Parsing in Practice

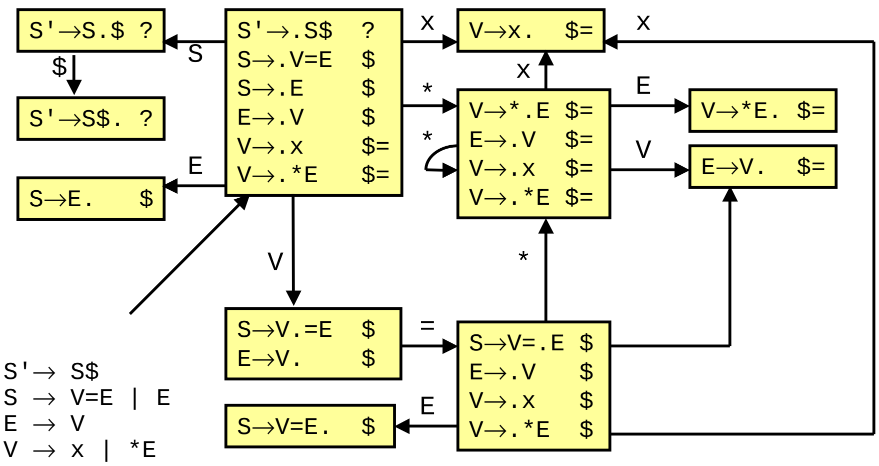
January 31, 2001

CS 132: Compiler Design

Review: Parsing Algorithm

- Let α be the current stack and `t` the next input token.
  - If we've reduced the entire input to the start symbol: success.
  - Otherwise, run the DFA on α (the stack)
    - If it rejects, we've detected an error.
    - If the resulting state contains an item $[E \to \alpha., t]$ then reduce, and repeat.
    - If the resulting state contains an item containing `.t` then shift, and repeat.
    - Otherwise, an error has been detected

Review: A LALR(1) DFA




```
S'→ S$
S → V=E | E
E → V
V → x | *E
```

Parsing Ambiguous Grammars

- Many languages have grammar rules such as

```
S → if E then S else S
S → if E then S
S → other
```

- How should we interpret:

```
if a then if b then s1 else s2
```

Dangling Else Problem

- Since this grammar is ambiguous, it cannot be LR(k) for any k.
- Thus we know there will be a state with a conflict.
  - In this case, a shift-reduce conflict.

```
[S → if E then S. , else]
[S → if E then S. else S,any]
...
```

Solution 1: Fix the grammar

- We could rewrite the grammar to remove the ambiguity. For example:

```
S → M
S → U
M → if E then M else M
M → other
U → if E then S
U → if E then M else U
```

(prohibits **else**-less if in a **then** branch)

Solution 2: Change Language

- Add an end marker to conditionals

```
S → if E then S else S fi
S → if E then S fi
S → other
```

- Then forced to say

```
if a then if b then s1 fi else s2 fi
if a then if b then s1 else s2 fi fi
```

Solution 3: Hack the Parser

- Original problem was that in this state the parser didn't know whether to shift or reduce.
- So just tell it to always reduce in this case
  - No more ambiguity!

- Implements rule that **`else`** must match the most recent possible **`then`.**
  - This rule holds in most languages.
  - Yacc will default to shifting when there is a shift/reduce conflict, so you just have to live with the warning.

Parsing Ambiguous Grammars

- How about arithmetic expressions? The following grammar is highly ambiguous:

```
E → Int | E + E | E - E | E * E | (E)
```

- For example, consider `2*3+4` and `5-6-7`

Arithmetic Precedence

- This grammar will generate several shift-reduce conflicts, including

```
[E → E * E . , +]
[E → E . + E , any]
```

```
[E → E + E . , *]
[E → E . * E , any]
```

```
[E → E - E . , -]
[E → E . - E , any]
```

Solution 1: Fix the grammar

- We can make the grammar unambiguous by adding new nonterminals.

```
E → E + T | E - T | T
T → T * F | F
F → (E) | Int
```

Solution 2: Change Language

- Change the language to something like

```
E → Int | (E + E) | (E - E) | (E * E) | (E)
```

or

```
E → Int | E E + | E E - | E E *
```

Solution 3: Hack the Parser

- Or we could just resolve the conflicts:

[E → E * E . , +] [E → E . + E , *any*]	always reduce
[E → E + E . , *] [E → E . * E , *any*]	always shift
[E → E - E . , -] [E → E . - E , *any*]	always reduce

Parsing Ambiguous Grammars

- The grammar for the EQN typesetting language includes the following productions:

```
E → E sub E sup E
E → E sub E
E → E sup E
E → { E }
E → other
```

- Aside from associativity and precedence issues, how do we handle

E **sub** E **sup** E

Special-Case Productions

- We will get shift/reduce conflicts due to associativity and
- Also, a reduce/reduce conflict

```
[E → E sub E sup E . , }]
[E → E sup E .       , }]
```

Solution: Hack Parser

- Always take the first reduction.
  - Simple enough to understand consequences
  - Would be much harder to modify grammar
- Note: ML-Yacc will default to the first production rule in a reduce/reduce conflict.

Parsing Ambiguous Grammars

- Suppose we try to distinguish arithmetic and boolean expressions in the grammar.

```
E  → A | B
A → id | A + A | A - A
B → id | B & B | A = A
```

- What is the reduce/reduce conflict?

Solution: Give Up

- Difficult to get the parser to do this checking
- Just do a typechecking pass later.

```
E  → id | E + E | E - E | E & E | E = E
```

Conflicts in Practice

- The dangling-else problem and arithmetic precedence problem are well-understood.
- Be very careful with any other conflict.
  - Reduce/reduce conflicts usually signal a problem with the grammar (though not always)
  - Examine any shift/reduce conflicts

Constructing Parsers

- The presentation you have seen is unrealistic in the following ways:
  - DFA's are generated directly, rather than by constructing the NFA and using the subset construction. (See Appel for details)
  - LALR parsers are generated directly, rather than by constructing the LR(1) automaton and compressing it.

Implementing Parsers

- First optimization:
  - After each step, prefix of the stack is unchanged
  - Wasteful to run this through the DFA
  - Solution: label each stack element with the state state one ends up in

$_1\ E_4\ +_5\ E_7\ *_8\ E_9$	\$	Reduce $E \to E*E$
$_1\ E_4\ +_5\ E_7$	\$	Reduce $E \to E+E$
...etc...		

Implementing Parsers

- For each automaton state and lookahead token we can precompute the action to take:
  - Shift token onto stack, tagged with state *n*
  - Reduce using Rule *n*
- Two tables (possibly merged)
  - Parsing table: indexed by top stack state and lookahead symbol
  - Goto table: indexed by stack states and nonterminals

Parsing Table

- Contains 4 types of entries

s(*n*):	Shift next token, tag with state *n*
r(*n*):	Reduce using *n*th rewrite rule A→b. (Pop β off the stack, look up A in the goto table to get a state, push A and this state on stack.
a:	Accept the input and stop parsing
e:	Error detected.

Goto Table

- Indexed by states and nonterminals
  - If I'm in state *n* and I see A, what is the next state?
- Just contains those edges of the DFA labeled by nonterminals.
- Frequently combined with the parsing table (as in Appel) into one big table.
  - Indexed by state and by stack symbol

ML-Yacc

- An LALR(1) parser generator for SML.
  - Modeled on Yacc, Bison, etc.
- File format:

Simple ML-Yacc Input File

```
(* User declarations *)
%%
%name Sample
%term ID | WHILE | BEGIN | END | DO
    | IF | THEN | ELSE | SEMI | ASSIGN | EOF
%nonterm prog | stm | stmlist
%start prog
%pos int
%eop EOF
%verbose

%%
...continued on next slide...
```

Simple ML-Yacc Input File

```
prog : stmlist                      ()

stm  : ID ASSIGN ID                 ()
     | WHILE ID DO stm              ()
     | BEGIN stmlist END            ()
     | IF ID THEN stm               ()
     | IF ID THEN stm ELSE stm      ()

stmlist : stm                       ()
        | stmlist SEMI stm          ()
```

Another Example: Precedence

```
%%
%term INT | PLUS | MINUS | TIMES | UMINUS | EQ | EOF
%nonterm exp
%start exp
...
%nonassoc EQ
%left PLUS MINUS
%right TIMES
%left UMINUS
%%
exp : INT                    ()
    | exp PLUS exp           ()
    | exp MINUS exp          ()
    | exp TIMES exp          ()
    | exp EQ exp             ()
    | MINUS exp %prec UMINUS ()
```

Semantic Actions

- We can tell the parser to perform an action every time it does a reduction.
- By default, this must be a piece of code of type `unit`.
- Effectively performed in postorder traversal of parse tree

```
exp : INT                      (print "saw int\n")
    | exp PLUS exp             (print "saw +\n")
    | exp MINUS exp            (print "saw -\n")
    | exp TIMES exp            (print "saw *\n")
    | exp EQ exp               (print "saw =\n")
    | MINUS exp %prec UMINUS   (print "saw unary -\n")
```

Terminals with Values

- Any real lexer won't just return the tokens `ID` or `INT` every time a variable or numeral is found; it also returns a string/integer/etc.

```
%term INT of int | ID of string | ...etc...
%%
exp : INT                      (print (Int.toString(INT)))
    | ID                       (print ID)
    | exp MINUS exp            (print "saw -\n")
```

- Value can be referred to as ID or INT within the semantic action. (Or ID1 and ID2 if ID occurs twice on the left, etc.)

Nonterminals with Values

- Nonterminals can also have values
  - All actions for this nonterminal must have the same type, but this type need not be `unit`.

```
%%
%term INT of int | PLUS | MINUS | TIMES | UMINUS | EOF
%nonterm exp of int
%start exp
%%
exp : INT                  (INT)
    | exp PLUS exp         (exp1 + exp2)
    | exp MINUS exp        (exp1 - exp2)
    | exp TIMES exp        (exp1 * exp2)
    | MINUS exp %prec UMINUS      (~ exp)
```