Compiler Design

INTRODUCTION

Preliminaries Required

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

Textbook:

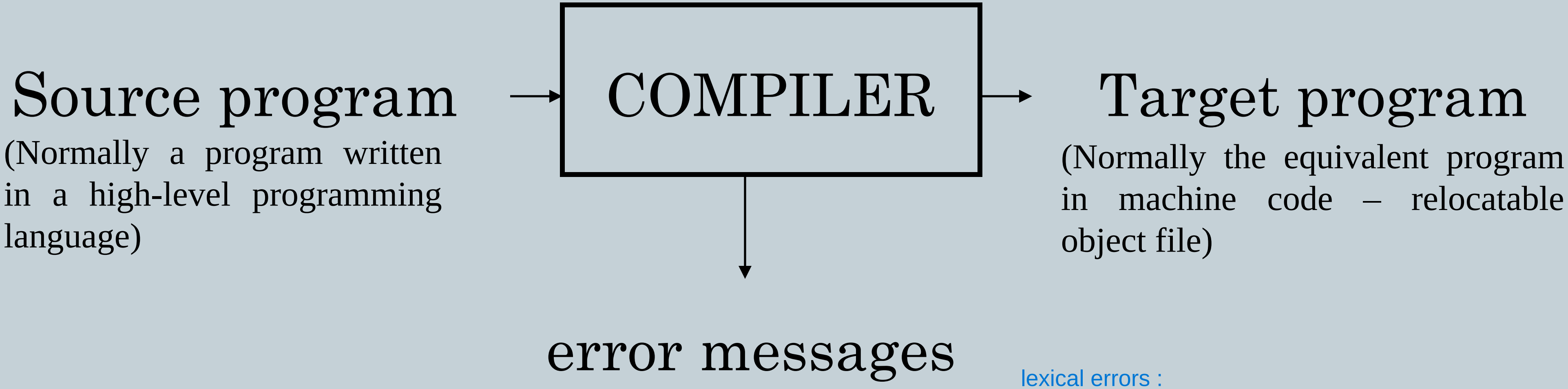
Alfred V. Aho, Ravi Sethi, and Jeffrey D. Ullman,
“*Compilers: Principles, Techniques, and Tools*”
Addison-Wesley, 1986.

Course Outline

- Introduction to Compiling convert high into assymply
- Lexical Analysis analysis char collect and create token
- Syntax Analysis grammer gomla
  - Context Free Grammars
  - Top-Down Parsing, LL Parsing create tree and sure is corect
  - Bottom-Up Parsing, LR Parsing
- Syntax-Directed Translation 6 attribute
  - Attribute Definitions
  - Evaluation of Attribute Definitions
- Semantic Analysis, Type Checking
- Run-Time Organization backend
- Intermediate Code Generation

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.



Source program

(Normally a program written in a high-level programming language)

COMPILER

Target program

(Normally the equivalent program in machine code – relocatable object file)

error messages

lexical errors :
syntax error:
semantic errors (meaning): i eat football

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.
  - lexical syntax symantic

    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**

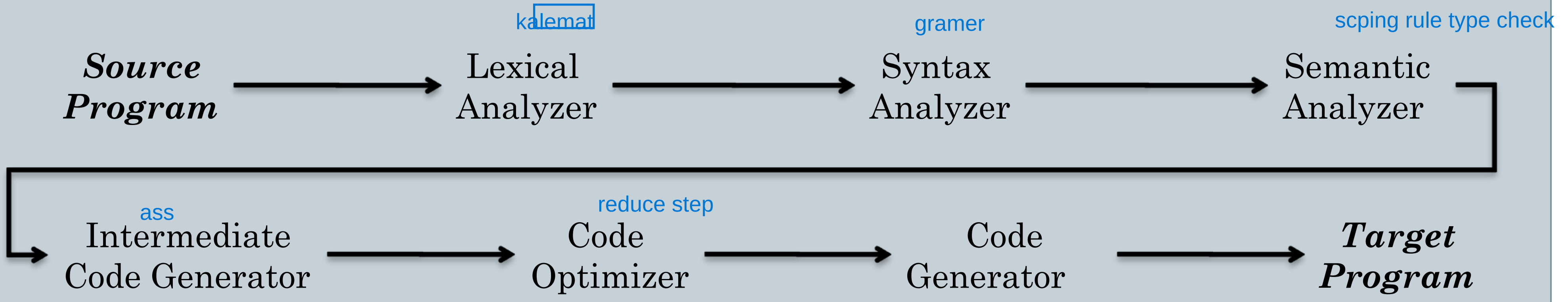
1 assumly

- 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.

2 constrcut machine code

- 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



Source Program

kalemat

Lexical Analyzer

gramer

Syntax Analyzer

scping rule type check

Semantic Analyzer

ass

Intermediate Code Generator

reduce step

Code Optimizer

Code Generator

Target Program

- Each phase transforms the source program from one representation into another representation.
- They communicate with error handlers. lexical symantic syntax
- They communicate with the symbol table. in all step

Lexical Analyzer

- **Lexical Analyzer** reads the source program character by character and returns the ***tokens*** of the source program. when space exist

- A *token* describes a pattern of characters having same meaning in the source program. (such as identifiers, operators, keywords, numbers, delimiters and so on)

patern :rule any token or lexems

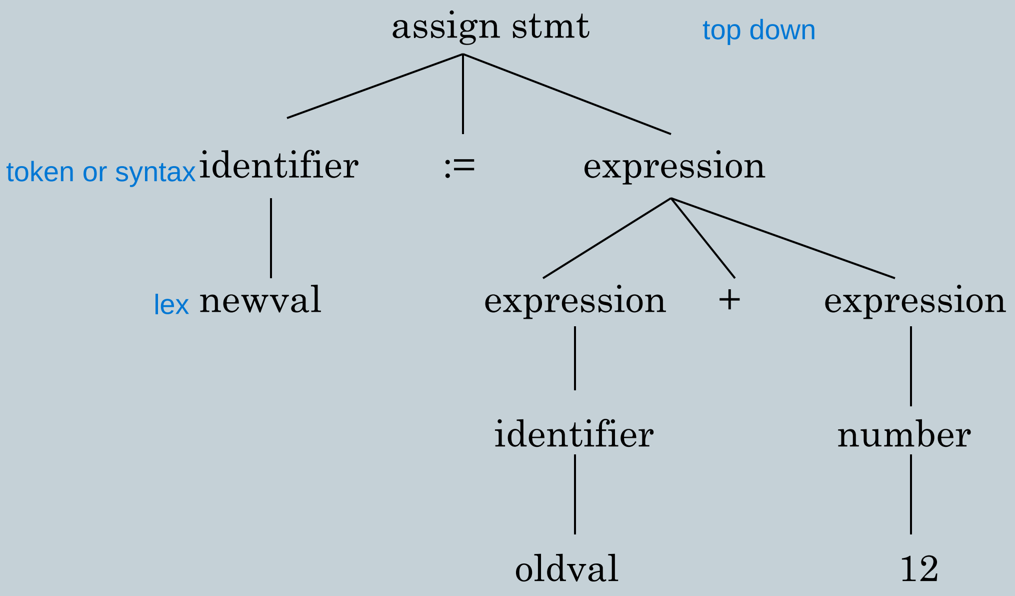
Ex: newval := oldval + 12 => tokens:

Lexemes	Tokens
newval	identifier
:=	assignment operator
oldval	identifier
+	add operator
12	a number 2 digit

- 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.



assign stmt

top down

token or syntax identifier := expression

lex newval

expression + expression

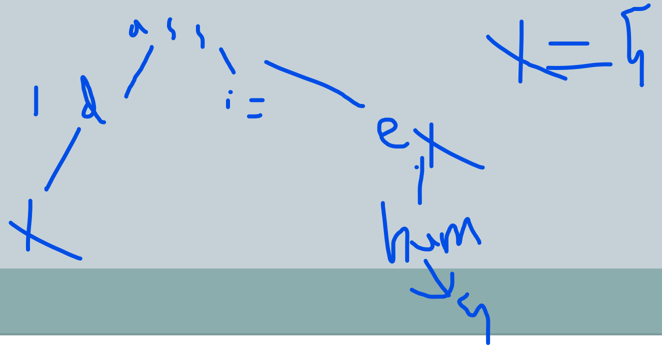
identifier number

oldval 12

- In a parse tree, all terminals are at leaves.

lexemes

- 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.

if its correct (parse tree)

5new lexical error

- Ex: We use ***BNF*** (**B**ackus **N**aur **F**orm) to specify a CFG

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

Syntax Analyzer versus Lexical Analyzer

- Which constructs of a program should be recognized by the lexical analyzer, and which ones by the syntax analyzer?

word

  - Both of them do similar things; But the lexical analyzer deals with simple non-recursive constructs of the language.
  - The syntax analyzer deals with recursive constructs of the language.
  - The lexical analyzer simplifies the job of the syntax analyzer.
  - The lexical analyzer recognizes the smallest meaningful units (tokens) in a source program.
  - The syntax analyzer works on the smallest meaningful units (tokens) in a source program to recognize meaningful structures in our programming language.

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 Intermediates Codes (Quadraples)
  - ADD temp1,#1,temp2
  - MOV temp2,,id1

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