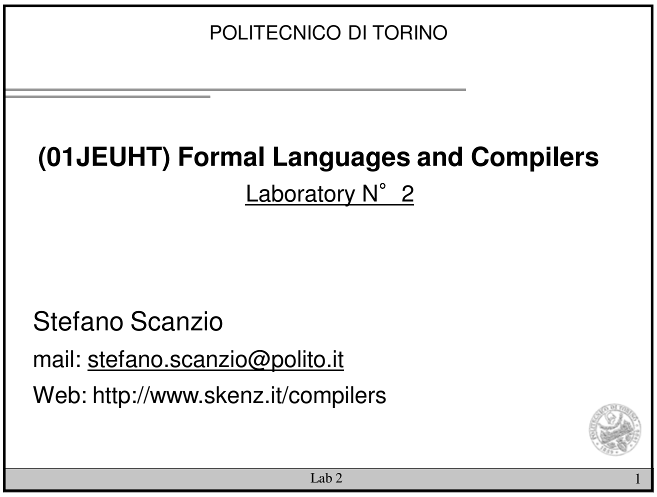

POLITECNICO DI TORINO

(01JEUHT) Formal Languages and Compilers

Laboratory N° 2

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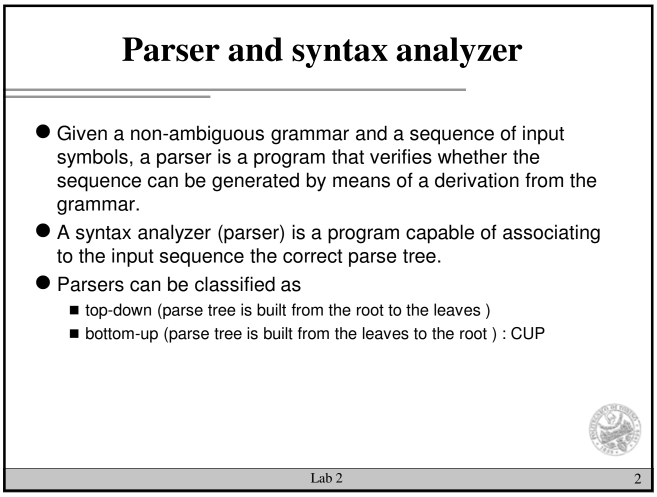
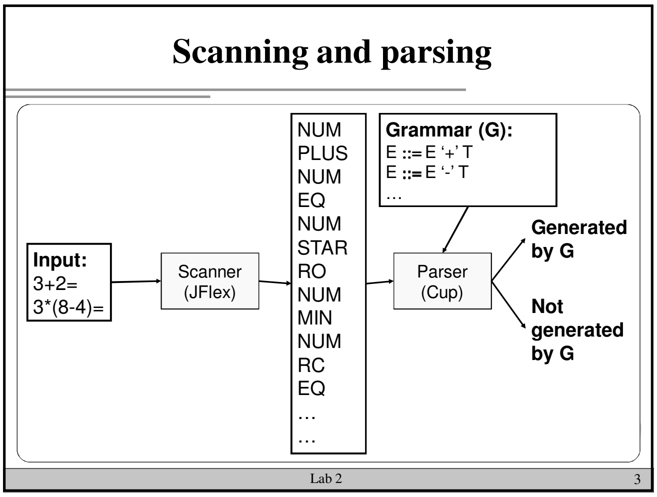
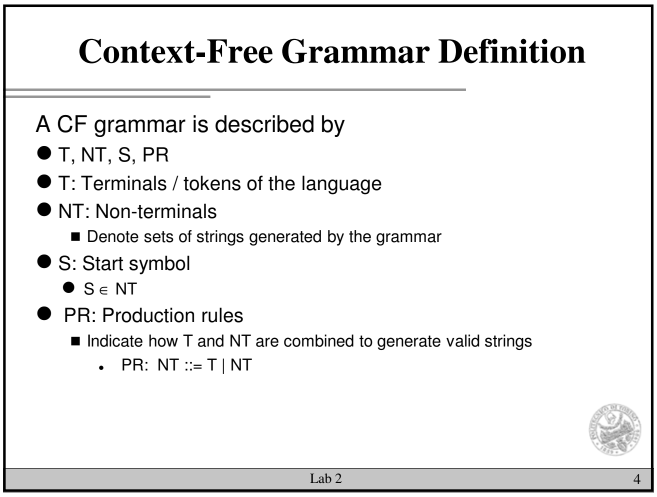


Parser and syntax analyzer

- Given a non-ambiguous grammar and a sequence of input symbols, a parser is a program that verifies whether the sequence can be generated by means of a derivation from the grammar.
- A syntax analyzer (parser) is a program capable of associating to the input sequence the correct parse tree.
- Parsers can be classified as
  - top-down (parse tree is built from the root to the leaves)
  - bottom-up (parse tree is built from the leaves to the root) : CUP



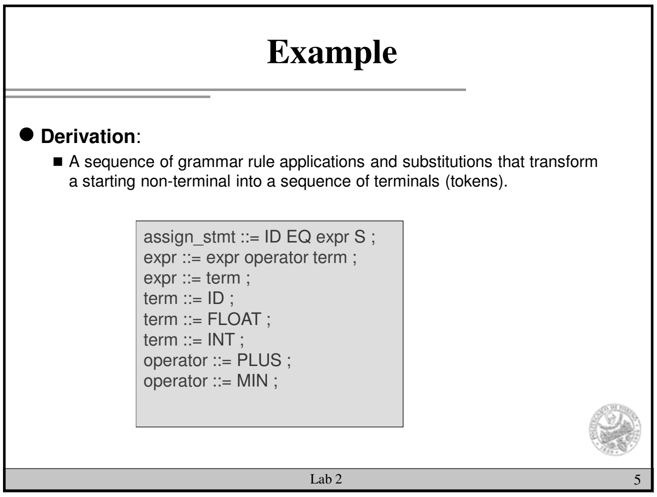
Scanning and parsing



Context-Free Grammar Definition

A CF grammar is described by

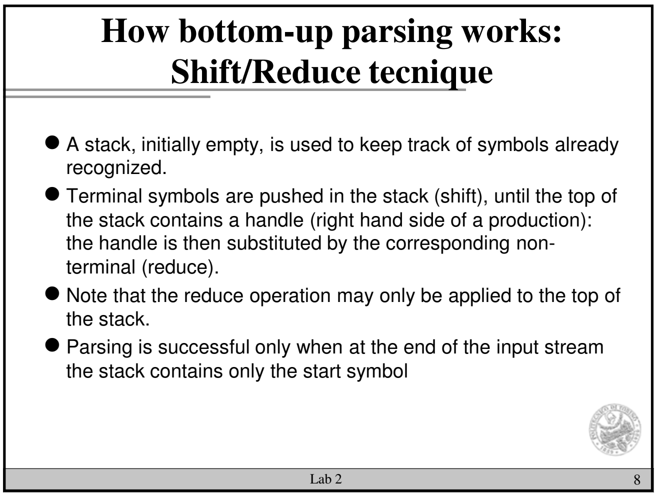
- T, NT, S, PR
- T: Terminals / tokens of the language
- NT: Non-terminals
  - Denote sets of strings generated by the grammar
- S: Start symbol
  - S ∊ NT
- PR: Production rules
  - Indicate how T and NT are combined to generate valid strings
    - PR: NT ::= T | NT



Example

- **Derivation**:
  - A sequence of grammar rule applications and substitutions that transform a starting non-terminal into a sequence of terminals (tokens).

```
assign_stmt ::= ID EQ expr S ;
expr ::= expr operator term ;
expr ::= term ;
term ::= ID ;
term ::= FLOAT ;
term ::= INT ;
operator ::= PLUS ;
operator ::= MIN ;
```



How bottom-up parsing works: Shift/Reduce tecnique

- A stack, initially empty, is used to keep track of symbols already recognized.
- Terminal symbols are pushed in the stack (shift), until the top of the stack contains a handle (right hand side of a production): the handle is then substituted by the corresponding non-terminal (reduce).
- Note that the reduce operation may only be applied to the top of the stack.
- Parsing is successful only when at the end of the input stream the stack contains only the start symbol

Parse Trees and Shift/Reduce

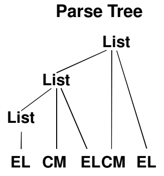
Input String:
a1 , a2 , a3

Scanner:
a1 , a2 , a3 → EL CM EL CM EL

Recursive Left Grammar

List ::= List CM EL
List ::= EL

Parse Tree



Action:	**Stack:**
	ε
Shift:	EL
Reduce:	List
Shift:	List CM
Shift:	List CM EL
Reduce:	List
Shift:	List CM
Shift:	List CM EL
Reduce:	List

Introduction to CUP

- Cup is a parser generator that transforms the definition of a context-free grammar in a Java program that parses sequences of input symbols according to the grammar itself.
- Besides defining syntax rules, it is possible to specify actions to be executed whenever a production is reduced.
- The parser must be integrated by a scanner: some conventions simplify the integration of Cup-generated parses with JFlex-generated scanners.

- Official manual:
  http://www2.cs.tum.edu/projects/cup/

Source file format

- A Cup source file has a syntax very similar to Java programs.
- It can be ideally divided in the following sections:
  - Setup
  - Terminals and non-Terminals
  - Precedences (Next lesson)
  - Rules
- Comments are allowed following Java syntax (included in `/*` and `*/`, or preceded by `//`)

Setup section

- This section contains all the directives needed for the parser
- Inclusion of Cup library and other libraries:
  import java_cup.runtime.*;

- User code: (Next lesson)
  - Ridefinition of Cup internal methods
  - Integration with scanner other than JFlex

Terminals / Non-Terminals section

- It contains the definition of
  - Terminals: passed by JFlex
  - Non-Terminals
  - The grammar start symbol

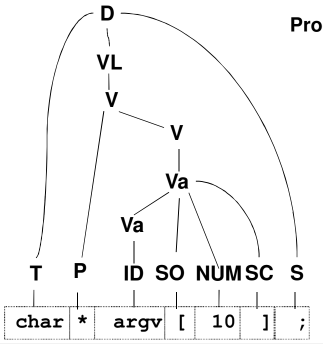
- Start symbol
  - start with <non_terminal_name> ;
  - It is the root of the parse tree
  - Only one occurrence of this keyword is allowed

Terminals / Non-Terminals section

- Terminals
  - terminal <terminal_1>,...,<terminal_n> ;
    - <terminal>: name containing letters, '_', '.' and digits (the first character must be a letter)
  - Terminals are recognized by Jflex

- Non-Terminals
  - non terminal <non_terminal_1>,...,<non_terminal_n> ;
    - <non_terminal>: name containing letters, '_', '.' and digits (the first character must be a letter).

Terminals / Non-Terminals section

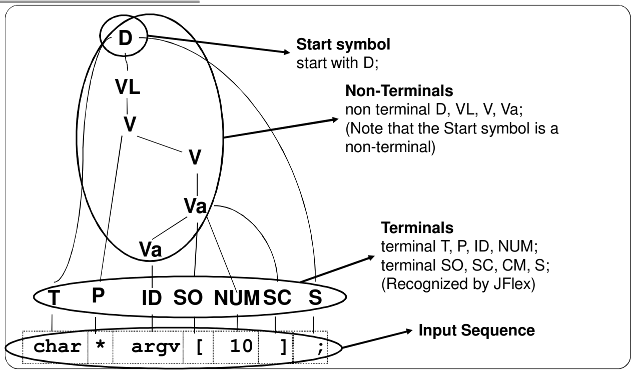


Productions (grammal rules):

D ⟶ T VL S
VL⟶ V
VL⟶ VL CM V
V ⟶ P V
V ⟶ Va
Va⟶ Va SO NUM SC
Va⟶ ID

Input string:
char *argv[10];

Terminals / Non-Terminals section



Start symbol
start with D;

Non-Terminals
non terminal D, VL, V, Va;
(Note that the Start symbol is a non-terminal)

Terminals
terminal T, P, ID, NUM;
terminal SO, SC, CM, S;
(Recognized by JFlex)

Input Sequence

Rules section

- The Rules section contains one or more productions in the form:

  <non_terminal> ::= Right_Hand_Side ;

- where *Right_Hand_Side* is a sequence of 0 or more symbols.
- To each prodution, an action can be associated, which must be enclosed between {: and :}
  - Note: the action is executed just before the reduce operation takes place
- Example:

```
D ::= T VL S
      {: System.out.println("Declaration found"); :}
;
```

Rules section (2)

- If more than one production exist for a given non-terminal, they must be grouped and separated by '|'.
- Es.

```
funz ::=    type ID RO VL RC S
                 {: System.out.println("Function prototype"); :}
          | type ID RO VL RC BO stmt_list BC
                 {: System.out.println("Function"); :}
 ;
```

- NB: the use of the "|" character generates two separates rules. It is important to remember that the code between {: and :} is executed only when a giver rule is matched.

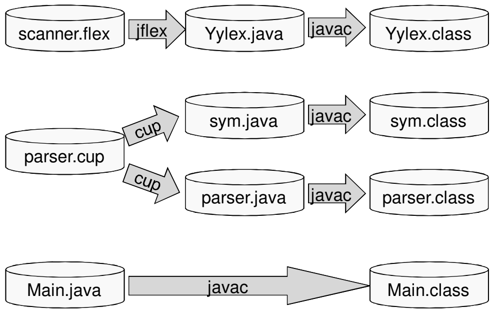
Rules section : Example

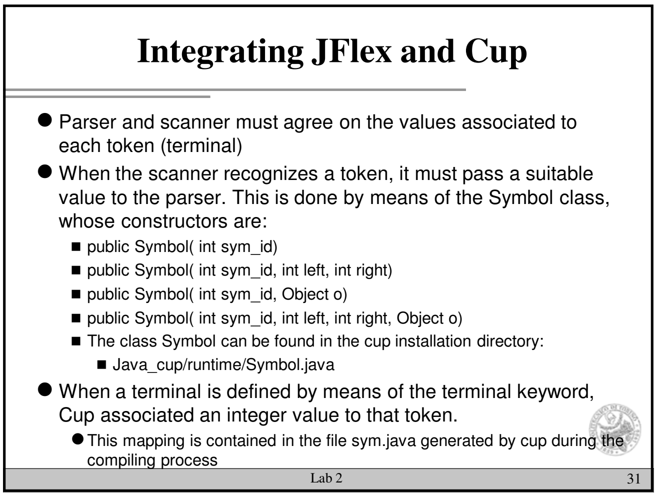
```
import java_cup.runtime.*;

//Terminals / Non-Terminals Section
terminal T, P, ID, NUM, S, CM, SO, SC;
non terminal D, V, VL, Va;
start with D;

//Rule Section
D ::= T VL S ;

VL::= V
    | VL CM V ;

V ::= P V
     | Va ;

Va::= Va SO NUM SC
     | ID ;
```

Productions:

D ⟶ T VL S
VL⟶ V
VL⟶ VL CM V
V ⟶ P V
V ⟶ Va
Va⟶ Va SO NUM SC
Va⟶ ID

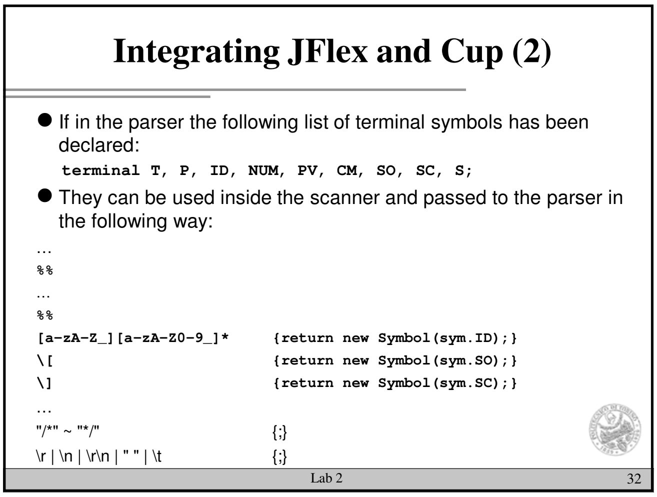
Integrating JFlex and Cup





Integrating JFlex and Cup

- Parser and scanner must agree on the values associated to each token (terminal)
- When the scanner recognizes a token, it must pass a suitable value to the parser. This is done by means of the Symbol class, whose constructors are:
  - public Symbol(int sym_id)
  - public Symbol(int sym_id, int left, int right)
  - public Symbol(int sym_id, Object o)
  - public Symbol(int sym_id, int left, int right, Object o)
  - The class Symbol can be found in the cup installation directory:
    - Java_cup/runtime/Symbol.java
- When a terminal is defined by means of the terminal keyword, Cup associated an integer value to that token.
  - This mapping is contained in the file sym.java generated by cup during the compiling process



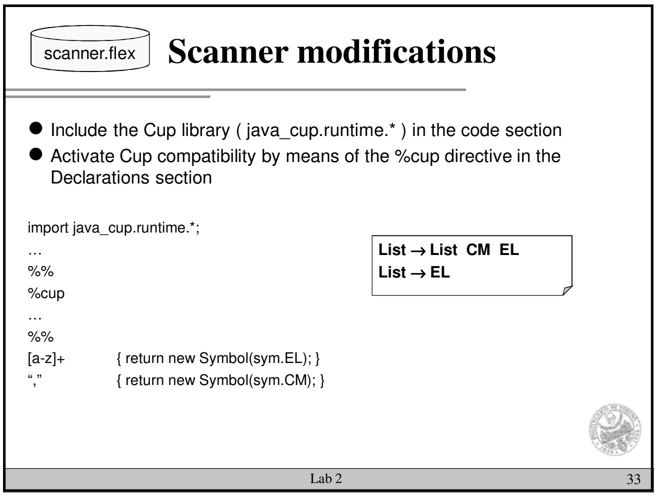
Integrating JFlex and Cup (2)

- If in the parser the following list of terminal symbols has been declared:

```
terminal T, P, ID, NUM, PV, CM, SO, SC, S;
```

- They can be used inside the scanner and passed to the parser in the following way:

```
…
%%
…
%%
[a-zA-Z_][a-zA-Z0-9_]*     {return new Symbol(sym.ID);}
\[                         {return new Symbol(sym.SO);}
\]                         {return new Symbol(sym.SC);}
…
"/*" ~ "*/"                {;}
\r | \n | \r\n | " " | \t  {;}
```



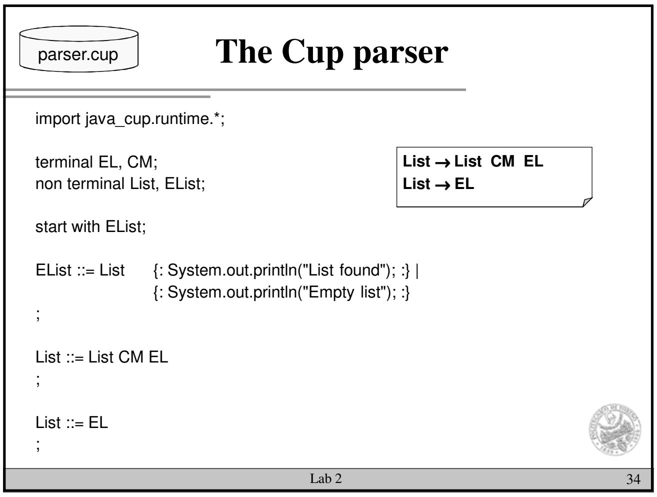
scanner.flex

Scanner modifications

- Include the Cup library (java_cup.runtime.*) in the code section
- Activate Cup compatibility by means of the %cup directive in the Declarations section

```
import java_cup.runtime.*;
…
%%
%cup
…
%%
[a-z]+      { return new Symbol(sym.EL); }
“,”         { return new Symbol(sym.CM); }
```

List → List CM EL
List → EL

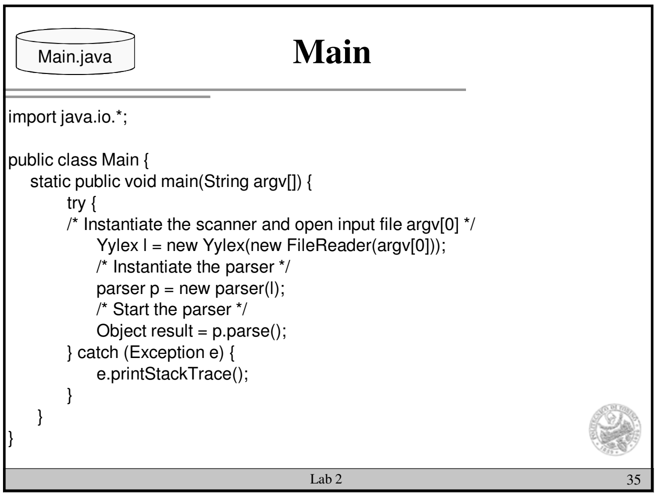


parser.cup

The Cup parser

```
import java_cup.runtime.*;

terminal EL, CM;
non terminal List, EList;

start with EList;

EList ::= List    {: System.out.println("List found"); :} |
                  {: System.out.println("Empty list"); :}
;

List ::= List CM EL
;

List ::= EL
;
```

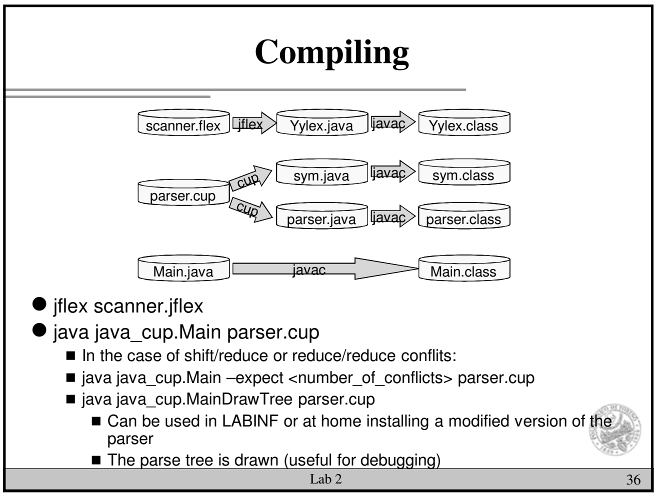
List → List CM EL
List → EL



Main.java

Main

```
import java.io.*;

public class Main {
    static public void main(String argv[]) {
        try {
        /* Instantiate the scanner and open input file argv[0] */
            Ylex l = new Yylex(new FileReader(argv[0]));
            /* Instantiate the parser */
            parser p = new parser(l);
            /* Start the parser */
            Object result = p.parse();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
}
```



Compiling

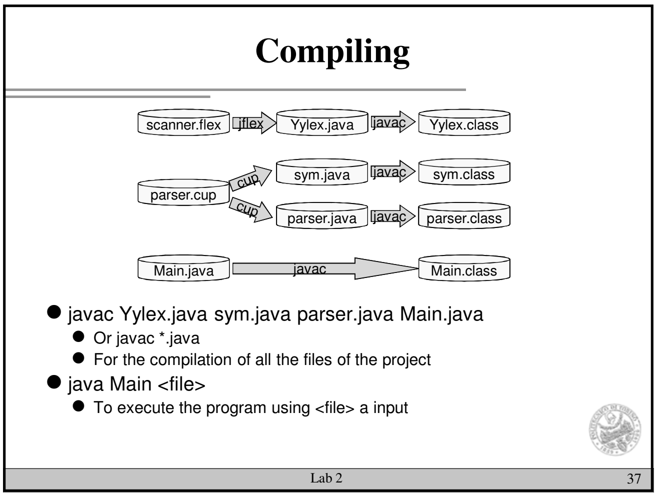
scanner.flex → jflex → Yylex.java → javac → Yylex.class

parser.cup → cup → sym.java → javac → sym.class

parser.cup → cup → parser.java → javac → parser.class

Main.java → javac → Main.class

- jflex scanner.jflex
- java java_cup.Main parser.cup
  - In the case of shift/reduce or reduce/reduce conflits:
  - java java_cup.Main –expect <number_of_conflicts> parser.cup
  - java java_cup.MainDrawTree parser.cup
    - Can be used in LABINF or at home installing a modified version of the parser
    - The parse tree is drawn (useful for debugging)



Compiling

- javac Yylex.java sym.java parser.java Main.java
  - Or javac *.java
  - For the compilation of all the files of the project
- java Main <file>
  - To execute the program using <file> a input