PLCC Overview

SIGCSE 2024 PLCC Workshop
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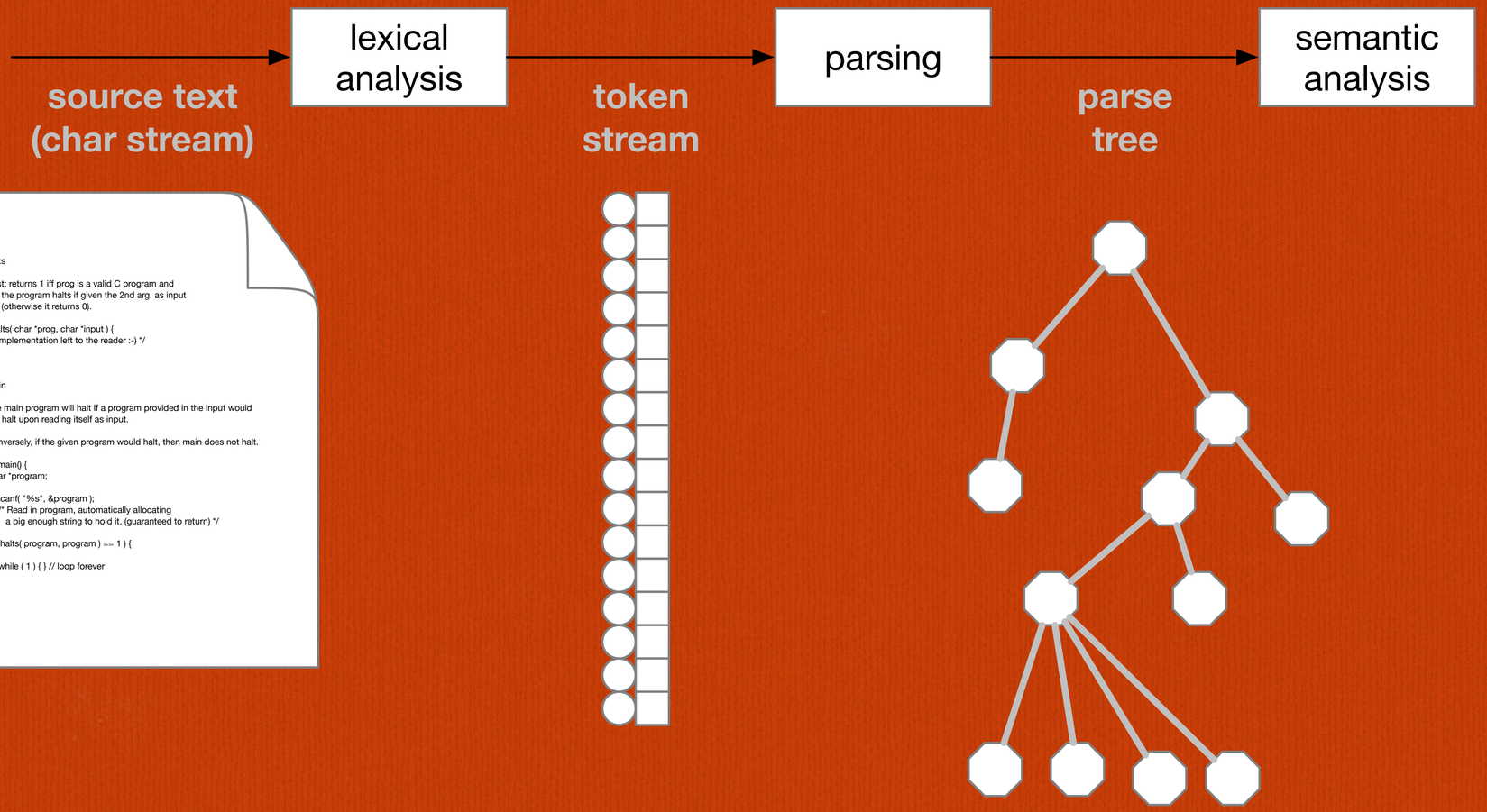
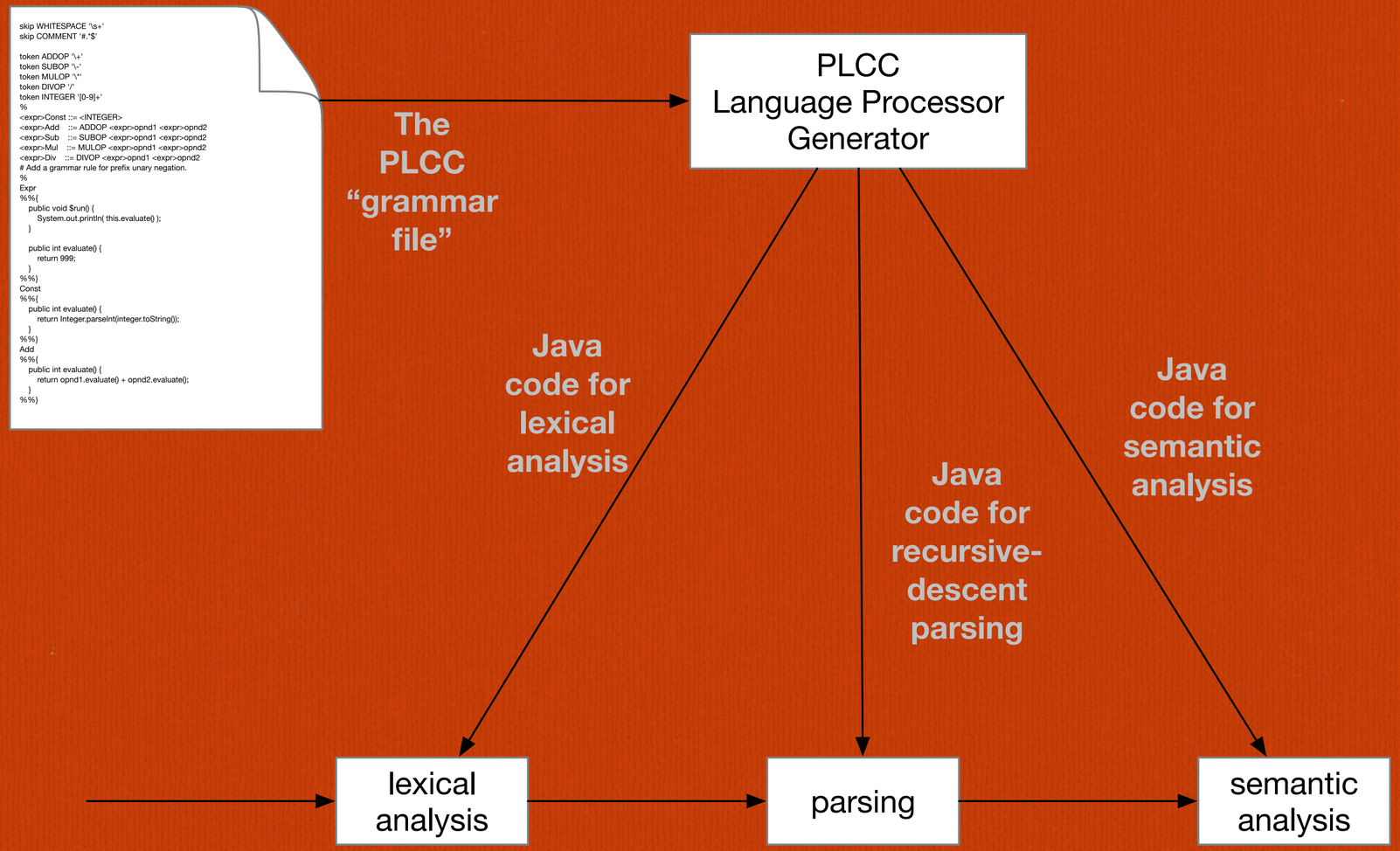
The Language Processing Model



Can be
Execution (interpretation)
Byte code
Machine code
Code metrics
Soundness checks
Type checking
Pattern matching

The Language Processing Model

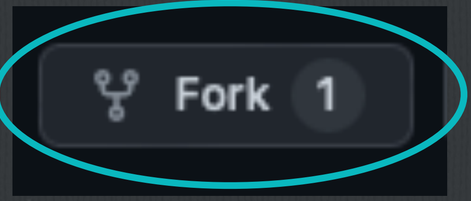


Break for Tool Setup

- The organizers will now help you organize yourselves into teams.
- If you have already done the setup on your computer there is no need to do more now.
- There should be one computer that has done the setup for the workshop.
  - Setup summary is on the next slide.
  - Details at https://github.com/ourPLCC/sigcse2024/blob/main/Docs/Pre-Workshop-Setup/README.md (but step 8 is different)

Break for Tool Setup

- Each team: Set up one computer to access the workshop materials.
  - Navigate the browser to https://github.com/ourPLCC/sigcse2024.
  - Push the "Fork" button to make a copy of the repository.
    - Share the new fork's URL with your teammates.
  - Prepend "https://gitpod.io/#" to that new URL and get that page.
  - Log in with your GitHub account.
  - Select the defaults on the next web page that appears.



Your GitPod Environment (1 of 2)

- Access your repository's contents using the pane on the left.
- Edit files in the pane at the top right.
  - The standard editor is VS Code.
- Run commands (git, plcc, …) using the bash terminal at the bottom right.
  - (Wait for it to complete the Git command that clones the repo.)

Your GitPod Environment (2 of 2)

- Confirm your environment by executing these commands in the bash shell.
  - `python --version`
  - `java --version`
  - `plcc --version`

PLCC File Syntax

- **plcc.py** (via **plcc** and **plccmk scripts**) is used to create language processors.
- It reads a file containing a specification of
  1. The tokens of your language
  2. The grammar of your language
  3. Additional support code (Java) to help process the resulting abstract syntax tree
- In **plcc** the filename defaults to **grammar** but you can use other file names and extensions as you wish.
  - Our files will have distinct names and will end in "**`.plcc`**".

Example: Parenthesized Number Lists

- In these notes we will fashion a language processor that reads expressions of the form

  (*integer integer* …)

  and echoes them back out, with any extra white space removed.
- The processor will be developed in three stages.
  - Lexical scanning stage
  - Parsing stage
  - Semantic stage

(Quick look at result)

```
$ rep
--> (1 2 3)
( 1 2 3 )
--> (23          59              )
( 23 59 )
--> (8)
( 8 )
--> ()
( )
--> ^D
```

"rep": read-evaluate-print loop

control-D: UNIX end-of-file

Team Exercises

- Teams will be assigned separate exercises to complete for each stage.

Section 1 of 3: Language Tokens

- Below is what we specify for the language processor's lexical scanner.

```
skip WHITESPACE '\s+'

token LPAREN '\('

token RPAREN '\)'

token NUMBER '\d+'
```

How to Generate the System and Run the System

```
skip WHITESPACE '\s+'

token LPAREN '\('

token RPAREN '\)'

token NUMBER '\d+'
```

```
$ plccmk -c numlistA.plcc
: (Some info prints here.)
$ scan
65
    1: NUMBER '65'
(
    2: LPAREN '('
)
    3: RPAREN ')'
)
    4: RPAREN ')'
hio
    5: !ERROR("h")
    5: !ERROR("i")
    5: !ERROR("o")
^D
$
```

Activity 1

- Each activity is in a separate directory and contains an **assignment.txt** file, some starter code in a **plcc** file, and test input.
- "**cd**" to the **Part1** directory.
- You are to add some additional tokens to the lexical specification.
- Be aware that token matches are attempted in the order they appear in the specification!

Section 2 of 3: Grammar (LL(1))

- Grammar rules are similar to BNF.
- They are built from two kinds of elements:
  - Terminals/tokens, and
  - Non-terminals/variables/rule-names.

  <*name*> ::= *TOKEN* <*name*> <*TOKEN*> <*name*>

- Angle brackets are used to mandate storage of the element's information and structure in the parse tree.

Section 2 of 3: Grammar (LL(1))

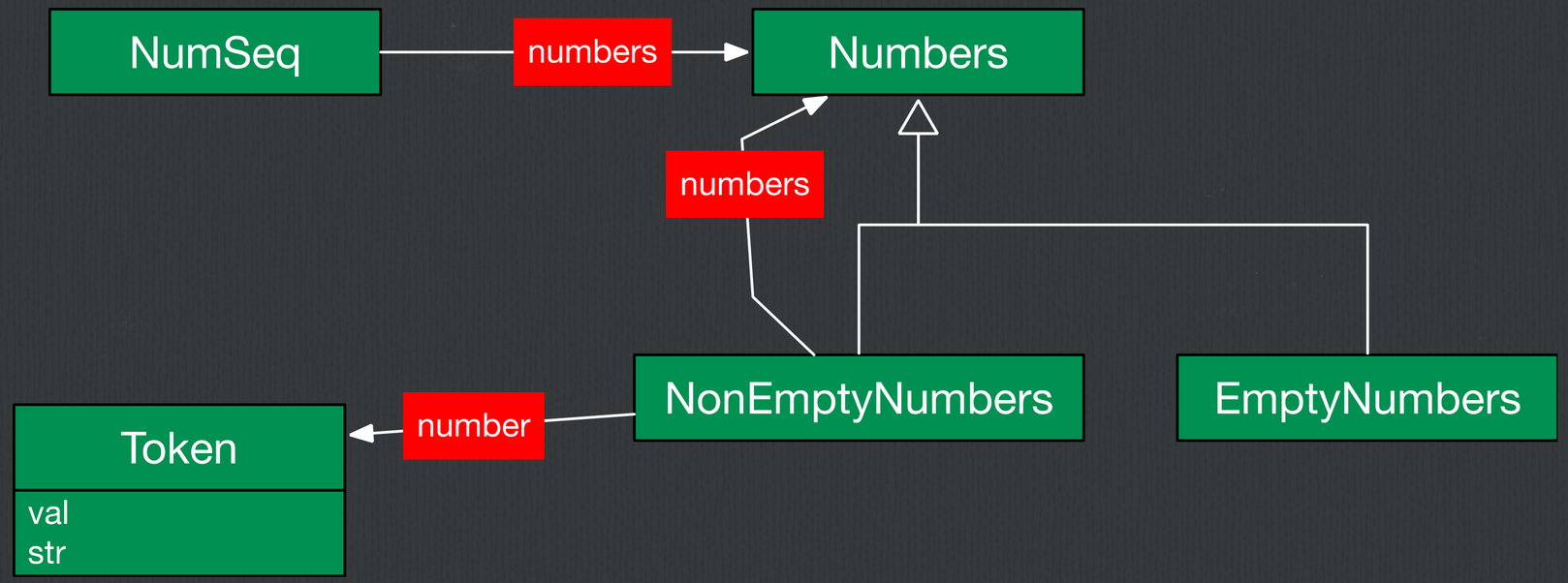
- *Terminal*: an identifier defined in the token section (section 1)
  - possibly surrounded by < … >, if the token's string name is needed
- Non-terminal, left hand side — rule name: *<name>*
  - *<name>*`:Sub_name` if there are multiple rules for *name*
- A non-terminal on the right-hand side refers to another rule: *<name>*
  - *<name>alt* – required if *<name>* appears multiple times on a single rule's right-hand side (disambiguation in code)

Section 2 of 3: Grammar (LL(1))

```
# Tokens
skip WHITESPACE '\s+'
token NUMBER '\d+'
token LPAREN '\('
token RPAREN '\)'
%
# BNF
<numSeq> ::= LPAREN <numbers> RPAREN
<numbers>:NonEmptyNumbers ::= <NUMBER> <numbers>
<numbers>:EmptyNumbers ::=
%
```

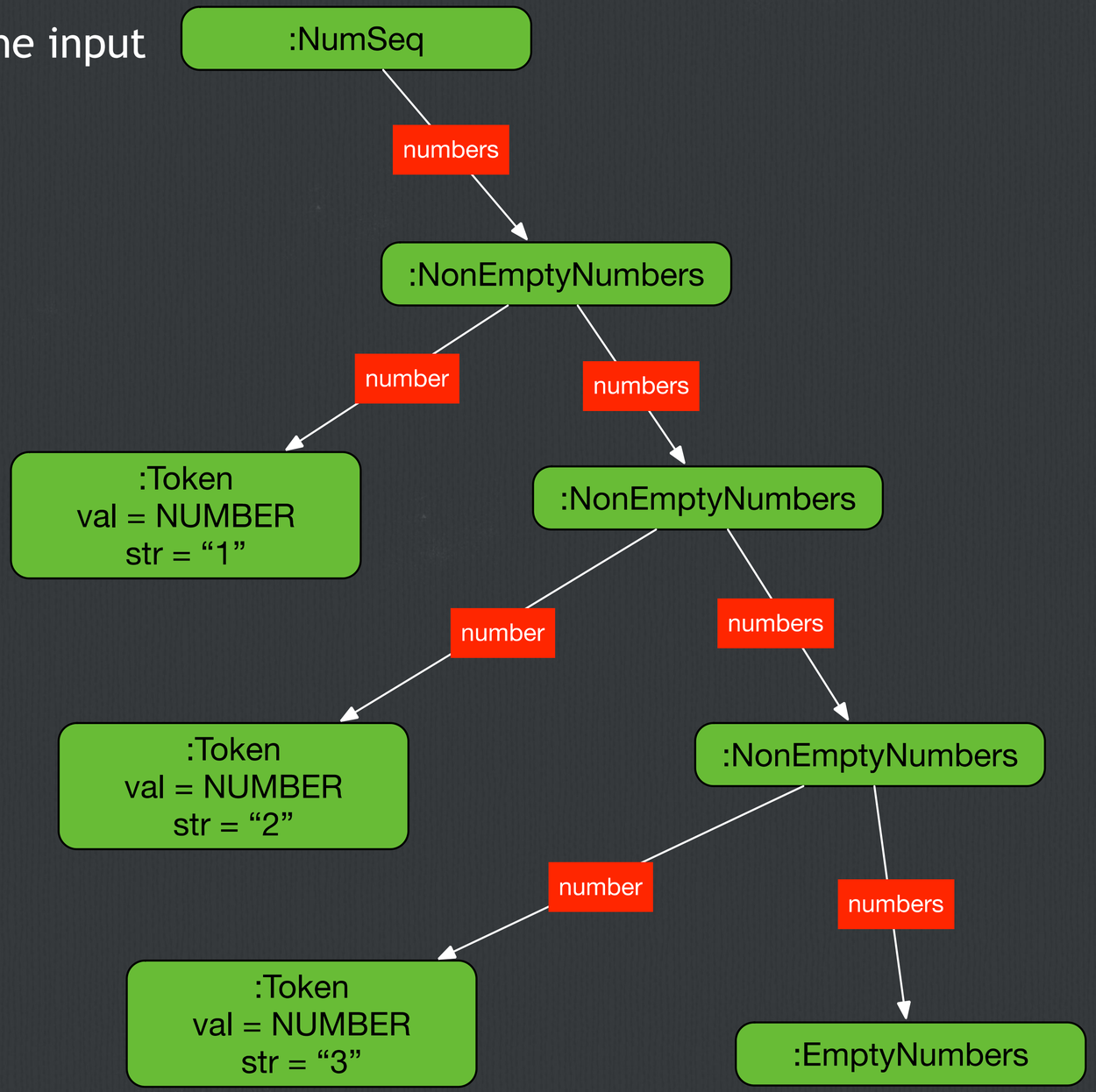
Java Class Correspondence

```
<numSeq> ::= LPAREN <numbers> RPAREN
<numbers>:NonEmptyNumbers ::= <NUMBER> <numbers>
<numbers>:EmptyNumbers ::=
```



The parse tree built from the input

(1 2 3)



How to Generate the System and Run the System

```
<numSeq> ::= LPAREN <numbers> RPAREN
<numbers>:NonEmptyNumbers ::= <NUMBER> <numbers>
<numbers>:EmptyNumbers ::=
```

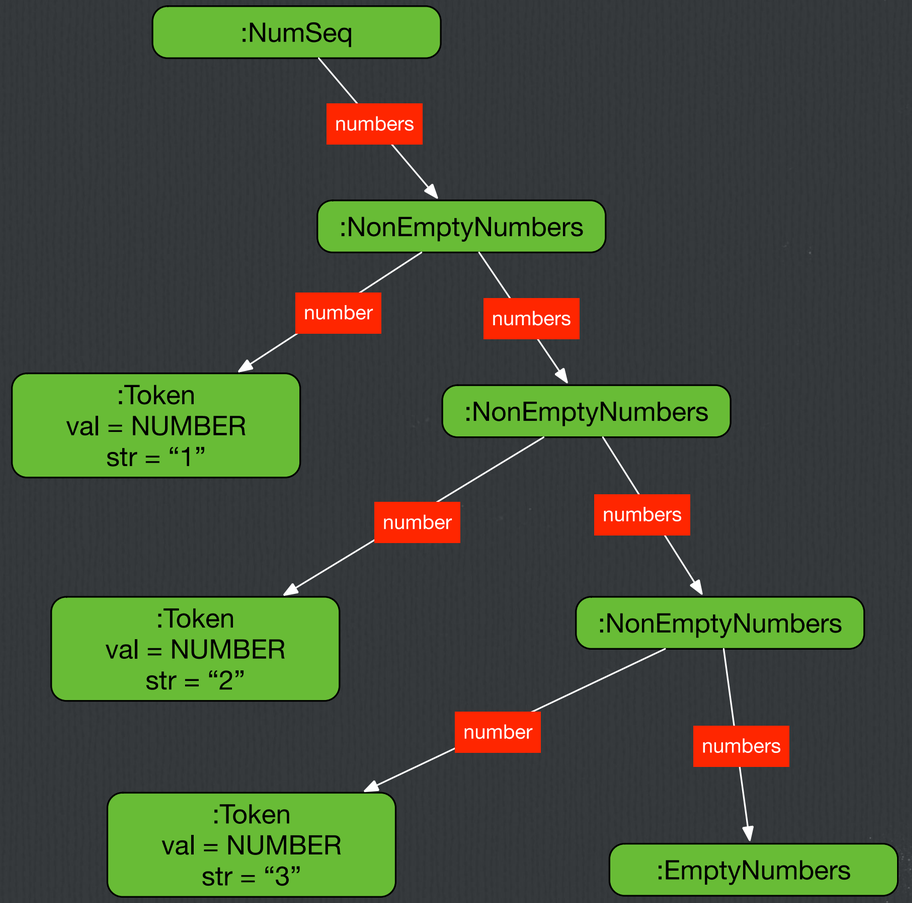
For `rep`*, the parse tree root node is displayed if the parse is successful.*

Note that there was no `toString` *method defined for* `NumSeq`*.*

```
$ plccmk -c numlistAB-rec.plcc
: (Some info prints here.)
$ parse
( 1 2   3)
OK
--> ^D
$ rep
--> ( 1 2 3 )
NumSeq@372f7a8d
--> ()
NumSeq@2f92e0f4
--> (456)
NumSeq@28a418fc
--> (1(2 3))
%%% Parse error: Numbers cannot begin with LPAREN
$
```

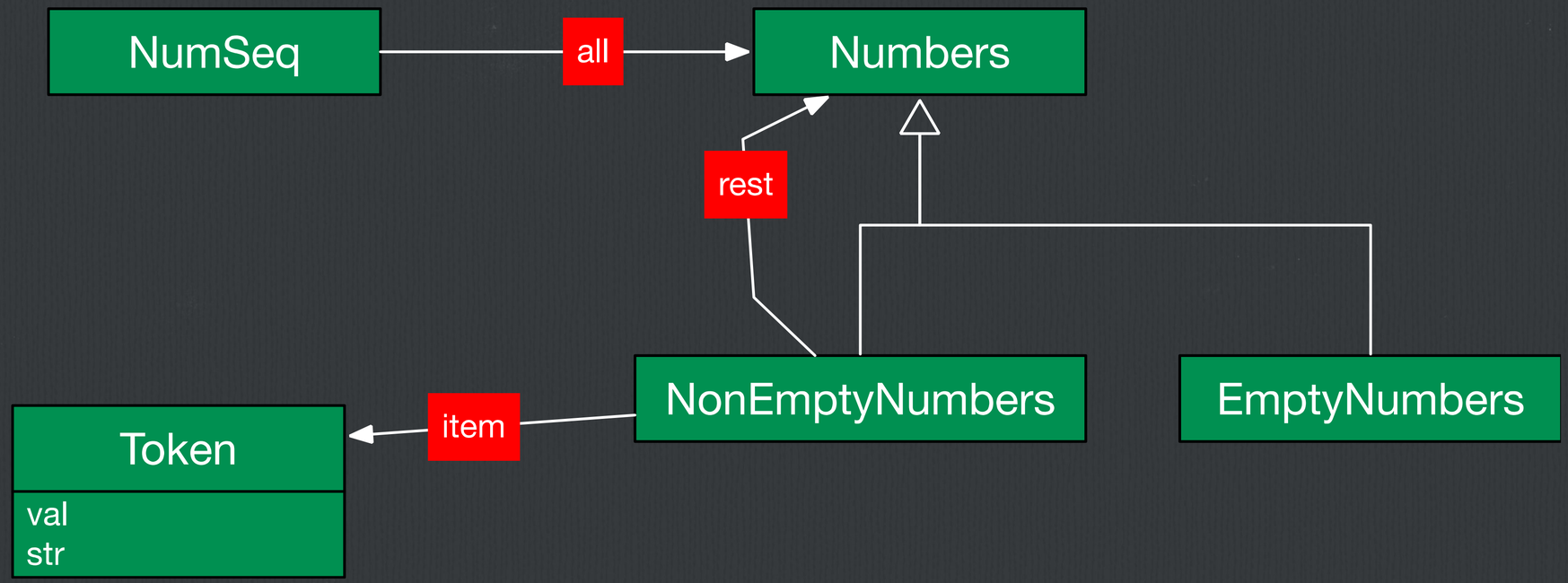
Executing the parse Command with Tracing

```
$ parse -t
--> (1 2 3)
    1: <numSeq>
    1: | LPAREN "("
    1: | <numbers>:NonEmptyNumbers
    1: | | NUMBER "1"
    1: | | <numbers>:NonEmptyNumbers
    1: | | | NUMBER "2"
    1: | | | <numbers>:NonEmptyNumbers
    1: | | | | NUMBER "3"
    1: | | | | <numbers>:EmptyNumbers
    1: | RPAREN ")"
OK
--> ^D
$
```



RHS Variable Renaming (not necessary for this grammar)

```
<numSeq> ::= LPAREN <numbers>all RPAREN
<numbers>:NonEmptyNumbers ::= <NUMBER>item <numbers>rest
<numbers>:EmptyNumbers ::=
```



Activity 2

- "**cd**" to the **Part2** directory.
- You will study the classic *dangling else* problem.
- It involves modifying a grammar, and the language it models, to fix the problem.

Section 3 of 3: Defining Semantics

```
§2  <numSeq> ::= LPAREN <numbers> RPAREN
    <numbers>   **= <NUMBER>
    %
§3  NumSeq
    %%{
        @Override
        public void $run() {
            System.out.println(
               "This is the root." );
        }
    %%}
```

I will now add features
To the (root) class NumSeq.

Here is a new method.

- After parsing, the run-time system will call `$run()` on the root node of the parse tree.

- If writing a new class, its entire definition should be put in section 3. (next slide)

Syntax of Semantics Section

- Adding Elements to an Existing Class (generated by PLCC from the grammar)

```
Expression
%%{
  public int cachedValue;
  public abstract int evaluate();
%%}
```

- Adding a new Class

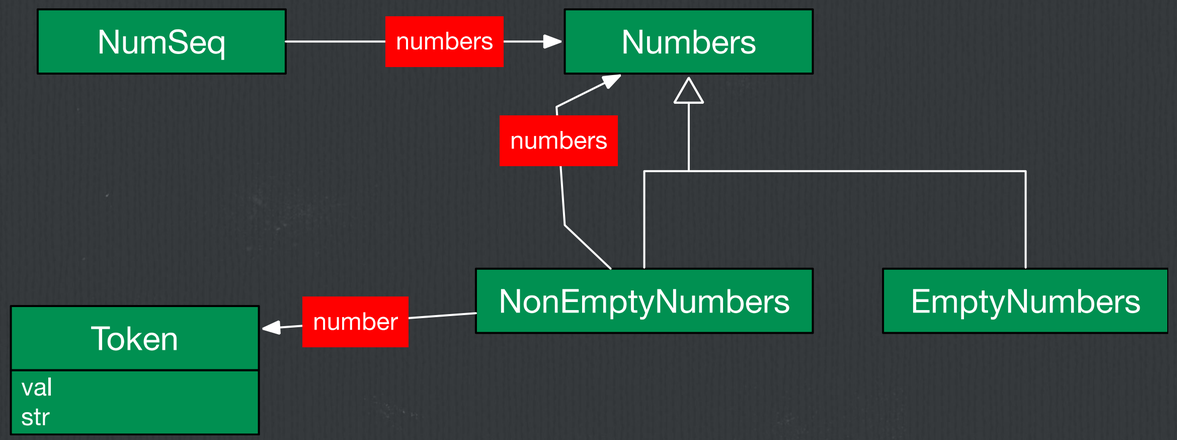
```
Binding
%%{
  public class Binding {
    public String name;
    public Val value;
  }
%%}
```

(Packages not supported.)

Defining Semantics to Echo the List

```
NumSeq
%%{

    @Override
    public void $run() {
        System.out.println(
            "(" + numbers + ")" );
    }
%%}
```




```
NonEmptyNumbers
%%{
    @Override
    public String toString() {
        return " " + number.str + numbers;
    }
%%}

EmptyNumbers
%%{
    @Override
    public String toString() {
        return " ";
    }
%%}
```

How to Generate and Run the New System


```
$ plccmk -c numlistABC-rec.plcc
Nonterminals (* indicates start symbol):
 *<numSeq>
  <numbers>

Abstract classes:
  Numbers

Java source files created:
  NumSeq.java
  Numbers.java
  NonEmptyNumbers.java
  EmptyNumbers.java
$ rep
--> (1 2 3)
( 1 2 3 )
--> (23          59           )
( 23 59 )
--> (8)
( 8 )
--> ()
( )
--> ^D
```

Rep Tool with Tracing Option

```
$ rep -t
--> (1 2 3)
    1: <numSeq>
    1: | LPAREN "("
    1: | <numbers>:NonEmptyNumbers
    1: | | NUMBER "1"
    1: | | <numbers>:NonEmptyNumbers
    1: | | | NUMBER "2"
    1: | | | <numbers>:NonEmptyNumbers
    1: | | | | NUMBER "3"
    1: | | | | <numbers>:EmptyNumbers
    1: | RPAREN ")"
( 1 2 3 )
```

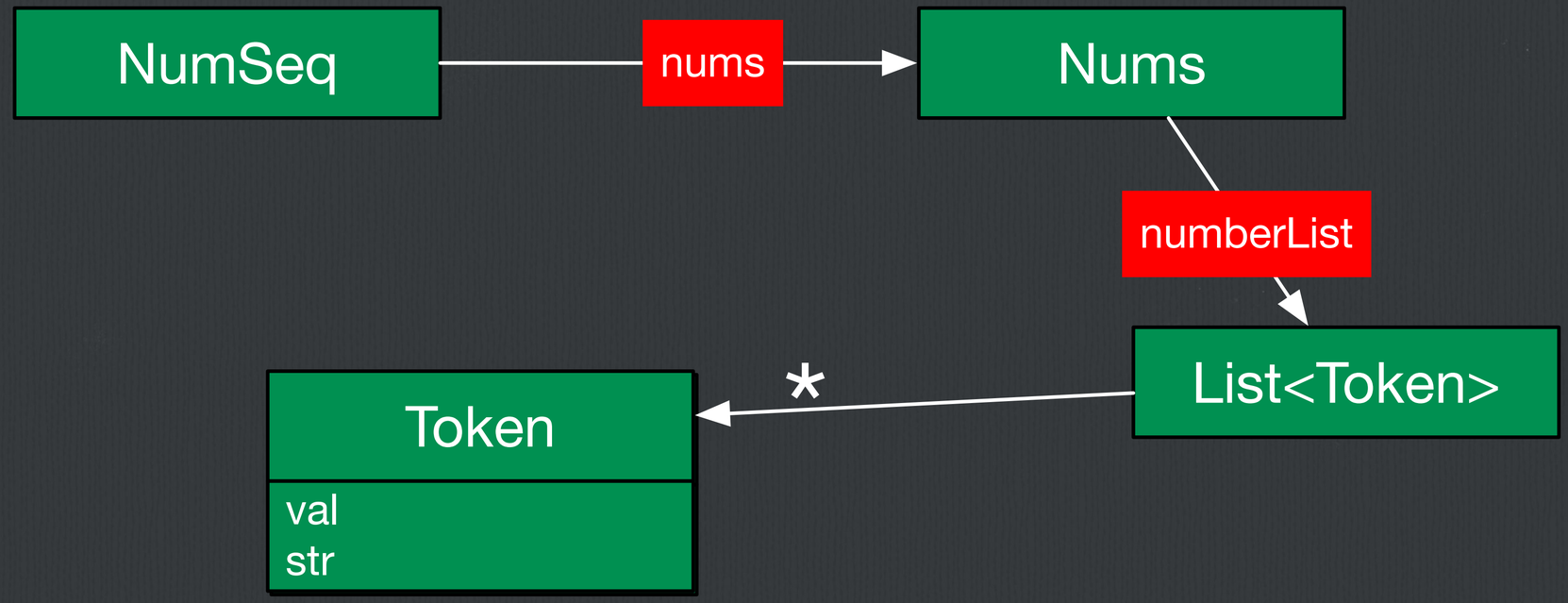
The only difference from the previous trace is that "OK" has changed to "(1 2 3)".

Activity 3

- "**cd**" to the **Part3** directory.
- There is a grammar there that recognizes a prefix expression.
- You will complete the semantics section, which evaluates the expression.

PLCC Alternative: Repeating Rule (employs Java Lists)

```
<numSeq> ::= LPAREN <nums> RPAREN
<nums> **= <NUMBER>
```



rep -t on Iterative Version

```
$ plccmk -c numlistABC-rep.plcc
:
:
$ rep -t
--> (1 2 3)
    1: <numSeq>
    1: | LPAREN "("
    1: | <numbers>
    1: | | NUMBER "1"
    1: | | NUMBER "2"
    1: | | NUMBER "3"
    1: | RPAREN ")"
( 1 2 3 )
```

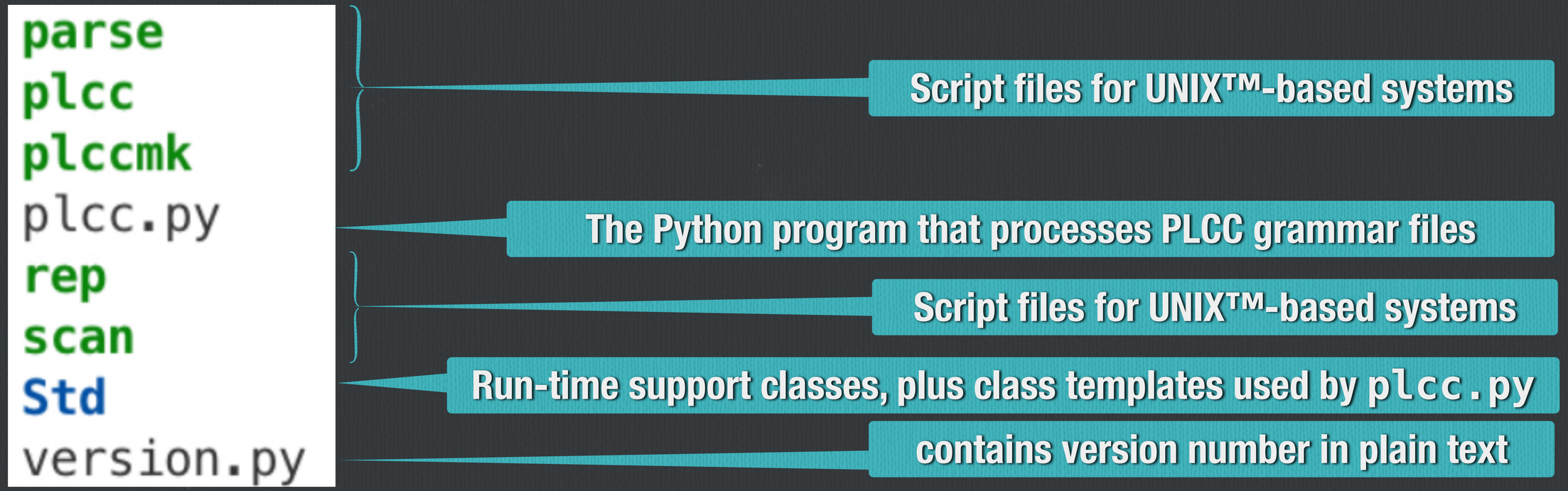
Activity 4

- This is a complete system that you can study and run
- "**cd**" to the **Part4** directory.
- There is a grammar and semantics there for processing a post fix expression.
- This is a bit more difficult.
  - The order of tokens is a bit less predictable.
  - The end of the expression is unknown.

Contents of the PLCC Package

The PLCC Package `src` Directory

This should be the value of the `LIBPLCC` environment variable.



Features Not Covered Today

- The repetition rule
  - You may include an element that separates those that are being repeated:

```
<numList> **= <NUMBER> +COMMA
```

- Complete Java classes can also be added to the semantics section.
  - See Environment code example.
- There is an `include` directive that can be used in the semantics section to allow placement of Java code in separate files.

Details of PLCC's Grammar Rules

- *lhs ::= term…*
- *lhs*:
  - *<id>*
  - *<id>:sub_id*
- *term*:
  - *<id>*
  - *<id>id2*
  - *TOKEN*
  - *<TOKEN>*
  - *<TOKEN>id2*

➛The syntax of each rule

➛Left-hand side can be

- ➛a class name, which is defined by this rule
- ➛a class and a subclass name, the latter of which is defined by this rule (required when class is used > once on LHS)

➛Each term in the sequence on the right side can be

- ➛a class name whose identifier has the name = *id*
- ➛a class name named *id2* with an identifier name = *id2* for the instance
- ➛a token name, which is not saved in a variable
- ➛a token name, which is saved as an instance of class `Token` and has the name = *token*
- ➛a token name, which is saved as an instance of `Token` but has the name = *id2*

id string begins with lower case in the grammar but its class's name begins with upper case.