Introduction to Compiler Design

Lecture 1

Chapter 1

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The Stages of Compilation

- Lexical Analysis
- Syntactic Analysis
- Semantic Analysis
- Intermediate Code Generation
- Optimization
- Machine Code Generation

Assignment
The stages of compilation

- Lexical analysis
- Syntactic analysis.
- Semantic analysis.
- Intermediate code generation.
- Optimization.
- Machine code generation.
Lexical Analysis

Definition (Token)
A token is a smallest meaningful group of symbols.

Definition (Lexical analyzer)
A lexical analyzer, also called a lexer or a scanner, receives a stream of characters from the source program and groups them into tokens.
Tokens

- Each token has a **type** and a **value**.
- For example,
  - The variable `count` has type `id` and value “count”.
  - The number `123` has type `num` and value “123”.
  - The keyword `int` has type `int` and value “int”.
Example (Lexical Analysis)

What are the tokens in the following program?

```c
int main()
{
    int a = 123;
    return 0;
}
```
Example (Lexical Analysis)

- The statement

\[ \text{position} = \text{initial} + \text{rate} \times 60; \]

would be viewed as

\[ \text{id}_1 = \text{id}_2 + \text{id}_3 \times \text{num}; \]

or

\[ \text{id}_1 \text{ assign} \ \text{id}_2 \text{ plus} \ \text{id}_3 \text{ times} \ \text{num} \ \text{semi} \]

by the lexer.
There are tools available to assist in the writing of lexical analyzers.

- `lex` - produces C source code (UNIX).
- `flex` - produces C source code (gnu).
- `JLex` - produces Java source code.

We will use `JLex`.
Definition (Syntax analyzer)

A syntax analyzer, also called a parser, receives a stream of tokens from the lexer and groups them into phrases that match specified grammatical patterns.
Definition (Abstract syntax tree)

The output of the parser is an abstract syntax tree representing the syntactical structure of the tokens.
Grammatical Patterns

- Grammatical patterns are described by a context-free grammar.
- For example, an assignment statement may be defined as

  \[
  \begin{align*}
  stmt & \rightarrow \text{id} = expr ; \\
  expr & \rightarrow expr + expr \mid expr \ast expr \mid \text{id} \mid \text{num}
  \end{align*}
  \]
Example (Syntactic Analysis)

The form

\[ id_1 = id_2 + id_3 \times num; \]

may be represented by the following tree.
Syntax Analysis Tools

There are tools available to assist in the writing of parsers.

- `yacc` - produces C source code (UNIX).
- `bison` - produces C source code (gnu).
- `CUP` - produces Java source code.

We will use `CUP`.
Semantic Analysis

Definition (Semantic analyzer)

A **semantic analyzer** traverses the abstract syntax tree, checking that each node is appropriate for its context, i.e., it checks for semantic errors. It outputs a refined abstract syntax tree.
Example: Semantic Analysis

The previous tree may be refined to

```
=    
|    
id1 +  
|     
id2 *  
|    
id3 inttoreal
|    
num  
```
**Definition (Intermediate code)**

**Intermediate code** is code that represents the semantics of a program, but is machine-independent.

**Definition (Intermediate code generator)**

An **intermediate code generator** receives the abstract syntax tree and it outputs intermediate code that semantically corresponds to the abstract syntax tree.
Intermediate Code

- This stage marks the boundary between the front end and the back end.
- The front end is language-specific and machine-independent.
- The back end is machine-specific and language-independent.
Intermediate Code

- C Program
- Java Program
- Pascal Program
- Intermediate Code

Front End

Back End

- x86 Code
- MIPS32 Code

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Assignment
Example (Intermediate Code Generation)

- The tree in our example may be expressed in intermediate code as

```plaintext
temp1 = inttoreal(60)
temp2 = id3 * temp1
temp3 = id2 + temp2
id1 = temp3
```
Definition (Optimizer)

An optimizer reviews the code, looking for ways to reduce the number of operations and the memory requirements.

- A program may be optimized for speed or for size.
- Typically there is a trade-off between speed and size.
Example

Example (Optimization)

- The intermediate code in this example may be optimized as

```
temp1 = id3 * 60.0
id1 = id2 + temp1
```
The code generator receives the (optimized) intermediate code.

It produces either
- Machine code for a specific machine, or
- Assembly code for a specific machine and assembler.

If it produces assembly code, then an assembler is used to produce the machine code.
Machine Code Generation

- **Intermediate Code**
- **Code Generator**
- **Assembly Code**
- **Assembler**
- **Machine Code**

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Assignment
Example: Machine Code Generation

- The intermediate code may be translated into the assembly code

```assembly
movf id3, R2  
mulf #60.0, R2  
movf id2, R1  
addf R2, R1  
movf R1, id1
```
Assignment

Homework

- Read Chapter 1.
- Install Cygwin on the lab machine of your choice. Arrange with me to turn off Deep Freeze.