Applying ML-Yacc

February 5, 2001
CS 132: Compiler Design

Review: Arithmetic Precedence

- Naive expression grammar generates shift-reduce conflicts, including

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

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

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

Review: Arithmetic Precedence

- In the case

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

we have seen `E * E` and the lookahead is +

- We can either shift the + onto the stack or reduce via `E → E * E`.
- Since we want multiplication to group more strongly than addition, correct answer is *reduce*.

Review: Arithmetic Precedence

- In the case

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

we have seen `E + E` and the lookahead is `*`

- We can either shift the `*` onto the stack or reduce via `E → E + E`.
- Since we want multiplication to group more strongly than addition, correct answer is *shift*.

Review: Arithmetic Precedence

- In the case

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

we have seen `E - E` and the lookahead is `-`

- We can either shift the `-` onto the stack or reduce via `E → E - E`.
- Since we want subtraction to be left-associative, correct answer is *reduce*.

Resolving Shift/Reduce Conflicts

- ML-Yacc permits terminals to be given a precedence and associativity.

```
%nonassoc EQ
%left PLUS MINUS
%right TIMES
```

- Each rule may have a precedence and associativity.
  - Defaults to that of rightmost terminal
  - Can be overridden by `%prec` specifier
    - Recall the unary-minus example

Resolving Shift/Reduce Conflicts

- Conflict resolution
  - Assume choices are
    - shift a terminal *t*
    - reduce a rule $A \rightarrow \beta$
  - Yacc will reduce
    - if rule's precedence > terminal's precedence
    - Or, if precedences are equal and both are left-associative
  - Otherwise shift.
    - Also shift if at least one missing a specified precedence
    - (Yields original rule of default-to-shift.)
- Consider the previous cases again.

Another Example: Dangling Else

- Keywords `then` and `else` may need precedences when we have, e.g., arithmetic operators around.
- Consider

```
if 1 then 2 + 4
if 1 then 2 else 3 + 4
```

- Solution: give `then` and `else` low precedence.
- What goes wrong if you make them left-associative, though?

Semantic Actions

- Many terminals carry semantic information
  - – e.g., INT terminal having a associated integer
  - – e.g., STRING terminal with associated string
- Can generalize this to having information associated with each node in the parse tree.
  - – *Semantic actions* compute information for nonterminals, in terms of the values of their children.

Semantic Actions in ML-Yacc

- ML-Yacc associates an arbitrary piece of SML code with each production rule.
  - – Stack now contains not symbols, but (symbol,value) pairs.
    - Well, technically there are two parallel stacks.
  - – When a reduction rule $A \rightarrow \beta$ applies, runs the corresponding semantic action to get the value for A.
    - Usually computed in terms of values for the symbols in β.
  - – LR parsing performs reductions in predictable order
    - As if values were computed in postorder parse tree traversal, although full parse tree may not actually be constructed.

Example: Calculator

```
%%
%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)
```

Example: RPN Generator

```
%%
%term INT of int | PLUS | MINUS | TIMES | UMINUS | EOF
%nonterm exp
%start exp
%%
exp : INT                  (emit(Push INT))
    | exp PLUS exp         (emit ADD)
    | exp MINUS exp        (emit SUB)
    | exp TIMES exp        (emit MULT)
    | MINUS exp %prec UMINUS      (emit NEG)
```

Example: PN Generator

```
%%
%term INT of int | PLUS | MINUS | TIMES | UMINUS | EOF
%nonterm exp of instruction list
%start exp
%%
exp : INT                  ([Num(INT)])
    | exp PLUS exp         ([Add] @ exp1 @ exp2)
    | exp MINUS exp        ([Sub] @ exp1 @ exp2)
    | exp TIMES exp        ([Mult] @ exp1 @ exp2)
    | MINUS exp %prec UMINUS      ([Neg] @ exp)
```

Abstract Syntax

- Another use of semantics actions is to build an abstract syntax tree

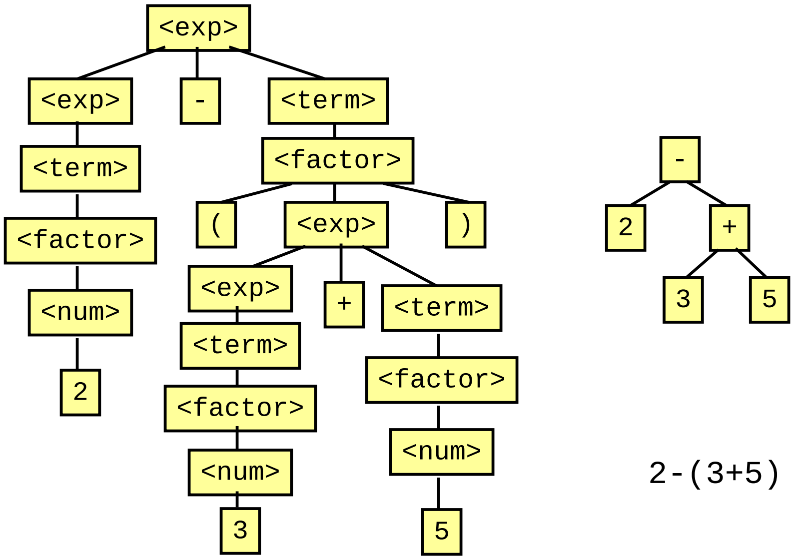
- Recall:
  - *Concrete syntax* refers to the parse tree generated corresponding to the grammar.
  - *Abstract syntax* retains only the essential information from the parse tree

Example

- Consider the following grammar:

```
<exp>    ::= <exp> + <term>
           | <exp> - <term>
           | <term>
<term>   ::= <term> * <factor>
           | <factor>
<factor> ::= ( <exp> )
           | <num>
```

Concrete & Abstract Syntax



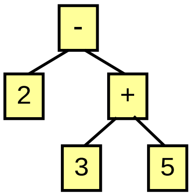
2-(3+5)

Concrete Syntax

- Concrete syntax is comparatively "arbitrary"

```
<num> ::= one | two | three | ...
<exp> ::= <num>
        | add <exp> and <exp>
        | subtract <exp> from <exp>
        | multiply <exp> by <exp>
        | ( exp )
```

```
subtract (add three plus five)
from two
```

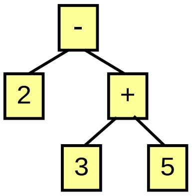


Review: Concrete Syntax

- Concrete syntax is comparatively "arbitrary"

```
<num> ::= 1 | 2 | 3 | ...
<exp> ::= <num>
        | <exp> <exp> +
        | <exp> <exp> -
        | <exp> <exp> *
```

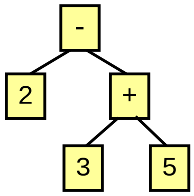
```
2 3 5 + -
```



Abstract Syntax

- Abstract syntax can be specified with a grammar as well
  - Doesn't matter if the grammar is ambiguous
  - We always have a *tree*, not just a string

```
n ::= 1 | 2 | 3 | ...
e ::= n | e + e
     | e - e | e * e
```



2-(3+5)

Straight-line Abstract Syntax

```
datatype binop = ... and stm = ... and exp = ...
%%
%term INT of int | ID of string | ...
%nonterm exp of exp | stm of stm | exps of exp list
%start stm
%%
stm : stm SEMICOLON stm          (CompoundStm(stm1,stm2))
    | ID ASSIGN exp              (AssignStm(ID,exp))
    | PRINT LPAREN exps RPAREN   (PrintStm(exps))
exps: exp                        ([exp])
    | exp COMMA exps             (exp :: exps)
exp : INT                        (NumExp(INT))
    | ID                         (IdExp(ID))
    | exp PLUS exp               (OpExp(exp1,Plus,exp2))
    | stm COMMA exp              (EseqExp(stm,exp))
    | LPAREN exp RPAREN          (exp)
```

Symbols (Hashable Strings)

```
signature SYMBOL =
sig
  eqtype symbol
  val symbol : string -> symbol
  val name : symbol -> string

  type 'a table
  val empty : 'a table
  val enter : 'a table * symbol * 'a -> 'a table
  val look  : 'a table * symbol -> 'a option
end
```

Tiger Abstract Syntax: L-values

```
type pos = int
and  symbol = Symbol.symbol

datatype var = SimpleVar   of symbol * pos
             | FieldVar     of var * symbol * pos
             | SubscriptVar of var * exp * pos

and oper = PlusOp | MinusOp | TimesOp | DivideOp
         | EqOp | NeqOp | LtOp | LeOp | GtOp | GeOp
```

Tiger Abstract Syntax: Exps

```
and exp = VarExp    of var
        | NilExp
        | IntExp    of int
        | StringExp of string * pos
        | CallExp   of {func: symbol, args: exp list, pos: pos}
        | OpExp     of {left: exp, oper: oper, right: exp, pos: pos}
        | RecordExp of {fields: (symbol * exp * pos) list,
                        typ: symbol, pos: pos}
        | SeqExp    of (exp * pos) list
        | AssignExp of {var: var, exp: exp, pos: pos}
        | IfExp     of {test: exp, then': exp, else': exp option,
                        pos: pos}
        | WhileExp  of {test: exp, body: exp, pos: pos}
        | ForExp    of {var: symbol, escape: bool ref,
                        lo: exp, hi: exp, body: exp, pos: pos}
        | BreakExp  of pos
        | LetExp    of {decs: dec list, body: exp, pos: pos}
        | ArrayExp  of {typ: symbol, size: exp, init: exp, pos: pos}
```

Tiger Abstract Syntax: Decs

```
and dec = FunctionDec of fundec list
        | VarDec      of {name  : symbol,
                          escape: bool ref,
                          typ   : (symbol * pos) option,
                          init  : exp,
                          pos   : pos}
        | TypeDec     of {name:symbol, ty:ty, pos:pos} list

withtype fundec = {name  : symbol,
                   params: field list,
                   result: (symbol * pos) option,
                   body  : exp,
                   pos   : pos}
     and field  = {name  : symbol, escape: bool ref,
                   typ   : symbol,  pos : pos}
```

Tiger Abstract Syntax: Types

```
and ty = NameTy   of symbol * pos
       | RecordTy of field list
       | ArrayTy  of symbol * pos

withtype field = {name  : symbol,
                  escape: bool ref,
                  typ   : symbol,
                  pos   : pos}
```

Example

- The Tiger program

```
(a := 5; a+1)
```

translates to

```
SeqExp[(AssignExp{var=SimpleVar(symbol "a", 2),
                  exp=IntExp 5,
                  pos=4},2),
       (OpExp{left=VarExp(SimpleVar(symbol "a", 10)),
              oper=PlusOp,
              right=IntExp 1,
              pos=11},10)]
```

Positions

- In semantic actions, the ML code can get not just values associated with tokens, but also their start/end positions in the source code
  - Instead of "`exp`" or "`exp1`" or "`exp2`"
  - Write "`expleft`" "`expright`", "`exp1left`", "`exp1right`", "`exp2left`", "`exp2right`"
- The abstract syntax tree contains only a single character position for each node
  - Choosing this is a "matter of taste"

A Final Digression

- In the SML language one can dynamically make operators infix:

```
fun plus(n:int,m:int) = n+m
val x = plus (3,4)
infix 4 plus
val y = 1 plus 2
```

- How is this handled in ML-Yacc?