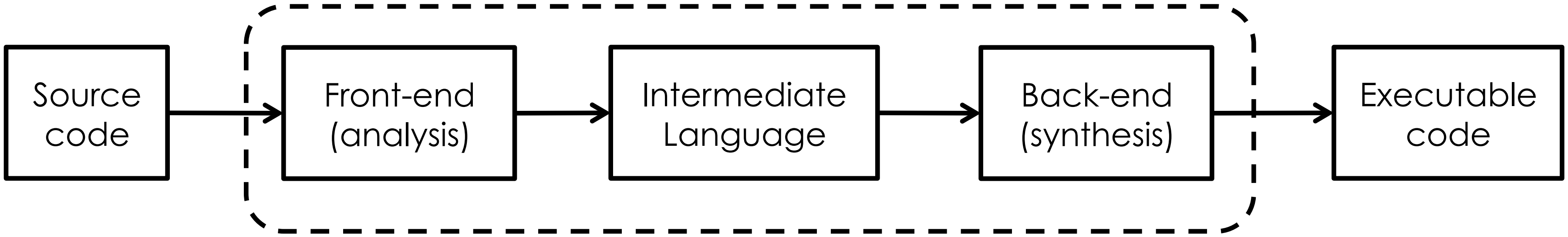
Lexer and parser generators

Lecture 3

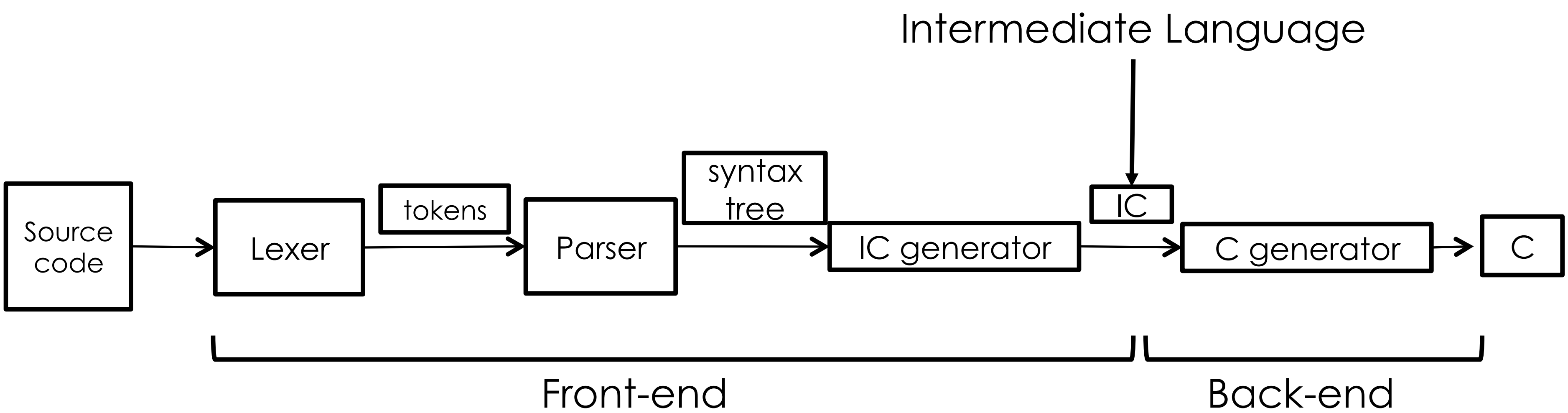
Formal Languages and Compilers 2011

Nataliia Bielova

Structure of a compiler



Front-end structure



Lexical analyzer (lexer)

- Input: program in source language
- Output: sequence of tokens (or error)

- Example:

17+3*2 → | 17 | + | 3 | * | 2 |

ocamllex

Generator of lexical analyzer

- Input: “semantic operations” associate with regular expressions
- Output: lexer
- Invocation:

  ocamllex <myfile>.mll

  produces <myfile>.ml with the code of the lexer

Regular expressions

‘a’	simple character
“string”	string
eof	end of file
_	(underscore) any character
[‘d’ -’ g’ ‘m’ -’ s’]	character set
[^ ‘a’ -’ c ‘ ‘t’ -’ z’]	“negated character set”
expr1 # expr2	difference (of two sets)
expr*	zero or more expr
expr+	one or more expr
expr?	zero or one expr
expr1 | expr2	either expr1 or expr2
expr1 expr2	expr1 followed by expr2
expr as ident	bind the matched string to ident

Semantic operations

- Can contain any OCaml code which returns a value AND
- Utility of the library Lexing:

Lexing.lexeme lexbuf	string recognized by regexp
Lexing.lexeme_char lexbuf n	n-th character of the matched string
Lexing.lexeme_start lexbuf	position in which the matched string starts

…

Example: calc_lexer.mll

```
{  open Calc_parser (* the type token is in the module calc_parser.mly *)
   exception Eof
}
let white_space = [' ']
rule token = parse
     white_space             { token lexbuf }   (* skip the white space *)
   | ['\n']                  { EOL }
   | ['0'-'9']+ as lxm       { INT(int_of_string lxm ) }
   | '+'                     { PLUS }
   | '*'                     { TIMES }
   | eof                     { raise Eof }
```

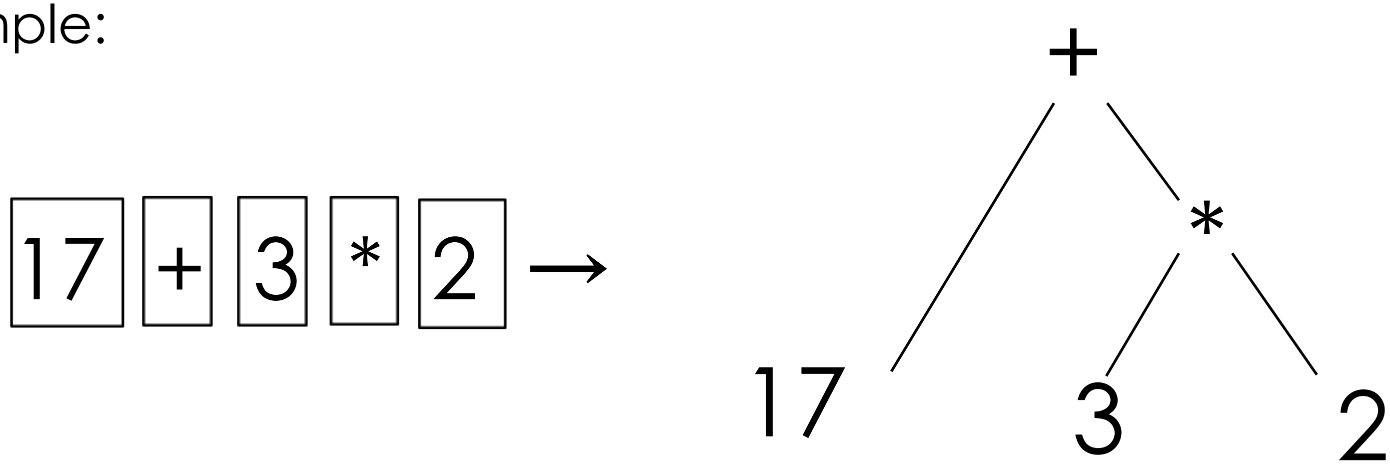
Structure of the .mll file

```
(* header section *)
   { header }

(* definitions section *)
   let ident = regexp
   let ...

(* rules section *)
   rule entrypoint [arg1... argn] = parse
             | pattern { action }
             | ...
             | pattern { action }
   and entrypoint [arg1... argn] = parse
             ...
   and ...

(* trailer section *)
   { trailer }
```

Syntactical analyzer (parser)

- Input: sequence of tokens (from lexer)
- Output: parse tree (or syntax tree)

Example:



ocamlyacc

- Generator of syntactic analyzer (*Yet Another Compiler Compiler*)
- Input: semantic actions associate with context-free grammar
- Output: parser
- Invocation:

  ocamlyacc <myfile>.mly

  produces <myfile>.ml with the code of the parser

Grammar and semantic actions

- Context-free grammar: puts together terminal and non-terminal symbols

  e.g. expr PLUS expr

- Semantic action: Ocaml code that does the job

Structure of the .mly file

```
%{
   header (OCaml code)
%}
   declarations  (%token,  %type,  ...)>
%%
   rules  (symbol {semantic action})>
%%
   trailer  (Ocaml code)
```

Comments are enclosed between /* and */ (as in C) in the "declarations" and "rules" sections, and between (* and *) (as in Caml) in the "header" and "trailer" sections.

Declarations

%token *name… name* /* *terminal symbols* */

%token < *type*> *name… name* /* *terminal symbols of specific type*/

%start *symbol … symbol* /* *nonterminal starting symbol,, for which type should be defined*/

%type < *type*> *symbol … symbol* /* *declare type of nonterminal symbol* */

%left *symbol … symbol*

%right *symbol … symbol*

%nonassoc *symbol … symbol*

Rules

nonterminal :
    symbol … symbol { semantic-action }
    | …
    | symbol … symbol { semantic-action }
;

Semantic actions

- are arbitrary Caml expressions
- can access the semantic attributes with the $ notation:
  expr PLUS expr { $1 + $3 }

Example: calc_parser.mly

```
%token <int> INT
%token PLUS TIMES
%token EOL
%left PLUS   /* lower precedence */
%left TIMES  /* higher precedence */

%start main
%type <int> main

%%
main:
    expr EOL              { $1 }
;
expr:
     INT                  { $1 }
    | expr PLUS expr      { $1 + $3 }
    | expr TIMES expr     { $1 * $3 } ;
```

Calculator

http://disi.unitn.it/~bielova/flc/exercises/03-Calculator.zip

- Definition of the lexer: calc_lexer.mll
- Definition of the parser: calc_parser.mly
- Main program: calc_main.ml

Compilation:

```
ocamllex  calc_lexer.mll  #  generates  calc_lexer.ml
ocamlyacc  calc_parser.mly  #  generates  calc_parser.ml  and  calc_parser.mli
ocamlc  -c  calc_parser.mli
ocamlc  -c  calc_lexer.ml
ocamlc  -c  calc_parser.ml
ocamlc  -c  calc_main.ml
ocamlc  -o  calc calc_lexer.cmo  calc_parser.cmo  calc_main.cmo
./calc
```

Excercise

Extend the calculator with:

- Add tabulations to the white spaces
- Add subtraction and division
- Add unary function “-”
- Parenthesis
- Change the syntax to prefix syntax:

  + * 3 4 5 = 17
- Add an operator with arbitrary number of operands:

  (+ (* 1 2 3) 4 5) = 15
- Try whatever you like