Yacc

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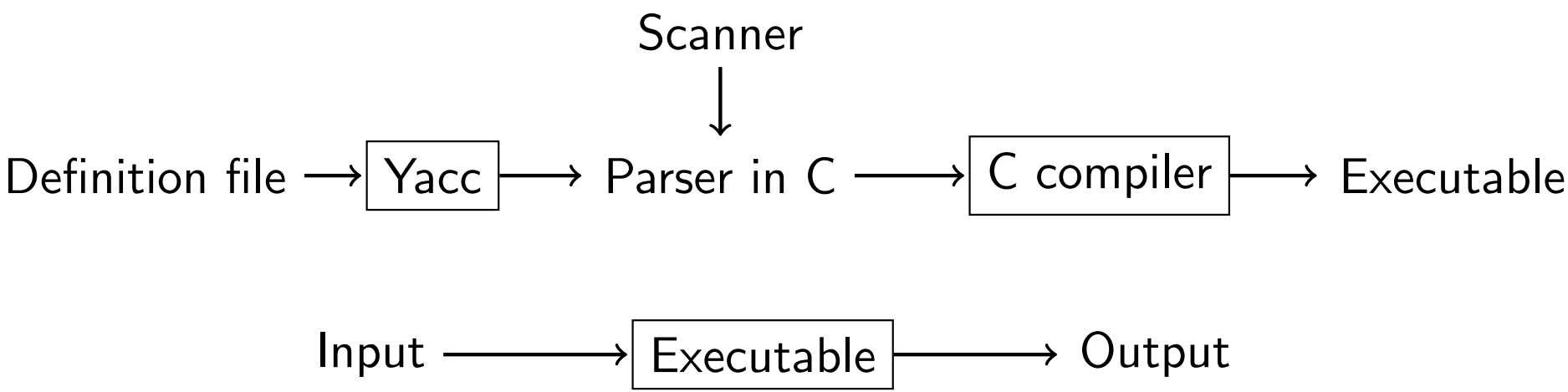
Yacc

- tool for generating parsers
- parser described by context-free productions in a definition file
- scanner has to be provided (written manually or generated by Lex)
- Yacc processes the definition file and outputs a parser written in C
- this parser can be compiled by a C compiler to produce an executable
- the executable performs (LALR) bottom up parsing of its input and performs associated actions to produce its output



Structure of Definition File I

Structure of Definition File

```
%{
  Prologue
%}

Yacc declarations

%%
Grammar rules
%%

Epilogue
```

Structure of Definition File II

- Yacc definition file divided into 3 parts which are separated by %%

Parts of Definition File

1. prologue and declarations
   - prologue
     - enclosed within %{ %}
     - contains any C code needed in actions (macros, function prototypes)
     - several prologues can be mixed with Yacc declarations
   - declarations
     - specification of nonterminals, tokens, operator precedence, value types and others
2. grammar rules
   - specification of grammar rules and associated actions performed when a rule is used in a reduction
3. epilogue
   - any other code (typically definitions of `main()`, `yylex()`, `yyerror()`)

Token Types

- defined by `%token`, `%left`, `%right`, or `%nonassoc` in the declarations part
- by convention, token name should be upper case

  ```
  %token NUM
  ```

- internally represented as C macros which assign a numerical code to every token type
- literal character tokens (`'+'`) and literal string tokens (`"<="`) do not have to be declared
- associativity defined by `%left`, `%right` and `%nonassoc`
- precedence defined by the order of their definition, lowest first

  ```
  %left '-' '+'   /* lowest precedence */
  %left '*' '/'
  %left NEG
  %right '^'      /* highest precedence */
  ```

Attributes

Attribute Types

1. if all tokens (and all semantic values) have the same type of their attributes, `YYSTYPE` macro can be used

```
%{
  #define YYSTYPE double
%}

%token NUM
```

2. if there are more types, all possible types defined by `%union`

```
%union {
  double val;
  symrec *tptr;
}
```

Attribute Type Assignment

Terminal Type Assignment

- each token is assigned its attribute type by putting <type> in its definition

```
%union {
  double val;
  symrec *tptr;
}

%token <val> NUM
```

Nonterminal Type Assignment

- if %union is used, each nonterminal has to be assigned the type of its semantic value

```
%type <val> expr1 expr2
```

Other Declarations I

`%initial-action`

- allows to perform some initial actions before `yyparse` is called
- `$$`, `@$` and arguments of `%parse-param` can be used

Example

```
%parse-param { char const *file_name };

%initial-action
{
  @$.initialize (file_name);
};
```

Other Declarations II

`%destructor`

- called when symbols are discarded to properly deallocate the memory (during error recovery, when the parser succeeds)

  ```
  %destructor { code } symbols
  ```

- $$ designates the semantic value associated with the discarded symbol
- invoked when user actions cannot change the memory
  1. stacked symbols popped during the first phase of error recovery
  2. incoming terminals during the second phase of error recovery
  3. the current look-ahead and the entire stack when the parser returns immediately
  4. the start symbol, when the parser succeeds

```
%union { char *string; }
%type  <string> STRING
%destructor { free($$); } STRING
```

Other Declarations III

`%defines`

- write a header file containing macro definitions for token type names defined in the grammar
- used by `yylex` if it is in another file
- if parser output file is `name.c` then the header file is `name.h`

`%start`

- possible to specify the start symbol

  ```
  %start S
  ```

- by default, the first rule's left-hand side is the start symbol

Grammar Rules

- consider the following context-free rules:

$$exp \longrightarrow \varepsilon$$
$$exp \longrightarrow exp + exp$$
$$exp \longrightarrow exp - exp$$
$$exp \longrightarrow exp * exp$$
$$exp \longrightarrow exp/exp$$

- in definition file, these rules are represented as follows:

```
exp:                    /* empty line = empty string */
     | exp '+' exp      /* | means alternative rhs */
     | exp '-' exp             /* for the same lhs */
     | exp '*' exp
     | exp '/' exp
       ;                /* end of rule */
```

- actions can be scattered among the symbols of the right-hand side
- rules in the grammar should be left recursive

Context-Dependent Precedence

%prec Modifier

- used to set priority when one operator is used for several functions (e.g. unary minus $\times$ binary minus)

```
%left '+' '-'
%left '*'
%left UMIN
/* dummy operator with the highest priority */

exp:    exp '+' exp          { }
      | exp '-' exp          { }
      | exp '*' exp          { }
      | '-' exp %prec UMIN   { }
/* in this context '-' has the same priority as UMIN */
        ;
```

Actions

- actions appear between { } anywhere on the right-hand side of a rule
- usually at the end of a rule

Semantic Values of Rule Components

`$$` semantic value of the nonterminal on the left-hand side

`$n` semantic value of the *n*th symbol on the right-hand side

- default action is `$$ = $1`
- if there are different types of semantic values (specified by `%union`), `$<type>$` and `$<type>n` have to be used

Example

```
exp:   NUM           /* default action: $$ = $1 */
     | exp '+' exp   { $$ = $1 + $3; }          ;
```

Locations I

- used to track locations of currently processed tokens in the input file
- useful for generating error messages

`YYLTYPE` **structure**

- for each token, the scanner has to save its position to the variable `yylloc` which is of the type `YYLTYPE`

```
typedef struct YYLTYPE
{
  int first_line;
  int first_column;
  int last_line;
  int last_column;
} YYLTYPE;
```

Locations II

Location Values of Rule Components

- in parser, access similar to semantic values:
  `@$` location of the nonterminal on the left-hand side
  `@n` location of the *n*th symbol on the right-hand side

Default Action for Locations

- executed each time a rule is matched
- by default, it sets the beginning of `@$` to the beginning of the first symbol, and the end of `@$` to the end of the last symbol on the rule's right-hand side – sufficient for most parsers
- can be redefined by `YYLLOC_DEFAULT` macro

Generated Parser

`int yyparse()`

- parses the input file
- returns 0 if parsing was successful, 1 if there was a syntax error, 2 if memory was exhausted
- in actions, `YYACCEPT` can be used to return 0 and `YYABORT` to return 1

`int yylex()`

- has to be provided by the user (written manually or by using Lex)
- returns token type
- attribute is stored in the global variable `yylval`
  - when using multiple attribute types (specified by `%union`), the corresponding member has to be used

```
yylval.intval = value; /* put value onto Yacc stack */
return INT;            /* return the type of the token */
```

Error Reporting and Recovery

```
void yyerror(char const *s)
```

- has to be provided by the user
- usually of the following form:

```
void yyerror (char const *s)
{
  fprintf (stderr, "%s\n", s);
}
```

Error Recovery

- special token `error` which is generated when no rule can be used
- if there is a rule with the `error` token, parsing can recover
- can be explicitly invoked by `YYERROR` macro

Error Recovery

Example

```
stmnts:   /* empty string */
        | stmnts '\n'
        | stmnts exp '\n'
        | stmnts error '\n'   { yyerrok; }
          ;
```

- if there is an error in `exp`, recovery is performed as follows:
  1. tokens from `exp` which are already on the stack are discarded
  2. `error` is shifted
  3. input symbols are discarded until `'\n'` is the current input token

- by default, error messages are suppressed until 3 tokens successfully shifted – to avoid this `yyerrok` can be used

Command Line Options

```
bison [OPTION]... FILE
```

Selected Parameters

`-o outf` output file name

`-p pref` specifies other prefix than `yy` for Yacc functions

`-d` same as `%defines`

Options Within Definition File

- many options can be specified within the declarations part of the definition file

  `%defines`

Example I

Example

```
/* Reverse polish notation calculator.  */

%{
  #define YYSTYPE double
  #include <math.h>
  #include <ctype.h>
  #include <stdio.h>
  int yylex (void);
  void yyerror (char const *);
%}

%token NUM

%% /* Grammar rules and actions follow.  */
```

Example II

Example

```
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; } /* Unary minus */
;
```

Example III

Example

```
%% /* Epilogue follows.  */

/* The lexical analyzer returns a double floating point
   number on the stack and the token NUM, or the numeric
   code of the character read if not a number. It skips
   all blanks and tabs, and returns 0 for end-of-input. */

   int yylex (void)
   {
     int c;

     /* Skip white space.  */
     while ((c = getchar ()) == ' ' || c == '\t')
       ;
```

Example IV

Example

```
  /* Process numbers.  */
  if (c == '.' || isdigit (c))
    {
      ungetc (c, stdin);
      scanf ("%lf", &yylval);
      return NUM;
    }
  /* Return end-of-input.  */
  if (c == EOF)
    return 0;
  /* Return a single char.  */
  return c;
}
```

Example V

Example

```
/* Called by yyparse on error.  */
void yyerror (char const *s)
{
  fprintf (stderr, "%s\n", s);
}

int main (void)
{
  return yyparse ();
}
```

Bibliography


Bison documentation.
http://www.gnu.org/software/bison/manual/index.html.