Chapter 6: Programming Languages

- 6.1 Historical Perspective
- 6.2 Traditional Programming Concepts
- 6.3 Procedural Units
- 6.4 Language Implementation
- 6.5 Object Oriented Programming
- 6.6 Programming Concurrent Activities
- 6.7 Declarative Programming

1st Generation: Machine Language

- *Machine language
- *Operations in op-codes
    - Operands
    - Numerical values
    - Register number
    - Memory location address

2nd Generation: Assembly Language

- *A mnemonic system for representing programs
    - *Mnemonic: easy to remember
- *More descriptive

- *Enabling programming without tables such as the one in Appendix C
- *Things are mnemonic
- *Op-codes in mnemonic names
- *Registers in mnemonic names
- *Memory locations in mnemonic names of the programmer’ s choice (Identifiers/variables)

Just a Little Step Further

- *One-to-one correspondence between machine instructions and assembly instructions
- *Inherently machine-dependent
- *Converted to machine language by a program called an assembler
- *Thing are easier to remember, yes.
- *But programmer still needs to think like the machine!

Third Generation Language

- *Uses high-level primitives
- *Similar to our pseudocode in Chapter 5
- *Machine independent (mostly)
- *Each primitive corresponds to a short sequence of machine language instructions
- Converted to machine language by a program called compiler
- *Examples: FORTRAN, COBOL, BASIC

Compilers vs. Interpreters

- *Compilers
- *Compile several machine instructions into short sequences to simulate the activity requested by a single

high-level primitive

- *Produce a machine-language copy of a program that would be executed later
- *Interpreters
- *Execute the instructions as they were translated

Imperative Paradigm

- *Procedural paradigm
- *Develops a sequence of commands that when followed, manipulate data to produce the desired result
- *Approaches a problem by trying to find an algorithm for solving it

Object-Oriented Paradigm

- *Grouping/classifying entities in the program
    - *Entities are the objects
    - *Groups are the classes
    - *Objects of a class share certain properties
    - *Properties are the variables or methods

*Encapsulation of data and procedures

- *Lists come with sorting functions
- *Natural modular structure and program reuse
    - *Inheriting from mother class definitions
- *Many large-scale software systems are developed in the object oriented fashion

Object vs. Class

- *Some objects can be categorized into the same class
    - *Desk , chair -> furniture
- *Objects in the same class might share the same property

- *Desk, chair -> four legs

Declarative Paradigm

- *Emphasizes
- * “What is the problem?”
- *Rather than “What algorithm is required to solve the problem?”
- *Implemented a general problem-solving algorithm
- *Develops a statement of the problem compatible with the algorithm and then applies the algorithm to solve it

Functional Paradigm

- *Views the process of program development as connecting predefined “black boxes,” each of which accepts inputs and produces outputs
- *Mathematicians refer to such “boxes” as functions
- *Constructs functions as nested complexes of simpler functions

LISP Expressions

```
(Divide (Sum Numbers)
        (Count Numbers))
(First (Sort List))
```

Advantages of FP

- *Constructing complex software from predefined primitive functions leads to well-organized systems
- *Provides an environment in which hierarchies of abstraction are easily implemented, enabling new software to be constructed from large predefined components rather than from scratch

Types of Statements

- *Declarative statements
    - *Define customized terminology that is used later in the program
- *Imperative statements
    - *Describe steps in the underlying algorithms
- *Comments
    - *Enhance the readability of a program

Declaration Statements

- *Data terms
    - *Variables 變量
    - *Literals 文字
    - *Constants 常數/固定的(const int)
- *Data types
    - *Common types
        - *Integer, real, character, Boolean
    - *Decides
        - *Interpretation of data
        - *Operations that can be performed on the data
- *Declaring data terms with proper types

    *Variable Declarations

    - *Pascal

        ```
              Length, width: real;
          Price, Tax, Total: integer;
        ```

    - *C, C++, Java

        ```
          float Length, width;
        ```

```
int Price, Tax, Total;
```

- *FORTRAN

```
REAL Length, Width
INTEGER Price, Tax, Total
```

- *Data structure
  - *Conceptual shape of data
  - *Common data structure
    - *Homogeneous array
      - *Heterogeneous array

Declaration of a 2D Array

- *C

```
int Scores[2][9];
```

- *Java

```
int Scores[][]=new int [2][9];
```

- *Pascal

```
Scores: array[3..4, 12..20] of integer;
```

Assignment Statements

- *C, C++, Java

```
Total = Price + Tax;
```

- *Ada, Pascal

```
Total := Price + Tax;
```

- *APL

```
Total <- Price + Tax;
```

Operators

- *Operator precedence
  - *Operator priority
  - *Plus and minus
  - *Multiply and divide
  - *Add and subtract
- *Operator overloading
  - *Exact function depends on the operand data types
  - *12 + 43
  - * ‘abc’ + ’ def’

Control Statements

- *Alter the execution sequence of the program
- *goto is the simplest control statement

Types of Controls

*for / if…else/switch/while

Comments

- *For inserting explanatory statements (internal documentation)
- *C++ and Java

```
/* This is a comment */
// This is a comment
```

- Explain the program, not to repeat it

Procedures

- *A procedure
    - *A set of instructions for performing a task
    - *Used as an abstract tool by other program units
- *Control
    - *Transferred to the procedure at the time its services are required
    - *Returned to the original program unit (calling unit) after the procedure is finished
- *The process of transferring control to a procedure is often referred to as calling or invoking the procedure

Pass by Value

a. When the procedure is called, a copy of the datais given to the procedure

5 → 5

b. and the procedue manipulates its copy

5 6

c. Thus, when the procedure has terminated, the calling environment has not been changed calling environment

5 ○

Pass by Reference

a. When the procedure is called, the formal parameter becomes a reference to the actual parameter

5 → 5

b. Thus changes directed by the procedure are made to the actual parameter

5 6

6 ← 6

c. and are, therefore, preserved after the procedure has terminated

6 ○

Functions

*The 6th type of control

*A program unit similar to procedure unit except that a value is transferred back to the calling unit

Input/Output Statements

・*I/O statements are often not primitives of programming languages

・*Not really a control

・*Most programming languages implement I/O operations as procedures or functions

The Translation Process

Source program → Lexical(詞語的) analyzer → Parser(語法分析程式) → Code generator → Object program

Lexical Analyzer

・*Reads the source program symbol by symbol, identifying which groups of symbols represent single units, and classifying those units

・*As each unit is classified, the lexical analyzer generates a bit pattern known as a token to represent the unit and hands the token to the parser

・*Like mapping words according to a dictionary, except the dictionary here is much smaller and non-ambiguous

Parsing

- *Group lexical units (tokens) into statements
- *Identify the grammatical structure of the program
- *Recognize the role of each component

Syntax(語法) Diagram

- *Pictorial representations of a program’s grammatical structure
- *Nonterminals (rectangles)矩形 statement / expression
- *Requires further description
- *Terminals (ovals)橢圓 --- if / else / ……

  *圓形 --- + / - / x / y / z / ……

Parse Tree

- *Pictorial form which represents a particular string conforming to a set of syntax diagrams
- *The process of parsing a program is essentially that of constructing a parse tree for the source program
- *A parse tree represents the parser’s understanding of the programmer’s grammatical composition

Syntax Tree Ambiguity

- *There could be multiple syntax trees for one statement
- *When the results are the same, it is OK
- *When the results are not the same, we call the statement an ambiguous statement

Code Generation

- *Given the parse tree, create machine code
-     *Z ・ X + Y;
-     *Load X
-     *Load Y

- *ADDI X Y
- *Complication
    - *When X is an integer and Y is a floating point number
    - *Convert X from integer to floating point number
    - *Use ADDF instead

Code Optimization

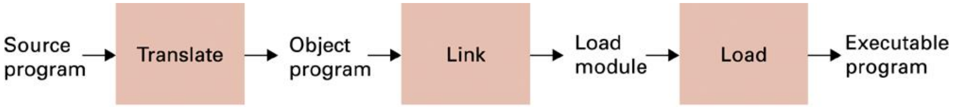
- Line 1. X • Y + Z;
- Line 2. W • X + Z;
- *Values of Y, Z, and X already in registers after Line 1
- *No need to store the values back to memory and then load again for Line 2.

Intertwined Process (相互交織的過程)

- *Lexical analyzer
    - *Recognize a token
    - *Pass to parser
- *Parser
    - *Analyze grammatical structure
    - *Might need another token
        - *Back to lexical analyzer
    - *Recognize a statement
        - *Pass to code generator
- *Code generator
    - *Generate machine code
    - *Might need another statement

- *Back to code generator

Extended Process



Linker

- *Most programming environments allow the modules of a program to be developed and translated as individual units at different times
- *Linker links several
    - *Object programs
    - *Operating system routines and utility software
        - #include <xxxx.h>
- *To produce a complete, executable program (load module) that is in turn stored as a file in the mass storage system

Loader

- *Often part of the operating system’ s scheduler
- *Places the load module in memory
- *Important in multitasking systems
    - *Exact memory area available to the programs is not known until it is time to execute it

- *Loader also makes any final adjustments that might be needed once the exact memory location of the program is known (e.g. dealing with the JUMP instruction)

Software Development Package

- *Editor
    - *Often customized
    - *Example
        - Color for reserved words
        - Aligned indentation
- *Translator
    - *The compiler/interpreter
    - *The most important part
- *Debugger
    - *To allow easy tracking of program states

Objects and Classes

*Object

- *Active program unit containing both data and procedures
- *Class
    - *A template for all objects of the same type

An Object is often called an instance of the class.

Components of an object

- *Instance variable
    - *Variable within an object

- *Method
    - *Function or procedure within an object
    - *Can manipulate the object’s instance variables
- *Constructor
    - *Special method to initialize a new object instance

Encapsulation

- *A way of restricting access to the internal components of an object
- *Private vs. Public

Additional Concepts

- *Inheritance
    - *Allows new classes to be defined in terms of previously defined classes
- *Polymorphism
    - *Allows method calls to be interpreted by the object that receives the call
    - *For example
        - *draw()
        - *Different for circle vs. square object

Program Concurrent Activities

- *Parallel or concurrent processing
- *Simultaneous execution of multiple processes
- *True concurrent processing requires multiple CPUs
- *Can be simulated using time-sharing with a single CPU
- *Examples: Ada task and Java thread

Basic Idea

- *Creating new process
- *Handling communication between processes
- *Problem accessing shared data
    - *Mutually exclusive access over critical regions
        - *Mechanism on the program
        - *Data accessed by only one process at a time
    - *Monitor
        - *Mechanism on the data
        - *A data item augmented with the ability to control access to itself

Prolog

- *PROgramming in LOGic
- *A Prolog program consists of a collection of initial statements upon which the underlying algorithm bases its deductive reasoning