Homework 2: Parser and Lexer

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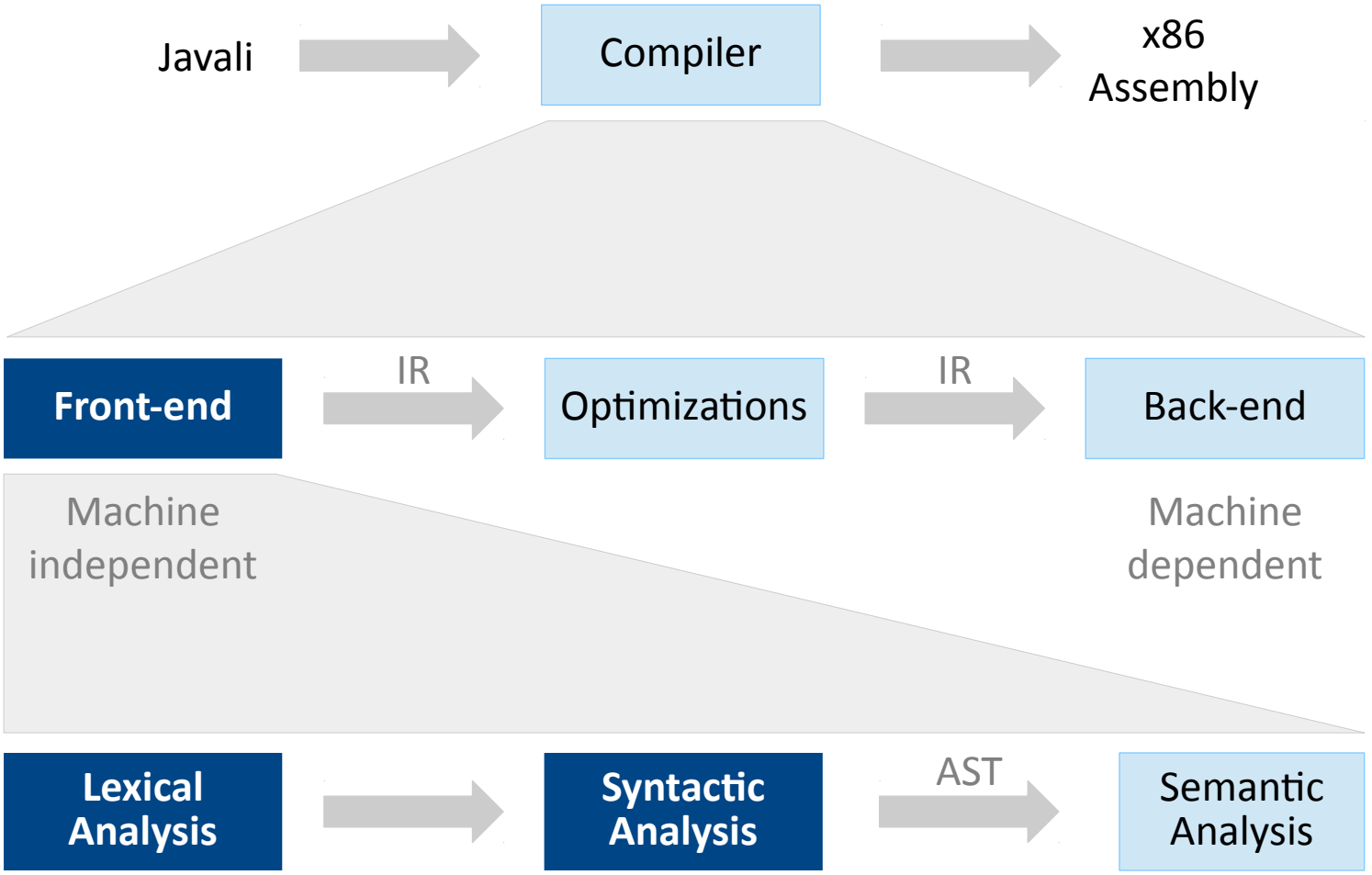
Compiler Design – 16.03.2017

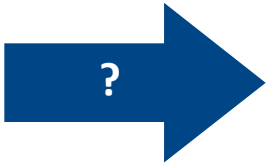
Compiler phases

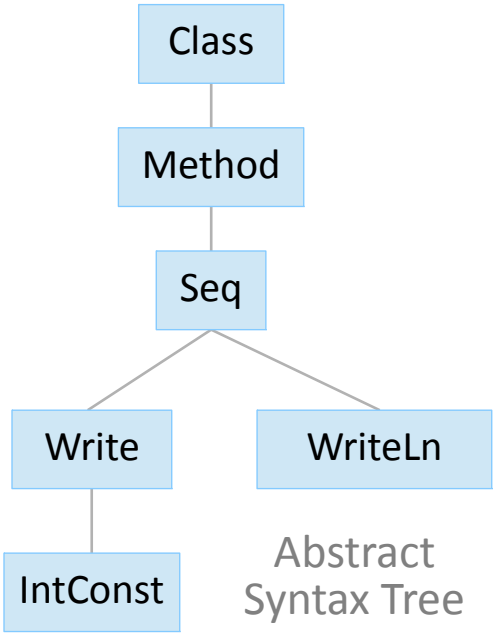


Homework 2

```
class Main {
     void main() {
          write(222);
          writeln();
     }
}
```

Text



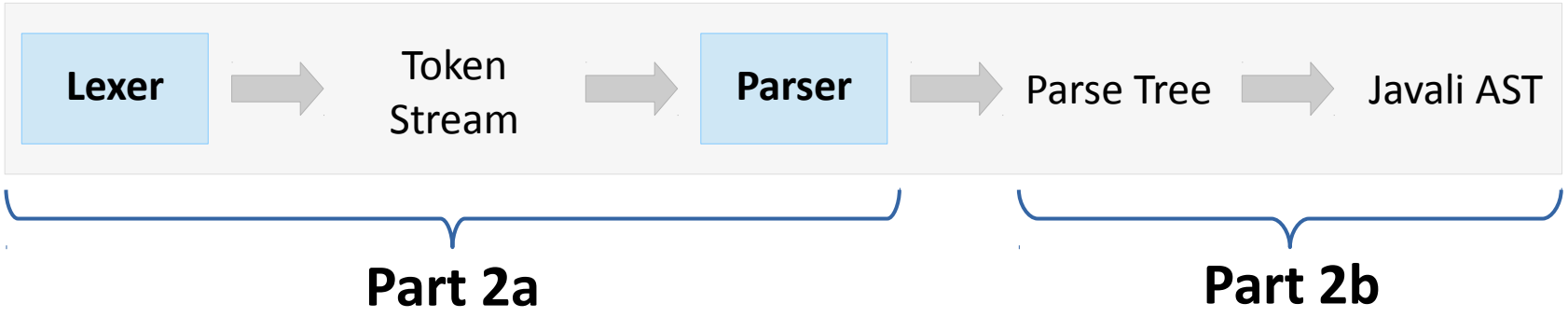


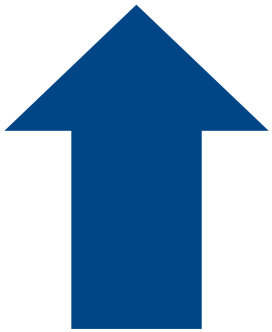
Abstract Syntax Tree

How do we…

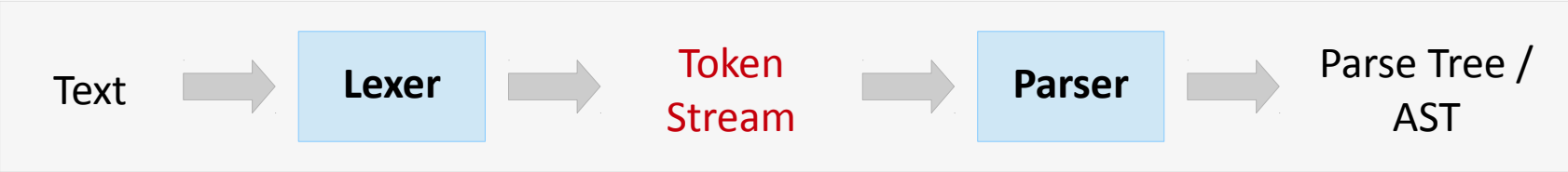
- check if a program follows the syntax of Javali?
- extract meaning / structure?

Homework 2


Lexer
Token Stream
Parser
Parse Tree
Javali AST
Part 2a
Part 2b



Lexical Analysis



Lexer

- Read input character by character
- Recognize character groups → tokens

Token

- Sequence of characters with a **collective meaning** → grammar terminals
- E.g. constants, identifiers, keywords, …

Lexical Analysis

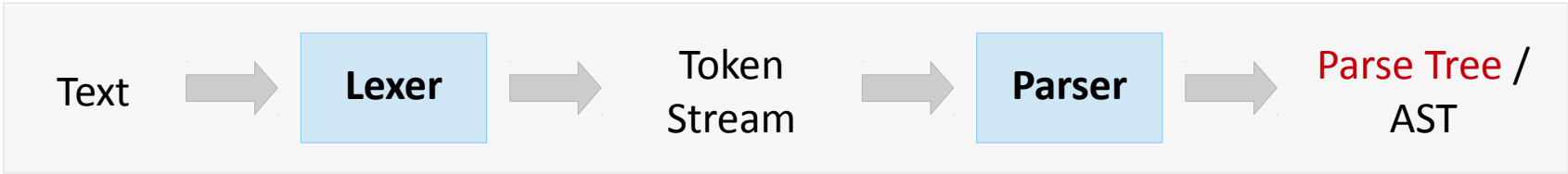
```
class Main {
     void main() {
          write(222);
          writeln();
     }
}
```

```
ID   : [a-zA-Z]+ ;
NUM  : [0-9]+ ;
MISC : [{()};] ;
WS   : ('\n'|' ') → skip ;
```

Token stream:

ID: *class* | **ID**: *Main* | **MISC**: *{* | **ID**: *void* | **ID**: *main* | **MISC**: *(* | **MISC**: *)* | **...**

Syntactic Analysis



Parser

- **Check** if token stream follows the grammar
- Group tokens hierarchically (**extract structure**)
  → Parse Tree / Abstract Syntax Tree

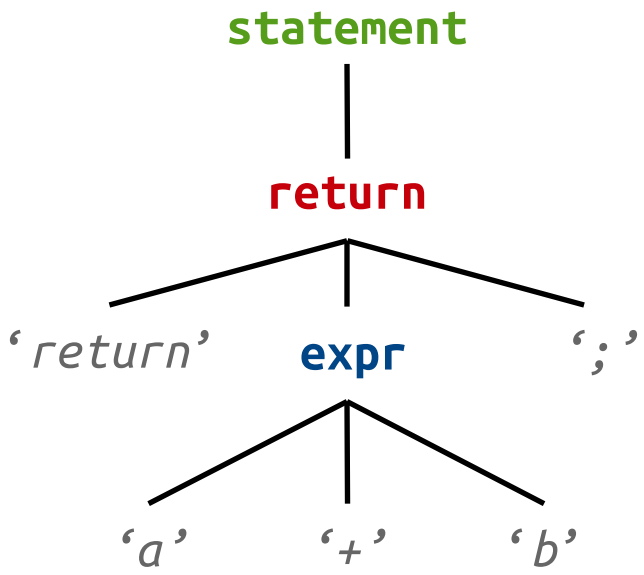
TOP-DOWN PARSER

Top-down parsers

Grammar in Extended Backus-Naur Form (EBNF):

```
statement:
      return
    | assign

return:
    'return' expr ';'

assign:
    ID '=' expr ';'

expr: ID '+' ID
```

return a + b ;



Implementation

Grammar in Extended Backus-Naur Form (EBNF):

```
statement:
    return
  | assign

return:
    'return' expr ';'

assign:
    ID '=' expr ';'

expr: ID '+' ID
```

```
void statement() {
    return();
    or assign();
}

void return() {
    match('return');
    expr();
    match(';');
}

void expr() {
    match(ID);
    match('+');
    match(ID);
}
```

How to deal with alternatives?

Lookahead

Grammar in Extended Backus-Naur Form (EBNF):

```
statement:
      return
    | assign

return:
    'return' expr ';'

assign:
    ID '=' expr ';'

expr: ID '+' ID
```

```
void statement() {
    if (next() is 'return') {
      return();
    } else if (next() is ID) {
      assign();
    }
}
```

LL(1)

http://www.antlr4.org/

(or HW2 fragment)

ANTLR

Token specifications + Grammar

MyLexer.java
MyParser.java

Top-down parser generator

- ALL(*) adaptive, arbitrary lookahead
- handles any non-left-recursive context-free grammar

ANTLR – Grammar description

Start rule matching end-of-file

Lower-case initial: Parser

Upper-case initial: Lexer

```
/* This is an example */
grammar Example;

/* Parser rules = Non-terminals */
program :
    statement* EOF ;


statement :
      assignment ';'
    | expression ';'
    ;


/* Lexer rules = Terminals */
Identifier : Letter (Letter | Digit)* ;
Letter : '\u0024' | '\u0041'..'\u005a';
```

ANTLR – Operators

Extended Backus-Naur Form (**EBNF**)

```
program :
    statement* EOF;

statement :
    assignment ';'
  | expression ';'
  ;

method :
    type name
        '(' params? ')'
  ;
```

EBNF operators	
`x | y | z`	(ordered) alternative
`x?`	at most once (optional)
`x*`	0 .. n times
`x+`	1 .. n times
`[charset]`	one of the chars, e.g.: `[a-zA-Z]`
`'x'..'y'`	characters in range

lexer-only

Demo 1

ANTLR – Troubleshooting

ANTLR does not warn about **ambiguous** rules

- resolves ambiguity at runtime
  → requires lots of testing

ANTLR does not handle indirect **left-recursion**

- direct left-recursion supported

ANTLR – Lexer ambiguity

What if some input is matched by multiple lexer rules?

```
parserRule : 'foo' parserRule ;


fragment
Letter : [a-z] ;

Identifier : Letter+ ;
```

creates implicit lexer rule
T123 : *'foo'*

fragment enforces that the rule never produces a token, but can be used in other lexer rules

can never match *foo*, but
e.g., *foot*

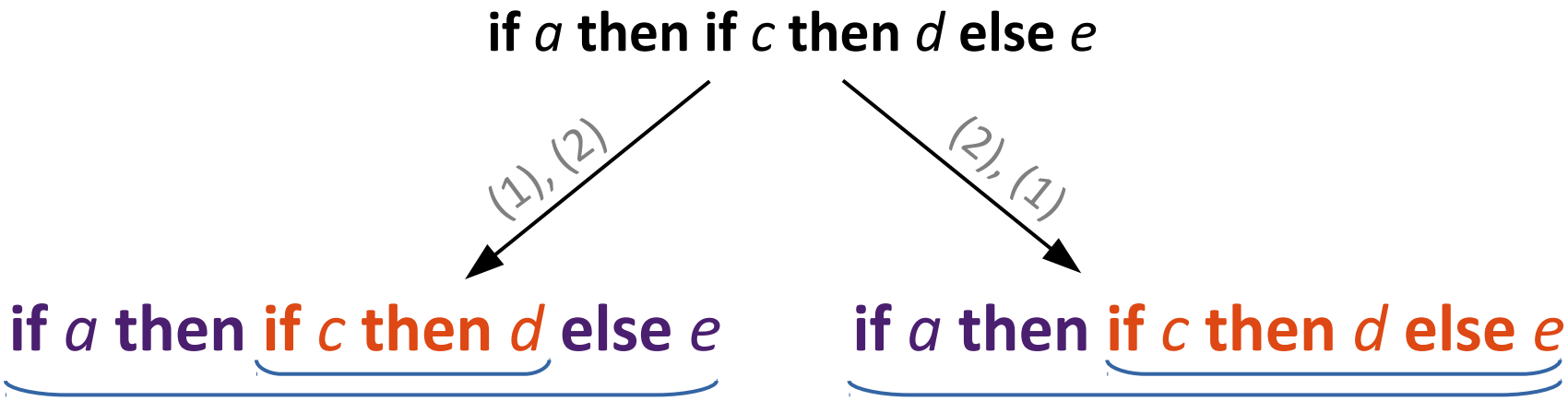
Lexer decides based on:

1. rule with the longest match first
2. literal tokens before all regular Lexer rules
3. document order
4. **fragment** rules never match on their own

ANTLR – Parser ambiguity

```
stmt: 'if' expr 'then' stmt 'else' stmt
    | 'if' expr 'then' stmt
    | ID '=' expr ;
```

(1)
(2)

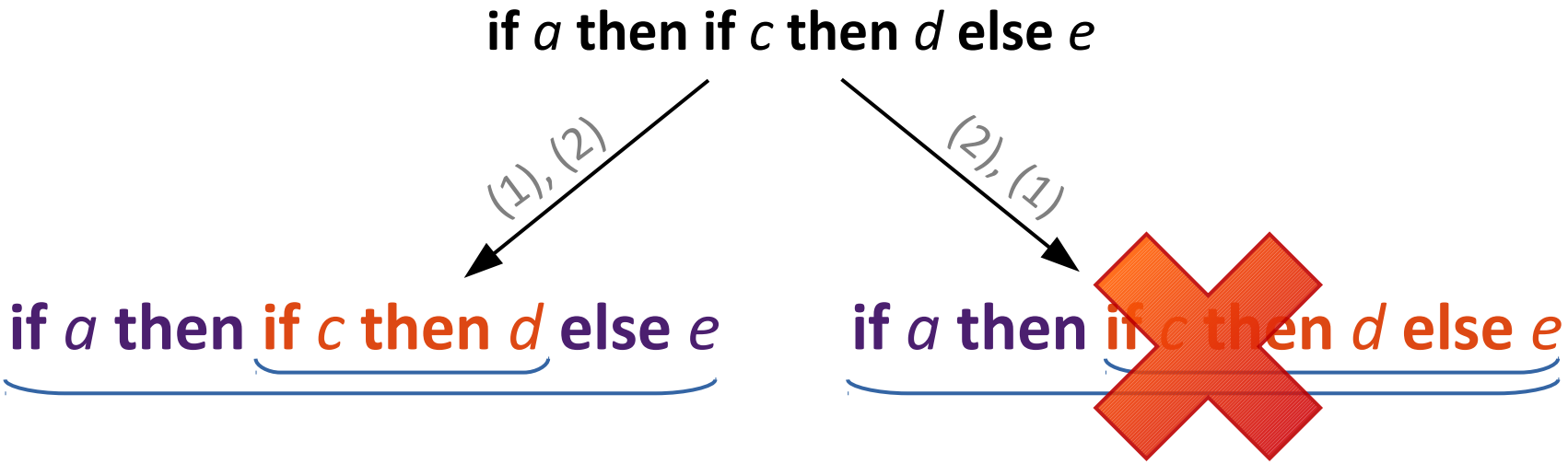


Ambiguous since there exist more than one parse trees for the same input.

ANTLR – Parser ambiguity

```
stmt: 'if' expr 'then' stmt 'else' stmt    (1)
    | 'if' expr 'then' stmt                (2)
    | ID '=' expr ;
```

At decision points, if more than one alternative matches a given input, follow **document order**.



ANTLR – Parser ambiguity

```
stmt: 'if' expr 'then' stmt 'else' stmt
    | 'if' expr 'then' stmt
    | ID '=' expr ;
```

(1)
(2)

At decision points, if more than one alternative matches a given input, follow **document order**.

Solution

```
stmt: 'if' expr 'then' stmt
    | 'if' expr 'then' stmt 'else' stmt
    | ID '=' expr ;
```

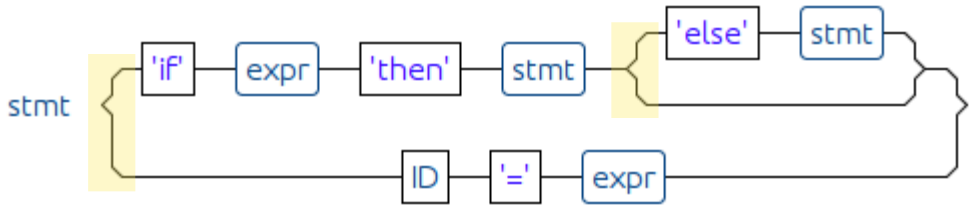
ANTLR – Parser ambiguity

At **decision points**, if more than one alternative matches a given input, follow **document order**.

Alternative solution:

```
stmt: 'if' expr 'then' stmt ('else' stmt)?
    | ID '=' expr ;
```

(…)? → (…|)



Sub-rules introduce additional decision points.

ANTLR – Left-recursion

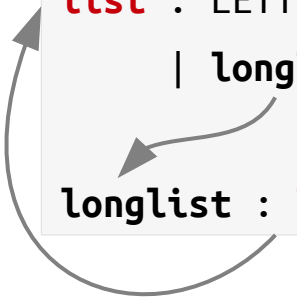
Without: *“a, b, c”*

```
list : LETTER (',' LETTER)*;
```

Direct:

```
list : list ',' LETTER
     | LETTER ;
```

Indirect:



```
list : LETTER
     | longlist ;

longlist : list ',' LETTER;
```

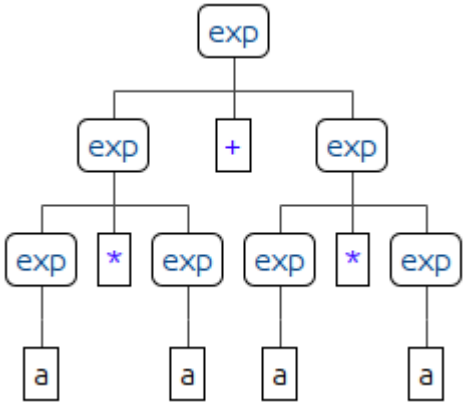
ANTLR – Direct left-recursion

```
exp : exp '*' exp
    | exp '+' exp
    | ID ;
```

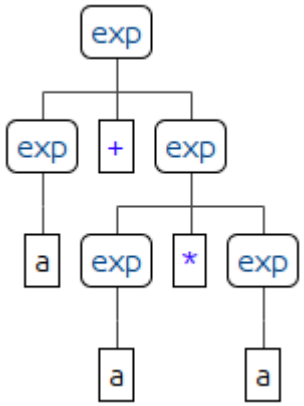
rewrite

A grammar that implicitly assigns **priorities** to alternatives in document order

*a * a + a * a*



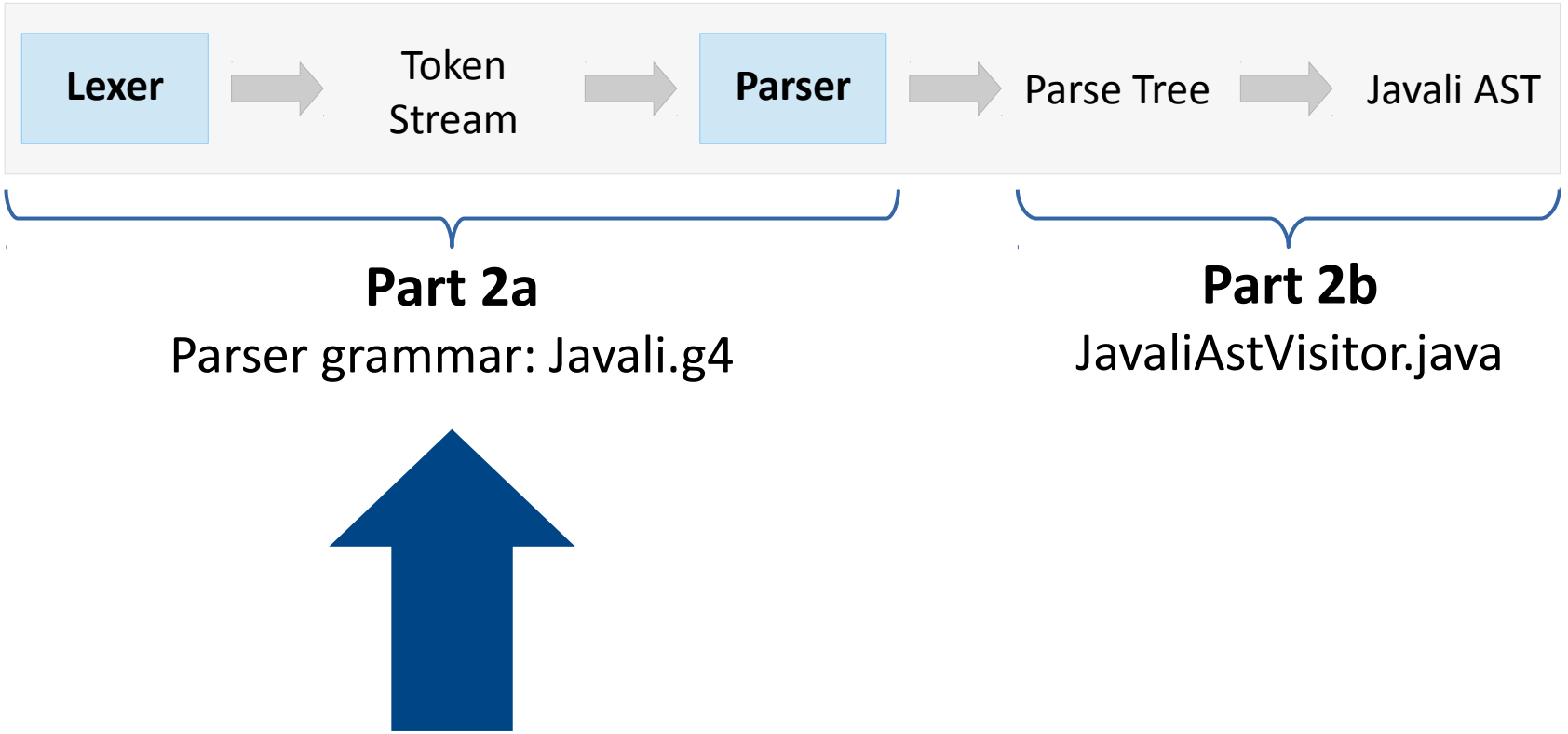
*a + a * a*



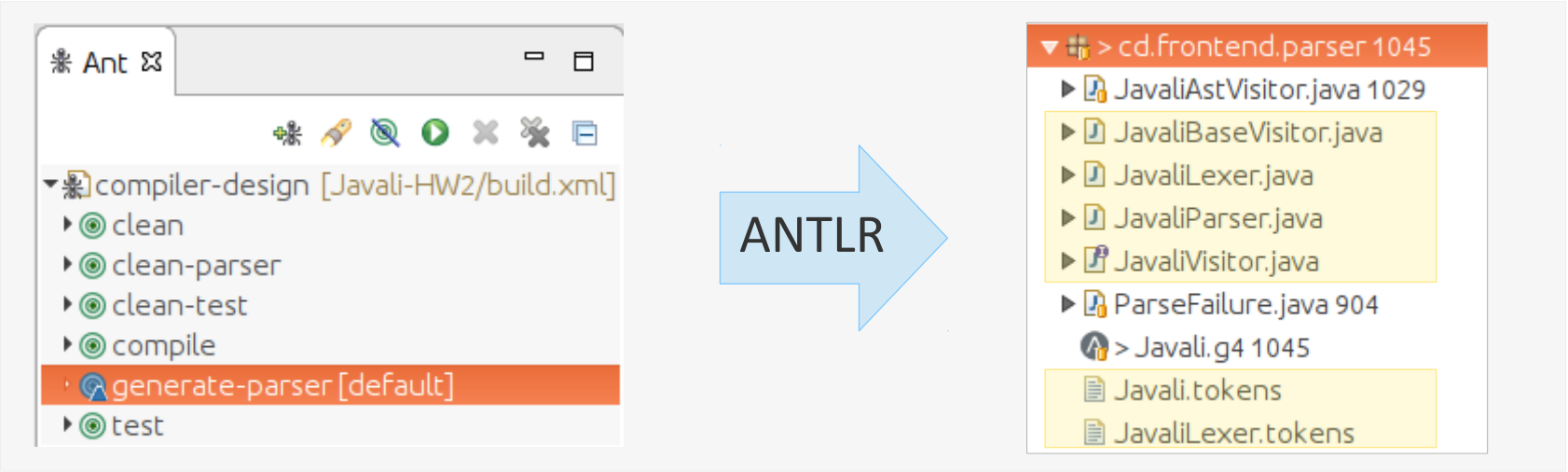
https://theantlrguy.atlassian.net/wiki/display/ANTLR4/Left-recursive+rules

Demo 2

Homework


Lexer
Token Stream
Parser
Parse Tree
Javali AST
Part 2a
Parser grammar: Javali.g4
Part 2b
JavaliAstVisitor.java

Generated files



Javali***Lexer***/***Parser***.java

- the real thing

Javali(***Base***)***Visitor***.java

- base class for parse-tree visitor

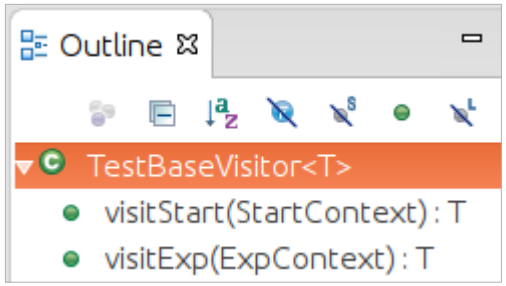
Javali(***Lexer***).tokens

- token → number mapping for debugging

Generated visitor

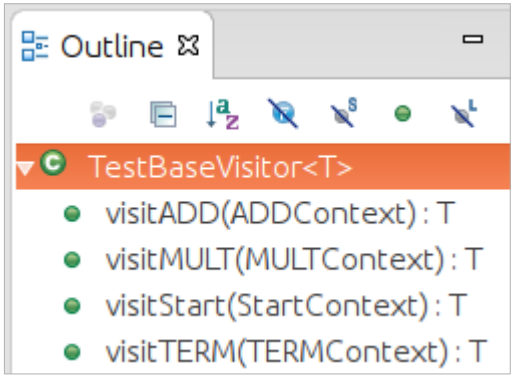
```
start : exp EOF
      ;

exp : exp '*' exp
    | exp '+' exp
    | ID
    ;
```

one method per rule




```
start : exp EOF
      ;

exp : exp '*' exp # MULT
    | exp '+' exp # ADD
    | ID          # TERM
    ;
```

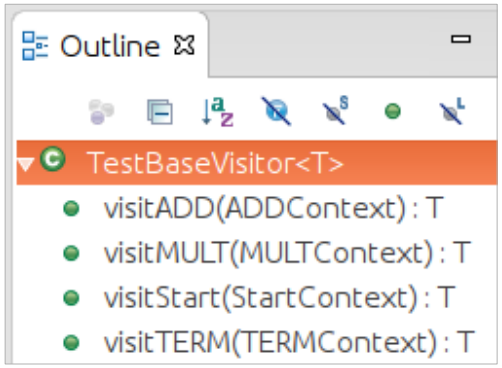
one method per label / rule



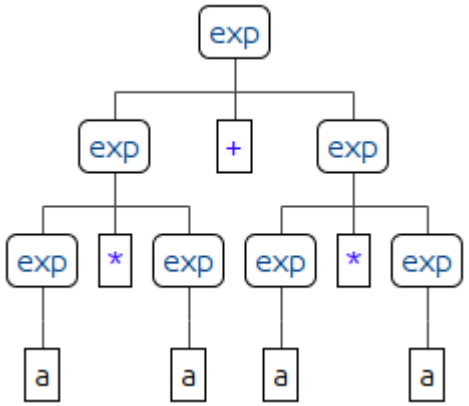
https://theantlrguy.atlassian.net/wiki/display/ANTLR4/Parser+Rules

Constructing the Javali AST

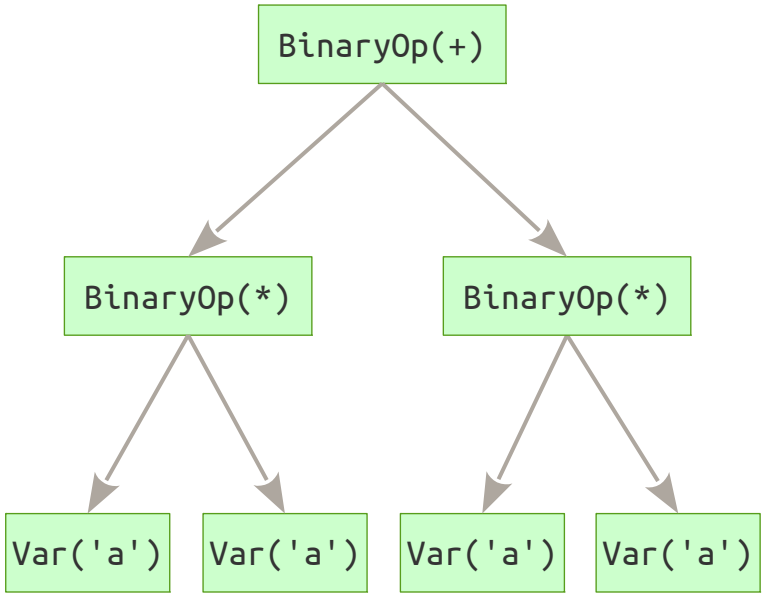
```
start : exp EOF
      ;

exp : exp '*' exp # MULT
    | exp '+' exp # ADD
    | ID          # TERM
    ;
```



"a * a + a * a"



Visitor



Demo 3

Notes

- You are not allowed to use **syntactic predicates**.
- Look on our website for more material.
- Due date is **March, 30th**