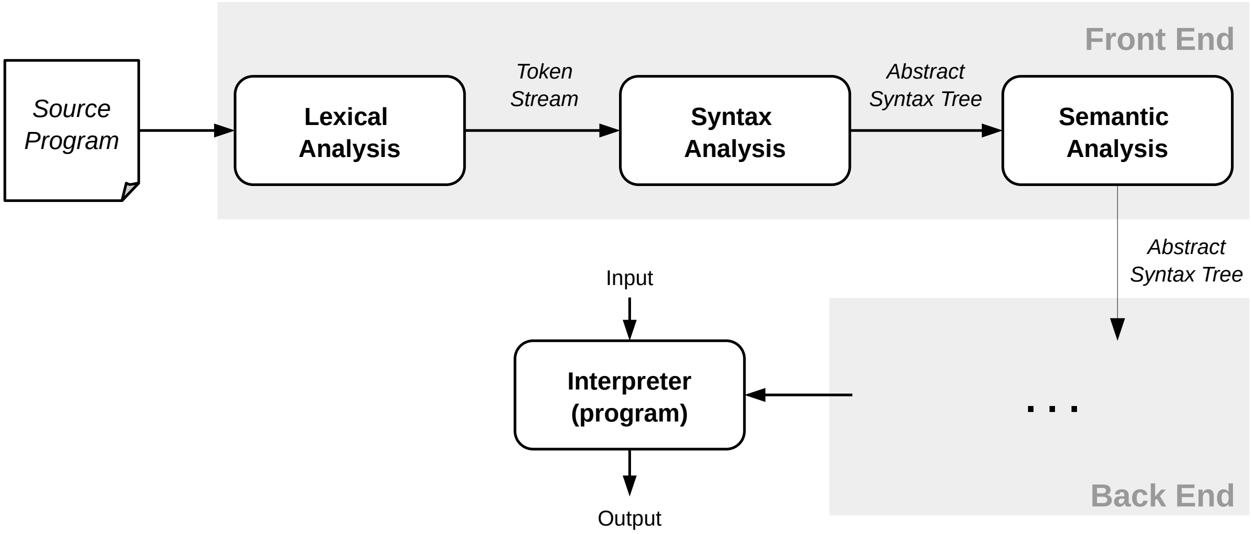
Lecture 4:

- Compilation and Interpretation (cont)
- Lexical Analysis

Announcements:

- HW-1 out
- Quiz 1 on Friday: MyPL (e.g., write code), Compilation/Interpretation steps

PL Implementation Basics: Interpretation



Abstract Syntax Tree (AST) Interpreters

- execute the program directly from the AST

Bytecode Interpreters (aka VMs) ... what we'll do

- intermediate representation is bytecode
- interpreter runs bytecode directly ... "write once run anywhere"

Just-in-time Compiler (JIT)

- instead of interpreting bytecode, generates and runs machine code
- monitor running code (e.g., frequent "hot spots") and optimize accordingly

Additional Notes on Approaches

Transpilers:

- Convert from one language into another
- Often include same "front-end" compilation steps (e.g., to an AST)

Transpiler vs Compiler:

- Compilers typically go from high-level to low-level languages
- Transpilers typically go from high-level to high-level languages

Compiler vs JIT:

- JIT sometimes called a "hybrid" approach (between compiled and interpreted)
- Popular implementation approach today

Other places where similar approaches used:

- Read-Eval-Print-Loops (REPLs)
- Integrated Development Environments (IDEs)
- Domain-Specific Languages (DSLs)
- "Data" Languages (e.g., HTML, JSON, XML, SQL, Graph QLs)

Lexical Analysis – Tokens

Tokens are the smallest meaningful units of a program

Some examples:

- Special words ("reserved" words)

  `int`, `if`, `while`, `new`, `class`, `public`, and so on

- Operators and Punctuation

  `+`, `=`, `==`, `<=`, `(`, `;`, `.`, and so on

- Identifiers

  variable names, function names, class names, etc.

- Constant (i.e., "*literal*") values

  `42`, `3.14`, `true`, `"abc"`, and so on

- Others (e.g., comments, annotations)

White space (usually) not tokens

- some exceptions such as Python

Tokens include a type and a lexeme (a value)

- the lexeme is just the token's value in the source file
- e.g., in the statement: `x = 42;`
  - the token types might be `ID`, `ASSIGN`, `INT_VAL`, `SEMICOLON`
  - and the corresponding lexemes "`x`", "=", "`42`", and "`;`"
- for some tokens, the lexemes are needed for program execution
  - e.g., the variable name of the identifier ("`x`") and the int value "`42`"

Lexical Analysis – Basics

Goal: simplify syntax analysis (parsing) and detect (token) errors early

- a "lexer" only deals with building tokens, not checking how they "go together"
- allows parser to focus on checking syntax rules (separation of concerns)

The basic idea:

```
Source Code:     Token Sequence as TYPE(lexeme):
------------     ---------------------------------------------------------------------
int f()          INT_TYPE("int"), ID("f"), LPAREN("("), RPAREN(")"),
{                LBRACE("{"),
  int x = 0;     INT_TYPE("var"), ID("x"), ASSIGN("="), INT_VAL("0"), SEMICOLON(";"),
  return x;      RETURN("return"), ID("x"), SEMICOLON(";"),
}                RBRACE("}")
```

How it works:

- Source code converted to a sequence (or a stream) of tokens
- Skip over non-tokens (white space, comments)
- Keep line and column numbers as part of tokens

Note:

- a sequence is similar to a list
- a stream is similar to an iterator

Check in: Give the token sequence (token type, lexeme, line, column) for the following MyPL code snippets. Assume the token types:

```
ASSIGN, ID, INT_VAL, LPAREN, RPAREN, LBRACE, RBRACE,
LESS_EQ, PLUS, STRING_VAL, WHILE, EOS
```

Snippet 1:

```
print("Hello World!")
```

Snippet 2:

```
int x = 0;
while (x <= 10) {
  x = x + 2;
}
```

Summary – Things to Know

1. Difference between compilation and interpretation (steps)

4. The basic idea of a bytecode intrepreter

5. What is meant by a transpiler

6. Whether a given language's primary implementation is an interpreter or a compiler (e.g., C/C++, Python, Java, ASM)

7. What a token represents and its basic components

8. Given a code snippet, the corresponding token stream