Bottom-Up Parsing – LR(1)

- Previously we have studied top-down or LL(1) parsing.
- The idea here was to start with the start symbol and keep expanding it until the whole input was read and matched.
- In bottom-up or LR(1) parsing we do exactly the opposite, we try to match the input to a rule and then keep *reducing* the input replacing it with the non-terminal of the rule. The last step is to replace the current input with the start-symbol.
- **Observation:** in LR(1) parsing we apply the rules backwards – this is called *reduction*

Bottom-Up Parsing – LR(1)

- In our LL(1) parsing example we replaced non-terminal symbols with functions that did the expansions and the matching for us.
- In LR(1) parsing we use a stack to help us find the correct reductions.
- Given a stack, an LR(1) parser has four available actions:
  - **Shift** – push an input token on the stack
  - **Reduce** – pop elements from the stack and replace by a non-terminal (apply a rule ‘backwards’)
  - **Accept** – accept the current program
  - **Reject** – reject the current program

Bottom-Up Parsing – LR(1)

p + x 1 ;

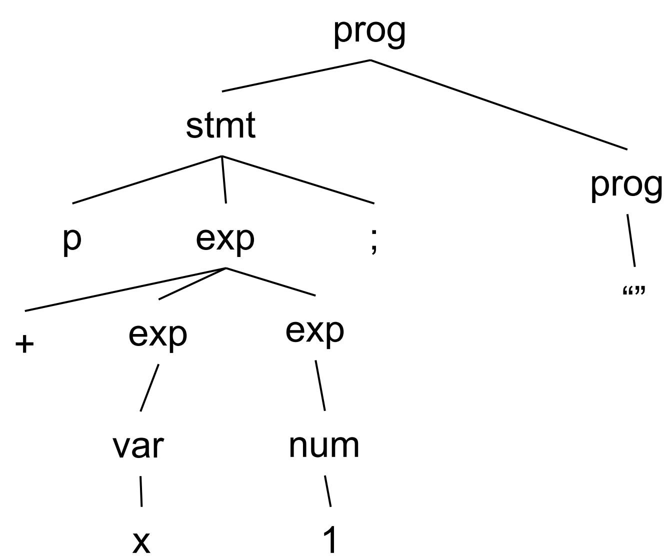
```
grammar exp0;

prog    :    stmt prog
        |    ""
        ;

stmt    :    'p' exp ';'
        |    's' var exp ';'
        ;

exp     :    '+' exp exp
        |    '-' exp exp
        |    '(' exp ')'
        |    var
        |    num
        ;

var     :    'x' | 'y' | 'z'
        ;

num     :    '0' …'9'
        ;
```

Stack	Input	Action
<empty>	p + x 1 ;	Shift
p	+ x 1 ;	Shift
p +	x 1 ;	Shift
p + x	1 ;	Reduce
p + var	1 ;	Reduce
p + exp	1 ;	Shift
p + exp 1	;	Reduce
p + exp num	;	Reduce
p + exp exp	;	Reduce
p exp	;	Shift
p exp ;	<empty>	Reduce
stmt	<empty>	Shift
stmt <empty>	<empty>	Reduce
stmt prog	<empty>	Reduce
prog	<empty>	Accept

Bottom-Up Parsing – LR(1)

Stack
<empty>
p
p +
p + x
p + var
p + exp
p + exp 1
p + exp num
p + exp exp
p exp
p exp ;
stmt
stmt <empty>
stmt prog
prog

p + x 1 ;



Bottom-Up Parsing – LR(1)

Let's try an illegal sentence

p + x s ;

```
grammar exp0;

prog    :    stmt prog
        |    ""
        ;

stmt    :    'p' exp ';'
        |    's' var exp ';'
        ;

exp     :    '+' exp exp
        |    '-' exp exp
        |    '(' exp ')'
        |    var
        |    num
        ;

var     :    'x' | 'y' | 'z'
        ;

num     :    '0' …'9'
        ;
```

Stack	Input	Action
<empty>	p + x s ;	Shift
p	+ x s ;	Shift
p +	x s ;	Shift
p + x	s ;	Reduce
p + var	s ;	Reduce
p + exp	s ;	Shift
p + exp s	;	Shift
p + exp s ;	<empty>	Reject

Bottom-Up Parsing – LR(1)

Let's try it with the a grammar where left-hand side and right-hand variables are differentiated.

p + x 1 ;

```
prog    :   stmt prog
        |   ""
        ;

stmt    :   'p' exp ';'
        |   's' lhsvar exp ';'
        ;

exp     :   '+' exp exp
        |   '-' exp exp
        |   '(' exp ')'
        |   rhsvar
        |   num
        ;

lhsvar  :   'x' | 'y' | 'z'
        ;

rhsvar  :   'x' | 'y' | 'z'
        ;

num     :   '0' …'9'
        ;
```

Stack	Input	Action
<empty>	p + x 1 ;	Shift
p	+ x 1 ;	Shift
p +	x 1 ;	Shift
p + x	1 ;	Reject

There is a conflict between the lhsvar rule and rhsvar rule here, we do not have enough information to select one rule over the other. This is called a **reduce/reduce conflict** in bottom-up parsing terminology.

That means, even though our grammar is a perfectly legal context-free grammar, it is not a grammar that can be used by a bottom-up parser, we say that the **grammar is not LR(1)**.

We didn't point this out but there are also grammars which are perfectly legal CFG's that are not LL(1).

Bottom-Up Parsing – LR(1)

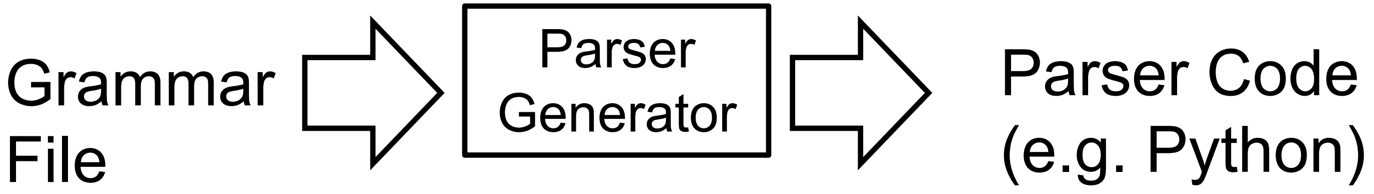
- LR(1) parsers are implemented in such tools as Yacc (Unix) and Bison (Linux)
- The tool we will be using, Ply, also implements LR(1) parsing.
- Other tools such as ANTLR implement LL(1) parsing*

* Actually ANTLR implement LL(k) parsing a slightly more powerful version of LL(1) parsing.

Parser Generators

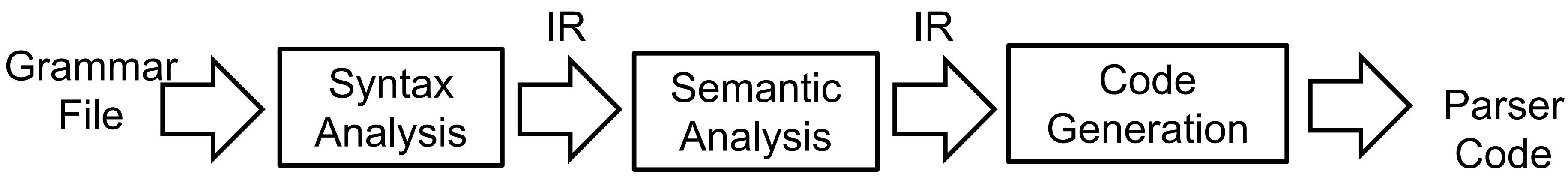
- Writing parsers by hand if difficult and time consuming
- The resulting parsers are difficult to maintain and extend
- Ideally we would like a tool that reads a grammar definition and generates a parser from that description

Parser Generators



That looks very much like a translator!

Parser Generators



Parser generators are an example of a domain specific language translator!

Ply is a parser generator, it translates a grammar specification into parser code written in Python.

Using Ply

- Recall:
  - The examples assume that you have cloned or downloaded the Plipy book and have access to the 'code' folder on your local machine
  - For notebook demos it is assumed that you navigated Jupyter to the 'code' folder and started a new notebook
- Documentation on Ply can be found here:
  - http://www.dabeaz.com/ply/ply.html
- Documentation on Ply grammar specifications can be found here:
  - http://www.dabeaz.com/ply/ply.html#ply_nn23

Using Ply

- This is our ‘exp0_gram.py’ file
- In Ply the grammar is specified in the docstring of the grammar functions
- Don’t worry about the lex stuff – it simply sets up a character input stream for the parser to read
- Goal is to generate a parser from this specification

```
from ply import yacc
from exp0_lex import tokens, lexer

def p_grammar(_):
    """
    prog : stmt prog
         | empty

    stmt : 'p' exp ';'
        | 's' var exp ';'

    exp : '+' exp exp
        | '-' exp exp
        | '(' exp ')'
        | var
        | num

    var : 'x'
        | 'y'
        | 'z'

    num : '0'
         | '1'
         | '2'
         | '3'
         | '4'
         | '5'
         | '6'
         | '7'
         | '8'
         | '9'
    """
    pass

def p_empty(p):
     'empty :'
    pass

def p_error(t):
    print("Syntax error at '%s'" % t.value)

parser = yacc.yacc(debug=False,tabmodule='exp0parsetab')
```

Using Ply

```
In [10]: from exp0_gram import parser
         from exp0_lex import lexer

In [11]: parser.parse(input="p + 1 2 ;", lexer=lexer)

In [12]: parser.parse(input="q + 1 2 ;", lexer=lexer)

         Illegal character q
         Syntax error at '+'

In [ ]:
```

Actions

- Making the generated parser do something useful.
- In the hand-coded parser you can add code anywhere in order to make the parser do something useful…like counting ‘p’ statements.
- In parsers generated by parser generators we use something called ‘actions’ we insert into the grammar.
- In Ply actions are inserted into the grammar specification as Python code:

```
def p_exp_var(_):
    '''
    exp : var
    '''
    global count
    count += 1
```

Actions

Actions

- In order to insert actions we need to break the Ply grammar into smaller functions
- The idea of our language processor is to count the number of right-hand side variables in a program

```
def p_grammar(_):
   """
   prog : stmt prog
        | empty

...
```

```
def p_prog(_):
   '''
   prog : stmt prog
   '''
   pass

def p_prog_empty(_):
   '''
   prog : empty
   '''
   print("count = {}".format(count))
```

Actions

Actions

```
def p_grammar(_):
  """
  …
   exp : '+' exp exp
       | '–' exp exp
       | '(' exp ')'
       | var
       | num
  …
  """
```

Actions

```
def p_exp(_):
  '''
  exp : '+' exp exp
     | '–' exp exp
     | '(' exp ')'
     | num
  '''
  pass

def p_exp_var(_):
  '''
    exp : var
  '''
    global count
    count += 1
```

Actions

```
In [1]: from exp0_count import parser, init_count
        from exp0_lex import lexer

In [2]: init_count()
        parser.parse(input="s x + y 1 ;", lexer=lexer)

        count = 1

In [3]: init_count()
        parser.parse(input="s x + y 1 ; p x ;", lexer=lexer)

        count = 2

In [ ]:
```

Assignment

- Assignment #2 – see website