of no competitors. However, if your data format is well known, then there are format-specific parsers that already exist:

☞ `BeautifulSoap` for HTML

☞ `xlrd` for Excel

☞ `pdfminer` for pdfs

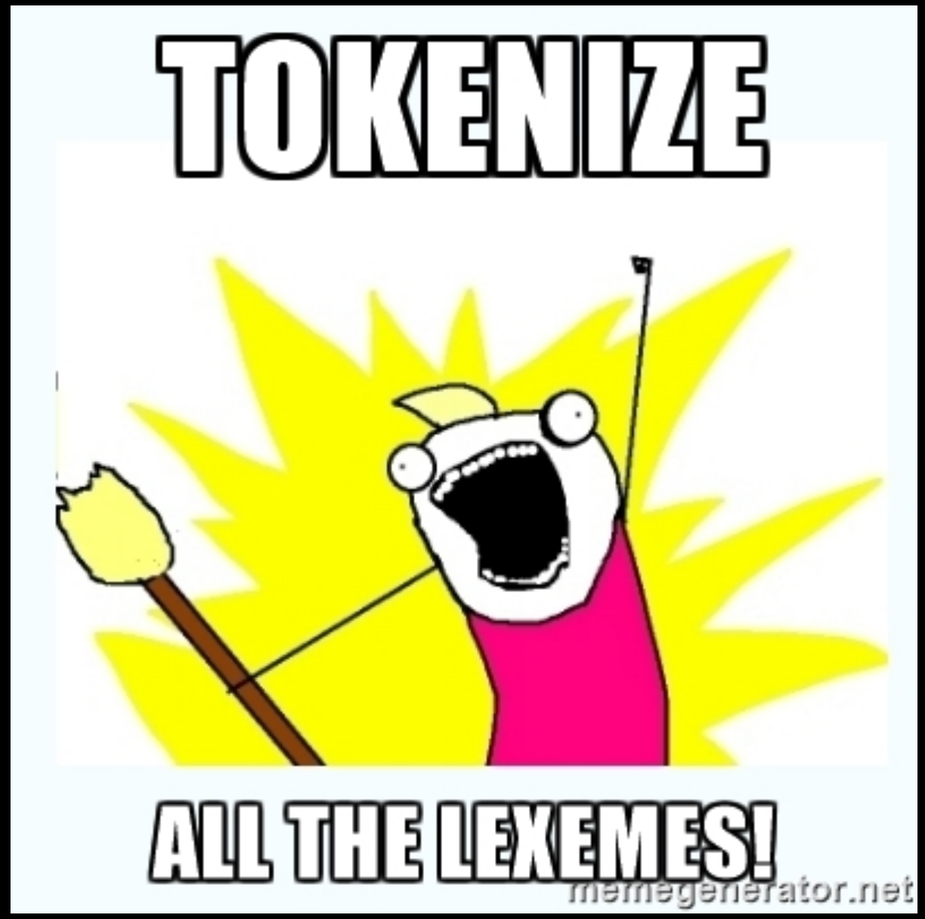
pyparsing

Note: We're not even close to a full-fledged C parser; for instance

```
double x=7, y=3;
```

is valid C, but our parser chokes:

```
>>> cstatement.parseString('double x=7, y=3;')
...
pyparsing.ParseException: Expected ";" (at char 10), (line:1, col:11)
```


TOKENIZE
ALL THE LEXEMES!
memegenerator.net

Tokenize the lexemes via `setResultsName`:

```
>>> cstatement=type.setResultsName("type") \
... + identifier.setResultsName("new_identifier") \
... + assignment \
... + (number|identifier).setResultsName("rhs") + eos
>>> out = cstatement.parseString("double x = 7;")
>>> out.type
'double'
>>> out.rhs
'7'
```

Once you've parsed a statement, you might not care about certain tokens such as ';'' or '='.

So you can ignore them with the following syntax:

```
>>> from pyparsing import Suppress
>>> assignment = Suppress(Literal("="))
>>> eos = Suppress(Literal(";"))
>>> cstatement=reserved + identifier + assignment + (number|identifier) + eos
>>> keyword, id, rhs = cstatement.parseString("double x = 7;")
>>> keyword
'double'
>>> id
'x'
>>> rhs
'7'
```

Now let's step up our game:

```
char* c = "He said \"hello friend!\"";
```

The lexemes are

① `char*`

② `c`

③ `=`

④ `"He said \"hello friend!\"";`

Backus-Naur form for C-strings

C string definition ::= type specifier + identifier + assignment + (identifier|string)

Pain in parsing strings: Escape characters.

```
char* s="he said \"hello friend!\"";
```

We can't just match double quotes; we need an escape string.

pyparsing C string definitions

```
>>> type_specifier = Literal("char*")
>>> identifier = Word(alphas, alphanums+"_")
>>> assignment = Suppress(Literal("="))
>>> string = QuotedString('"', escChar='\\')
>>> eos = Suppress(Literal(";"))
>>> cstringdef = type_specifier + identifier + assignment + string + eos
>>> s = r'''char* s="he said \"hello friend!\"";'''
>>> keyword, id, string = cstringdef.parseString(s)
>>> keyword
'char*'
>>> id
's'
>>> string
'he said "hello friend!"'
```

pyparsing: Defining parse actions

While parsing

```
double pi = 3.14;
```

we really need to represent `pi` as IEEE 64 bit in memory, not just the string `3.14`.

This can be achieved via parse actions, which are simply callbacks.

pyparsing: Defining parse actions

```
number = Word(nums+".").setParseAction(lambda t:float(t[0]))
...
cstatement=reserved + identifier + assignment + number + eos
keyword, id, rhs = cstatement.parseString("double pi = 3.14;")
print(rhs)
# 3.14
```

pyparsing: A bit too forgiving?

If `double x = 3.14;` parses, then

```
double x = 3.14; &\;random&\;syntactically&\;incorrect&\;garbage
```

will also parse.

pyparsing: `stringEnd`

Use `stringEnd` to make sure that strings don't have random garbage at the end:

```
from pyparsing import stringEnd
...
# Will throw exception:
parse_result = (cstatement + stringEnd).parseString("double x = 3.14; random garbage")
```

How to write a forgiving parser: Advice

① Get a big pile of test data

② Pass 1: Remove all the comments, strip all whitespace from line end/beginning

③ Pass 2: Group data, don't parse it, (e.g., group in `<head>` and `<body>` before a full parse)

④ Pass 3: Parse groups individually.

How to write a forgiving parser: Advice

① Attempt to parse each group multiple ways (e.g., `parseString(line)` and `line.split()`)

② Pass a logger to your parser, if you can't parse, log, don't fail

③ Most data you parse is irrelevant; don't get hung up on special cases unless you actually need them

pyparsing: Hacking on unstructured data

Let's try to parse:

```
'C' C 'He3' C14
```

The lexemes are easy enough to identify for a human, let's see what the computer thinks.

```
>>> from pyparsing import *
>>> s = r''' 'C' C 'He3' C14 '''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums) | QuotedString("'", escChar="\\"))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14'], {})
```

```
>>> s = r''' 'C' C 'He3' C14 Sn2+ '''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums+"+") | QuotedString("'", escChar="\\"))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14', 'Sn2+'], {})
```

```
>>> s = r''' 'C' C 'He3' C14 Sn2+ 732 '''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums+"+") | QuotedString("'", escChar="\\") | Word(nums))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14', 'Sn2+', '732'], {})
```

```
>>> s = r''' 'C' C 'He3' C14 Sn2+ 732 0.732 '''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums+"+") | QuotedString("'", escChar="\\") | Word(nums+"."))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14', 'Sn2+', '732'], {})
```

```
>>> s = r''' 'C' C 'He3' C14 Sn2+ 732 0.732 -0.32 '''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums+"+") | QuotedString("'", escChar="\\") | Word(nums+"."+"-"))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14', 'Sn2+', '732', '0.732', '-0.32'], {})
```

```
>>> s = r''' 'C' C 'He3' C14 Sn2+ 732 0.732 -0.32 4.6(3)'''
>>> lexeme_gen = OneOrMore(Word(alphas, alphanums+"+") | QuotedString("'", escChar="\\") | Word(nums+"."+"-"+"("+")"))
>>> lexeme_gen.parseString(s)
(['C', 'C', 'He3', 'C14', 'Sn2+', '732'], {})
```

What do we do with malformed input data?

- ☞ If you are a C compiler, give the user an inscrutable error message.
- ☞ If you are a web brower, be forgiving, do your best to render what you've got.

Why should browsers be forgiving parsers?

- ☞ Users will try to open the page in a different browser if your browser doesn't render it.

Writing a forgiving parser is hard

“The death spiral of frustration that is so common when you have to write parsers is not easy to avoid.”

—Paul McGuire, author of PyParsing

Forgiving Parsers Become Insane

Is there an alternative?

Alternative to a Parser: Memcopy your data structure to disk

This is called blitting, or serialization, but there are tradeoffs.

Blitting/Serialization

- ☞ Fast, but not portable. (Ever opened a binary file you couldn't interpret? Ever read data with incorrect endianness?)
- ☞ Line between serialization and parser isn't clear (e.g., HDF5: Binary data segments organized into a B-tree)