Principles of Programming Languages

COMP251: Lex (Flex) and Yacc (Bison)

Prof. Dekai Wu

Department of Computer Science and Engineering
The Hong Kong University of Science and Technology
Hong Kong, China

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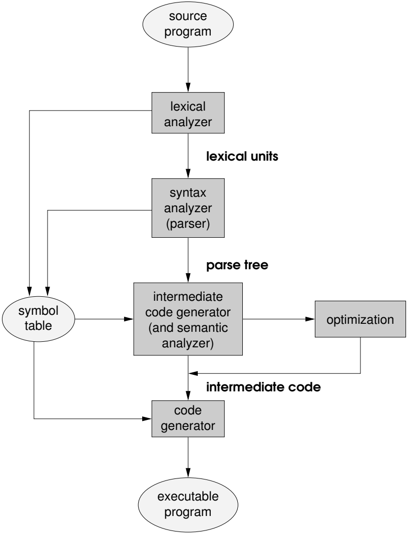
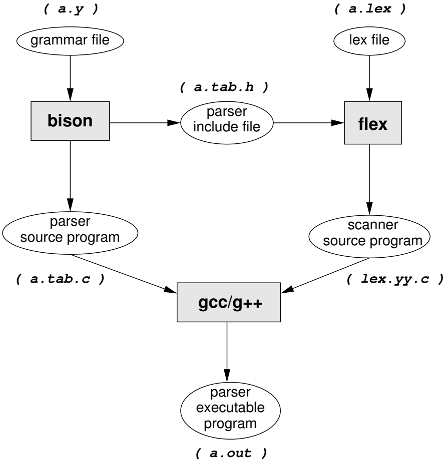
Part II

bison

Compilation (a revisit)



Syntax Analysis using bison and flex



bison : a Parser Generator

- bison is GNU's extended version of the standard UNIX utility yacc, that generates a parser for a given CFG. It is backward compatible with yacc (Yet Another Compiler Compiler), which was perhaps the first popular parser generator.
- bison reads a description of a CFG written in a bison Grammar File, and output a C program containing a routine called `yyparse()`.
- The default name of the output C program is `*.tab.c`. Compile `*.tab.c` to `a.out` which will be the parser.
- bison can only parse a subset of CFGs called LALR(1) grammars, using a bottom-up parsing algorithm with one look-ahead token.
- bison only generates a parser and does NOT provide a scanner automatically. To get both a parser and a scanner:
  - run both bison and flex
  - put the lexical analysis code in the section Additional C Code.

bison Grammar File Format

```
%{
C Declarations
%}

bison Declarations

%%
Grammar Rules + Actions
%%

Additional C Codes
```

- Similar to flex, any statements between the %{ and %}, as well as any additional C code will be copied verbatim to the output.

bison Example 1: Reverse Polish Notation Calculator

```
%{
#define YYSTYPE double
#include <math.h>
%}

%token NUM

%% /* grammar rules and actions follow */
input: /* empty */
     | input line
     ;

line: '\n'
    | exp '\n' { printf("\t%.10g\n", $1); }
    ;

exp: NUM { $$ = $1; }
   | exp exp '+' { $$ = $1 + $2; }
   | exp exp '-' { $$ = $1 - $2; }
   | exp exp '*' { $$ = $1 * $2; }
   | exp exp '/' { $$ = $1 / $2; }
   | exp exp '^' { $$ = pow($1, $2); }
   | exp 'n' { $$ = -$1; }
   ;
%%
```

bison Example 1 ..

```
/* additional C code */
#include <ctype.h>
#include <stdio.h>

int yylex(void)
{
    int c;

    while ((c = getchar()) == ' ' || c == '\t') ; /* skip white spaces */

    if (c == '.' || isdigit(c)) {
        /* process numbers */
        ungetc(c, stdin);
        scanf("%lf", &yylval);
        return NUM;
    }

    if (c == EOF) return 0;
    return c;
}

int main() { return yyparse(); }

int yyerror(const char* s) { printf("%s\n", s); return 0; }
```

bison Grammar File

1. C Declarations
   - define types and variables
   - `#define`'s and `#include`'s
2. bison Declarations
   - declares names of the terminals/non-terminals symbols
   - describe operator precedence and associativity
   - data types of semantic values of variables
3. Grammar Rules
   - production rules of the CFG
4. Additional C code
   - definition of `yylex()`
   - definition of `yyerror()` and other supporting routines

Description of bison Grammar Rules

- Three ways to represent terminals:
  1. character literals. e.g. '+' for the + operator.
  2. C string constants. e.g. "else" for the keyword **else**.
  3. C-like identifiers. e.g. NUM (for numbers). The convention is to write it in upper case.
- Non-terminals are represented as C-like identifiers. The convention is to write them in lower case.
  e.g. exp for `<Expression>`.
- Use : to represent ::=.
- A rule ends with a ';'.
- Example of a (production) rule in bison:

```
if-stmt : "if" bool-expr "then" stmt ';'
        | "if" bool-expr "then" stmt "else" stmt ';'
        ;
```

Type and Semantic Value

- Most terminals or tokens have
  1. a type
  2. a semantic value

  e.g. the integer 123 has:

type	:	INTEGER
semantic value	:	one hundred twenty-three

- But *some* terminals do NOT. e.g. operator '+'.
- Non-terminals also have semantic values. e.g.
  - the semantic value of a math expression (e.g. $E = a + b$) is a real number — result computed from its constituents.
  - the semantic value of a compiled statement is a parse tree.

Semantic Actions

- Define the semantics of a program!
- Compute the semantic value of the non-terminal on the LHS of a grammar production rule based on the semantic values of the terminals and non-terminals on the RHS of the rule.
  For example,

```
expr : expr '+' term    { $$ = $1 + $3 }
```

  where

```
$$ = semantic value of ``expr'' on the LHS.
$1 = semantic value of the 1st token on the
     RHS, which is the non-terminal ``expr''.
$3 = semantic value of the 3rd token on the
     RHS, which is the non-terminal ``term''.
```

bison Types, Variables, Functions

Entity	Meaning
YYSTYPE	macro for the token type (default: int)
extern YYSTYPE yylval	value of an input token
extern int yyparse(void)	parser function
extern int yyerror(const char*)	error reporting function

- When no action is specified, the default action is: `$$ = $1`.
- Token type code of EOF = any non-positive value (including 0).

bison Example 1 again: rpn-calc.y

```
%{
#define YYSTYPE double
#include <math.h>
#include <stdio.h>
%}

%token NUM

%% /* Grammar rules and actions follow */
input: /* empty */
     | input line
     ;
line: '\n'
    | exp '\n' { printf("\t%.10g\n", $1); }
    ;
exp: NUM { $$ = $1; }
   | exp exp '+' { $$ = $1 + $2; }
   | exp exp '-' { $$ = $1 - $2; }
   | exp exp '*' { $$ = $1 * $2; }
   | exp exp '/' { $$ = $1 / $2; }
   | exp exp '^' { $$ = pow($1, $2); }
   | exp 'n' { $$ = -$1; }
   ;
%%

int main() { return yyparse(); }
int yyerror(const char* s) { printf("%s\n", s); return 0; }
```

bison Example 1 again: rpn-calc.tab.h

```
bison -d rpn-calc.y
```

produces 2 files:

- rpn-calc.tab.h: Some C declarations needed by the lex file
- rpn-calc.tab.c: Source program of the parser

```
#ifndef YYSTYPE
#define YYSTYPE int
#endif
#define NUM 257

extern YYSTYPE yylval;
```

bison Example 1 again: rpn-calc.lex

```
%option noyywrap

%{
#define YYSTYPE double      /* type for bison's var: yylval */
#include <stdlib.h>         /* for atof(const char*) */
#include "rpn-calc.tab.h"
%}

digits [0-9]
rn     (0|[1-9]+{digits}*)\.?{digits}*
op     [+*^n/\-]
ws     [ \t]+

%%
{rn}    yylval = atof(yytext); return NUM;
{op}    |
\n      return *yytext;
{ws}    /* eats up white spaces */
%%

/* There is NO main function! */
```

bison Example 2: Infix-Notation Calculator

```
%{
#define YYSTYPE double
#include <math.h>
#include <stdio.h>
%}

%token NUM
%left '-' '+'
%left '*' '/'
%left NEG
%right '^'

%% /* Grammar rules and actions follow */
input:     /* empty */ | input line ;
line:      '\n' | exp '\n' { printf("\t%.10g\n", $1); } ;
exp: NUM { $$ = $1; }
   | exp '+' exp { $$ = $1 + $3; }
   | exp '-' exp { $$ = $1 - $3; }
   | exp '*' exp { $$ = $1 * $3; }
   | exp '/' exp { $$ = $1 / $3; }
   | '-' exp %prec NEG { $$ = -$2; }
   | exp '^' exp { $$ = pow($1, $3); }
   | '(' exp ')' { $$ = $2; } ;
%%

int main() { return yyparse(); }
int yyerror(const char* s) { printf("%s\n", s); return 0; }
```