Program Analysis:
Introduction and Basics (Part 3)

Course page:
http://software-lab.org/teaching/winter2020/pa/

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Plan for Today

- **Introduction**
  - What the course is about
  - Why it is interesting
  - How it can help you

- **Organization**
  - Course projects
  - Term paper
  - Mid-term and final exam

- **Foundations**
  - Grammars, ASTs, CFGs, etc.
PL = syntax + semantics + implementation

- form
- meaning
- execution

Implementation

a) Compilation

Source code → **Lexical analysis** → Tokens → **Syntax analyzer (parser)** → Syntax tree → **Semantic analysis** → Machine code generator → Machine lang.

b) Interpretation

c) Hybrid

- e.g., Java, JavaScript
a) Grammar → Which programs are syntactically correct?

4 parts: terminals Σ, non-terminals N, productions P, initial symbol s ∈ N

Example: Arithmetic expression

Σ = {0, 1, 2, ..., 9, +, -}
N = {Exp, Num, Op, Digit}
S = Exp
P = Exp → Num | Exp Op Exp
Op → + | -
Num → Digit | Digit Num
Digit → 0 1 2 3 4 5 6 7 8 9

What is part of the language?

A) 12-2 ✓
B) 2+ (12-4) ✗
C) 11 × 4 ✗
D) 1235470987 ✓
b) Abstract syntax trees

- abstract grammar

  \[ E \rightarrow n \mid \text{Op} (E, E) \]

  \[ \text{Op} \rightarrow + \mid - \]

- terminals = tokens

Example: \( 3 + 45 \)

```
+   \\
|   \\
3   45
```
Control flow graphs

1. Models flow of control through program

\[ G = (N, E) \] where \( N \) = basic blocks (seq. of operations executed together)

\( E \) = possible transfer of control

**Ex. 1**

```javascript
if (c)
  x = 5
else
  x = 7
console.log(x)
```

![Diagram](image.png)
Ex. 2

```javascript
while (c) {
    x++;
    y = x;
}
console.log(x);
```

Diagram:

- `while (c)`
- `x++`
- `y = x`
- `console.log(x)`
Data Dependence Graphs

To model flow of data from "definitions" to "uses"

\[ G = (N, E) \]

where \( N \) are operations
\( E \) are possible def-use relations

\( e = (n_1, n_2) \) means: \( n_2 \) may use data defined at \( n_1 \)

**Ex. 1**

\[
\begin{align*}
x &= 5 \\
y &= x + 1
\end{align*}
\]
Ex. 2

\[ x = 3 \]
\[ y = 5 \]
\[ \text{if } (x \geq 1) \]
\[ y = x \]
\[ z = x + y \]