Project 2: Yacc Programming

Introduction to Compilers
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Contents

1 Introduction

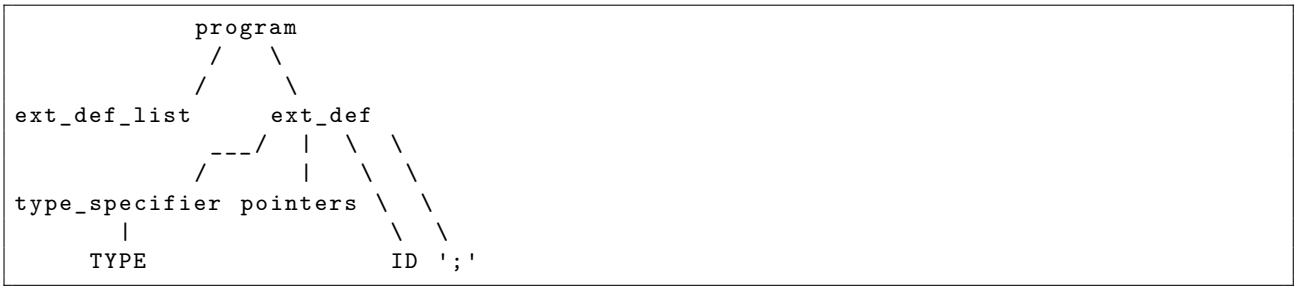
1.1 Parsing

Syntactic analysis, also known as parsing, is the process of revealing the grammatical structure of a program by analyzing a sequence of tokens according to the language's grammar. This process is handled by the syntactic analyzer, also known as the parser. The parser accepts tokens analyzed by the lexer and finds a possible derivation in the grammar rules to build a structural representation of the program. This representation, known as the intermediate representation (IR), can take various forms such as a parse tree, an abstract syntax tree (AST), or intermediate code, which is widely adopted in modern compilers.

For example, consider the following code as an input program.

```
int a;
```

Then the lexer tokenizes it into `TYPE, ID, ';'`. The parser analyzes the structure of the program using these tokens. It finally builds a parse tree just like the following diagram.



Since the syntactic analysis was successful, now we can determine that the input program is grammatically correct. In this project, we will build a parser that can accept and analyze programs conforming to the subC grammar.

1.2 Building Parsers

Parser generators can automatically build a parser with only a few lines of grammar rules. Similarly to lexers, there is no need to build a parser from scratch. GNU Bison is a widely used open-source LALR parser generator which is upward compatible with POSIX yacc (Yet Another Compiler-Compiler), a standard parser generator on Unix. Throughout this course, we will utilize Bison to generate parsers for subC.

2 Setting up the Project Environment

2.1 Pull the repository

Attach to the container and pull the repository to set up the environment for this project.

```
docker exec -it intcmp_2025 bash
cd intcmp-2025
git pull
```

2.2 How to build and test

Navigate to the `src` directory, and build the project using `make` command.

```
cd ./src
make all
```

Once the build is completed, you can test it with the following command. If you do not specify the `[input_file]`, `stdin` will be used as the input stream.

```
./subc [input_file]
```

3 Different Features of subC from the Standard C

- No `typedef`.
- No `union`.
- No multi-dimensional array.
- No pointer to a function.
- No forward declarations.
- No `long`, `short`, `float`, `double`, `unsigned`, `void`.
- Only `int` and `char` built-in data types.
- Definitions of structures and functions are only allowed in the global scope.
- Allow nested comments (not a parsing issue).
- No explicit type conversion.
- Strong type checking (semantic analysis issue, not a parsing one).

4 Grammar of subC

This section demonstrates the incomplete grammar of our toy language, subC.

Unlike project #1, please note that `float` *and* `..` *are removed in this project. Float constants are also deprecated.*

4.1 Symbols

'Symbol name' refers to terminal symbols that used in the parser to recognize each terminals, and 'Symbol' is an actual token read by the lexer.

Symbol Name	Symbol
TYPE	int, char
ID	an identifier
STRUCT	struct
SYM_NULL	NULL
RETURN	return
INTEGER_CONST	an integer constant
CHAR_CONST	a character constant
STRING	a string constant
IF	if
ELSE	else
WHILE	while
FOR	for
BREAK	break
CONTINUE	continue
LOGICAL_OR	||
LOGICAL_AND	&&
RELOP	<, <=, >, >=
EQUOP	==, !=
INCOP	++
DECOP	--
STRUCTOP	->

4.2 Operator Precedence and Associativity

The operators assigned with the same precedence level are evaluated with the equal precedence, even if they are split across multiple rows.

Precedence	Operator	Name	Associativity
1	++ -- ( ) . ->	Suffix increment/decrement Function call and grouping Structure member access Structure member access through pointer	Left
2	++ -- - ! * &	Prefix increment/decrement Unary minus Logical NOT Indirection (dereference) Address-of	Right
3	* / %	Multiplication, division, and remainder	Left
4	+ -	Addition and subtraction	Left
5	< <= > >=	Less-than and less-than-or-equal Greater-than and greater-than-or-equal	Left
6	== !=	Equal and not-equal	Left
7	&&	Logical AND	Left
8	||	Logical OR	Left
9	=	Assignment	Right
10	,	Comma	Left

4.3 Productions

The following productions are written in the syntax of Bison grammar rules.

```
program
  : ext_def_list
  ;
```

```
ext_def_list
  : ext_def_list ext_def
  | %empty
  ;

ext_def
  : type_specifier pointers ID ';'
  | type_specifier pointers ID '[' INTEGER_CONST ']' ';'
  | struct_specifier ';'
  | func_decl compound_stmt
  ;

type_specifier
  : TYPE
  | struct_specifier
  ;

struct_specifier
  : STRUCT ID '{' def_list '}'
  | STRUCT ID
  ;

func_decl
  : type_specifier pointers ID '(' ')'
  | type_specifier pointers ID '(' param_list ')'
  ;

pointers
  : '*'
  | %empty
  ;

param_list
  : param_decl
  | param_list ',' param_decl
  ;

param_decl
  : type_specifier pointers ID
  | type_specifier pointers ID '[' INTEGER_CONST ']'
  ;

def_list
  : def_list def
  | %empty
  ;

def
  : type_specifier pointers ID ';'
  | type_specifier pointers ID '[' INTEGER_CONST ']' ';'
  ;

compound_stmt
  : '{' def_list stmt_list '}'
  ;

stmt_list
  : stmt_list stmt
  | %empty
  ;

stmt
  : expr ';'
  | compound_stmt
  | RETURN ';'
  | RETURN expr ';'
```

```
  | ';'
  | IF '(' expr ')' stmt
  | IF '(' expr ')' stmt ELSE stmt
  | WHILE '(' expr ')' stmt
  | FOR '(' expr_e ';' expr_e ';' expr_e ')' stmt
  | BREAK ';'
  | CONTINUE ';'
  ;

expr_e
  : expr
  | %empty
  ;

expr
  : unary '=' expr
  | binary
  ;

binary
  : binary RELOP binary
  | binary EQUOP binary
  | binary '+' binary
  | binary '-' binary
  | binary '*' binary
  | binary '/' binary
  | binary '%' binary
  | unary %prec '='
  | binary LOGICAL_AND binary
  | binary LOGICAL_OR binary
  ;

unary
  : '(' expr ')'
  | INTEGER_CONST
  | CHAR_CONST
  | STRING
  | ID
  | '-' unary %prec '!'
  | '!' unary
  | unary INCOP
  | unary DECOP
  | INCOP unary
  | DECOP unary
  | '&' unary
  | '*' unary %prec '!'
  | unary '[' expr ']'
  | unary '.' ID
  | unary STRUCTOP ID
  | unary '(' args ')'
  | unary '(' ')'
  | SYM_NULL
  ;

args
  : expr
  | args ',' expr
  ;
```

5 Goal of the Project

You have to build a parser using Bison, which accepts the subC grammar and prints the production at each reduction.

Complete the code in `subc.l`, `subc.y`, and `hash.c`. You may add or modify any files in the `src` directory as

needed, but please make sure that the project can be built using `make all` command.

The provided grammar is incomplete, which means that there are some conflicts. Carefully inspect and resolve those conflicts. By adding the `-Wcounterexamples` flag, Bison will provide some counterexamples that can help you resolve conflicts. In the report, briefly describe the type of each conflict (reduce-reduce/shift-reduce) and how you resolved it in two pages or less. **Modifying the productions of the grammar is prohibited.** Please resolve the conflicts by adjusting only the precedence and associativity rules.

5.1 Output format

At each reduction, print the grammar rule used for reduction to stdout. A demonstrative example of an input-output pair is given below. Please double-check before submission, as there is a high chance of making a typo.

Disregarding the output rules will result in a penalty to your project score.

I/O Example

Input: `./examples/open_test.c`

```
int main(){
  int a;
  char b;

  a = 10;
  b = 5;

  if (a==10 || b==5) {
    return 1;
  } else {
    return 0;
  }
}
```

Output:

```
$ ./subc ../examples/open_test.c
ext_def_list->epsilon
type_specifier->TYPE
pointers->epsilon
func_decl->type_specifier pointers ID '(' ')'
def_list->epsilon
type_specifier->TYPE
pointers->epsilon
def->type_specifier pointers ID ';'
def_list->def_list def
type_specifier->TYPE
pointers->epsilon
def->type_specifier pointers ID ';'
def_list->def_list def
stmt_list->epsilon
unary->ID
unary->INTEGER_CONST
binary->unary
expr->binary
expr->unary '=' expr
stmt->expr ';'
stmt_list->stmt_list stmt
unary->ID
unary->INTEGER_CONST
binary->unary
expr->binary
expr->unary '=' expr
stmt->expr ';'
stmt_list->stmt_list stmt
unary->ID
```

```
binary->unary
unary->INTEGER_CONST
binary->unary
binary->binary EQUOP binary
unary->ID
binary->unary
unary->INTEGER_CONST
binary->unary
binary->binary EQUOP binary
binary->binary LOGICAL_OR binary
expr->binary
def_list->epsilon
stmt_list->epsilon
unary->INTEGER_CONST
binary->unary
expr->binary
stmt->RETURN expr ';'
stmt_list->stmt_list stmt
compound_stmt->'{' def_list stmt_list '}'
stmt->compound_stmt
def_list->epsilon
stmt_list->epsilon
unary->INTEGER_CONST
binary->unary
expr->binary
stmt->RETURN expr ';'
stmt_list->stmt_list stmt
compound_stmt->'{' def_list stmt_list '}'
stmt->compound_stmt
stmt->IF '(' expr ')' stmt ELSE stmt
stmt_list->stmt_list stmt
compound_stmt->'{' def_list stmt_list '}'
ext_def->func_decl compound_stmt
ext_def_list->ext_def_list ext_def
program->ext_def_list
```

6 Submission

- Place your report somewhere in the project directory. The file name must be `report.pdf`.
- Run `./submit.sh <student_number>` in the container. For example, `./submit.sh 1234-56789`. It will compress `src` directory and `report.pdf`.
- Submit the compressed archive on eTL.
- Please make sure that the name of the archive is `project2_<student_number>.zip` and your student number is correct. **Incorrect student number may result in a penalty to your project score.**
- For delayed submissions, there will be a 20% deduction in scores per day.

Appendix

GNU Bison Manual

Yash (VS Code extension for Flex/Bison syntax highlighting)