# CS1352 Compiler Design

# Preliminaries Required

- Basic knowledge of programming languages.
- Basic knowledge of FSA and CFG.
- Knowledge of a high programming language for the programming assignments.

## Textbook:

Alfred V. Aho, Ravi Sethi, and Jeffrey D. Ullman,

"*Compilers: Principles, Techniques, and Tools*"

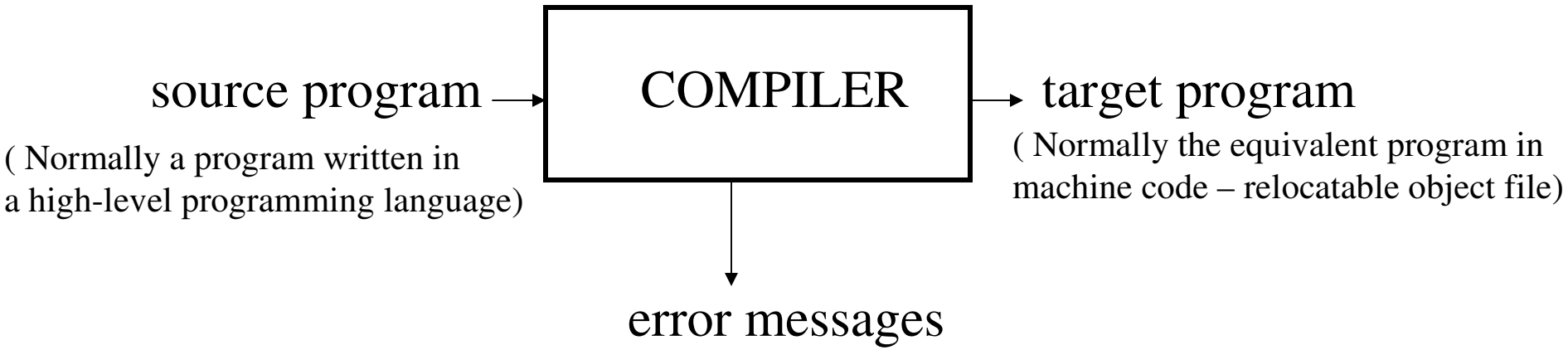
Addison-Wesley, 1986.

# Course Outline

- Introduction to Compiling
- Lexical Analysis
  - Token recognizer – NFA, DFA
- Syntax Analysis
  - Context Free Grammars
  - Top-Down Parsing, LL Parsing
  - Bottom-Up Parsing, LR Parsing
- Semantic Analysis, Type Checking
- Intermediate Code Generation
- Code Generation
- Code Optimization and runtime environments

# COMPILERS

- A **compiler** is a program takes a program written in a source language and translates it into an equivalent program in a target language.



# Other Applications

- In addition to the development of a compiler, the techniques used in compiler design can be applicable to many problems in computer science.
  - Techniques used in a lexical analyzer can be used in text editors, information retrieval system, and pattern recognition programs.
  - Techniques used in a parser can be used in a query processing system such as SQL.
  - Many software having a complex front-end may need techniques used in compiler design.
    - A symbolic equation solver which takes an equation as input. That program should parse the given input equation.
  - Most of the techniques used in compiler design can be used in Natural Language Processing (NLP) systems.

# Major Parts of Compilers

- There are two major parts of a compiler: **Analysis** and **Synthesis**

- In analysis phase, an intermediate representation is created from the given source program.
  - Lexical Analyzer, Syntax Analyzer and Semantic Analyzer are the parts of this phase.
- In synthesis phase, the equivalent target program is created from this intermediate representation.
  - Intermediate Code Generator, Code Generator, and Code Optimizer are the parts of this phase.

# Phases of A Compiler


- Each phase transforms the source program from one representation into another representation.
- They communicate with error handlers.
- They communicate with the symbol table.

# Lexical Analyzer

- **Lexical Analyzer** reads the source program character by character and returns the *tokens* of the source program.
- A *token* describes a pattern of characters having same meaning in the source program. (such as identifiers, operators, keywords, numbers, delimeters and so on)

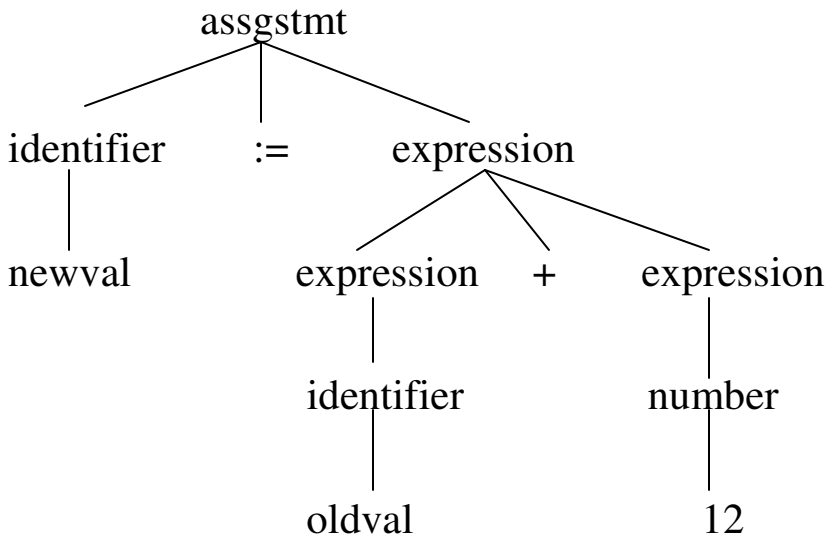
  Ex: newval := oldval + 12 => tokens:

| | |
|---|---|
| newval | identifier |
| := | assignment operator |
| oldval | identifier |
| + | add operator |
| 12 | a number |

- Puts information about identifiers into the symbol table.
- Regular expressions are used to describe tokens (lexical constructs).
- A (Deterministic) Finite State Automaton can be used in the implementation of a lexical analyzer.

# Syntax Analyzer

- A **Syntax Analyzer** creates the syntactic structure (generally a parse tree) of the given program.
- A syntax analyzer is also called as a **parser**.
- A **parse tree** describes a syntactic structure.




- In a parse tree, all terminals are at leaves.
- All inner nodes are non-terminals in a context free grammar.

# Syntax Analyzer (CFG)

- The syntax of a language is specified by a **context free grammar** (CFG).
- The rules in a CFG are mostly recursive.
- A syntax analyzer checks whether a given program satisfies the rules implied by a CFG or not.
  - If it satisfies, the syntax analyzer creates a parse tree for the given program.

- Ex: We use BNF (Backus Naur Form) to specify a CFG

  assgstmt -> identifier := expression
  expression -> identifier
  expression -> number
  expression -> expression + expression

# Parsing Techniques

- Depending on how the parse tree is created, there are different parsing techniques.
- These parsing techniques are categorized into two groups:
  - ***Top-Down Parsing,***
  - ***Bottom-Up Parsing***
- **Top-Down Parsing:**
  - Construction of the parse tree starts at the root, and proceeds towards the leaves.
  - Efficient top-down parsers can be easily constructed by hand.
  - Recursive Predictive Parsing, Non-Recursive Predictive Parsing (LL Parsing).
- **Bottom-Up Parsing:**
  - Construction of the parse tree starts at the leaves, and proceeds towards the root.
  - Normally efficient bottom-up parsers are created with the help of some software tools.
  - Bottom-up parsing is also known as shift-reduce parsing.
  - Operator-Precedence Parsing – simple, restrictive, easy to implement
  - LR Parsing – much general form of shift-reduce parsing, LR, SLR, LALR

# Semantic Analyzer

- A semantic analyzer checks the source program for semantic errors and collects the type information for the code generation.
- Type-checking is an important part of semantic analyzer.
- Normally semantic information cannot be represented by a context-free language used in syntax analyzers.
- Context-free grammars used in the syntax analysis are integrated with attributes (semantic rules)
  - the result is a syntax-directed translation,
  - Attribute grammars
- Ex:

  newval := oldval + 12

    - The type of the identifier *newval* must match with type of the expression *(oldval+12)*

# Intermediate Code Generation

- A compiler may produce an explicit intermediate codes representing the source program.
- These intermediate codes are generally machine (architecture independent). But the level of intermediate codes is close to the level of machine codes.
- Ex:

```
newval  :=  oldval * fact + 1
            ↓
id1  :=  id2 * id3 + 1
            ↓
MULT     id2,id3,temp1
ADD      temp1,#1,temp2
MOV      temp2,,id1
```

*Intermediates Codes (Quadraples)*

# Code Optimizer (for Intermediate Code Generator)

- The code optimizer optimizes the code produced by the intermediate code generator in the terms of time and space.

- Ex:

```
MULT    id2,id3,temp1
ADD     temp1,#1,id1
```

# Code Generator

- Produces the target language in a specific architecture.
- The target program is normally is a relocatable object file containing the machine codes.

- Ex:

  ( assume that we have an architecture with instructions whose at least one of its operands is a machine register)

```
MOVE    id2,R1
MULT    id3,R1
ADD     #1,R1
MOVE    R1,id1
```